सत्यमेव जयते

Ministry of Housing and Urban Affairs
Government of India

Training Module on

Urban Water Management

Sustainable Cities Integrated Approach Pilot in India

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UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

National Institute of Urban Affairs

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THE FULL MODULE SHOULD BE REFERENCED AS FOLLOWS
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About this Module	This module is a part of the second deliverable for the project to provide training modules for three sectors.

ABOUT THE PROJECT

"Sustainable Cities Integrated Approach Pilot in India" is one of the child projects under GEF's Sustainable Cities Programme in the GEF 6 cycle. The aim of the project is to integrate sustainability strategies into urban planning and management to create a favourable environment for investment in infrastructure and service delivery, thus building resilience of pilot cities. The three main project components comprise- Sustainable Urban Planning and Management, Investment Projects and Technology Demonstration and Partnerships and Knowledge Management Platform.

National Institute of Urban Affairs (NIUA) has been engaged to undertake the implementation of Component 3 – Partnerships, Knowledge Management and Capacity Building. As a part of this component of the Project, a Training and Assistance Needs Assessment (TANA) was conducted from February 2020 to August 2020 for the ULBs of five cities - Bhopal, Jaipur, Mysuru, Vijayawada and Guntur to assess and identify the needs of the ULB officials to prepare on-the-job training modules.

ABOUT THE TRAINING MODULE

Based on the results of TANA, training modules on Solid Waste, Wastewater and Water Management have been developed by NIUA. The modules are an outcome of the activity 2 of the project which included the following tasks:

- On the basis of TANA results, training modules were prepared for relevant stakeholders
- For developing the Module & Pedagogy, NIUA has synergized the experience of practitioners and subject experts.
- The modules have been finalized in coordination with experts and officials from cities.

This module on Urban Water Management is a part of the series of modules that would supplement the training activities.

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List of abbreviations and acronyms

ADRI	Asian Development Research Institute
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AWWA	American Water Works Association
BCC	Behavioural Change Communication
BCM	Billion Cubic Metre
BMP	Best Management Practice
BPP	Best Planning Practice
CDP	City Development Plan
CPHEEO	Central Public Health and Environmental Engineering Organisation
CSS	Centrally Sponsored Scheme
CWC	Central Water Commission
DBFOT	Design, Build, Finance, Operate & Transfer
DBOT	Design, Build, Operate & Transfer
DDMA	District Disaster Management Authority
DDWS	Department of Drinking Water and Sanitation
DJB	Delhi Jal Board
DPR	Detailed Project Report
EIRR	Economic Internal Rate of Return
EPC	Engineering, Procurement, and Construction
ERR	Economic Rate of Return
GIS	Geographic Information System
GoAP	Government of Andhra Pradesh
GoI	Government of India
GoK	Government of Karnataka
GoMP	Government of Madhya Pradesh
GoR	Government of Rajasthan
GWSSB	Gujrat Water Supply and Sanitation Board

IEC	Information Education and Communication
IPC	Inter-Personal Communication
IRR	Internal Rate of Return
IUWM	Integrated Urban Water Management
IWCM	Integrated Water Cycle Management
IWRM	Integrated Water Resources Management
MDG	Millennium Development Goals
MoHUA	Ministry of Housing and Urban Affairs
MoWR	Ministry of Water Resources
MoWRRDGR	Ministry of Water Resources, River Development and Ganga Rejuvenation
NAPCC	National Action Plan on Climate Change
NPV	Net Present Value
NRW	Non-Revenue Water
NWP	National Water Policy
OHT	Overhead Tanks
PIB	Press Information Bureau
PPP	Public-Private Partnership
RBMP	River Basin Management Plan
RWA	Resident Welfare Associations
RWH	Rainwater Harvesting
SAAP	State Annual Action Plans
SCADA	Supervisory Control and Data Analysis
SGD	Sustainable Development Goals
SLB	Service Level Becnhmarks
SPV	Special Purpose Vehicle
UNIDO	United Nation Industrial Development Organisation
UYRB	Upper Yamuna River Board
WRI	World Resources Institute
WSS	Water Supply and Sanitation
WSUD	Water Sensitive Urban Design
WTP	Willingness to pay
YVW	Yarra Valley Water

Chapter 1

Urban Water Management Landscape of India

Summary

Understanding the water supply sector in urban India, its linkages with health and climate, and providing aspects that need to be revisited to achieve the sanitation goals. This gives brief ideas towards urban water landscape in India.

Training Objectives

- To understand the linkages of water with SDGs.
- Overview of the urbanisation trends in India.
- Overview of the available water resources in India.
- Insights into the stresses that India faces with respect to water availability.
- Understanding the link between safe water and human health.
- Rethinking the current approaches towards water management in India given the need to act for climate change.

Training Outcomes

- Able to understand the importance of water
- Able to understand the importance of conservation of water.
- Gather an understanding of the linkages and interactions that water resources and supply have with health.
- Gather an understanding of how water interacts with climate.

Chapter Contents

1.1 Introduction
1.2 Urbanisation and Urban Water Management in India
1.3 Available Water Resources in India
1.4 Health and Water Supply
1.5 Climate Change and Water
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1.1 Introduction

Water being such an important asset and resource for human life, its conservation has always been the concern of cultures and people for centuries. As the world entered the 21st century, the Millennium Development Goals (MDG) were introduced to improve the lives of people. In 2015, the Sustainable Development Goals (SDG) were introduced to improve the lives and the environment across the globe, targeting holistic sustainable development. Out of the 17 SDGs covering various aspects of human habitats and life, SDG 6 focusses completely on water and sanitation. Other than this, water is an important factor that contributes to various other SDGs, directly or indirectly (Figure 1.1).

Figure 1.1: The SDGs linked with Water management

Source: Author

Table 1.1 shows in detail the goals and targets associated with water management. The domains cover aspects of health, water and sanitation, consumption, climate change, and preservation of ecosystems on land and water.

Table 1.1: The Sustainable Development Goals and Targets associated with Water Management

SDG Number	Goal	Target Number	Target
3	Ensure healthy lives and promote well-being for all at all ages	3.3	By 2030 end the epidemics of AIDS, tuberculosis, malaria, and neglected tropical diseases and combat hepatitis, water-borne diseases, and other communicable diseases
		3.9	By 2030 substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination
6	Ensure availability and sustainable management of water and sanitation for all	6.1	By 2030, achieve universal and equitable access to safe and affordable drinking water for all.
		6.2	By 2030, achieve access to adequate and equitable sanitation and hygiene for all, and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.
		6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and increasing recycling and safe reuse by x% globally.
		6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity, and substantially reduce the number of people suffering from water scarcity.
		6.5	By 2030 implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.
		6.6	By 2020 protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.
		6.A	By 2030, expand international cooperation and capacity-building support to developing countries in water and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.
		6.B	Support and strengthen the participation of local communities for improving water and sanitation management.

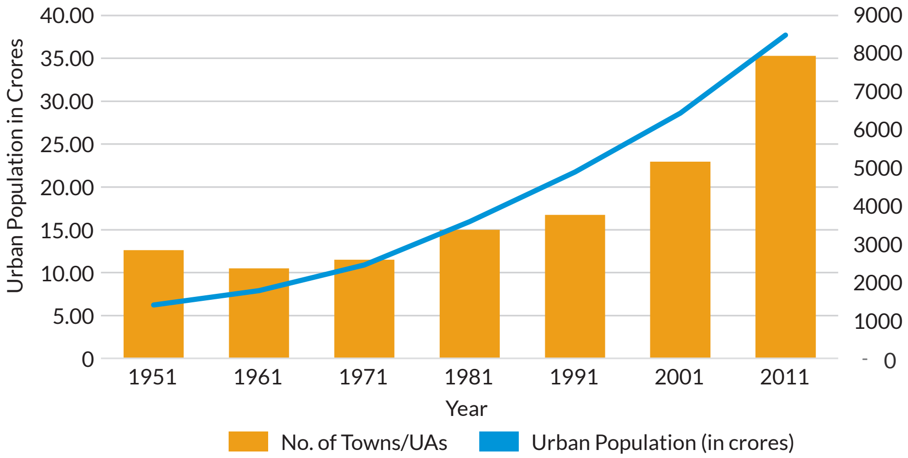
SDG Number	Goal	Target Number	Target
11	Make cities and human settlements inclusive, safe, resilient and sustainable	11.5	By 2030 significantly reduce the number of deaths and the number of affected people and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.
12	Ensure sustainable consumption and production patterns	12.4	By 2020 achieve environmentally sound management of chemicals and all wastes throughout their life cycle in accordance with agreed international frameworks and significantly reduce their release to air, water and soil to minimize their adverse impacts on human health and the environment
13	Take urgent action to combat climate change and its impacts	13.1	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
		13.2	Integrate climate change measures into national policies, strategies and planning
		13.B	Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities
15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	15.1	By 2020 ensure conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements
		15.8	By 2020 introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems, and control or eradicate the priority species.

Source: Author

1.2 Urbanisation and Urban Water Management in India

Since independence, India has witnessed rapid urbanisation. The urban population has been constantly rising due to two factors- the natural growth of the urban areas, and the migration of people from rural areas to the urban areas. Cities and urban areas becoming the centres of economic activity has been the cause of the population migrating towards the cities.

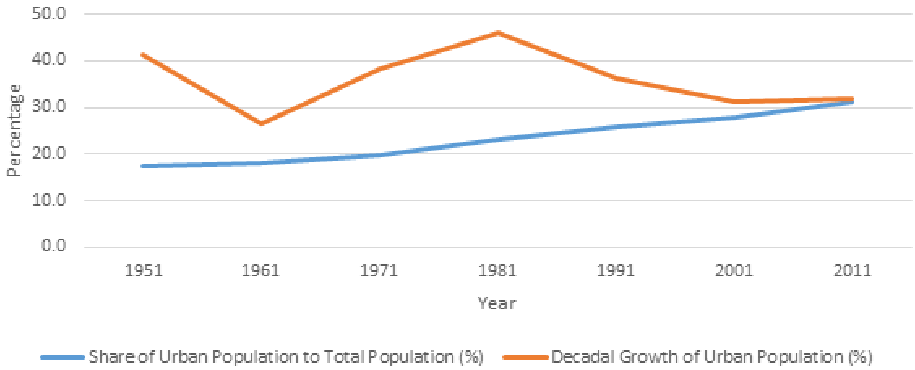
Figure 1.2: Urban Population Trends India – 1



Source- Adapted from Sadashivam & Tabassum (2016)

Such increasing population adds to the growing demands for resources, including water. Indian cities depend largely on groundwater within their boundaries for their freshwater needs, along with water abstracted from rivers sourced from distant reservoirs. This is despite the fact, that most cities have certain water bodies such as lakes and rivers within their geographic and administrative boundaries. However, most surface water sources in Indian cities are in a bad state, owing to pollution and contamination from domestic and/or industrial waste.

Figure 1.3: Urban Population Trends in India – 2



Source- Adapted from Sadashivam & Tabassum (2016)

Stats about Urban Water at household level from census 2011 (CPHEEO, N.D.)

1. 62% of households depend on tapwater from treated sources
2. About 71% of households have drinking water source within their premises, while 8% of household don't have it

Groundwater is another major source of water that is used to suffice the water demands of the cities. Groundwater is abstracted by the municipalities in certain areas, while a large share of the groundwater abstraction remains unchecked. This major consumption of groundwater is the direct abstraction by the domestic and commercial consumers in areas where public water supply is inadequate or unaffordable. Industries also use groundwater abstracted directly within the campuses of such establishments to fulfil their water needs.

In India, the Twelfth Schedule provided by the Constitution (Seventy-fourth Amendment) Act, 1992 confers the Municipalities and Urban Local Bodies with the responsibility of providing the services and carrying out functions for providing water supply to the domestic, industrial and commercial consumers. This is however subject to provisions of the State legislature. Therefore, in India, the governance landscape concerning water supply services spans over a spectrum ranging from the ULB managing complete autonomy over the various aspects of water services to certain parastatal agencies handling complete autonomy and authority over the water supply services in urban India. The responsibilities are shared at various degrees among the ULBs and the parastatal agencies. These functions are planning, financing and funding, execution and implementation, operation and maintenance, monitoring, and levy of taxes and tariffs.

The per capita water supply levels are decided based on the city sanitation systems of the respective cities. The Central Public Health and Environmental Engineering Organisation (CPHEEO) has recommended the minimum water supply levels in the Manual on Water Supply and Treatment. The recommended levels are mentioned in Table 1.2. Despite the recommended supply levels, the water that reaches the consumers is often less than the specified levels.

Table 1.2: Recommended Water Supply Levels in Indian cities

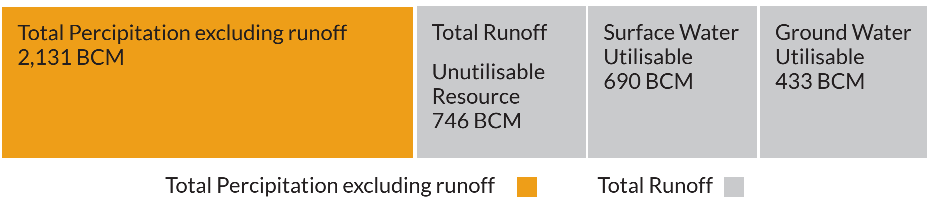
Sr. No.	Classification of Towns/Cities	Recommended Minimum Water Supply Levels (lpcd)
1	Towns provided with piped water supply but without sewerage systems	70
2	Cities provided with piped water supply where sewerage system is existing/contemplated	135
3	Metropolitan and Mega Cities provided with piped water supply where sewerage system is existing/contemplated	150

Source – (CPHEEO, 1999)

1.3 Available Water Resources in India

As of 2019, India is estimated to have about 17.8% of the world population residing in about 2.5% of the geographical area of the world (World Bank, 2020). In terms of water resources, India owns about 4% of the total water available in the world (ADRI, 2017). A total of 1869 Billion Cubic Metre (BCM) of water is the Mean Annual Natural Runoff flowing to the rivers and surface water bodies of India.

Figure 1.4: Available Water Resources in India



Source – Author Generated

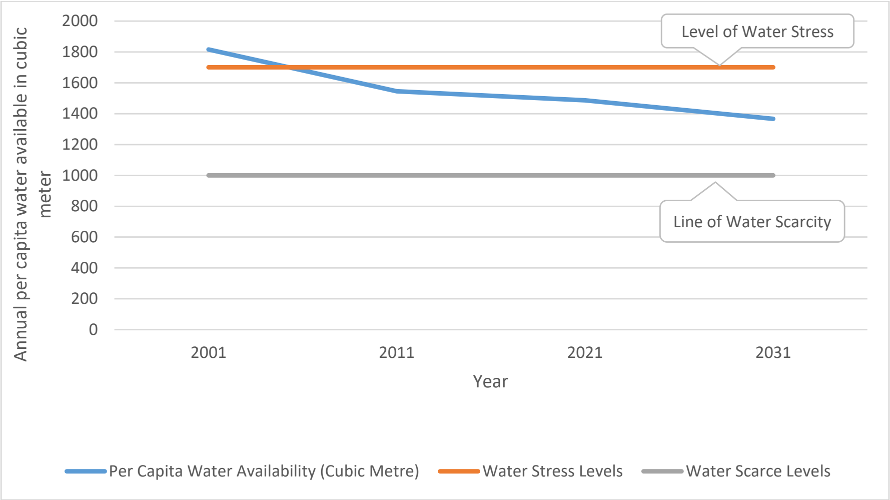
However, only 1,123 BCM is the utilisable resource of water available, inclusive of both 433 BCM Ground Water and 690 BCM of Surface Water (CWC, 2016). The average annual per capita water availability in the years 2001 and 2011 was assessed as 1816 cubic meters and 1545 cubic meters respectively which may further reduce to 1486 cubic meters and 1367 cubic meters in the years 2021 and 2031 respectively (PIB, 2020). This water is distributed unequally across geographic regions, rural and urban areas, and social classes. Following the trend, India is water-stressed since 2011 and is anticipated to slide into the water-scarce zone by 2050 (Figure 1.5).

1.3.1 Water in India- Demand, Supply, Stresses

Considering the value of water and the importance of the proper management for water in the wake of the looming crisis the world faces, various indicators and measures have been formulated to put into perspective the urgency of the matter, and compare the performance of various regions at national and international level. These indicators also help devise policies and legislations for judicious usage of water.

Water Availability Index is a measure that estimates surface water availability by recording water level in open surface water. Positive values are typically open water areas and negative values are non-water features (i.e. terrestrial vegetation, bare soil etc.). As per the calculations of the World Resources Institute (WRI) for the Water Availability Index, about two-thirds of India falls under extremely low to the medium category of the Index, denoting low available open surface water (Figure 1.6). However, this is staggeringly misleading if one compares population vis-à-vis the water available.

Figure 1.5: Per Capita Water Availability in India



Source – Author Generated

Baseline Water Stress Index measures total annual water withdrawals (municipal, industrial, agricultural) expressed at a percentage of the total annual available flow. Higher values of the index indicate more competition among users. Globally, India ranks 13 out of 164 countries when measured for Baseline Water Stress (WRI Aqueduct, 2019), along with the highly stressed countries ranked on top. Within India, about two-thirds of the country is facing High to Extremely High Baseline Water Stress as of 2019, as shown in Figure 17 (WRI, 2020).

Such situations are expected to worsen and make it immensely difficult to continue living in a manner as we know now. Pressure from changing demographics is only a part of the problem, where the other tug is from the changing water landscape across the world. This is aggravated by various impacts caused by climate change.

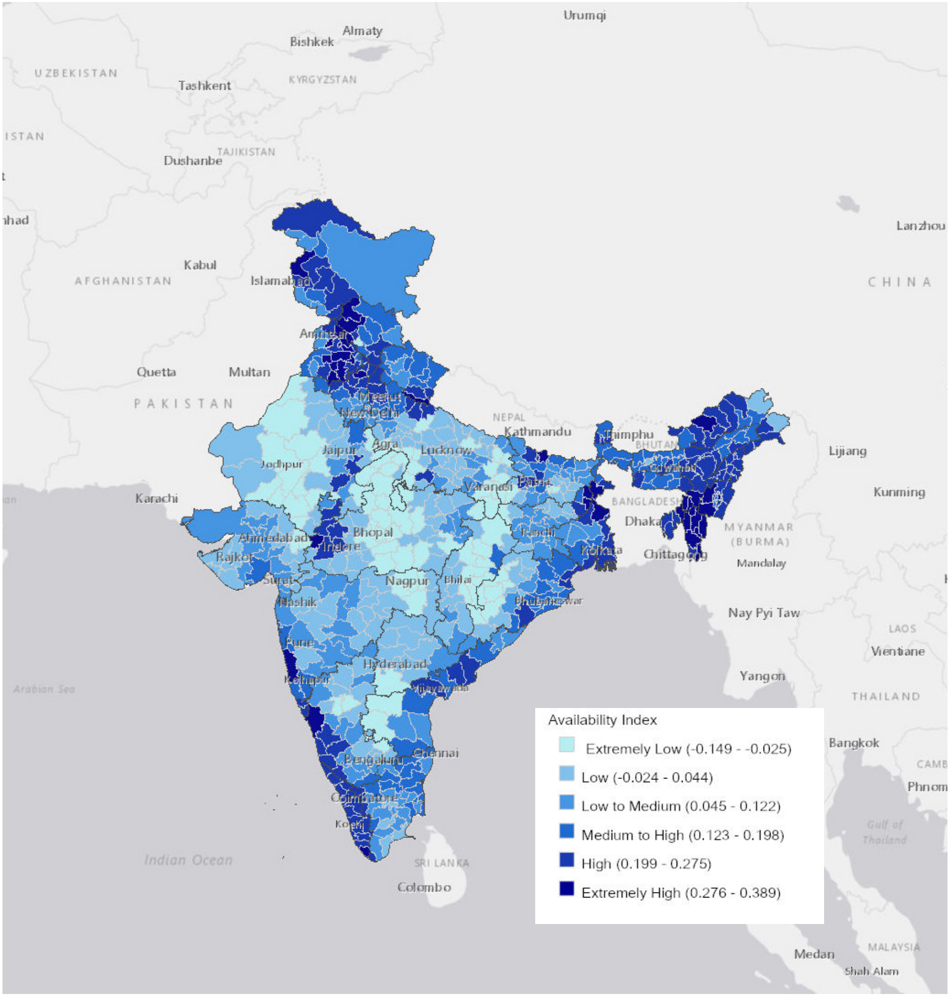
1.4 Health and Water Supply

Water is a vital element for all life forms on earth. Historically, humans have evolved around water, biologically, emotionally, and culturally. Our first civilisations were around major rivers, invariably across the globe. While our uses of water have changed and diversified over millennia, the interaction with water has also changed significantly. In our modern world, water is an important asset to maintain a healthy life, in which, not only the quantity, but the quality, access, and economics, reliability, and ease of management of water matter equally (Hunter, et al., 2010).

Research shows that there is a strong correlation between the GDP of a country or state, the infant mortality rate of the country, and the access to the inadequate water supply as shown in Figure 1.8 (Hunter, et al., 2010). While this is an argument in favour of an increased quantity of water to be supplied, it doesn't capture the importance of the quality and

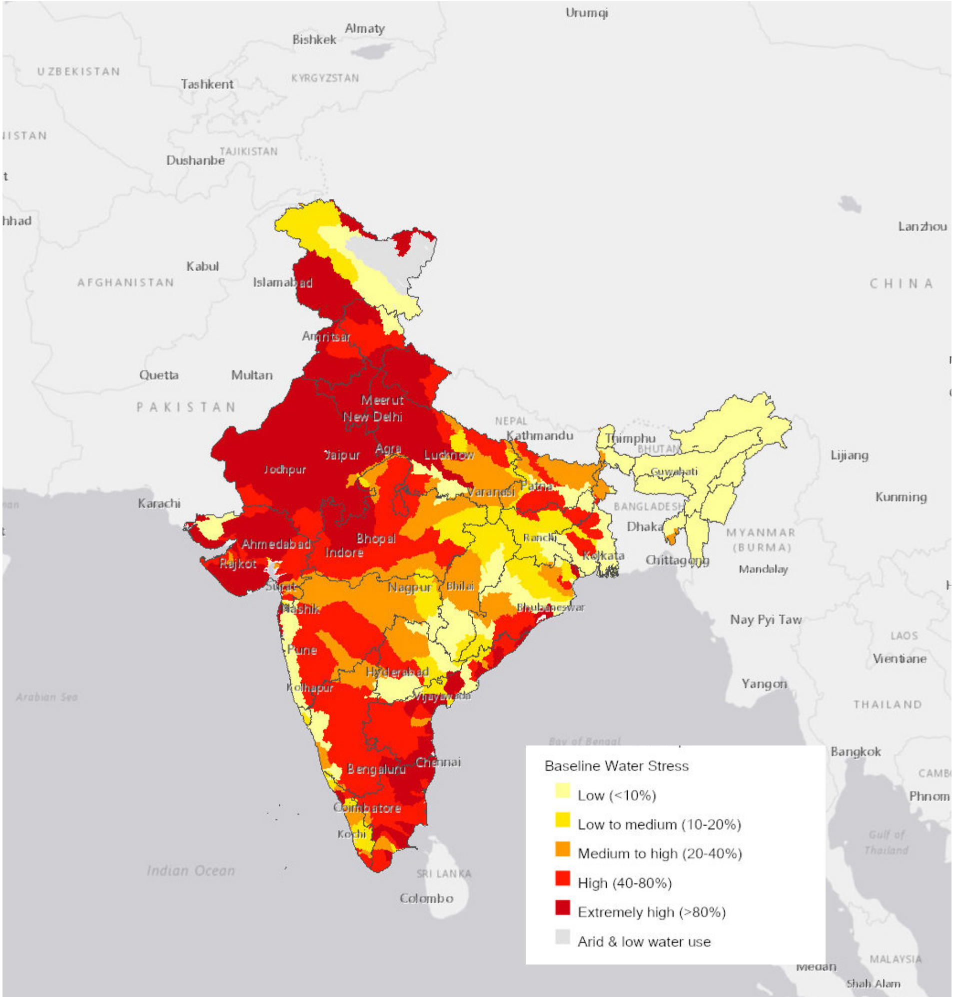
affordability of water. Exposure to heavy metals and chemicals through water leads to many diseases such as cancer, dental and skeletal fluorosis, foetal abnormalities, etc. Improved water supply is essential to a better living standard not only from a direct consumption point of view but also from the perspective to provide access to better sanitation for the abatement of diseases caused by unhygienic environments and living conditions.

Figure 1.6: Water Availability Index



Source- WRI, https://www.indiawatertool.in/

Figure 1.7: Baseline Water Stress

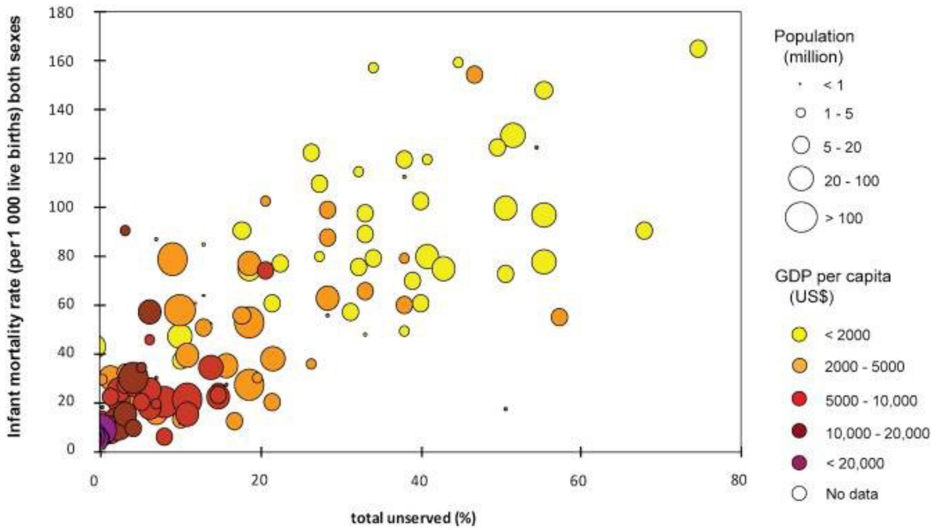


Source- WRI, https://www.indiawatertool.in/

1.5 Climate Change and Water- Interactions, Incidents and Impacts

The changing climate poses many threats to water resources around the world. This gets manifested in various forms and locations, irrespective of the origin of the issue. Water, in any state and form, is acted upon by the environment and the climate. Hence, the changing climate directly impacts the water cycle. It changes the natural rates and prerequisites water needs, to succeed through the cycle, thereby influencing the rates of freezing and melting of water. This results in a direct impact in form of floods, droughts, melting of glaciers, and rising sea levels. This, in turn, impacts the climate creating erratic weather patterns, causing extreme storms, scanty or above-average rainfall in non-rainy seasons, etc.

Figure 1.8: Global association between national access to an improved water source, GDP and infant mortality



Source- (Hunter, et al., 2010)

Secondly, climate change further increases the disparity in the availability of water, making access to water unequal and inequitable. Certain communities and sections of society get ample water for consumption, while others have less than the needed amount available for their usage. This changes the dynamics of relationships between communities, leading to conflict between communities, governments, states, etc. Many such cases have come to light in the past few decades, such as the Water Wars in Bolivia, the transboundary river water conflict between the states of Karnataka and Tamil Nadu in India, and the Day Zero in Johannesburg in 2018. Water Security becomes an important aspect that develops out of inequitable water availability and usage.

Thirdly, changing climate modifies the natural cycles of the earth which is extremely essential for the survival of most, if not all, species on earth. The erratic weather patterns influence the life cycles of various aquatic and terrestrial species, also affecting their dependence on resources and habitat patterns.

While the urban areas in India may not necessarily face all the issues as discussed above, disruptive weather events such as urban floods, seasonal water scarcity and extreme heat are becoming ever more common in India. In 2020 many major cities in India such as Mumbai, Hyderabad, Delhi, Guwahati, Dibrugarh, Jaipur, etc. have faced torrential rains and floods.

Managing urban water services and resources is imperative for all stakeholders including the government and citizens for securing water for their future. In India, while the citizens can create water movements at the grassroots level, important policy and management strategies from the ULBs and state agencies need to be implemented to complement the efforts of the citizens and nudge them in directions other than these efforts of the agencies.

While the management of water is an important aspect of its own, given the urgency of climate change, conscious efforts towards low-carbon emission projects and sustainable interventions are equally necessary. There is a need to invest in low-carbon emission projects and strategies not only to secure a better environment for ourselves, but also to achieve financial sustainability through low-cost natural strategies which are often also low energy-intensive and carbon-conscious, and generating revenue through mechanisms such as trading of carbon credits as per the guidelines of UNFCC and Kyoto Protocol at carbon markets.

1.6 Further Readings

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Chapter
2

Legislative Framework in India for UWM

Recap

The previous chapter spoke of water supply sector in urban India, with its linkages with health and climate, and providing aspects that need to be revisited to achieve the sanitation goals. This gives brief ideas towards urban water landscape in India.

Training Objectives

- To understand in brief the various Acts pertaining to urban water at National level.
- To understand the existing policies for water governance in India.
- To understand the relevant aspects and provisions for water supply management, in schemes and programmes of India.
- To know the relevant standards and norms for urban water supply in India.

Training Outcomes

- Gather understanding of the relevant provisions of acts and policies in India for urban water supply.
- Gather understanding of the relevant provisions of schemes and programmes in India for urban water supply.
- Awareness regarding important rules and standards for various aspects of urban water supply.

Chapter Contents

1.1 Acts

1.2 Policies

1.3 Schemes and Programmes

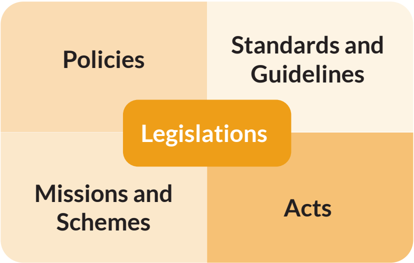
1.4 Norms, Guidelines and Standards

1.5 Further Readings

References

2.1 Introduction

Water Management is a complex system and therefore needs multi sectoral approach. It has to be approached from various dimensions. Legislation is an important aspect of water management in India. This chapter explores the legislative enabling environment for water management in India. The legislations include acts and rules, policies, missions and schemes, and standards and guidelines. The relevant legislations are mentioned in brief below.



2.2 Acts

The acts applicable for the India regarding water management are listed in Table 2.1. The following paragraphs briefly describe the relevant provisions of each Acts.

Table 2.1: Relevant Acts for water management in India

Sr. No.	Act
1	The Water (Prevention and Control of Pollution) Cess Act, 1977 (GoI, 1977)
2	The Environment (Protection) Act, 1986 (GoI, 1984)
3	National Green Tribunal Act, 2010 (GoI, 2010)

The Water (Prevention and Control of Pollution) Cess Act, 1977 (GoI, 1977)

The Water Cess Act was passed to generate financial resources to meet expenses of the Central and State Pollution Boards. The Act creates economic incentives for pollution control and requires local authorities and certain designated industries to pay a cess (tax) for water effluent discharge. The Central Government, after deducting the expenses of collection, pays the central and state boards such sums, as it seems necessary. To encourage capital investment in pollution control, the Act gives a polluter a 25% rebate of the applicable cess upon installing effluent treatment equipment.

Other important sections from the Act are as follows.

- **Section 3:** It prescribes for higher rates of cess in the event of the assesse not meeting the standards prescribed under the Environment Protection Act 1986 or with the provisions of Section 25 of the Water (Prevention and Control of Pollution) Act 1974.
- **Section 4:** The persons liable to pay cess should install water meters of such standards and at such positions
- **Section 5:** Every person liable to pay cess shall have to submit cess returns in the in the prescribed format periodically.

- **Section 9:** Any officer or authority of the state government, duly empowered on this behalf can enter any premises or any industry at any reasonable time for carrying out the functions as according to this Act including the testing of the correctness of the meters affixed under Section-4.
- **Section 10:** Interest of 2% for every month will be charged for those who fails to pay the cess amount.
- **Section 14:** The Act punishes the furnishing of a false return and wilful evasion of cess.

The Environment (Protection) Act, 1986 (GoI, 1984)

This Act covers all forms of pollution; air, water, soil and noise. It provides the safe standards for the presence of various pollutants in the environment. It prohibits the use of hazardous material unless prior permission is taken from the Central Government and it allows the central government to assign authorities in various jurisdictions to carry out the laws of this Act.

- **Section 3:** Some of the general powers to the Central Government listed are:
  - The central government has the authority to lay down the standards for different pollutants, and also the safe limit of emissions or discharge of wastes from industries.
  - It can restrict the areas in which industries can operate.
  - It has the power to lay down the safety measures and procedures for the prevention of accidents, and specify the protocol and remedies if such an accident occurs.
  - The central government has the responsibility to carry out and fund research on environmental pollution.
  - It needs to establish environmental laboratories.
  - It is responsible for the collection and dissemination of information related to environmental pollution.
- Chapter III of the legislation titled Prevention, Control and Abatement of Environment pollution has sections specifying the powers and steps that the government can take to tackle environment pollution.
- **Section 10:** Any person appointed by the central government the right to enter, within reasonable hours, at any place for inspection or examination.
- **Section 11** provides power to take samples and procedure to be followed in connection therewith. The results of such testing can be submitted as evidence during an investigation.
- **Section 12** allows the central government to establish environmental labs or declare existing labs as environmental labs. Such labs carry out all the testing of samples pertaining to any investigation under this Act. They also act as the official environmental referrers, for the central government.
- **Section 15** states that any person who is not complying to the provisions stated in this act and its failure or contravention will make him liable and punishable.

National Green Tribunal Act, 2010 (GoI, 2010)

The act provides for the establishment of a Green Tribunal, which is a special court dealing with cases related to environmental protection and conservation of natural resources and forests. It would replace the existing National Environment Tribunal and the National Environment Appellate Authority. The tribunal, which would function under the Supreme Court, shall have jurisdiction over all civil cases relating to environment and have powers to order relief and compensation to victims of pollution and other environmental damage, including accidents occurring while handling hazardous substance. Other salient features are:

- The tribunal shall consist of a full time Chairperson and full time judicial and expert member. Members of tribunal shall minimum 10 and maximum 20 in number from each judicial and expert member.
- The Chairperson, judicial members and expert members shall be appointed by central government in consultation with the chief justice of India and the judicial members and expert members shall be appointed on the recommendation of selection committee.
- The Tribunal shall have as the power of civil court to passing any order or decision or award. While passing any order or decision or award, he must apply the principle of sustainable development, the precautionary principle and the polluter pay principle.
- This Act also provides the appeal and review provisions. Any aggrieved person may appeal before Supreme Court against the tribunals order or decision or award. The tribunal shall have power to review its own decision.
- The tribunal shall have power to take cognizance of offence and impose penalty for failure to comply with any order or award or decision.

2.3 Policies

Apart from the laws, the following policies provide important directions for the authorities concerned with water management in India.

National Water Policy

The need for a national water policy is abundantly clear: water is a scarce and a precious national resource that needs to be planned, developed and conserved as such, in an integrated and environmentally sound basis, keeping in view the needs of the concerned states. The first National Water Policy, in 1987, put forth the importance of a well-developed standardized national information system for efficient planning and operation of water resources. It argued to enable a free exchange of data among various agencies to avoid data duplication and redundancy. The information system should include the availability and uses of water along with the projections for future.

National Water Policy, 1987

The National Water Policy, 1987 recommended the following for water management in urban India:

- National Water Policy (NWP) 1987, advocated the reuse and recycling of water.
- The policy aimed at providing drinking water for all by 1991.
- It mandated the annual provision for maintenance of water related structures and systems in budgets.
- Water allocation priority was set with highest priority given for drinking purpose and industrial use with least in the list.
- Fixing charges for water is important for ensuring the judicious use of the scarce resource as well as for the operation and maintenance of the systems and structures.
- Water quality of surface and ground water was another aspect addressed in the policy. It proposed regular monitoring for ensuring good quality.
- As per the policy of 1987, economic development and activities including agricultural, industrial and urban development, should be planned with due regard to the constraints imposed by the configuration of water availability.
- Water zoning of the country and the economic activities guided and regulated in accordance with such zoning was proposed.
- The policy had separate sections for flood and drought management. The necessity of flood control master plans for flood prone basins and efficient flood forecast & mitigation mechanisms were proposed.
- A perspective plan for standardized training as an integral part of water resource development was suggested. It was suggested to cover training in information systems, sector planning, project planning and formulation, project management, operation of projects and their physical structures and systems and the management of the water distribution systems.

National Water Policy, 2002

National Water Policy 2002 proposed some additions and changes to the previous one. The suggested changes are as follows:

- It advised the use of advanced information technologies for creating a modern information system with standards for coding, classification, processing of data and methods / procedures for its collection.
- Non-conventional methods for utilisation of water such as through inter-basin transfers, artificial recharge of ground water and desalination of brackish or sea water as well as traditional water conservation practices like rainwater harvesting, including roof-top rainwater harvesting, were proposed for further increase of utilisable water resources.
- It emphasized the importance of a multi-sectoral, multi-disciplinary and participatory approach in the institutional mechanism for integrating quality, quantity and the environmental aspects in water related projects planning and implementation.

- It also addressed the problems of over exploitation of ground water and necessity of implementation of ground water recharge techniques. Integrated and coordinated development of surface water and ground water resources and their conjunctive use was found to be important.
- Regarding the water rates, the policy added to the previous document that the rates have to be directly linked to the quality of service provided to the users and the subsidy on water rates to the disadvantaged and poorer sections of the society should be well targeted and transparent.
- A participatory approach involving users and the government agencies in various aspects of planning, design, development and management of the water resources schemes were found to be effective.
- NWP 2002 had also addressed the problems on water quality. Treatment of effluents to accepted levels or standards before discharging them into natural streams was found essential.
- Principle of 'polluter pays' was suggested for the management of polluted water.
- It also pointed out the necessity for legislation for preservation of existing water bodies by preventing encroachment and deterioration of water quality.

National Water Policy, 2012

The NWP 2012 was prepared not as an addendum to the previous two policies, but as a different entity in terms of the content of the document. It pointed out the need to evolve a National Framework Law as an umbrella statement of general principles governing the exercise of legislative and/or executive (or devolved) powers by the Centre, the States and the local governing bodies. In addition, the NWP suggests the following:

- A recommended minimum quantity of potable water for essential health and hygiene to all its citizens, was advised to be made available within easy reach of the household.
- A National Water Informatics Centre was proposed to collect, collate and process hydrologic data regularly from all over the country, conduct the preliminary processing, and maintain in open and transparent manner on a GIS platform.
- Climate change is likely to increase the variability of water resources affecting human health and livelihoods. Therefore, special impetus should be given towards mitigation at micro level by enhancing the capabilities of community to adopt climate resilient technological options. So, the policy suggested that anticipated increase in variability in availability of water because of climate change should be dealt with by increasing water storage in its various forms, namely, soil moisture, ponds, ground water, small and large reservoirs and their combination. The adaptation strategies could also include better demand management.
- Industrial processes should be made more water efficient.
- Direct use of rainfall, desalination and avoidance of inadvertent evapo-transpiration are the new additional strategies suggested for augmenting utilizable water resources.

- Ground water levels were found to be declining in some of the over- exploited regions and this needs to be arrested by introducing improved technologies of water use, incentivizing efficient water use and encouraging community based management of aquifers. In addition, where necessary, artificial recharging projects should be undertaken so that extraction is less than the recharge. This would allow the aquifers to provide base flows to the surface system, and maintain ecology.
- Demand management and efficient use of water was suggested. Water footprints and water auditing were proposed to promote and incentivize efficient use of water.
- An independent statutory Water Regulatory Authority, set up by each State, after wide ranging consultation with all stakeholders has to be responsible for ensuring equitable access and fair price for water.
- Periodic review of the charges, incentivizing efficient use and differential pricing for various uses were found as important strategies in water pricing.
- In addition to previous policy documents, NWP 2012 suggested the improvement of flood forecasting by linking with real time data acquisition system.
- The importance of methods for coping with floods or draughts were highlighted. Frequency based flood inundation maps should be prepared to evolve coping strategies, including preparedness to supply safe water during and immediately after flood events. Communities need to be involved in preparing an action plan for dealing with the flood/ drought situations.
- The policy finds need for a source with better reliability and quality to be assigned to domestic water supply.
- NWP 2012 suggested the integration of urban water supply and sewage treatment schemes and combining sewage charges with water bills. Reuse of urban water effluents from kitchens and bathrooms, after primary treatment, in flush toilets should be encouraged, ensuring no human contact.
- Urban domestic water systems were asked to collect and publish water accounts and water audit reports indicating leakages and pilferages.
- Industries in water short regions may be allowed to either withdraw only the makeup water or should have an obligation to return treated effluent to a specified standard back to the hydrologic system.
- The policy pointed out that the importance of a national campaign for water literacy for capacity building of different stakeholders in the water sector.

2.3 Schemes and Programmes

To improve the living standards of the people, there are various schemes and flagship programmes run by the various governments in India. The following paragraphs mention the relevant ones and their provisions with respect to water management.

National Water Mission (National Water Mission, GoI, 2011)

National Action Plan on Climate Change (NAPCC) has been prepared by the Government of India, which has been released by the Hon'ble Prime Minister on 30th June 2008. The NAPCC has laid down the principles and has identified the approach to be adopted to meet the challenges of impact of climate change through eight National Missions. National Water Mission is one among that. The main objective of the National Water Mission is "conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within States through integrated water resources development and management".

The five identified goals of the Mission are shown in Figure 2.1.

Figure 2.1: Goals of National Water Mission

Comprehensive water data base in public domain and assessment of impact of climate change on water resource
Promotion of citizen and state action for water conservation, augmentation and preservation
Focused attention to vulnerable areas including over-exploited areas
Increasing water use efficiency by 20%
Promotion of basin level integrated water resource management

Source – Author

Water resources schemes and projects are multidisciplinary in nature and are implemented by several departments and agencies of State Governments and various ministries/ departments of Central Government. Therefore, it has been considered necessary to examine all related issue through a consultative process. Accordingly, the then Ministry of Water Resources (MoWR) constituted six Sub-Committees to examine all related aspects in the field of:

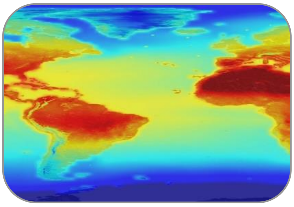
- Policy and Institutional Framework;
- Surface Water Management;
- Ground Water Management;

- Domestic and Industrial Water Management;
- Efficient Use of Water for Various Purposes and
- Basin Level Planning and Management

Salient Features of the National Water Mission are mentioned in Figure 2.2.

Figure 2.2: Salient Features of National Water Mission

Review of National Water Policy



Research and studies on all aspects related to impact of climate change on water resources including quality aspects of water resources

Expeditious implementation of water resources projects particularly the multipurpose projects with carry over storages

Promotion of traditional system of water conservation

Intensive programme for ground water recharge in over-exploited areas

Incentivize for recycling of water including wastewater

Planning on the principle of integrated water resources development and management

Ensuring convergence among various water resources programmes

Intensive capacity building and awareness programme including those for Panchayati Raj Institutions, urban local bodies and youths

Source – Author

Atal Mission for Rejuvenation and Urban Transformation (AMRUT) (MoHUA, GoI, 2015)

Atal Mission for Rejuvenation and Urban Transformation (AMRUT) was launched by Prime Minister of India in June 2015 with the focus to establish infrastructure that could ensure adequate robust sewage networks and water supply for urban transformation by implementing urban revival projects. The purpose of AMRUT is to:

- Ensure that every household has access to a tap with the assured supply of water and a sewerage connection.
- Increase the amenity value of cities by developing greenery and well maintained open spaces (e.g. parks) and
- Reduce pollution by switching to public transport or constructing facilities for non-motorized transport (e.g. walking and cycling). All these outcomes are valued by citizens, particularly women, and indicators and standards have been prescribed by the Ministry of Housing and Urban Affairs (MoHUA) in the form of Service Level Benchmarks (SLBs).

The Mission is planned to focus on the following thrust areas as mentioned in Figure 2.3.

Figure 2.3: Thrust Areas of Atal Mission of Rejuvenation and Urban Transformation

Water supply:
Augmentation of existing water supply, water treatment plants and universal metering.
Rehabilitation of old water supply systems, including treatment plants.
Rejuvenation of water bodies specially for drinking water supply and recharging of ground water.
Special water supply arrangement for difficult areas, hill and coastal cities, including those having water quality problems (e.g. arsenic, fluoride).
Recycling/reuse of water water and reduction of non-revenue water.

Sewarage facilities and septage management

Storm water drains to reduce flooding

Pedestrian, non-motorized and public transport facilities, parking spaces

Enhancing amenity value of cities by creating and upgrading green spaces, park and recreation centers, especially for children

Source – Author

The Mission focuses on development of basic urban infrastructure in water supply sector in the Mission cities with the expected outcome of Universal coverage for access to potable water for every household in Mission cities. This includes end to end solution to facilitate universal coverage of household water supply such as source improvement work, water treatment plants, storage facilities like underground and & overhead tanks (OHT), distribution network, improvement in pumping machinery and universal metering.

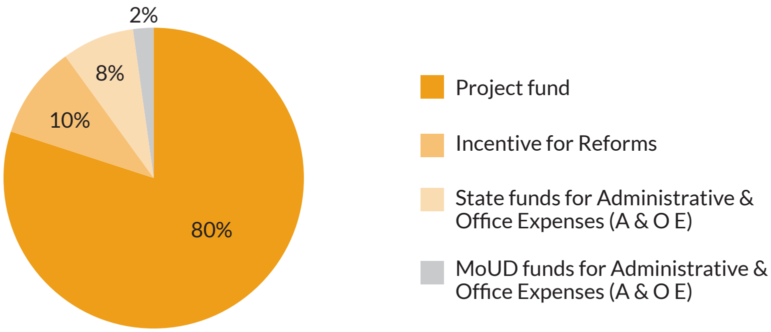
Five hundred cities are taken up under AMRUT. The category of cities that will be covered in the AMRUT are:

- All Cities and Towns with a population of over one lakh with notified Municipalities, including Cantonment Boards (Civilian areas),
- All Capital Cities/Towns of States/ UTs, not covered in above.
- All Cities/ Towns classified as Heritage Cities by MoHUA under the HRIDAY Scheme
- Thirteen Cities and Towns on the stem of the main rivers with a population above 75,000 and less than 1 lakh, and
- Ten Cities from hill states, islands and tourist destinations (not more than one from each State).

The total outlay for AMRUT is Rs. 50,000 crores for five years from FY 2015-16 to FY 2019-20 and the Mission is operated as a Centrally Sponsored Scheme.

The Mission funds consist of four parts as mentioned in Figure 2.4.

Figure 2.4: Annual budgetary allocation of Mission Funds



Source – Author

The project fund is divided among States/UTs at the beginning of each year. An equitable formula is used to distribute the annual budgetary allocation in which equal (50:50) weightage is given to the urban population of each State/UT (Census 2011) and the number of statutory towns in the State/UT. As the number of statutory towns are notified by States/ UTs and change during the Mission period, the formula takes into account changes in this number every year. The Central Assistance for the projects was in three instalments of 20:40:40 of the approved cost.

The projects related to water supply, sewerage, septage, urban transport and storm water drains have one-third of the project cost as grant from GoI for cities with a population of above 10 lakh or one-half of the project cost as grant for cities/towns with population up to 10 lakh and balance funding by State Governments / ULBs or through private investment.

Universal coverage of water supply is the priority sectors under the Mission. At the inception of AMRUT, the water supply coverage was 64%. By the end of the Mission, it aims to cover 100% households. The target is to provide 139 lakh water tap connections to achieve universal coverage. So far 22.89 lakh tap connections have been provided. Against the total plan size of Rs.77,640 crore of all the State Annual Action Plans (SAAPs), Rs.39,011 crore (50%) has been allocated to water supply. A comparison of Sanctioned funds and Dispatched funds for the five pilot cities under SCIAP are given in Table 2.2.

Table 2.2: Comparison of Sanctioned and Dispatched funds under AMRUT for the five pilot cities under SCIAP

City	SAAP Sanctioned Fund for water supply (in Crores)	Dispatched Fund (in Crores)
Guntur (A.P.) (GoAP, 2017)	25	2.91
Vijayawada (A.P.) (GoAP, 2017)	-	-
Mysore (Karnataka) (GoK, 2017)	77.16	10.802
Jaipur (Rajasthan) (GoR, 2017)	-	-
Bhopal (M.P.) (GoMP, 2017)	316	-

Source – Author's compilation

Smart City Mission (MoHUA, 2015)

The Government of India launched its flagship program, 'Smart Cities' on 25th June 2015. As part of the program, the government has decided to develop 100 Smart Cities by 2024. It aims to address challenges associated with India's rapid growth and massive urbanization in coming years. Smart Cities Mission envisions developing an area within 100 cities in the country as model areas based on an area development plan, which is expected to have a rub-off effect on other parts of the city, and nearby cities and towns. Cities were selected based on the Smart Cities challenge, where cities competed in a countrywide competition to obtain the benefits from this mission. In June 2018, 100 smart cities have been selected under the Smart Cities Mission.

The objective is to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions. The focus is on sustainable and inclusive development and the idea is to look at compact areas, create a replicable model which will act like a light house to other aspiring cities.

The core infrastructure elements in a Smart City include various sectors. These have been listed in Figure 2.5.

Figure 2.5: Core infrastructure elements of the Smart City

Source – Author

The strategic components of Area-based development in the Smart Cities Mission are:

1. Pan-city initiative in which at least one Smart Solution is applied city-wide
2. Develop areas step-by-step – three models of area-based developments
    - **Retrofitting** will introduce planning in an existing built-up area to achieve Smart City objectives, along with other objectives, to make the existing area more efficient and liveable.
    - **Redevelopment** will effect a replacement of the existing built-up environment and enable co-creation of a new layout with enhanced infrastructure using mixed land use and increased density.
    - **Greenfield** development will introduce most of the Smart Solutions in a previously vacant area (more than 250 acres) using innovative planning, plan financing and plan implementation tools.

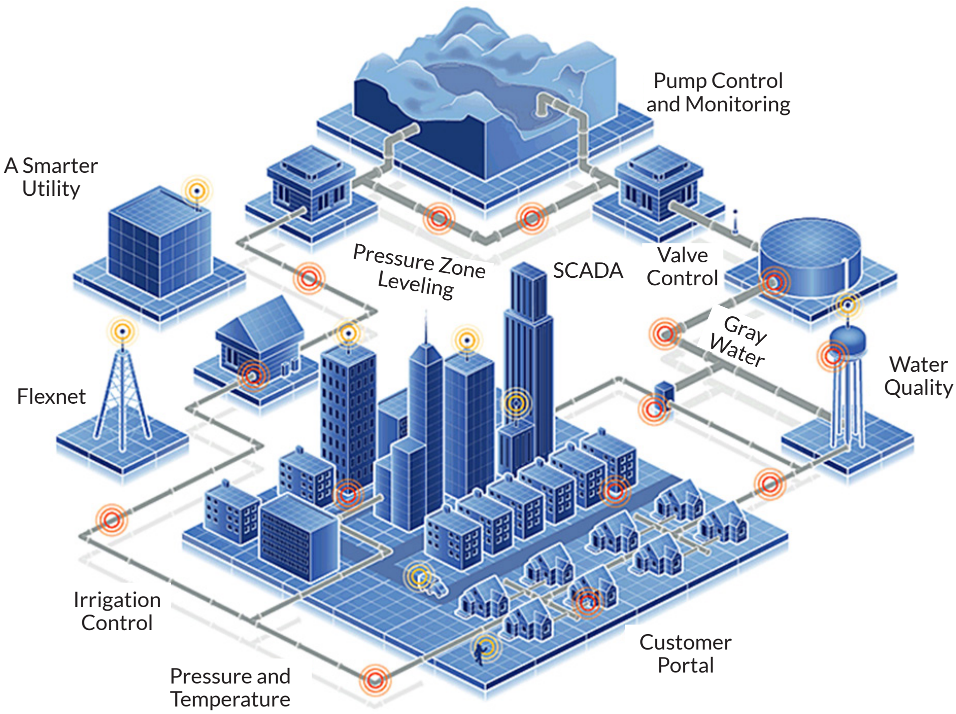
The Smart City Mission is operated as a Centrally Sponsored Scheme (CSS) and the Central Government proposed to give financial support to the Mission to the extent of Rs. 48,000 crores over five years i.e. on an average Rs. 100 crores per city per year. An equal amount, on a matching basis, is contributed by the State/ULB; therefore, nearly Rupees one lakh crore of Government/ULB funds is available for Smart Cities development.

Comprehensive development occurs in areas by integrating the physical, institutional, social and economic infrastructure. Many of the sectoral schemes of the Government converge in this goal, although the path is different. There is a strong complementarity between the AMRUT and Smart Cities Mission in achieving urban transformation. While AMRUT follows a project-based approach, the Smart Cities Mission follows an area-based strategy. The progress of smart cities is monitored at national level, state level and city level by Apex Committee, High Powered Steering Committee and Smart City Advisory Forum respectively.

Case Study - Smart Water Network Project at Thiruvananthapram

Highlights	
Location	Thiruvananthapuram, Kerala, India
Estimated Cost	58.55 Crores

Figure 2.6: Schematic Diagram of the Smart Water network



Source - Smart City Thiruvananthapuram Ltd. (2020)

This smart water network will enable 24 x7 water supply and metering the entire water supply network through a combination of conventional meters and Automatic Meter Reading (AMR). The AMRs would be installed for bulk consumers and at the distribution zones at ABD area. Pressure sensors and water quality sensors would be installed to monitor the service parameters across the network and Supervisory Control and Data Analysis (SCADA) based monitoring system for the entire network. Billing would be done using handheld devices and payments would be enabled through web and mobile. This data will also be integrated to ICCC which is central control command centre where top decision makers can sit and analyse in an integrated and holistic manner with other respective departments and authorities to solve the emergency raised in city (Smart City Thiruvananthapuram Ltd, 2020).

Jal Shakti Abhiyan (MoHUA, GoI, 2019)

The Jal Shakti Abhiyan is a campaign for water conservation and water security in the country. The campaign will run through citizen participation in two phases, firstly, during the monsoon season, from 1st July, 2019 to 15th September, 2019 and then from 1st October, 2019 to 30th November, 2019 for states receiving the North East retreating monsoons.

It is a collaborative effort of various ministries of the Government of India and state governments, being coordinated by the Department of Drinking Water and Sanitation (DDWS) that comes under the Jal Shakti Ministry. The focus of the campaign is on water stressed districts and blocks. The teams of officers from the central government will visit and work with district administration in 1592 water stressed blocks in 256 districts, to ensure five important water conservation interventions.

The five important water conservation interventions are:

- Water conservation and rainwater harvesting,
- Renovation of traditional and other water bodies/tanks,
- Reuse of water and recharging of structures,
- Watershed development and
- Intensive afforestation.

2.4 Norms, Guidelines and Standards

There are various agencies that are responsible for setting the norms and standards for overall water management to be referred by the various governments and private entities. The following table describes the standards and norms related to water prescribed by these agencies.

Table 2.3: Standards and norms concerning water management and its various aspects

Standards/ Guidelines	Agency	Focus
Water Quality	BIS[1]	• IS 10500 : 2012 Drinking Water — Standards & Specifications. • IS 15185 : 2016, IS 15186 : 2002, IS 15187 : 2016 Methods for detection of *E-coli* & coliform bacteria, intestinal enterococci and salmonella species respectively. • Other tests: IS 15188 : 2012, IS 15669 : 2006, IS 15670:2006. • IS 12918 : 1990 Guide for removal of iron from water for rural drinking water supply (Chemical Treatment Method).
Standards for various plumbing components	BIS	• SP 57 (QAWSM) : 1993 Handbook on pipes and fittings for drinking water supply. • IS 13114 : 1991 Forged brass gate, globe and check valves for water works purposes • IS 13349 : 1992 Cast Iron Single Faced Thimble Mounted Sluice Gates • IS 14845 : 2000 Resilient seated cast iron air relief valves for water works purposes - specification • IS 2692 : 1989 Ferrules for water services • IS 9739 : 1981 Pressure reducing valves for domestic water supply systems • IS 3004 : 1979 Plug cocks for water supply purposes • IS 4038 : 1986 Foot Valves For Water Works Purposes • IS 4346 : 1982 Washers For Use With Fittings For Water Services
Standards for measurement of water & water meters	BIS	• IS 14615 Part I: 1999 : 2018 Measurement of fluid flow by means of pressure differential devices • IS 779 : 1994 Water meters (Domestic Type) • IS 2373 : 1981 Water Meters (Bulk Type) • IS 6784 : 1996 Reaffirmed Year : 2017 Methods for Performance Testing of Water Meters

[1] *Bureau of Indian Standards*

Standards/ Guidelines	Agency	Focus
Standards for water treatment	BIS	• IS 9222 : Part 1 : 1990 Recommendations for handling and dosing devices for chemicals for water treatment: Part 1 –coagulants • IS 10037 : Part 1 : 1981 Requirements for sludge dewatering equipment • IS 10313 : 1982 Requirements for settling tank (clarifier equipment) for water treatment plant • IS 10553 : 1983 Requirements for chlorination equipment
Ground water sampling and recharge	BIS	• IS 13969 : 1994 Sampling of Ground water - Guidelines • IS 15792 : 2008 Artificial recharge to ground water guidelines • IS 15797 : 2008 Roof top rainwater harvesting - Guidelines • IS 15896 : 2011 Manual methods for measurement of ground water level in a well
Advisory on Water Meters, Instrumentation & SCADA (CPHEEO, 2020)	CPHEEO[2]	• Details of various types of water meters with their advantages & disadvantages, guidelines for installation, measures for repairs, maintenance and troubleshooting of water meters are mentioned.
Advisory on Pipe Materials for Transmission of Water (CPHEEO, 2020)	CPHEEO	• Depending on topography and local conditions, conveyance may be designed for free flow (gravity flow) channel or conduit or pressure conduits. Transmission of water accounts for an appreciable part of the capital outlay and hence careful consideration of the economics is called for, before deciding on the best mode of conveyance. While water is being conveyed, it is necessary to ensure that there is no possibility of pollution from surrounding areas.
Advisory on GIS Mapping of Water Supply and Sewerage Infrastructure (CPHEEO, 2020)	CPHEEO	• This emphasise on bringing in harmony among the spatial, social, economic and environmental aspects of a city/towns, and their inhabitants, for successful timely execution of the projects & effective operation and maintenance of Water supply & Sewerage infrastructure across India.
Advisory on Control Valves for Water Supply Systems (CPHEEO, 2020)	CPHEEO	• This provides technical details including specifications, general requirements, advantages, limitations, applications etc. of various types of control valves depending on the design and functions to be performed.
Manual on Water Supply and Treatment Systems (CPHEEO, 1999)	CPHEEO	• Includes basic norms, standards and latest developments in water supply and treatment systems.

[2] *Central Public Health and Environmental Engineering Organisation*

Standards/ Guidelines	Agency	Focus
Manual on Operation & Maintenance of Water Supply System (CPHEEO, 2005)	CPHEEO	• A guide to strengthen the technical, operational and managerial capabilities required of the concerned personal to operate and maintain water supply services as per acceptable norms of quantity quality, sustainability, reliability and cost.
Manual on Rainwater Harvesting and Conservation (CPHEEO, 2002)	CPHEEO	• A guide to operationalize the efficient use of rain water for recharging the ground water and direct application.

Source – Author's compilation

2.5 Further Readings

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Chapter

3

Integrated Urban Water Management

Recap

Understanding the water supply sector in urban India with respect to the legislative framework at the central level. Various policies were explored around water management. In conclusion, the norms and standards applicable in various aspects of urban water management were listed.

Training Objectives

- To understand the urban water cycle.
- To understand the concept of IUWM.
- To familiarise the audience with the framework and principles of IUWM
- To understand the phases involved in planning for IUWM.

Training Outcomes

- Gain understanding of the urban water cycle.
- Understand IUWM and its framework.
- Understand the framework of IUWM.
- Ability to understand its implementation principles.

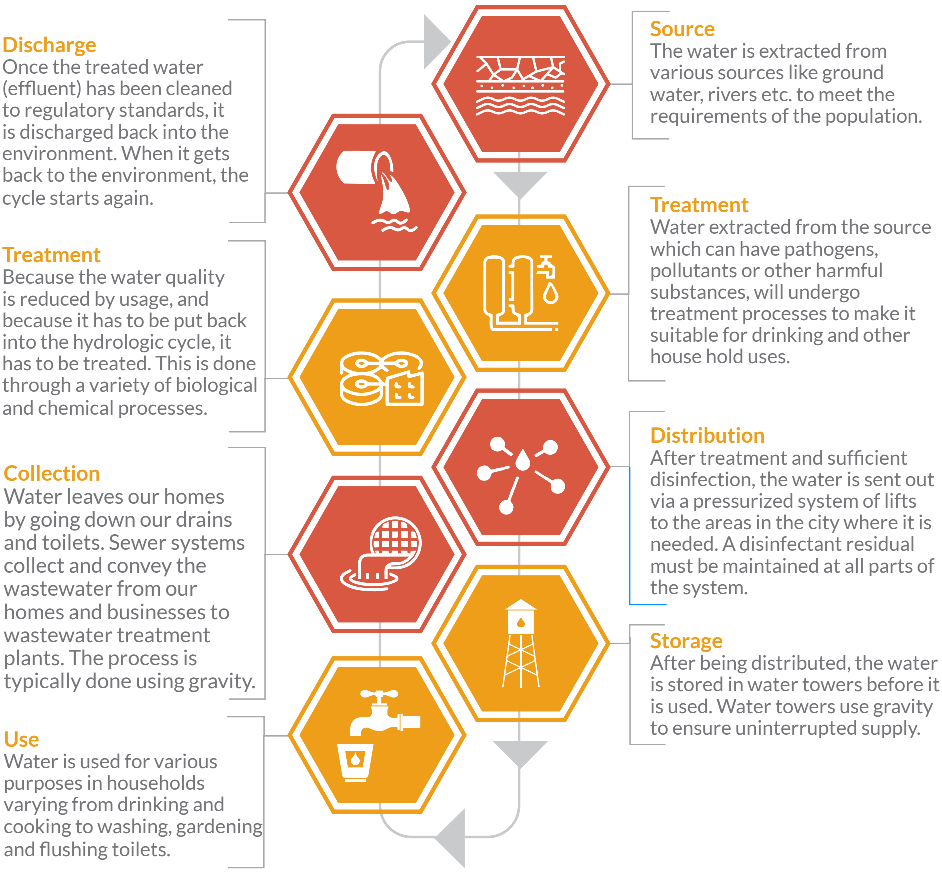
Chapter Contents

3.1 Urban Water Cycle
3.2 Concept of IUWM
3.3 Need for IUWM
3.4 Framework of IUWM
3.5 Principles of IUWM
3.6 Process of IUMW
3.7 Enabling Framework
3.8 IUWM Tools and strategies
3.9 Challenges to IUWM
3.10 Phases to strategic planning for IUWM
References

3.1 Urban Water Cycle

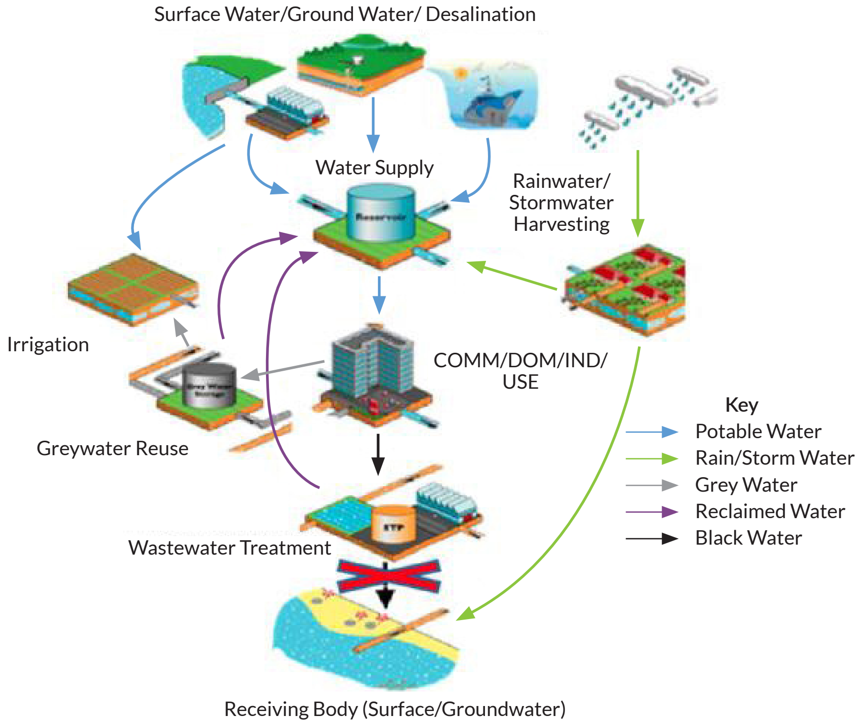
The basics of the hydrologic cycle, or the water cycle, are condensation, precipitation, transportation, and evaporation. These processes operate on global scales and in natural environments. But on local scales and in engineered environments like cities, a different cycle dominates — the urban water cycle. The urban water cycle includes components such as water treatment, distribution, stormwater drainage, wastewater drainage, wastewater treatment, recycling or disposal. This consists of an interaction of the natural water cycle with the social water cycle. Important stages in the urban water cycle are shown in Figure 3.1 and Figure 3.2.

Figure 3.1: Stages of Urban Water Cycle



Source – Author

Figure 3.2: Urban Water Cycle



Source — Khatri, et al. (2014)

The excessive human intervention caused some distortions to the natural solar water cycle. A large area of impervious pavements affects the groundwater recharging and result in an increased run-off to the sea. To tackle this, direct extraction of precipitation and artificial recharging of groundwater has been practised in various cities. Climate change poses a great threat to the existing urban water cycle; there is a noticeable increase in the variability of precipitation and the reliability of water sources throughout the year. Efficient water management strategies are thus required for ensuring the sustainability of water services in cities, because water unlike most resources, does not stay limited to any geopolitical and physical boundaries created by man. Because of this transient and fluid nature of water, any pressure or impact to the water resources or the dynamics of the interaction of water with other resources, such as soil, air, climate, etc., results in changes in the dynamics of the water cycle.

3.2 Concept of Integrated Urban Water Management

The availability of water for cities in the catchment of a river is shrinking due to land-use changes, demands for irrigation and energy, environmental degradation, climate change, and new urban settlements upstream. Often there is not enough water to satisfy all users. Integrated Urban Water Management (IUWM) is an approach that seeks to develop efficient and flexible urban water systems by adopting a diversity of existing technologies, management, and institutional practices to supply and secure water for urban areas. The focus of this approach is the integration of planning, management, and stakeholder participation across institutions at each stage. IUWM's view on the urban water cycle is a holistic one by which all components of the cycle (water supply, sanitation, stormwater management) are integrated within the wider watershed. IUWM offers a set of principles that underpin better coordinated, responsive, and sustainable resource management practice (Vairavamoorthy *et al.*, 2015).

The characteristics of IUWM are:

- Recognizes alternative water sources.
- Differentiates the qualities and potential uses of water sources.
- Consideration of water storage, distribution, treatment, recycling, and disposal as part of the same resource management cycle.
- Seeks to protect, conserve and exploit water at its source.
- Accounts for rural and peri-urban users that are dependent on the same water source.
- Aligns formal institutions (organizations, legislation, and policies) and informal practices (norms and conventions) that govern water in and for cities.
- Recognizes the relationships between water resources, land use, and energy.
- Simultaneously pursues economic efficiency, social equity, and environmental sustainability.
- Encourages participation by all stakeholders.

Unlike conventional water management systems, IUWM promotes the use of wastewater, considers stormwater as a resource that can be collected, and enables the integration and decentralization of institutional arrangements involved in different stages of the urban water cycle (Khatri, et al., 2014).

3.3 Need for IUWM

Today cities all over the world are facing a range of challenges due to dynamic regional and global pressures that impact the way urban water systems are managed. The most important of these global change pressures are population growth, urbanization, climate change, ageing infrastructure and emerging contaminants. These change pressures will exacerbate the challenges of conventional urban water management problems in addition to their inherent drawbacks. It is anticipated that with the increasing global and local change-pressures the business as usual approach will be unsustainable and not suited to achieve the goal of global coverage of water and sanitation, resulting in the danger of a steady decline of the health and well-being of citizens.

An integrated approach to urban water management addresses the challenges created by the conventional systems of water management and its problems. These issues of a conventional system of water management that IUWM addresses are as follows:

- **Fragmentation** – The various elements of the urban water system are often operated in isolation. Such a fragmented approach can result in technical choices that are based on the benefits to an individual part of the system but may neglect the impacts caused elsewhere.
- **Short-term solutions** – Water management in both developing and developed countries often focus on today's problems, opting for short-term solutions despite the risk that the implemented measures are not cost-effective or sustainable in the long-term.
- **Lack of flexibility** – Conventional water infrastructure and management tend to be inflexible to changing circumstances. Water supply, wastewater treatment and stormwater drainage systems are constructed to match fixed capacities and when these are exceeded, problems occur. Likewise, the management of these systems becomes dysfunctional when faced, for example, with increasing climate variability and rapidly growing urban demand.
- **Energy-intensive** – Conventional water distribution and treatment infrastructure are energy-intensive. Power cuts and rapid increases in fuel costs can disrupt services. Intensive energy use also results in high levels of CO_2 emissions at a time when many cities are trying to reduce their carbon footprint.

In IUWM, all aspects of the urban water cycle are treated as one system, and all relevant institutions are involved in ensuring that such integration is achieved. Preference is given to innovative and flexible technologies that have been selected based on a holistic evaluation of the water cycle and the long-term sustainability of the system as a whole.

3.4 Framework of IUWM

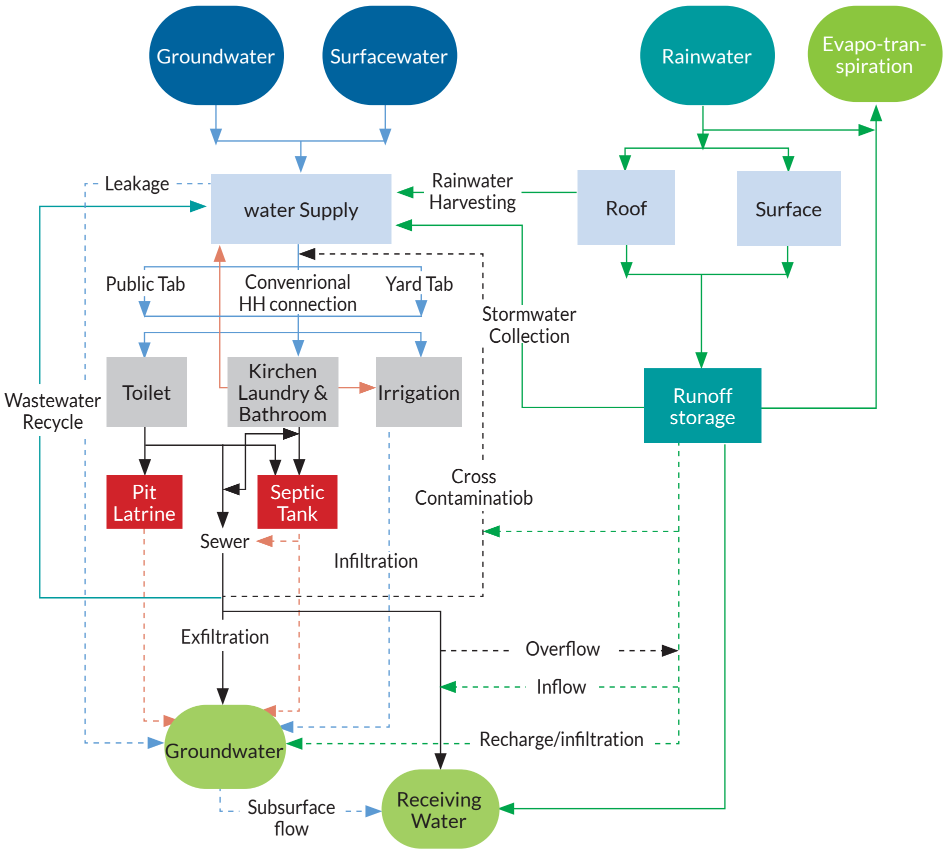
An integrated urban water management framework is an important instrument to consider when operationalizing IUWM. The framework for IUWM is based on an integrated urban water cycle model including approaches of system engineering. It includes both 'standard' urban water flows (potable water, wastewater, and runoff), as well as their integration through recycling schemes (greywater, reclaimed water, and rainwater harvesting). The framework emphasizes the linkages within the urban water cycle. It facilitates a structured and holistic analysis of water management strategies. When ignored, the interactions between the different elements of the urban water cycle can affect each other negatively, while at the same time, positive synergies can be missed. To capture the complex interactions and linkages, modelling tools for IUWM are required to predict the impacts of possible interventions throughout the system.

Some characteristics of the IUWM framework are:

- **Integration of all parts of the urban water cycle:** IUWM considers all subsystems in the urban water cycle such as water supply, wastewater, stormwater and solid waste management. IUWM aims to take advantage of positive interactions between the different subsystems of the urban water systems and to minimize negative impacts.
- **Integration of all water uses:** IUWM takes all water uses into account both human and ecological. The objective is to provide water services to communities while at the same time ensuring the ecological integrity of the natural environment. IUWM aspires to integration across all social, economic and environmental dimensions, looking for approaches to optimize water use for different sectors.
- **Integration of all institutions, stakeholders and water users:** IUWM aims at institutional integration which enhances communication, collaborative organizational relationships, sectoral coordination, community participation and stakeholder engagement and information sharing.
- **Integration of all urban services:** IUWM addresses the complex interactions of urban infrastructure systems, the physical environment, the level of services and social factors. The interactions between the different urban services like urban water system, transport, housing, communication and other utilities are considered.
- **Integration of different spatial scales:** IUWM considers different spatial levels from the whole region down to the single site to address the complex interactions of the urban water system. In this regard, individual sites fit as incremental parts in the management strategy of the catchment.

Figure 3.3 shows an example of the IUWM framework for low-income areas.

Figure 3.3: Integrated Urban Water Management framework for Low-Income Areas



Source — Adapted from Khatri, et al. (2014)

3.5 Principles of IUWM

The concept of IUWM is based on certain principles which have evolved to overcome the shortcomings of conventional water management practices within a city, to provide sustainable and inclusive access to water. These principles showcase how working with an IUWM-based approach is different from how we conventionally work with urban water sectors in our cities (Tandon, et al., 2017).

- Recognizes the significance of the local context and addresses it from an environmental, social, cultural and economic perspective. Local consultation is also ensured by the conventional water management approach.

- Includes all stakeholders in the planning and decision-making process, while the usual practice involves the last stage participation for approval or objections.
- Acknowledges that water can have multiple uses, and matches water quality (surface, recycled, reclaimed) with water use so that different quality of water can be used for different uses. This overcomes the unnecessary treatment of all-purpose water to drinking water standards.
- Addresses all water requirements: anthropogenic as well as ecological. Accounts for non-urban users that are dependent on the same water source. Ecological flows, rural and other marginalized stakeholders are given representation in the planning process.
- It considers all parts of the water loop, natural and manmade, surface and subsurface while recognizing them as a part of an integrated system. This approach plans an integrated system for water supply along with provisions for recycle, reuse and recharge.
- Recognizes water storage, distribution, treatment, recycling and disposal as part of the same resource management cycle. Dedicated entities/parastatals can be constituted for the integration of urban water sectors; as well as integration with other urban sectors. Source management is done by the Irrigation Department and water supply management is carried out by the Municipal authority in a conventional system.
- Seeks to protect, conserve and utilize water resources at the source which was not taken care of in the conventional approach.
- Encompasses alternative water sources. This principle seeks to promote water extraction from multiple sources which hasn't been the prevalent practice.
- Recognizes linkages between water, land use and energy. Currently, water land use and energy are separate sectors managed by separate departments.
- It aligns formal institutions (organisations, legislation, and policies) and informal practices (norms and conventions) that govern water in and for cities, where private water tanker suppliers are not recognized in the present scenario.
- Aims at sustainability, efficiency and equity; while balancing environmental, social and economic needs (and sustainability) for the short, medium and long term. A balance between demand and supply is crucial.
- Recognizes impacts of climate change and vulnerability of urban poor to extreme events, and seeks to address these.
- Recognizes the need for capacity building and mobilization of stakeholders.

3.6 Process of IUWM

The IUWM process is cyclic: once the city has completed one cycle of the IUWM process, it should periodically revisit the process (in totality or parts) for continued integration of urban water sectors. The IUWM Process is divided into six main stages as given below:

Figure 3.4: Process of IUWM

Source - Author

3.7 Enabling Framework

There are different factors responsible for providing an enabling environment for the implementation of the framework for IUWM. They are described in the following sections.

Stakeholder involvement

The IUWM approach depends on stakeholders' engagement in designing and managing urban water systems. Although widely accepted in principle, stakeholder engagement can vary substantially. In some cases, it entails genuine involvement in decision-making; in others, it amounts to informing people about decisions already taken. All user groups should participate in designing or restructuring systems for basic services. Participation in project planning, municipal planning, and budgeting can ensure appropriate design and informed contributions that improve living conditions, particularly in low-income settlements.

Legal mechanisms may be needed to define the roles for stakeholders and set the conditions for the involvement of groups not traditionally considered relevant for urban decision-making, such as upstream farmers' associations, industry representatives, and energy utilities. In addition to forging upstream-downstream linkages, legislation can also be a vehicle for cross-sectoral integration. Laws guaranteeing the right to wastewater encourage farmers to install appropriate treatment and irrigation infrastructure; they also establish standards for water quality and monitoring authority for public health purposes (Bahri, 2012).

Internal coordination in administration

IUWM requires the participation and cooperation of various departments and institutions that may not be accustomed to working together. Different options may be considered on how to position the coordination unit within given administrative structures. These include:

- A separate, higher-level office that oversees all relevant departments and institutions.
- A unit within or associated with an existing department or institution.

The coordination unit can also play a role in collaborating with relevant players beyond the local boundaries. IUWM purposefully centres on the city boundaries as the planning arena over which the local government has control (Philip & Anton, 2011).

Role of local politics

IUWM can only be achieved if management units are working in coordination with the politicians who are directing local development and allocating the accompanying finances and other resources. A formal endorsement by the Municipal Corporation, or equivalent, to gain high-level support for the strategic planning process is therefore essential to put the transformation in motion (Philip & Anton, 2011).

Also, strong political backing is necessary:

- To gain legitimacy for the IUWM approach and the strategic planning process;
- To gain credibility vis-à-vis the stakeholders;
- To formalize the process of involving the stakeholders and get the outputs and results of their collaboration officially acknowledged;
- To initiate and realise the necessary institutional reforms; and
- To maintain the motivation of all people involved despite setbacks.

Decentralized approach

The application of an integrated approach to urban water management and in particular, harvesting of resources, appears to foster a more decentralized approach to urban water management. The clustered approach allows us to grow our systems in stages and line with urban growth (less anticipation required), creates greater benefits from improved urban water management as it encourages resource recovery, it creates a diversity of solutions that allows exploitation of local sources. In decentralized systems, water is abstracted, used, reused and discharged within short distances.

In addition to being more efficient, decentralized systems are generally more resilient – better equipped to withstand or bounce back from major disruption – than centralized systems. Decentralized systems are smaller and easier to locate in less flood-prone areas, and it is generally easier to maintain power for distributed systems using back-up generators (Khatri, et al., 2014).

When decentralized systems are linked to broader or more centralized infrastructure, they become part of "networked" solutions with beneficial redundancy built into the system. If a distributed system does fail, it is easier to identify and isolate the problem to prevent cascading failures and direct resources to repair assets.

Distributed systems offer communities and utilities more flexibility and adaptive capacity in how they provide service to new developments. In contrast to large-scale centralized systems that are typically built based on long-term demand projections and optimized at higher population density, distributed approaches can be designed and implemented in a more incremental or modular manner as demand develops over time or used to intentionally manage development for lower population density. This reduces investment costs and makes the project easier to manage (Khatri, et al., 2014).

Modern technologies and participation

IUWM aims to make use of innovative technological solutions for urban water systems. Practical applications of a variety of innovative technologies, such as membrane filtration systems, including membrane bioreactors, advanced oxidation, hybrid systems of natural and advanced treatment, microbial fuel cells, electrochemical processes, and source separation of different waste streams (separation of greywater, black and yellow waters) have led to new ways of managing urban water systems. The potential for more efficient reuse of water and nutrients and the recovery of energy is a major advantage of the new treatment technologies. Those new technologies are, in many cases, instrumental in the concept of integrated management approaches. Moreover, IUWM offers different innovative approaches to cope with the challenges for urban water management (Bahri, 2012).

3.8 IUWM tools and strategies

Various researchers and organisations have developed numbers tools and toolkits to assess and implement IUWM. These toolkits include CSIRO IUWM toolkit developed by Australian Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Water Research Foundation, SWITCH IUWM Toolkit developed under the SWITCH Project, the IRAP Toolkit developed by Institute for Resource Analysis and Policy (IRAP) and the Arghyam Trust, AdoptIUWM Toolkit developed by the ICLEI South Asia with ICLEI European Secretariat (ICLEI ES) and VVSG (Association of Flemish Cities and Municipalities, Belgium), and the GWP Toolkit developed by the Global Water Partnership. Table 3.1 provides an overview of the various toolkits.

Table 3.1: Overview of various tool and toolkits for IUWM

Criteria	CSIRO	GWP	SWITCH	Adopt IUWM	IRAP
Allows multi-level stakeholder integration	Yes	Yes	Yes	Yes	Yes
Is computer-based	No	Yes	No	No	No
Includes climate- change adaptation	Yes	Yes	Yes	Yes	Yes
Includes a methodology for boundary delineation	No	No	No	No	Yes
Includes a Water Balance Model	No	Yes	Yes	No	Yes
Allows economic analysis	Yes	Yes	Yes	Yes	Yes

Source - Semasingha, et al. (2020)

3.9 Challenges to IUWM

Although the concept of IUWM is very interesting and many will agree with it, there are still many challenges to the implementation of IUWM. It is necessary to address or understand these challenges beforehand to plan an efficient implementation (Khatri, et al., 2014).

- Lack of performance indicator — Lack of measurable criteria or an operational definition makes it difficult to assess the level of integration achieved or to be attained. A clearly defined set of methodology can overcome this challenge.
- Lack of knowledge among practitioners in this novel approach hinders the transition from the conventional water management system. Capacity building is needed for water professionals, urban planners and engineers from local governments and water utilities.
- There is a lack of understanding on how to contextualize water supply, sanitation and stormwater within an integrated urban water framework that will allow water professionals to articulate the relationship between the various components of the urban water system. IUWM scoping models which already exist, are not widely used by urban practitioners.
- Departmentalized institutional structure with a narrow field of interest and poor interdepartmental communication is one major challenge for IUWM implementation. This institutional structure needs to be revised or improved and a new institutional set up could be created if necessary. There has been also doubts regarding the practicality of integrated institutions which should possess strong expertise in each field.
- The implementation of IUWM requires comprehensive stakeholder engagement as well as strong political commitment, which could be difficult to garner. Early and continuous engagement of all stakeholders in the planning, decision and implementation process is critical for the success of IUWM.
- A clear picture of the economic realities of a conventional approach compared to the new IUWM paradigm is required for analyzing the feasibility. However, there are no sufficient and detailed cost figures available for IUWM solutions, while this type of data does exist for conventional solutions. This makes it difficult to estimate the costs and benefits of IUWM solutions.

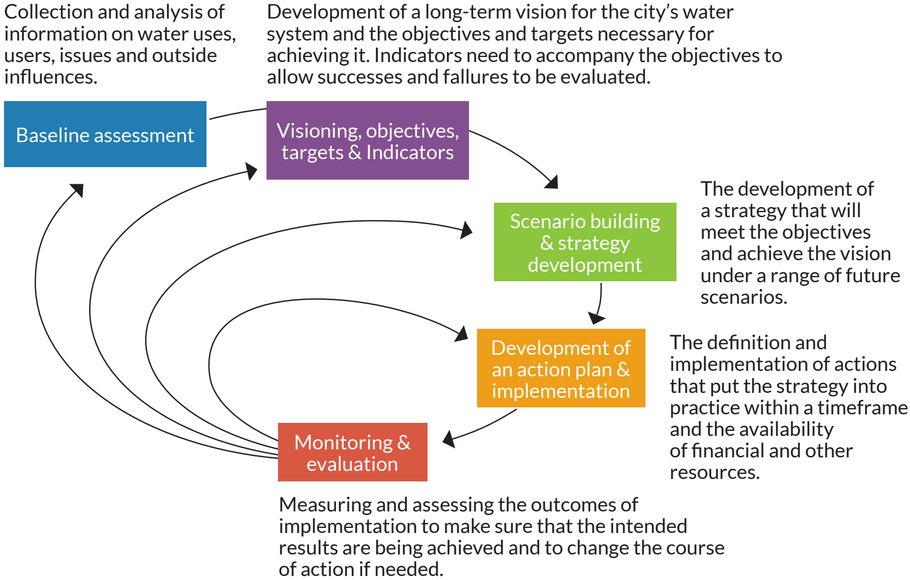
3.10 Phases of Strategic Planning for IUWM

IUWM can best be achieved through a strategic planning process with a continuous mechanism of reflection and adaptation. Different phases of the process are discussed here:

Baseline assessment

Before entering into a process of change, a city needs to know its starting point. The baseline assessment provides an overview of the current water management situation, identifies key issues and collects the information that is necessary to carry out the subsequent phases of the strategic planning process. The data required for a baseline assessment is likely to be dispersed over many institutions. Support will be needed from authorised sources in several different local government departments, institutions and water utilities.

Figure 3.5: Phases of Strategic Planning



Source – Philip & Anton (2011)

Creating vision, objectives and selection of indicators and targets

The vision will only set the strategic planning process in motion if it can rely on sufficient political backing. Local politicians should ideally participate in the creation of the vision or at least endorse its outcome so that it becomes part of official policy-making. Local government, or the equivalent, is therefore often the ideal candidate for kicking off the visioning exercise. The vision should be disseminated for wider consultation both within the city as well as potentially also through higher levels of administration beyond the city boundaries. Constructive comments received at this stage should be taken into account for the final version. The vision is deliberately written in a clear and concise style without going into the details of the change that is required.

Reaching each aspect of the vision – such as having universal access to sanitation or healthy rivers and lakes – will potentially require the achievement of several objectives. The objectives specify what changes in the existing state need to be achieved for the vision to become reality. Indicators are tools to measure and/or visualise progress towards objectives (and thus the vision). The targets are the aspirational indicator values, usually expressed in specific figures (number of units, percentage, costs, etc.).

Scenario building

The next phase in the strategic planning process is working out how the objectives and the vision can be achieved. The difficulty with this is the same as for any organisation, business or individual that wants to make plans for the future: uncertainty. Researchers and specialists will be needed to support the development of scenarios, especially when modelling programmes and similar tools are used. Informed judgements and expert interpretation of data are necessary to extrapolate current trends and assess the degree of probability surrounding results. Strategy development: The strategy aims to define the main avenues through which the city will, under a range of scenarios, achieve the identified objectives.

Development of an action plan and implementation

The action plan aims to devise the different departmental implementation programmes necessary to convert the strategy into tangible results and turn the targets, objectives and vision into reality. Selected implementation programmes should include the details of the different projects and measures, as well as the relevant departmental plans into which they will be embedded. The development of an action plan should also include the prioritisation and scheduling of the identified actions, their estimated costs and the sources through which they will be funded. Table 3.2 presents various instruments, tools and strategies that can be implemented at two levels in the cities.

Implementation requires considerable preparation and continuous management of budgets, staff, and timelines. Work plans should be developed with the programme broken down into smaller units. Responsibilities need to be allocated and the necessary equipment and materials made available.

Table 3.2: IUWM goals and tools at different levels of management

Level	Goal	Tools or Strategies
Household, community	Conserve supplies	In-factory and in-house recycling
		Rainwater harvesting
		Water-efficient consumer durables
	Meet basic needs	Small-scale community networks
		Authorisation of private vendors
Municipality, city utility	Conserve supplies and reallocate supplies	Leak control and network maintenance
		Planned reuse at urban scale
		Dual supplies
		Cost-based tariffs and metering
		Retrofitting of water-use equipment
	Improve health and meet basic needs	Targeted subsidies
		Education on water hygiene
		Facilitating community-level provision
		Removing land-tenure restrictions on provision
		Preventing waste infiltration into supply
	Increase investment	Cost-based tariffs
		Better revenue collection
		Higher operating efficiency
		Curbing illegal connections
	Source protection or quality protection	Groundwater abstraction controls
		Leak control to curb infiltration
		Land zoning
		Industrial and domestic waste pollution controls

Source – Adapted from Bahri (2012)

Monitoring and evaluation

Monitoring and evaluation are necessary for maintaining accountability over the strategic planning process. As the local government is likely to have had a large say in the setting of the targets, they are not necessarily best placed to carry out the monitoring and evaluation of these. An impartial body from outside the process is, therefore, better suited to the task. Evaluated results should be presented to senior levels of the municipality and the council as well as externally to sponsors, stakeholders and the public, to ensure transparency in the implementation process and to allow for an independent review of whether targets and objectives are being met.

The purpose of the strategic planning process is to facilitate the adoption of IUWM and move towards sustainable water management as defined through its social, economic and environmental dimensions. The process is not a one-off undertaking and the different stages need to be reassessed regularly to ensure that the course of action leads to the desired results (Philip & Anton, 2011).

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Chapter
4

Water Sensitive Urban Design

Recap

Understanding the concept of Integrated Urban Water Management, its importance with the current issues of climate change and resource loss, and steps to create a better system involving IUWM.

Training Objectives

- To understand the concept of Water Sensitive Urban Design.
- To familiarise the audience with the framework and principles of WSUD.
- To understand the implementation strategies of WSUD.

Training Outcomes

- Gain understanding of the WSUD.
- Ability to see the possibilities of implementation of WSUD in their cities.
- A perspective to view the differences and benefits of WSUD.

Chapter Contents

4.1 Concept of WSUD

4.2 Principles

4.3 Need for WSUD

4.4 Comparison between conventional approach and WSUD

4.5 Steps involved in WSUD

4.6 Benefits of WSUD

4.7 WSUD Implementation Strategies

4.8 Case Studies

4.9 Further readings

References

4.1 Concept of Water Sensitive Urban Design

The spread of the built-up area in the Indian cities has created progressive and unrelenting impermeability or soil sealing, which is causing numerous environmental problems in our cities. Water Sensitive Urban Design (WSUD) is the process of integrating water cycle management with the built environment through planning and urban design. It is an interdisciplinary cooperation of water management, urban design, and landscape planning. It considers all parts of the urban water cycle and combines the functionality of water management with principles of urban design. WSUD develops integrative strategies for ecological, economic, social, and cultural sustainability.

The objective of Water Sensitive Urban Design is to combine the demands of sustainable stormwater management with the demands of urban planning, and thus bringing the urban water cycle closer to a natural one. (Hoyer, et al., 2011).

Figure 4.1: Water Sensitive Urban Design

Source – Morgan, et al. (2013)

Features of WSUD are (Kumar, et al., 2017):

- Protecting local water bodies (lakes, ponds and wetlands) for supplementary water sources
- Storm-water management at public places, including open areas in cities through elements of landscape design (e.g. vegetated swales and buffer strips, bio-retention systems)
- Recycling and reusing wastewater naturally (low cost/low energy) and not treating it as a liability
- Increasing water-conservation approaches at various scales (buildings/ campus)—i.e. by adopting water-efficient fixtures, xeriscaping landscape (i.e. planting native species) and using water-efficient irrigation methods— thereby minimizing the load on the municipal supply system and groundwater sources. On-site water conservation with rainwater harvesting (RWH) is also important to reduce water scarcity.
- Adding value to the social and ecological aspects of areas by planning and designing the built environment as per the community needs and water issues
- Connecting the urban water cycle by collaborating with practitioners of different disciplines to bring different perspectives and expertise
- Associating upcoming policies, regulations and approvals with WSUD.

4.2 Principles

There are some principles essential for the application of WSUD (Hoyer, et al., 2011). They are:

- Use decentralized methods to bring urban water management closer to the natural water cycle.
- Provide an aesthetic benefit where possible.
- Adapt to the design of the surrounding area.
- Adapt to the local basic conditions and the intended use.
- Consider the corresponding maintenance requirements.
- Consider possibilities for adaptation to uncertain and changing basic conditions.
- Create places that are usable for recreation and/or nature conservation
- Consider the demands of all stakeholders and involve them in the planning process.
- Costs should be comparable to the costs of conventional solutions.
- Combine function, aesthetics and use.
- Interdisciplinary planning with the co-operation of urban planning, urban design, landscape architecture and water management.
- It should be designed in an aesthetic, well-functioning and usable way to improve the public perception and acceptability of WSUD.

4.3 Need for WSUD

The move towards WSUD practices is part of an international trend towards integrated urban water management. This integrated approach is gaining acceptance as being preferred to the more traditional (separate) potable, wastewater, stormwater systems, and a conveyance-oriented approach to stormwater management because it can:

- Reduce the quantities of potable water required, and wastewater produced, by a development;
- Minimise stormwater pollution and water balance problems by ensuring hydrological regimes change minimally from pre-development conditions;
- Solutions need to be community-specific and environment-specific – design has to be central. WSUD enables these solutions;
- Reduce development costs.

This integrated approach also has synergistic benefits between what were (formerly) separate urban water streams. For example, harvesting stormwater for open space irrigation has downstream river morphology/flood/water quality benefits, potable water supply security benefits and local open space and groundwater benefits. WSUD is also a very practical opportunity to develop locally appropriate responses for water management that also deliver green infrastructure and habitat (Morgan, et al., 2013; JSCWSC, 2009).

4.4 Comparison between conventional practice and WSUD

Table 4.1 provides a comparison between the conventional approach and the WSUD approach to stormwater containment and management.

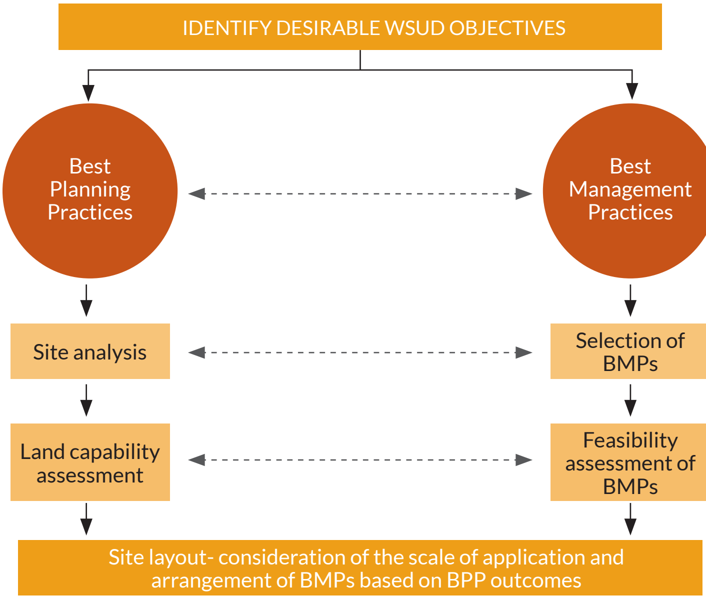
Table 4.1: Comparison between the conventional practice and WSUD

Conventional approach	WSUD approach
Fragmented approach: Integration is by accident. Water supply, wastewater and stormwater may be managed by the same agency as a matter of historical coincidence but physically the three systems are separated.	**Integrated approach:** Physical and institutional integration is by design. Linkages are made between water supply, wastewater and stormwater as well as other areas of urban development through highly coordinated management.
Linear urban water cycle: Water follows a one-way path from the supply, to single-use, to treatment and disposal to the environment.	**Closed urban water cycle:** Reuse and reclamation. Water can be used multiple times, by cascading from higher to lower quality needs, and reclamation treatment for return to the supply side of infrastructure.
Increased demand: Increased demand is met through investments in resources and centralized infrastructure leading to leakage losses. Potable quality water is supplied for all uses.	**Reduced demand:** Options to reduce demand by conservation, harvesting rainwater and reuse. The decentralized system also leads to leakage reduction. Potable quality water is provided only for uses that require it. Alternative sources are sought for non-potable demand.

Conventional approach	WSUD approach
Stormwater as a nuisance: Stormwater is conveyed away from urban areas as rapidly as possible	**Stormwater as a resource:** Stormwater is attenuated and retained at the source allowing it to infiltrate into aquifers and flow gradually into receipting water bodies. Storm-water infrastructure is designed to enhance the urban landscape and provide recreational opportunities.
Bigger/centralized is better: To get water from a distant source and then to treat wastewater at far places, thereby increasing the overall infrastructure.	**Small/decentralized is possible:** Make use of the local resource and treat waste near the source to attain a sustainable and affordable approach.

4.5 Steps involved in WSUD

Figure 4.2: Steps involved in implementing the WSUD philosophy



Source —Lloyd (2000)

Best Planning Practice (BPP) refers to the site assessment and planning component of WSUD. Initially, the physical attributes of a site, such as a climate, geology, drainage patterns and significant natural features (eg. wetlands and remnant vegetation) should be identified. Subsequently, an assessment of land capability should be undertaken to ensure the physical attributes of the site are matched to the proposed land-use requirements.

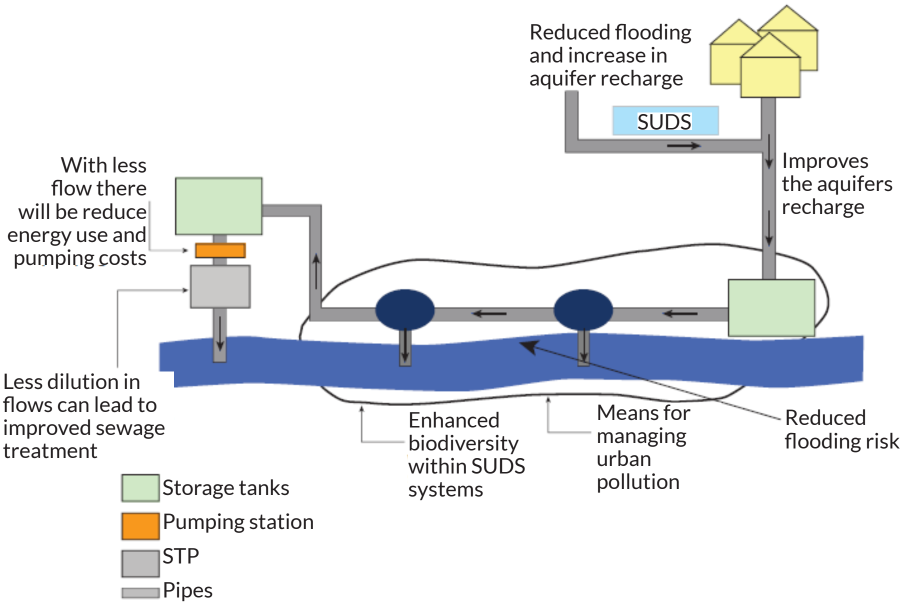
Best Management Practice (BMP) refers to the structural and non-structural elements that perform the prevention, collection, treatment, conveyance, storage or reuse functions of a water management scheme. Selecting the appropriate BMPs to target specific flow management or water quality control function requires the undertaking of a feasibility assessment. This assessment may include the consideration of such factors such as the hydraulic operating conditions and life cycle costs (ie capital and maintenance). The final site layout is based on the outcomes of the analysis of physical attributes and the land capability assessment. These factors determine the most suitable placement and arrangement of BMPs and site amenities. This process minimizes the impact of land-use on the land and water environment. The selection, placement and sequencing of BMPs are important to optimise beneficial outcomes, and to reduce the impact of catchment urbanisation on the receiving waters. This sequencing of BMPs is referred to as the 'treatment train'.

4.6 Benefits of WSUD

The nature and extent of benefits will depend on local condition. Local benefits include (Kumar, et al., 2017):

- Flood management – Extensive use of WSUDP will lessen the amount of urban run-off into the drainage and sewer system and hence lessen run-off load. Additionally, by reducing run-off load, WSUDP will contribute to the reduction of flooding risks.
- Controlling pollution content – WSUDP provides a means of managing and treating urban pollution before returning it to waterbodies.
- Meeting water efficiency targets – Some systems, such as RWH, provide an alternative source for non-potable water within domestic and commercial settings.
- Additional recharge of aquifers – WSUDP provides a route for recharge thus helping to make savings on new water resource investment.
- Reducing energy costs – Reducing or limiting the volume of flow to the STP will help to reduce cost. Reduced pumping from storage facilities and less diluted sewage may result in more efficient treatment of wastewater.
- Enhancement of biodiversity – WSUDP mimics the natural environment, retaining water that will attract wildlife, creating stable habitats and providing corridors along which wildlife can move.
- Effect of climate change – Some SUDS approaches can help reduce the urban heat island effect. For example, adding 10 per cent green cover will keep maximum surface temperatures in high-density residential areas and town centres at or below the 1961–90 baseline up until the 2080s.

Figure 4.3: Benefits of WSUD



Source — Kumar, et al. (2017)

4.7 WSUD Implementation Strategies

There are various technologies and strategies that are align with the principles of WSUD. Based on where the rain falls the elements have been categorised. These are listed in Table 4.2.

Table 4.2: WSUD elements based on where the rain falls

Rainwater falls on	Water Sensitive Urban Design elements
Green Areas (Parks, Forest, etc.)	Retention Ponds, Detention Ponds
Roads / Green Streets	Bio Swales, Vegetated Filters, Gravel Filters along the Roads, Pervious Paving on Footpaths, Underground Storage Tanks (for RW and TWW storage) to use it for roadside Landscaping and Horticulture, Rain Gardens
Open Parking Lots	Bio Swales, Vegetated Filters, Gravel Filters, Pervious Paving
Open Land	Retention Ponds, Detention Ponds, Dry Swales
Flood Plain / Water Bodies / Drains	Constructed Wetlands (to rejuvenate water bodies / lakes)

Source – Author

Table 4.3 provides an overview of the WSUD technologies alogn with their potential functions.

Table 4.3: Overview of WSUD technologies

Sr. No.	WSUD Technol-ogy	Reten-tion/De-tention	Convey-ance	Infil-tra-tion	Eva-po-tran-spi-ra-tion	Treat-ment	Har-vest-ing
1	Aquifer storage and recovery			✓		✓	✓
2	Bioretention/ Raingardens	✓		✓	✓	✓	✓
3	Green roofs	✓			✓	✓	✓
4	Green walls/Living walls	✓		✓	✓	✓	✓
5	Infiltration systems			✓		✓	
6	Oil and sediment separators					✓	
7	Permeable pavements	✓		✓			
8	Ponds and lakes	✓			✓	✓	✓
9	Sand filters					✓	✓
10	Screens					✓	
11	Sediment basins	✓				✓	
12	Swales		✓	✓	✓	✓	
13	Tanks	✓				✓	✓
14	Wetlands	✓	✓		✓	✓	✓

Source – Kuller, et al. (2017)

Table 4.4 shows the potential WSUD technologies, their scale of application, suitable urban environments where these could be applied, the difficulty in retrofitting such, if they are publicaly implementable, and related issues.

Table 4.4: WSUD technologies and their implemetation characteristics

Sr. No	WSUD Technology	Application Scale[a]	Suitable Urban Environment	Difficulty of retrofitting	Public Implementation	Issues
15	Aquifer storage and recovery	N, B	Low density	Low	Yes	Needs advanced pre-treatment
16	Bioretention/ Raingardens	L, S, N, B	Flexible. Streetscape, gardens, parks	Low	No	Clogging, low resilience against draught, sanitation and tropical disease vectors
17	Green roofs	L, S, N, B	Rooftops	Low	No	Needs irrigation in dry climates
18	Green walls/ Living walls	L, S, N, B	Walls	Low	No	Same as green roofs
19	Infiltration systems	L, S, N, B	Dense urban areas, along roads and highways	Moderate	No	Clogging, soil contamination, system failure
20	Oil and sediment separators	S, N, B	Sewer inlet	Very low	Yes	
21	Permeable pavements	L, S, N, B	Any paved area	Low	No	High maintenance and system failure
22	Ponds and lakes	N, B	Public open space, parks	High	No	Bank erosion, algal blooms, flocking birds, mosquitoes, sanitation, tropical disease vectors
23	Sand filters	L, S, N, B	Any	Very low	No	Clogging, high maintenance
24	Screens	N, B	River, stream, sewer	Very low	Yes	
25	Sediment basins	S, N, B	Flexible. Streetscape, gardens, parks	Moderate to high (depending on size)	Yes	Sanitation and tropical disease vectors
26	Swales	S, N	Streetscape: median strip, carpark	Low	Yes	High maintenance, sanitation, tropical disease vectors and mosquitoes when inundated

Sr. No	WSUD Technology	Application Scale[a]	Suitable Urban Environment	Difficulty of retrofitting	Public Implementation	Issues
27	Tanks	L, N, B	Any	Very low	No	Water quality, trade-off between flood protection and water supply
28	Wetlands	N, B	Public open sapce	High	Yes	Mosquitoes, Clogging, low resilience against draught, sanitation, tropical disease vectors
[a] L: lot, S: street, N: Neighbourhood, B: sub-basin/district.						

Source – Adapted from Kuller, et al. (2017)

4.8 Case Studies - Melbourne

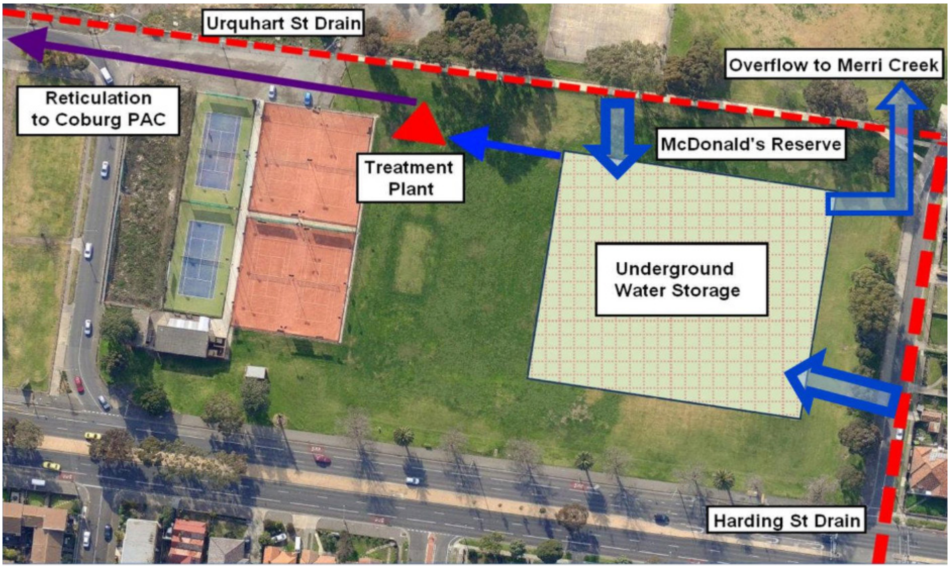
WSUD is being encouraged widely across Australia, with the transition of such to real, on the ground, works have been more readily accepted in some areas than others. Over four million people live within the Port Phillip Bay catchment, which includes most of the Greater Melbourne region. When it rains, the resulting stormwater carries litter and pollutants from built-up areas of the catchment and transports them long distances. Rainfall can cause stormwater to pollute the Bay, and heavy falls mean much more rainwater than usual infiltrates the soil and enters the sewerage system. During extremely heavy storms, this infiltration can push the local sewerage system to its limit, and sometimes diluted sewage overflows through emergency release valves into creeks and rivers. In summer, even moderate rain can cause poor water quality in the Bay, leading to beach closures. While we expect less rainfall overall as the climate changes, storms will likely become more intense and more frequent in summer, exacerbating these problems. As the population living in the Port Phillip Bay catchment grows, the increase in hard surfaces like roofs and roads means more stormwater and sewage. Without ongoing active management, even more nutrients, litter and other pollutants will be washed into the Bay. This will increase the risk of problems like algal blooms and poor water quality after storms.

Sewage and stormwater are no longer considered waste products. In the face of climate change and enabled by new technology, Melbourne Water is using sewage to generate valuable resources such as recycled water, biosolids, and biogas (renewable energy). This is part of the integrated water management approach, considering all water as a potential resource (JSCWSC, 2009).

The Coburg and Merrifield stormwater harvest projects represent a major step forward in Integrated Water Cycle Management (IWCM). The knowledge gained from the projects has the potential to educate and inform other cities around the world and will be invaluable when planning how best to deliver services to a variety of growth areas. The profiled projects prove that an alternative, integrated approach to IWCM can deliver significant improvements such as reduced water consumption, reduced pollutant levels in waterways, reduced stormwater flow volumes following urbanisation and a 75% reduction in energy consumption compared to conventional centralised supply enhancers such as desalination (J. McGrath, et al., 2012).

Coburg

Figure 4.4: Coburg stormwater harvest site overview



Source - J. McGrath, et al. (2012)

Before the Coburg stormwater harvesting project was undertaken, various options to supply additional water to new developments in Coburg were considered. Planners at Yarra Valley Water (YVW) considered alternative sources of supply such as recycled sewage as well as a traditional augmentation of potable water supply. YVW determined the lowest community cost option to meet the projected increase in water demand at Coburg was to supply reticulated non-potable stormwater treated to meet household and business demands. Stormwater will be harvested from existing stormwater drains. Captured stormwater will be stored underground at McDonald's Reserve and then treated to a 'Class A equivalent' standard before being reticulated via a dual-pipe system. This method of supplying treated stormwater to new development in Coburg was identified as the most sustainable way to reduce the impact of the redevelopment of Coburg on existing potable water infrastructure.

The Coburg stormwater harvesting project will capture, treat, store and supply treated stormwater to approximately 9,000 new residents in the Central Coburg PAC. The harvested stormwater will be available for non-potable uses, substituting the demand for potable water in new houses and apartments. The project will also provide treated stormwater for traditional stormwater re-use purposes such as irrigation of public open spaces.

The project will also provide treated stormwater for traditional stormwater re-use purposes such as irrigation of public open spaces. The Coburg stormwater harvesting project provides a decentralised urban water solution that enhances the stormwater quality of the 159 ha urban catchment. It is expected that 228 ML of urban runoff per annum will be harvested with a resulting 30% reduction of potable water use. An approximate 27% reduction in total nitrogen and a 42% reduction in total phosphorus will result from the capture of stormwater from the urban catchment. Besides, the mean annual runoff volume to Merri Creek will be reduced by approximately 25%. This project will provide an innovative, decentralised and sustainable solution to the challenges posed by the capture, storage and treatment of significant quantities of stormwater in a highly built-up urban environment (J. McGrath, et al., 2012).

Merrifield

Merrifield is a mixed-used development located approximately 30 km north of Melbourne's Central Business District. The development is located in the centre of Melbourne's Northern Growth Area, which has been identified by the Growth Areas Authority as land suitable for residential and commercial development to meet Melbourne's growing population demands.

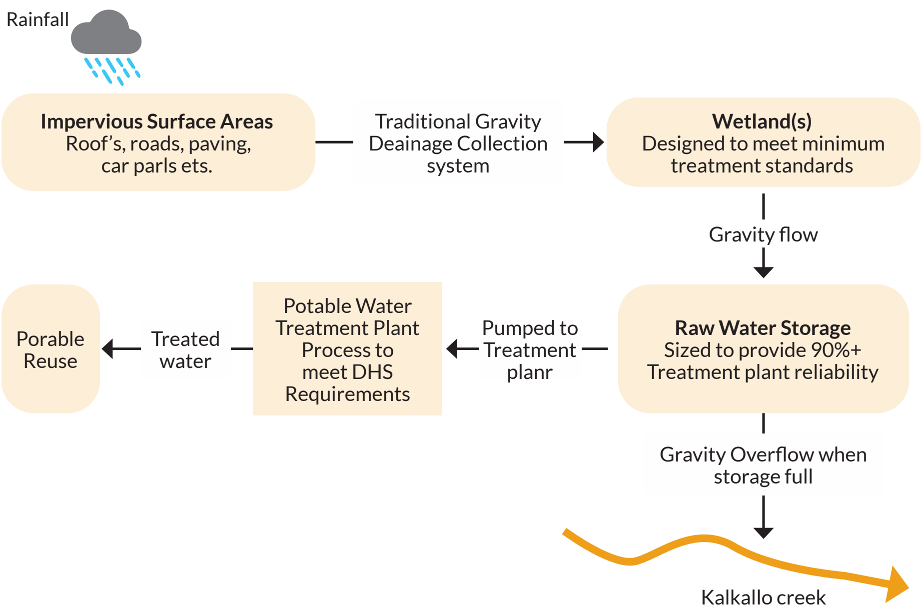
The Merrifield stormwater harvesting project is located at the eastern side of the development adjacent to the Hume Freeway and will harvest stormwater from the commercial precinct. Yarra Valley Water (YVW), the responsible water retailer, has identified that Melbourne's Northern Growth Area, including Merrifield, will be particularly expensive to service from the metropolitan system as a result of its geographic location. YVW identified the lowest community cost option will require the construction of a new localised sewage treatment plant that will produce recycled Class A water and be reticulated to meet the non-potable water demands for the household.

The integration of collecting, treating and using stormwater for potable demands reduces the amount of imported water that will have to be drawn from the metropolitan system. As part of the planned development, 400 ha of the 1,500-ha site will be developed for commercial use.

Merrifield is a 'greenfield' development site. As a result, the urban reservoir in addition to the sedimentation ponds and wetland systems need to be integrated into the future urban landscape. The project will be owned and operated by YVW, the region's water retailer. The raw water storage will act as an urban reservoir to supply an YVW stormwater treatment plant. The inclusion of a treatment plant as part of the Merrifield project will enable stormwater to be treated to potable standard and used to supply potable water demands. The Merrifield stormwater harvesting project will provide potable water to the surrounding development.

Treatment of stormwater to potable standards at Merrifield will be achieved using an advanced treatment train. The stormwater will be treated through a constructed wetland with multiple sedimentation ponds before being stored in the raw water storage basin. The treatment plant will draw from the basin to treat water to a potable standard. Stormwater will be collected from roof areas, roads, car parks and other impermeable surfaces via a traditional drainage system (an underground gravity pipe system) and The Merrifield stormwater harvesting project will provide a sustainable water supply by harvesting and treating local stormwater. By supplying potable water from a local source, the environmental footprint of the development is reduced and the natural characteristics of the region's waterways can be retained despite the urbanisation (J. McGrath, et al., 2012).

Figure 4.5: Schematic of Merrifield stormwater harvest process



Source - J. McGrath, et al. (2012)

4.9 Further Reading

1. *WSUD Guidelines, Melbourne Water: https://www.melbournewater.com.au/sites/default/files/South-Eastern-councils-WSUD-guidelines.pdf*
2. *Water Sensitive Urban Design Principles and Inspiration for Sustainable Stormwater Management in the City of the Future: https://www.hcu-hamburg.de/fileadmin/documents/Research/Forschungsgruppen/REAP/WD_Publikationen/Hoyer_Dickhaut_Kronawitter_Weber_Manual_WSUD_2011.pdf*
3. *Water-Sensitive Urban Design and Planning: A Practitioner's Guide, Centre for Science and Environment: https://cdn.cseindia.org/userfiles/WATER-SENSITIVE-URBAN-dESIGN-pLANNING-practitioners-guide.pdf*

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RAINWATER HARVESTING
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Chapter 5

Demand Management - Shift from Supply to Demand

Recap

Understanding the concept of water sensitive urban design and its principles of application in urban India. The application strategies and components of WSUD are an important aspect of WSUD application.

Training Objectives

- To understand in brief the need of managing water demand in water.
- To understand the benefits and costs of water demand management.
- To identify the constraints and challenges of implementing a successful water demand management strategy in a city
- To familiarise oneself with the different methods of urban water demand management

Training Outcomes

- Gather understanding of water demand management in urban areas.
- Suggestions and potential strategies for urban water demand management.

Chapter Contents

5.1 Approach to Water Demand Management - Need and Rationale
5.2 Benefit and Costs of Water Demand Management
5.3 Constraints and Challenges for UWDM in developing countries
5.4 Measures of Water Demand Management
References

5.1 Approach to Water Demand Management - Need and Rationale

Water demand management is not just a conservation strategy but also a solution to the inequity of water supply (Sharma & Vairavamoorthy, 2009). The current water supply approach in almost all Indian cities is 'supply driven', which means that in face of a crisis of available water, water scarcity or shortages, they tend to invest capital in new treatment technologies and infrastructures, water supply networks, etc. As discussed in previous chapters, the Indian cities have explored options far and beyond the limits of the city to source water. Such a practice is capital intensive and resources exhaustive. Often this water has to be sourced from a different state, it leads to conflicts in times of water crisis when the need for water is higher and everyone contests to fulfil their needs from the same source. Therefore, Indian city managers must move from a supply-driven approach to a demand-driven approach.

Research across the world shows that increasing the efficiency of the water system is cheaper than finding and relying on new sources of water to meet the increasing demands. A new source of water requires setting up the infrastructure and developing networks to transport and supply water. This is a very capital intensive process. Instead, through retrofitting and using soft measures such as water charges, economic regulation, legislation, etc., efficiency can be achieved in a very easy and cheaper manner. Conserving water is fairly cheaper compared to all other options (Haddad & Lindner, 2001; as qtd. in Sharma & Vairavamoorthy, 2009).

Demand management is defined as (DWAF, 1999; as qtd. in Vairavamoorthy & Mansoor, 2006):

"The adaptation and implementation of a strategy (policies and initiatives) by a water institution to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability".

The strategies adopted to implement demand management do not have to result in a drop in the service levels of the water supply in any manner. Implementing water demand management for urban consumers result in numerous benefits for the city and citizens.

5.2 Benefit and Costs of Water Demand Management

The costs and benefits of a successful water demand management programme can be categorised as environmental, economic and social (Kayaga, 2011). These three are as follows:

- **Environmental benefits and costs** – since water demand management results in reduced extraction of water from the surface water source, today's reduced demand for water means more water available for the future. It also reduces the greenhouse gas emissions that is spent in treating and supplying water. Recycling wastewater and greywater results in a reduced amount of pollutants released in the water sources. On the other hand, installation and functioning of smart devices, metres, etc. for monitoring results in increased electricity consumption.
- **Economic benefits and costs** – reduced water consumption results in reduced expenditure and capital investments on new infrastructure. Simultaneously, the consumers can save money if the water tariffs are designed properly. The negative economic externalities of UWDM involve borrowing from a bank to invest in water monitoring facilities, etc.
- **Social benefits involve** the benefits of an equitable supply of water. Women and citizens who had to travel distances to fetch water can save on time and resources and spend more time with their families or households.

5.3 Constraints and Challenges for UWDM in developing countries (Sharma & Vairavamoorthy, 2009)

In developing countries, the implementation of urban water demand management (UWDM) faces certain challenges due to the distinct nature of issues and systems that they have. Some of these challenges are as follows:

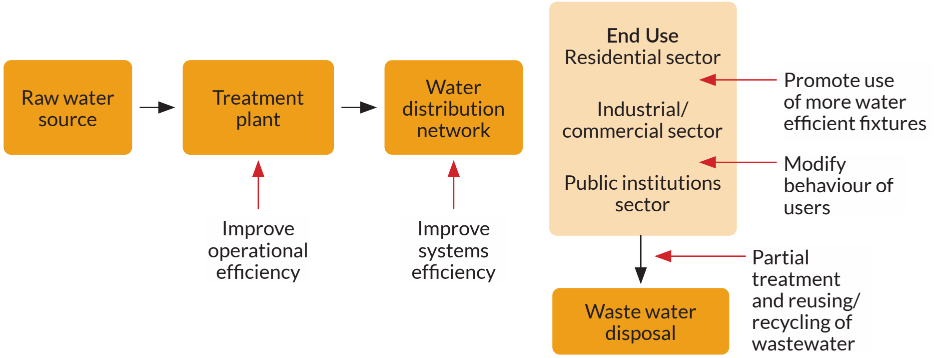
- The institutions such as municipal corporations and other parastatal bodies lack the skilled human resources to implement the mechanism of the UWDM measures.
- The affinity of ULBs and local bodies to invest time and resources in engineering and construction activities creates an institutional bias that prevents them from exploring options that do not require planning for the construction of new facilities.
- Underpricing or not pricing water creates a disadvantaged position for the local body to earn revenue and reduce consumption of water.
- There is a lack of legal and institutional framework for promoting UWDM.
- The local bodies do not possess updated databases of network and infrastructure in the city, consumption patterns of the citizens, improperly designed DMAs, etc.

5.4 Measures of Water Demand Management

Throughout the network and system of water supply water demand management measures can be implemented (Figure 5.1). The UWDM measures can be classified into three major categories (Sharma & Vairavamoorthy, 2009). These are as follows (Figure 5.2) –

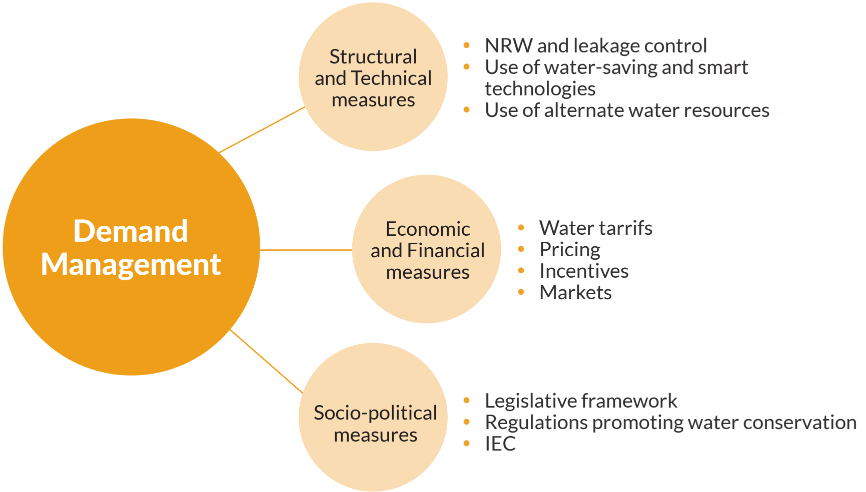
- Structural and Technical measures such as NRW and leakage control, use of water-saving devices and smart technologies, and use of alternate water resources.
- Economic and Financial measures such as water tariffs, pricing, incentives and markets.
- Socio-political measures such as legislative framework, regulations promoting water conservation, IEC, etc.

Figure 5.1: Schematic diagram of a water supply system, highlighting key potential areas for WDM interventions



Source - (Kayaga, 2011)

Figure 5.2: Demand Management Measures and Instruments



Source – Author

Some of the strategies and activities of water demand management that ULBs can use are listed in Table 5.1.

Table 5.1: Strategies of Urban Water Demand Management

UWDM approach	Activity
Increase system efficiency	• No change in usage, but a change in system operation • Reduction of water loss in the distribution system (leak detection and repair, pressure management and control, water meter management)
Increase end-use efficiency	• Less resource use by consumers by using water advertising, awareness campaigns and education and use of water-efficient devices and systems (low-volume flush, water-saving shower head and washing machine, water-efficient urinal, dishwasher, etc.)
Promote distributed sources of supply	• Providing service via other local water resources that are not being used; Encouraging rainwater use and greywater reuse, water recycling and reuse in industries
Substitute resource use	• Providing the same service without resource use e.g. waterless sanitation, low water-use garden plants and shrubs, plants adapted to local rainfall
Improve the market on resource usage	• Full cost pricing of water, universal metering; using financial and economic instruments (tax, rebates, subsidy and loans) • Informing consumers about the full cost of water and the impact of excessive use of water resource

Source - Sharma & Vairavamoorthy (2009)

It is worth mentioning here, before exploring in detail the measures and instruments, that the applicability of UWDM instruments varies across consumer groups. Different income groups of consumers have different feasible measures (Vairavamoorthy & Mansoor, 2006).

Table 5.2: Different applicable measures of UWDM based on the consumer group

Income group of consumers	Applicable and feasible measures and instruments of UWDM
High income	• In-house retrofitting and out-of-house water-saving measures (garden, swimming pool). • Water pricing measures may only be effective in combination with extensive IEC campaigns, as rich people are not bothered much by the costs of water.
Middle income	• The most effective water DM options for this group are water-pricing measures, especially increasing block tariff rates and an effective awareness-raising strategy. • Since the spectrum of middle income is diverse and wide, the measures applicable to customers on both ends of the group can be pegged similar to the measures applicable to the customers of the other two income groups.
Low income	• Achieving enhanced access to water supply through increased water availability and an equitable distribution network with an active, community-focused strategy in this group.

Source – Adapted from Vairavamoorthy & Mansoor (2006)

The following sections explore in detail these measures and instruments.

Structural and technical measures

Structural and technical measures to manage urban water demand adopts an approach to retrofitting, upgrading and repairing the water supply system. It seeks to introduce technologies in the existing system to improve the efficiency of water supply, such as leak detection technologies, water metering, etc. Apart from introducing new technologies in the system, it also seeks to improve the existing water supply network by repairing the defects and issues in the network.

- The aim is to reduce the losses of water that may arise due to a faulty system. Therefore, it includes objectives such as reducing NRW, creating a water balance, use of ICT and technology to monitor water demand and consumption. These technologies may include sensors, monitors, water meters, etc. In certain cases, it may also involve creating or developing an alternate source of water. In areas or cities where 24 hour supply is not possible or there is an intermittent supply, the system can be designed and modified to utilise intermittent supply as a demand management measure but compensating it with adequate service standards (Vairavamoorthy & Mansoor, 2006).

Intermittent Supply

Only a few cities in India supply 24-hour water supply to all their citizens. In other cities, however, intermittent supply is a common phenomenon arising out of necessity. This leads to several problems. To start with, it creates low pressures in the distribution system, which also further leads to creating an inequitable distribution of water in-network, because consumers in high-pressure zone store and consume more water and leaving little for the consumers in the low-pressure areas. Following this, consumers spend and invest in infrastructures such as overhead and underground tanks to store water, treatment facilities, etc. Low-income consumers often cannot afford such investments and therefore face coping cost problems in two folds — firstly, they spend a large share of their income in such facilities which are makeshift or not up to the mark; and secondly, due to improper facilities, they are more susceptible to diseases caused by poor water supply and spend money in treatment and hospitalisation costs. Furthermore, due to the absence of water in the network for large periods between supplies, intrusion of pollutants due to leakage from the sewerage system can contaminate the network. This can lead to diseases outbreaks on vast scales as verified by various researches (Vairavamoorthy & Mansoor, 2006).

However, intermittent supply can be designed in the network as an approach to demand management supply ensuring adequate supply service levels in the system. This can be achieved through two ways – improving equity of the supply and improving the quality of water in the intermittent supply (Vairavamoorthy & Mansoor, 2006).

Apart from leveraging and improving an intermittent supply for the demand management, there are other structural measures such as usage of technology to reduce water losses, reduction in non-revenue water, etc. These subjects require a detailed discussion, and hence the following three chapters discuss in detail water audit, NRW reduction, and recycling and reusing wastewater to develop an alternate source of water respectively. Table 5.3 shows the needs and requirements for developing a sound structural system for UWDM.

Table 5.3: Developing tools and skills for water demand management: Technical standards, methodologies and guidelines

Resource Planning level	Need
Municipal	• Improved distribution network maintenance • Co-ordinated universal metering • Improved levels of access to, & reliability of, water supplies • Software & programs for effective billing systems • Metering management & process control systems
Integrated Water Resource Planning	• Standards to ensure that rivers & water resources are not over-abstracted • More detailed analyses, including methods for temporal supply & demand in sub-catchments • Investigations into long-term interactions between streamflow, irrigation strategies, water demand & available storage

Source - (Herbertson & Tate, 2001)

Economic and financial measures

Economic measures incentivise, penalise or regulate the behaviour of consumers. These can be done through various economic instruments. It is the "use of market-based signals to motivate desired types of decision-making. They either provide financial rewards for desired behaviour or impose costs for undesirable behaviour" (Stratos, Inc., 2003; as qtd. in PRI, 2004). For water demand management, it identifies fee-based measures, and a combination of property rights and tradeable permits based measures are best suited. These are fees, water charges and tariffs, and water markets respectively.

Water Pricing

Charging water has been used as a measure to contain the consumption patterns well within limits and necessities of demand. It internalises the environmental and social costs that are accrued while procuring and producing potable water. The revenue generated from the charging water also helps the water utility or the municipal corporation to raise funds to operate and maintain water supply infrastructure for better service, making them self-reliant.

However, it is important to understand that a one-size-fits-all approach does not work while fixing water prices. Water prices are different for each user depending on various factors of utility, consumer characteristics and output. For a similar kind of use, the water charge must vary considering the different pay-capacities of the consumers and the socio-economic burden that they may bear.

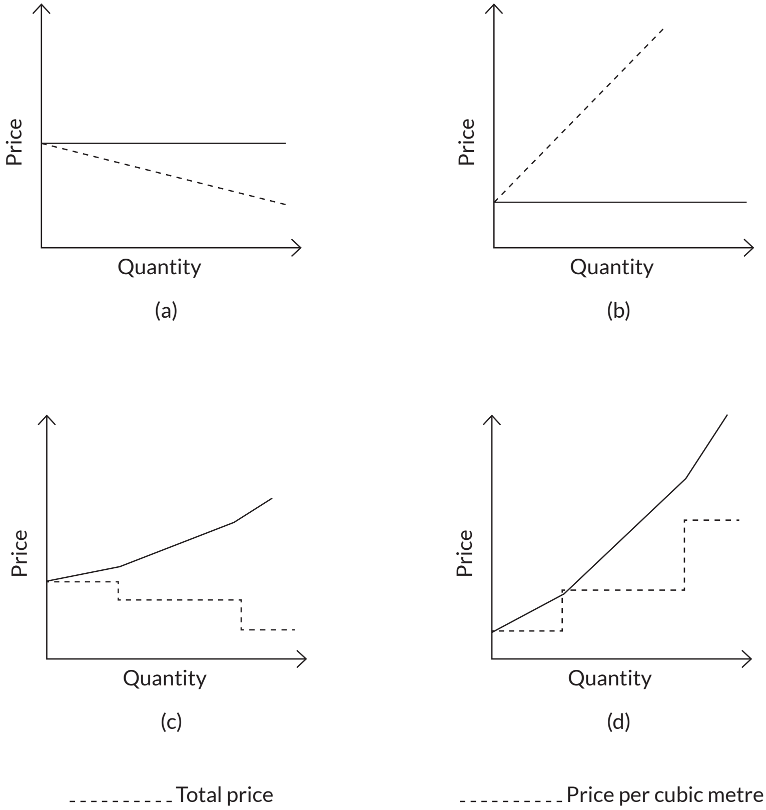
While price should not stay the same across the spectrum of consumers, it should also change with time. Factoring in the environmental costs of producing water means keeping the costs volatile according to the changing environmental circumstances and costs (PRI, 2004).

Prices and charges of water are signals in themselves about the value of water that a community or city has for its resources. Flat-rate pricing may suggest wasteful behaviours of water consumption. Declining block rates may encourage larger water usage for those on the marginal consumption in a block (PRI, 2004).

Structures of water charges are as follows (Figure 5.3):

- Flat Rate – The charges of water remain the same across user groups regardless of the amount of water consumed.
- Uniform Rate – The water is charged at a certain price per unit charged volumetrically, for example, INR 20 per kilolitres of water.
- Decreasing Block Rate (DBR) – In this structure, the price of water reduces as consumption increases. The price of water per unit is linked to a block or bracket of consumption. For example, INR 10 per kL of water in the first block of 10 kL and INR 7 per kL in the second block for 10-15 kL. The charges of block could also be flat rate charges, for example, INR 100 for 0-10 kL and INR 70 for 10-20 kL of water consumed.
- Increasing Block Rate (IBR) – IBR is the opposite of DBR, in which the price of water increases with an increase in the blocks. Like DBR, the prices of each block may be charged volumetrically or flat rate for each block. It may also be a combination of the two. For example, INR 5 per kL of water in the first block of 10 kL and INR 7 per kL in the second block for 10-15 kL. The charges of block could also be flat rate charges, for example, INR 80 for 0-10 kL and INR 120 for 10-20 kL of water consumed.
- Seasonal Rates – This structure of water pricing is linked to a seasonal variation of water consumption. The rate may be higher in a peak season, say in summer, to incentivise water conservation.

Figure 5.3: Schematic tariff structures (a) Flat rate, (b) Uniform rate, (c) Decreasing block rate, (d) Increasing block rate



Source – Author

Experts suggest that the highest efficiency for water pricing via-a-vis the usage of water is by tagging the price of water at marginal cost. Given so, the users can make decisions about efficiently using their water. When fixing water prices, it is important to note that cost recovery and efficient pricing are two different objectives. While ULBs understand that the average cost and marginal costs of water from a single source of water will decrease as the quantity of water supplied increases. But when a new source of water for increasing the capacity is added, the marginal costs see a decreasing trend, however, the average costs increase as the quantity of water supplied is higher.

ULBs often times use a two-part structure, having one fixed component to cover the capital costs of the infrastructure and a second component linked with the volumetric consumption to cover the O&M costs. Table 5.4 shows the needs and requirements for developing the economic measures for UWDM.

Table 5.4: Developing tools and skills for water demand management: Economic methods

Resource Planning level	Need
Municipal	• Information systems • Cost-benefit & financial analysis tools • Understanding of social implications of pricing mechanisms • Performance assessment, with monitoring & evaluation • Social & environmental costing
Integrated Water Resource Planning	• Better co-ordinated tariff setting • Stronger budget control • Clear tariff guidelines • Cost-benefit analysis of WDM measures • Consideration of equity issues when pricing water • Presentation of information on economic impacts to politicians • Phased introduction of water pricing towards full cost recovery • Subsidies, rebates & tax exemptions • Transparency & political intervention

Source - (Herbertson & Tate, 2001)

Water Markets

Water markets enable users to access a regulated and approved amount of water to extract or utilise, and trade with other users for prices as per demand and supply. Markets may be built with existing resource management frameworks, managed by the community or controlled by the state. These can take the form of shared institutional systems, with common property resources or licensing respectively.

To trade water, it is important to consider that the laws that define property rights are critical to the functioning of water markets. Water rights have certain restrictions as follows – firstly, the 'use it or lose it' principle assumes that the water rights that are saved due to less consumption are lost if not utilised fully. Secondly, the priorities of various activities and functions of water allocation would influence the investments in the regime. Lower priority functions often do not receive the investments considering the returns (PRI, 2004).

Socio-political measures

The socio-political measures that are used for demand management involve few or all out of legislation, policy, rules and regulations, education and communication through IEC activities. These can be supporting the structural and economic measures or standalone. However, preference must be given to measures that act as a support to the structural and economic measures. These also involve creating and strengthening the institutional capacity of the city to support the measures from an administration, monitoring and implementation perspective.

Institutional arrangements

To ensure effective implementation of the demand management instruments and measures, it is crucial to develop an ecosystem of legislation and institutions to support the measures. These support methods involve the following (Farley & Trow, 2003; as qtd. in Vairavamoorthy & Mansoor, 2006):

- **Adequate staffing** – there should be adequate staff t implement the plans and strategies as decided by the ULB.
- **Staff training** – There must be continuous knowledge enhancement programmes for the staff to efficiently implement the measures. Suggestively, the senior staff should be trained through seminars, there can be training workshops for the engineering and technical staff, often at the middle level, and the ground staff can be delivered practical training.
- **Operation and Maintenance** – O&M upkeep is important to maintain the infrastructure up to the required standards of the systems and minimise wastage of resources.
- **Assessment and monitoring** – The progress of the measures are to be monitored and assessed consistently to map the progress and efficiency of the UWDM measures against predetermined and set targets. This can be done on three levels –

"Strategic (analysis of trends and projections); Tactical (maintain and periodic inspections of facilities that have been established during the DM programme); and Operational (regular monitoring of systems performance)."

Table 5.5 shows the possible requirements for institutional support for UWDM.

Table 5.5: Integrating demand management into water resources planning: Institutions and administration

Resource Planning level	Need
Municipal	• Water supply tariffs are related to the economic price of water whilst recognising the need for social welfare.
Integrated Water Resource Planning	• Institutional changes with *local* political support • Networking within both *countries* & *regions* • Practical strategies capable of meeting stakeholder expectations –preferably involving stakeholders & interest groups in process of development • Clarification of roles & responsibilities of new institutional staff • Revolving funds, from revenue, to manage WDM projects & research • Capacity building: properly trained institutions to carry out WDM activities • Management information systems to assist institutions to manage increasing volumes of data & information • Institutions are accountable for their performance to reduce financial losses and regulate levels of service between communities • Clarification of roles for environmental NGOs

Source - (Herbertson & Tate, 2001)

Regulatory instruments

Apart from improving the capacity of the institutions, there must be in place certain regulatory measures such as rules introduced and enforced by the municipality or other local governments, incentivised and disincentivised (penalised) consumption through appropriate rules and bye-laws. The governments can also put in place laws to limit, restrict and/or abolish the abstraction of groundwater from private consumers such as industries, households, etc. In certain places, the industries can be mandated to reuse wastewater after treatment, install groundwater recharge facilities in their premises, etc. These rules that can be introduced in the cities have to be developed in consideration of the local context, consumer profiles and behaviours, etc.

Table 5.6 shows the possible requirements for legislative support for UWDM.

Table 5.6: Integrating demand management into water resources planning: Legislation and Policy

Resource Planning level	Need
Municipal	• Inclusion of WDM in water & sanitation sector policy • Policies specifically formulated for rural water supply • Strong, regulatory approaches, with specific contracts to ensure that private water companies deliver water services to the poor
Integrated Water Resource Planning	• Adoption of WDM into regional policies for planning, managing & sharing water resources, particularly international river basins • Co-ordination of policy & legislation both within & outside the water sector • Legislation to balance sustainability, efficiency & equity • Local political support, with stakeholder involvement at all stages • Development of integrated planning for water supply & efficient discharge • Specific groundwater policy to enable control over the resource • Better management of water abstraction permits • Recognition of the natural environment as a 'user'

Source - (Herbertson & Tate, 2001)

Public awareness

While there are strategies and measures implemented from top-down in various domains and sectors of urban water supply to manage demand it is equally important to engage with the public to sensitise them towards water conservation and make them aware of various plans, policies and regulations that the governments propose to manage demand. Chapter 9 of this module covers in detail the IEC activities and the various aspects that one needs to consider in planning such activities.

Table 5.7 shows the possible requirements for IEC and awareness support for UWDM.

Table 5.7: Demand management into water resources planning: Education and communication

Resource Planning level	Need
Municipal	• Development of regional public awareness & communications programmes to increase community awareness on sustainable water management. • Raised institutional awareness of cultural issues (e.g. relating to effluent reuse for drinking water) • Involving community leaders in applying WDM in their own homes & farms – teaching by example & raising awareness among leaders • Community participation in Water User Associations to help control demand
Integrated Water Resource Planning	• Raised awareness of benefits of WDM, for water managers & policymakers. • Education of more technocrats to overcome lack of implementation capacity, especially with decentralisation to catchment management • Direct, appropriate levels of communication to (& between): Policymakers, Users, Schools, NGOs, Catchment Boards, Municipal authorities. • Training required to overcome the lack of expertise (e.g. plumbing) • More resources for promoting demand management (e.g. financial, human) • Published results of efficiency campaigns – both positive & negative aspects (overcome resistance to release of information by regulators), with documentation & dissemination of best practices • Improved scientific methodologies for water resources assessment • Use of window of opportunity provided by drought – finding ways to extend water awareness during wetter years • Promotion of a culture of social awareness/consultation/communication

Source - (Herbertson & Tate, 2001)

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Chapter 6

Water Audit – an Accounting Approach to Water Conservation

Recap

Understanding the concept of urban water demand management and its principles of application in urban India. Various principles & instruments of UWDM are an important aspect of application.

Training Objectives

- To understand in brief the need of accounting water in a city.
- To understand the water balance and how to prepare a water balance chart.
- To understand the concept of closure and its relevance to water audit.
- To familiarise oneself with the two methods of performing a water audit and their details.
- To understand the guidelines of water audit proposed by Government of India.

Training Outcomes

- Gather understanding of water balance and water audit.
- Gain an understanding of the methods of conducting a water audit.
- Awareness regarding important aspects of preparing a water balance chart.

Chapter Contents

6.1 The need for accounting water

6.2 Water balance in a city

6.3 Closure

6.4 Performing a water audit

6.5 Case study – Kalol, Gujrat

6.6 Further readings

References

6.1 The Need for Accounting Water

Despite the understanding of water being such an essential resource for all human activities and existence, the practical approach to handling water in India is abysmal. On one hand where the population of urban India is growing at a rapid rate, leading to increasing demand of water, the supply of water is dwindling given the one-sided approach to understanding and exploring water sources.

Water Audit is an approach to accounting water to map the complete availability of water resources available to a city vis-à-vis the functions and operations that utilise water to identify issues in the water supply system and suggest best management practices. An audit of water can be done using any of the two approaches mentioned in detail in the following sections. Another tool, water balance is beneficial to map the water utilisation and consumption pattern in a city.

Water auditing is important from two perspectives – resource management and municipal finances. With increasing stresses to water management from both supply and demand sides, it has become ever more important to efficiently manage water with a complete inventorisation of the available resources and processes that consume water for both present and future requirements. According to the CPHEEO guidelines, the per capita requirement of water to be supplied to the users is capped at 150 lpcd with varying amounts as per the city attributes. However, research suggests that the actual amount of water supplied is disproportionately low and varies as per the user profile. This inequitable distribution of resources poses several threats to health and livelihood of the citizens.

Secondly, while calculating the water demands based on the per capita requirements of water along with the industrial, irrigational and other uses of water, in principle, 15% of the computed amount is added additionally to account for the transmission losses and non-revenue water. However, estimates suggest that in Indian cities, the NRW and transmission losses are as high as 30-40% of the total water supplied. Where the government at all levels are in the pursuit of maximising revenue from their resources, such a loss of untapped revenue goes unnoticed.

6.2 Water Balance in a City

Water Balance is a process to map the total amount of water that is available for consumption, total supplied water, amount of water billed etc. within a system. It is important to measure the apparent losses within a system and the non-revenue water. Water balance is computed and represented in a water balance chart as shown in Figure 6.1.

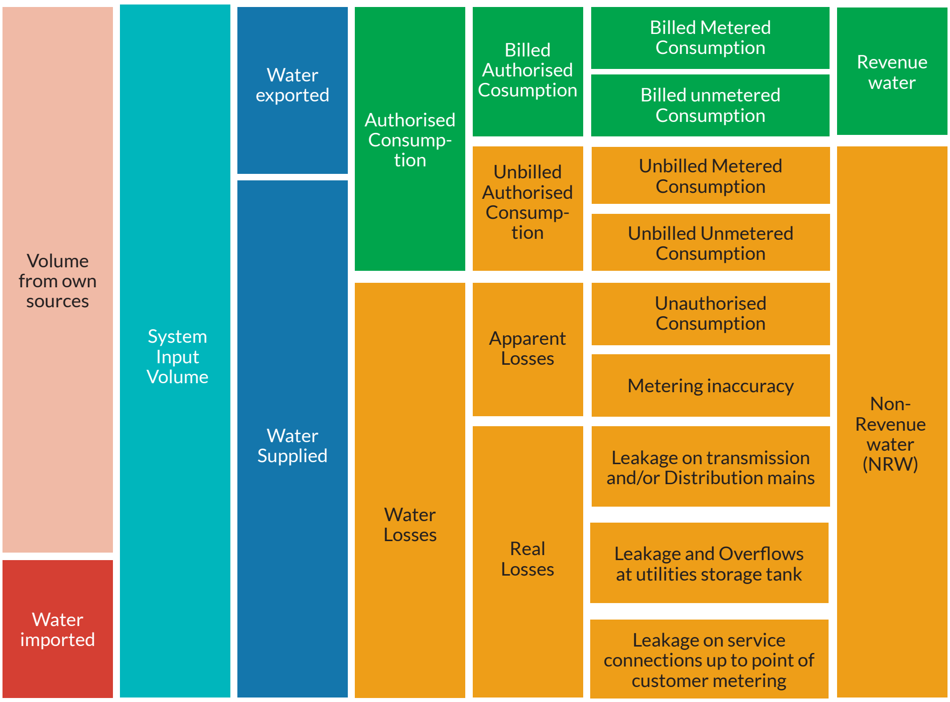
The idea is to account all water that exists in a domain or system. It provides a summary of the components under which water is being utilised. It accurately determines the unaccounted water in a city.

Objectives of water balance

The objectives of water balance are as follows:

- To assess the amount of water procured, produced and obtained in the city,
- To assess the amount of water supplied to the users in the city or other city,
- To determine the physical and intangible losses of water in the city/system,
- To identify and thus prioritise the areas that require immediate attention to conserve water and optimise water demand and utilisation.

Figure 6.1: AWWA Water Balance Chart



Source – Adapted from American Water Works Association (AWWA, 2016)

Components

The components of water balance that are mentioned in Figure 6.1 are described as follows:

1. **Volume from own sources** – The volume of water obtained from the sources owned by the auditee or the client. These are sources of water that include groundwater such as bore wells and wells; surface water such as lakes, rivers, water bodies, dams etc., and any rainwater that has been captured into the system for direct use.

2. **Water imported** – The volume of water obtained from sources that are owned by other people, and those sources that are accounted as own sources. These could also be groundwater, surface water, and ground water.
3. **System Input Volume** – The amount of water supplied into the system, corrected for any errors of metering at any level. In case of multiple sources, it is the sum of all the production metres.
4. **Water exported** – This is the amount of water supplied for uses outside the water audit domain. This could be water exported to other city, or irrigation, etc.
5. **Water supplied** – The amount of water supplied to various users in the water audit domain through the water distribution system.
6. **Authorised consumption** – The sum of amount of water that is authorised by the auditee or the water supply board for consumption by various users.
    - **Billed authorised consumption** – The sum of amount of water consumed by all the users with the authorised connections that are billed regularly.
        - **Billed metre consumption** – The sum of amount of water consumed by all the users with the authorised connections that are billed regularly based on the metre readings.
        - **Billed unmetered consumption** – The sum of amount of water consumed by all the users with the authorised connections that are billed without metre readings, such as flat rate consumption.
    - **Unbilled authorised consumption** – This is the sum of all the amount of water consumed by a set of users that have authorised connections but are not billed.
        - **Unbilled metered consumption** – The amount of water consumed by users authorised by the utility or the water supply board but are not billed, such as parks, government offices, etc.
        - **Unbilled unmetered consumption** – This constitutes all the amount of water that is unbilled and unmetered, such as all the water used for line flushing, etc.
7. **Water losses** – The water losses are computed as a difference of the System Input Volume and Authorised consumption.
    - **Apparent losses** – Apparent losses include all the amount of water that the utility supplied but has not been paid or accounted for. This is computed as the sum of amount of water lost due to discrepancy in measurement or payment at the user end, and all the water used by unauthorised connections.
        - **Unauthorised consumption** – The amount of water consumed by unauthorised connections to water supply network. This has to be obtained and quantified from a sample survey of different user groups.
        - **Metering inaccuracy** – The amount of water that is lost due to the installation of inaccurate metres or inaccurate reading of metres. Such a value is also obtained from sample surveys across the city or water audit domain.
    - **Real losses** – This is calculated as a difference between the Water Loss and the Apparent Losses.

- **Leakages on distribution mains** – These are assessed by active leak detection using various technologies and techniques on the supply mains of water distribution system.
- **Leakages and overflows on utility's storage tanks** – The amount of water that lost due to the overflows at water storage tanks of the water utility or water supply board.
- **Leakages on service connections up to the point of consumer meters or end** – The leakages on service connections are assessed by portable metres etc. measured at various location in the distribution network except the supply mains.

8. **Revenue water** – Revenue water is the amount of water that earns revenue to the water utility or the water board. The revenue water is equal to the amount of water that is billed and authorised by the utility.
9. **Non-revenue water** – Non-revenue water is the amount of water that does not earn revenue to the water utility. It is computed as the difference of system input volume and revenue water.

6.3 Closure

Closure is a measurement tool that measures the water entering in the audit domain and the water output of the domain. Such a measure is useful to determine preliminarily the losses in the system or the audit domain. Closures are calculated after conducting the audit. However, it is a good practice to assign a tentative value in anticipation of the closure, against which the calculate value is compared. The closure as a tool is suggested by Sturman et al. (2004), and is calculated as the difference between the input water and the output water of a system measured as a percentage of the input water. The mathematical formula is described as below;

$$\text{Closure of a system} = \left[\frac{\text{Sum of amount of water input in the system} - \text{Sum of amount water output of the system}}{\text{Sum of amount of water input in the system}}\right] \times 100$$

or simply written as;

$$\text{Closure of a system} = \left[\frac{I - O}{I}\right] \times 100$$

where, *I = Sum of amount of water input in the system*
O = Sum of amount of water output of the system

A predetermined closure of 10% is the convention, while 10% closure is also an accepted limit of closure of water quantity in the system. A closure applied to individual processes is better to assess the losses than applied at the whole system.

6.4 Performing a Water Audit

There are various methods established by different agencies and individuals that have been used in practice of preparing a water audit. This chapter details out two prominent methods – first, the IWA method elaborated and proposed by Jeffrey Sturman and his colleagues in the book 'Water auditing and water conservation' published in 2004; and the second one proposed by the Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India in 'Draft Guidelines for Water Audit and Water Conservation' published in 2017. Both the methods are described in detail in the following sections.

Method 1 – by Sturman, et al. (2004) in 'Water auditing and water conservation'

With slight modifications to a previous definition of the procedure (Dawson, 1997) Sturman, et al. (2004) describe the process of water auditing as follows — 'Water auditing is a repetitive, systematic and documented process of objectively obtaining a balance between water input to, and water output from, an operation. Water quality is measured as needed. Opportunities are sought for a reduction of water use, for water reuse, recycling and for water resource substitution. Financial evaluations are made of all opportunities identified. A water management strategy is devised which is consistent with legal requirements, the enterprise's environmental policy and its movement towards sustainable development. The results of this process are communicated to the client and to the auditee where different'. This process has been summarised in Figure 6.2.

The details of the four phases have been described in detail in the following sections. The water audit method that is widely used and referred to around the world is formulated by Sturman and his colleagues, which is also known as the IWA method. They propose a four-phase process. It starts with audit preparation, conducting the audit, devising a water management strategy based on the audit prepared in the previous stage, and finally producing an audit report. The details of the steps involved in each phase as mentioned and adapted from Sturman, et al. (2004) are briefly described below, while also considering the Indian landscape of water governance.

Phase 1 – Audit preparation

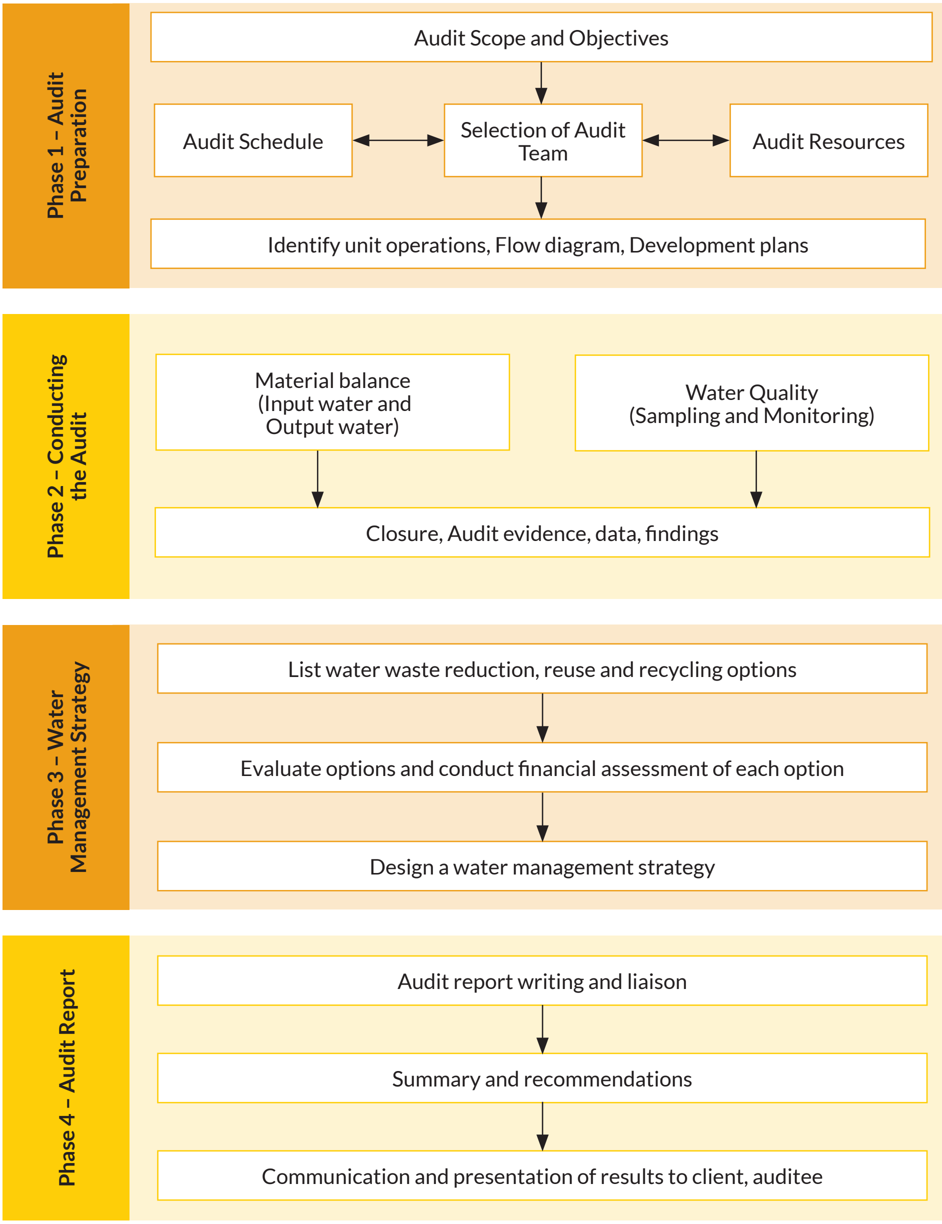
Initiating the audit

The water audit may be initiated by an enterprise, corporate entity, government or an organisation itself, or be suggested by a government or legislation for regulatory or compliance, or inform policy-making. The reasons for initiating the audit could also be motivated from various other reasons. Sturman, et al. (2004) lists a few reasons in their book. These could be, for example:

- Desire for a green corporate image,
- Community pressure,
- Increased demand outside enterprise might imply a higher unit price, and
- A desire to trade in water.

The initiation of the water audit requires firstly preparing an audit brief, acting as a guiding document to frame and execute the audit, for the auditor. The contents of the audit brief shall depend on who and why the water audit has been initiated.

Figure 6.2: Overview of the Water Audit Process



Source – Adapted from Sturman, et al. (2004)

The audit brief document is precursory to the detail framework of the audit itself. It provides the objectives of the water audit, demarcating the roles and responsibilities of the stakeholders involved, and define the scope of the water audit. The contents of the audit brief may include, but not limited to the following requests:

- identification of the various sources of water used in the area of study, or the domain of the water audit,
- to achieve a set standard of closure, or 'pre-determined tolerance',
- to suggest methods and techniques of achieving water use efficiency,
- estimate the costs of the suggested methods and options,
- to provide a financial plan and/or a capital investment plan with potential revenue streams and amounts,
- suggest ways to reduce water consumption at various level that could be established at the onset, or identified through the process of water audit,
- assess the legislative and/or regulatory compliance of the auditee (the organisation for which the audit is being conducted) with respect to water intake, abstraction, supply, discharge, etc.,
- evaluation of previously suggested solutions for water management and their outcomes,
- projecting water demand and use considering future growth,
- to discuss the above and others with the client prior to preparation of a final audit report.

Other than the above mentioned, the audit brief may also contain the scope and geographic and administrative boundaries that shall be the study area of the water audit. The definition of the boundary conditions of the water audit and the system is an important aspect. Based on the audit brief, next step is to assess the resources required for conducting the defined audit.

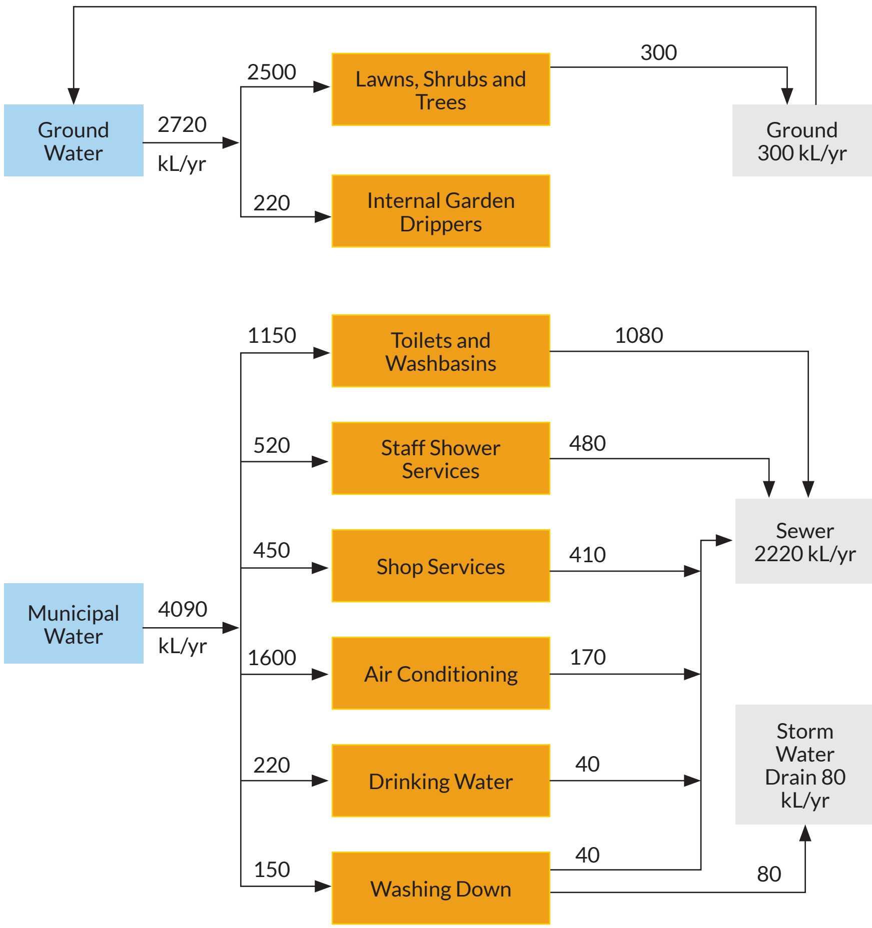
Audit resources

The audit brief is used to determine the resources that would be required in the process of conducting the water audit completely. Such an assessment includes resources of time, finances, people, infrastructure, and equipment. Initial site visits to the area of concern are important at this stage to determine the requirements. In certain cases, it may be required to establish a team to conduct the audit, which may comprise various experts for water quality, management, etc., headed by a lead auditor.

Preparing a water flow diagram

A water flow diagram, also sometimes called a water management diagram, is used to simplistically represent the complex relationships and network of water flows for various process, accounting for water sources and discharges. It is a critical management tool in the process of a water audit.

Figure 6.3: Water Flow Diagram



Source – Adapted from Sturman, et al. (2004)

A water flow diagram in basic form represents graphically the sources of water, amount of water input into the system that is abstracted from each of the sources listed, the various processes involved in the system boundary that utilise water and the amount of water allocated to each of them, and the various sinks and disposal areas of water obtained as a by-product or as an output of the processes. The water sources are listed on the left of the diagram, the processes (or unit operations) that utilise water are listed in the centre and the water sinks or the areas where water is disposed are mentioned on the right of the diagram. The entities of sources, processes and sinks are connected with arrows marking the direction of flow of water. The unit of quantity of the water must remain same throughout (preferably thousand litres per year represented as kL/year, or million litres per year represented as ML/year). This water flow diagram is also a 'water use inventory' in a graphical form. An example of a water flow diagram is represented in Figure 6.3.

A single unit operation or process includes all physical items of similar character and use, for example, all domestic connections with metres may be a single unit at the city level, or all showers and taps may be clubbed into a single unit operation at a building level. The blocks structured under the water flow diagram may or may not resemble any physical structure or process completely. The grouping depends on the scope of the water audit to be conducted.

Sturman, et al. (2004) list out the information that would be required to draft a water flow diagram. The information required may relate with the following:

- site plans, city plans, masterplans, including building layout and the plans of processes,
- drawings of pipeline layout and pipe network,
- water sources, whether reused, recycled, seawater, surface water, ground water, storm water or municipal water,
- previous water audits,
- process water usage,
- general water usage,
- personal water usage points,
- reticulation,
- bore water usage,
- water treatment,
- water disposal, whether removed as product or discharged to ocean, sewer, ground water (recharge), watercourse or evaporated,
- plans for units or total processes to be developed in the future.

Upon having prepared the basic water flow diagram based on the preliminary site visits, interviews, etc., the final flow diagram is prepared. The final flow diagram must have information regarding water quality, quantity, and flow rates, wherever necessary. Based on this preliminary water flow diagram, the audit is thus conducted, the detail of which has been described in the following section.

Phase 2 – Conducting the audit

After the initial steps of audit preparation are completed, the next phase is to execute the audit, dealing with the measurements and calculations and attempt closure. Various tools, techniques and methods may be deployed to gather data as per a specified standard. The accuracy of measurements vary for various circumstances. The accuracy may depend on the proportion of flow through that system vis-à-vis the total flow in the audit area.

A greater desired accuracy would reflect in increased prices of leasing and purchasing the instrument and apparatus required achieving that accuracy. The decision of the accuracy of measurement is to be taken on a case-to-case basis considering the available resources of time, money and human-power. Previous water audit reports may provide important pointers as to what could be required levels of accuracy of measurement. The measurements could be recorded by deploying a questionnaire or log-sheets, etc.

Questionnaires are a helpful tool for understanding the functions, uses and quantities of water utilised in particular unit operations or processes. Different processes may warrant different questionnaires based on the hierarchy of users, their dynamics, and the physical processed involved in the operation. Questionnaires must be drafted with great care and attention capturing the required important information correctly and effectively while also keeping it brief and short respecting the time the official spend at work.

Log-sheets may be utilised to record values and measurements in systems and processes that do not function at steady state. Electronic or manual logging at specified time-periods may be used in such cases.

Phase 3 – Water management strategy

Based on the audit prepared in phase 2, the next phase is to devise a water management strategy that proposes strategies to efficiently use the available water resources and streams. The steps involve listing the options, evaluating the options and designing a water management strategy.

Listing the options involves creating possible options showcasing avenues of reducing water demand, judicious utilisation of resources, steps to reduce water consumption in various processes, etc. It is an iterative process, going back and forth from one to the other and exploring its interactions with the other options and processes. It is to be noted that while listing the options, one may be as creative as required, without being limited by specific requirements or constraints.

The exploration of options vis-à-vis various factors and constrains of the site and scope of the audit is the next step, where the options are evaluated. The options may be evaluated and assessed against issues and challenges of water quality, water sources, environmental and ecological implications of the option in consideration, human aspects and impacts of options such as automation, financial capacity and issues of the auditee or the client. Each option must be accompanied with a preliminary financial analysis to assist and simplify decision-making. Detail analyses can be prepared for the finalised options while preparing a water management strategy. The capital costs and pay back periods are to be calculated for the options. The payback periods are classified as 'short term' (two to three years), 'medium term' (three to five years) and 'long term' (six or more years).

Based on such an analysis, a detail water management strategy must be constructed. The strategy is a combination of few options that are most likely to assimilate well with each other. The potential options of water management strategy must preferably contain multiple more than one strategies and be suggestive of the best of those. While being suggestive, each strategy option must be accompanied with a set of parameters to gauge the options. The parameters are an important tool to decision making from a client's perspective.

Phase 4 – The audit report

The last phase of activities in process to conduct a water audit is to prepare an audit report for dissemination of results, findings and suggestions. Sturman, et al. (2004) list the contents that must go in an audit report. They are as follows:

- Title page
- Participants
- Executive summary
- The brief
- Introduction
- Description of site
- Plans for further development
- Water sources and sinks (general)
- Each water source (specific)
- Recycled and re-used water
- Each water sink (specific)
- Present water use and flow diagram(s) (including flow measurement methods)
- Raw options for improved water use efficiency
- Evaluation of raw options
- Water management strategy (including proposed water flow diagram(s))
- Water audit process review
- Conclusion

Method 2 – 'Draft General Guidelines for Water Audit and Water Conservation' by Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India, (2017)

The Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India, launched 'Draft Guidelines for Water Audit and Water Conservation' in an attempt to encourage and sensitise cities towards water conservation and using water audit as a tool to achieve efficiency in water utilities. The guidelines list out steps that are required for a water audit. The steps are mentioned below.

Water supply and usage study

The first step is to prepare maps and layouts highlighting locations and capacities of water sources, distribution networks, points of delivery for users and returns of flows of excess water/waste water. This should be supported with the studies about usage and consumption patterns of the various organisations and processes. This would be beneficial to project future demands.

Process study

The individual processes need to assessed and monitoring the characteristics of the flow of water from various crucial points, such as source abstraction, the treatment plants, distribution mains, user end, etc. These should be monitored at regular intervals for the quality and quantity of the water in the system.

System audit

The next step is to zoom down to the level of various sectors involved in the system such as industrial, domestic, commercial, irrigation and agriculture, etc. This would be helpful to visualise the most water intensive systems and consumers in a city. Based on the demands and requirements of these individual sectors, the solutions could be proposed that would cater to the needs of the sectors, while achieving efficiency. If there are existing metering systems, their readings should be logged regularly for the consumption volume and amount.

Discharge analysis

The next step is to assess and evaluate the quantity and quality of water and wastewater as an output or by-product of various processes, operations and systems. The estimation of quantity and quality is required to explore potential zones for water treatment and reuse of wastewater.

Water audit report

Once the above-mentioned analyses have been conducted, the water audit is conducted assessing the water losses of the system for which the water audit has been conducted, measuring the financial costs and revenues, along with the water utilisation requirements. This may be supported along with a cost-benefit analysis study. The guidelines (MoWRRDGR, 2017) state that a water audit report may contain the following:

- Amount of water earmarked/made available to the service.
- Amount of water utilized both through metered and unmetered supplies.
- Water loss and efficiency of the system along with reasons for such losses.
- Suggested measures to check water loss and improve efficiency.

The guidelines suggest that a water audit must be conducted once annually.

Institutions involved

As discussed earlier, a water audit can be conducted for a city, an individual system such as commercial processes or industrial processes, a ward or a set of wards, a neighbourhood or any scale. Based on the audit domain the concerned institutions and stakeholders are determined and mapped.

For a water audit of a city and the other surrounding areas where municipal water supply is provided, where the municipal corporation or other ULB is the auditee, the following institutions and stakeholders are involved:

- The ULB or the municipal corporation,
- The water supply board or the infrastructure board, if any,
- The industries' association, if any,
- The Resident Welfare Associations (RWAs),
- Parastatal agencies involved with water supply and distribution,

There may be other stakeholders and institutions involved based on the local administrative structure and governance model.

6.5 Case Study – Preliminary Water Audit for Kalol, Gujrat

Table 6.1: Highlights of Kalol, Gujrat

Highlights	
Location	Kalol, Gujrat, India
Population (Census 2011)	1,33,737 people

Source – CEPT University (2010)

Kalol is a small city in Gujrat, with an estimated population of about 1.5 lakh people. It has a water demand of 23.8 MLD. A water audit was conducted as a part of research by CEPT University for Kalol. At the time of study, Kalol had in total 22 sources of water both surface and groundwater sources, including a water treatment plant at Pratappura. The Pratappura water treatment plant provides about 12.5 – 13 MLD. The total water supplied to the city is 17.26 MLD.

Gujrat Water Supply and Sanitation Board (GWSSB) charged Kalol at a rate of Rs 4 per kL for the water supplied from Pratappura water treatment plant. Including the cost of operation of services at the bore well, Kalol had a water production cost of Rs 2,64,75,613 per year. This amount is exclusive of the cost of maintenance and human resource incurred by the municipality for the operation of the water sources. An estimate of the revenue based on the water tax charged by the municipality revealed that the total revenue obtained from all the domestic and commercial customers was about Rs 76.5 Lakh. The revenue is about a fourth of the total production costs of water. Given such a statistics of revenue and expenditure and resource utilisation, Kalol had to reduce the NRW in the city water supply system. It would have reduced the operating costs of the supply system and abate the need to explore various other resources to fulfil demand. In an attempt to identify the NRW and reduce the same, a basic water audit was conducted by CEPT University for Kalol. The chart with computed values is shown in Figure 6.4. It was found that the NRW in Kalol was as high as 46%.

Figure 6.4: Water balance chart for Kalol

<table>
<tr><td rowspan="9">System input volume
6,299</td><td rowspan="4">Authorised consumption
(54.2%)
3,414</td><td rowspan="2">Billed authorised consumption
(53.7%)
3,381</td><td>Billed metered consumption
0.0</td><td rowspan="2">Revenue water
(53.7%)
3,381</td></tr>
<tr><td>Billed unmetered consumption
(53.7%)
3,381</td></tr>
<tr><td rowspan="2">Unbilled authorised consumption
(0.5%)
33</td><td>Unbilled metered consumption
0</td><td rowspan="7">Non-revenue water, NRW
(46.3%)
2,918</td></tr>
<tr><td>Unbilled unmetered consumption
(0.5%)
33</td></tr>
<tr><td rowspan="5">Water losses
(45.8%)
2,885</td><td rowspan="2">Apparent losses
(16.8%)
1,058</td><td>Unauthorised consumption (16.8%)
1,058</td></tr>
<tr><td>Consumer metering inaccuracies
0</td></tr>
<tr><td rowspan="3">Real losses
(29%)
1,827</td><td>Leakage on service connections up to point of customer metering (15.6%)
980</td></tr>
<tr><td>Leakage on transmission mains (9.9%)
624</td></tr>
<tr><td>Leakage and overflows at utility's storage tanks (3.5%)
223</td></tr>
</table>

Source – CEPT University (2010)

Note – The values mentioned are in ML per annum

Based on the preliminary water audit and water balance, a set of recommendations were made to reduce NRW. These are briefly listed below:

- Repair ESRs and leaking valves, and reduction of overflow of tanks to reduce the 3.5% of water wastage.
- Identification and regularisation of illegal connections.
- Establishment of a water quantity data recording and processing system.

6.6 Further Reading

1. *Draft General Guidelines for Water Audit and Water Conservation 2017 of Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India http://old.cwc.gov.in/main/downloads/DraftGuideline_Water_Audit.pdf*
2. *Water Auditing and Water Conservation by Jeffrey Sturman, Goen Ho and Kuruvilla Mathew published by IWA Publishing*
3. *Water Audit Manual by UN-Habitat*

References

1. *AWWA, 2016. M36 Water Audits and Loss Control Programs. s.l.:American Water Works Association.*
2. *CEPT, 2010. Preliminary Water Audit: Estimation of Water Losses and Strategy for Loss Reduction, City of Kalol, Gujarat, India, Ahmedabad: CEPT University.*
3. *Dawson, M., 1997. Water audit guide – Case study-Wesfarmers CSBP Limited Kwinana Works, Murdoch: Independent study contract dissertation, School of Environmental Science, Murdoch University.*
4. *MoWRRDGR, 2017. Draft General Guidelines for Water Audit and Water Conservation, New Delhi: Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India.*
5. *Sturman, J., Ho, G. & Mathew, K., 2004. Water Auditing and Water Conservation. London: IWA Publishing.*

Chapter
7

Technologies for Non-Revenue Water

Recap

Understanding the concept of water audit and water balance. Its principles of application in urban India. The water balance and closure are important tools in the process of water audit.

Training Objectives

- To understand the NRW
- To calculate NRW accurately
- To understand the major causes of NRW
- To identify major impacts of NRW
- To know the technologies available ecosystem for NRW reduction

Training Outcomes

- Understanding the causes of NRW
- Identification of NRW reductions possibilities
- Improving water balance
- Efficient Water supply system.

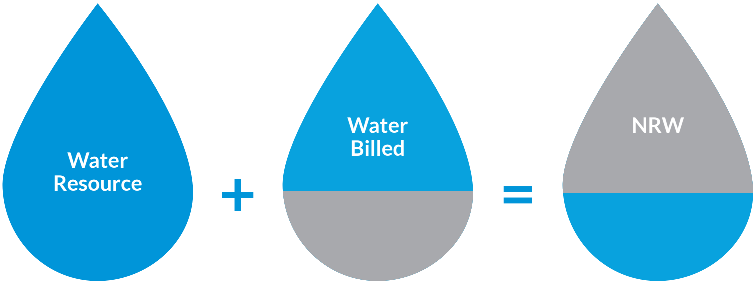
Chapter Contents

7.1 NRW: Terminology, and Approach
7.2 Knowing the water losses
7.3 Impact of NRW
7.4 Improving the Accuracy of water balance
7.5 District Metering Areas (DMA)
7.6 Developing a strategy for NRW Management
7.7 Case studies
7.8 Conclusion
References
Exercise

Non-revenue water (NRW) is water that has been produced and is lost before it reaches the customer. NRW is typically measured as the volume of water lost as a share of net water produced (Figure 7.1). However, it is sometimes also expressed as the volume of water lost per km of water distribution network per day.

NRW is a good indicator for water utility performance; high levels of NRW typically indicate a poorly managed water utility. In addition, published NRW data is often problematic, suspicious, inaccurate, or provide only partial information. Some utilities invent “creative” definitions of NRW, use wrong or misleading performance indicators, and fail to quote important information, such as average pressure and supply time.

Figure 7.1: Graphical representation of Non-revenue water



Source – Author

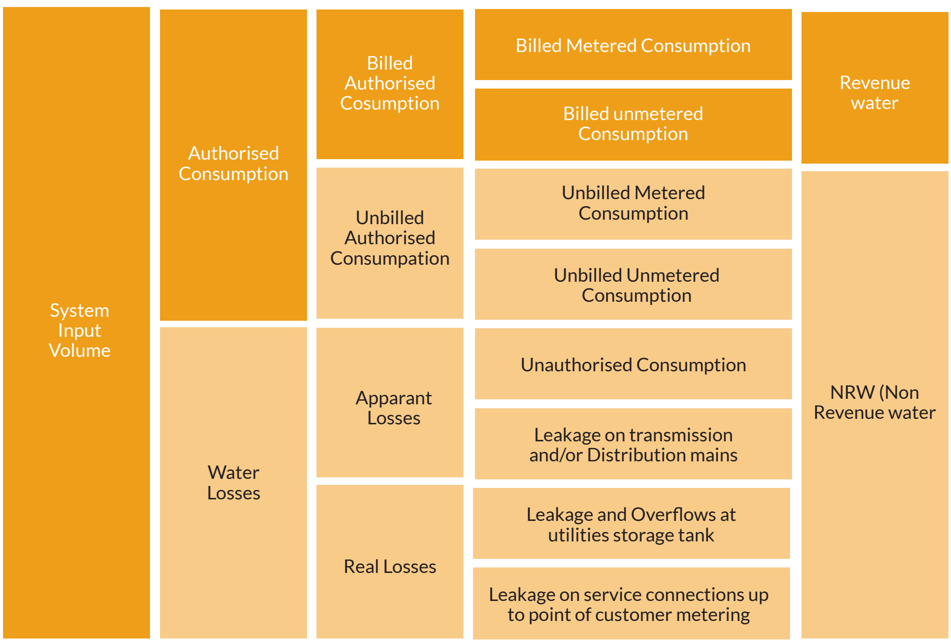
7.1 NRW Terminology and Approaches

Primarily non-revenue water (NRW), is water that is pumped and then lost or unaccounted for. The need to manage NRW better and protect precious water resources has become increasingly important. Non-revenue water (NRW) management allows utilities to expand and improve service, enhance financial performance, make cities more attractive, increase climate resilience and reduce energy consumption. In a water constrained environment, NRW management often offers superior cost-effectiveness compared to supply augmentation. At the same time, revenues from saved water improve a service providers bottom line whilst lower water abstraction increases city resilience. But the benefits that arise from reducing NRW are yet to become driving forces behind tackling this endemic challenge in developing countries. Despite the benefits and decades of training and advocacy from international and industry organizations, NRW reduction still receives scant attention amongst those utilities which would most benefit from it.

7.2 Knowing The Water Losses

For many cities, reducing NRW should be the first option to pursue when addressing low service coverage levels and increased demand for piped water supply. Expanding water networks without addressing water losses will only lead to a cycle of waste and inefficiency. Also, a high rate of NRW is closely related to poor energy efficiency, since water transported in networks is loaded with energy through the distribution and treatment processes. Thus, energy is lost along with the water. Therefore, reducing NRW is important to the overall efficiency and financial sustainability, since it provides additional revenues and reduces costs. Generally, NRW management in an open system is undertaken in a passive manner where NRW reduction activities are initiated only when the loss becomes visible or is reported. A more effective approach is to move towards Active NRW Management where dedicated teams are established and sent out to look for water losses, such as leaks, reservoir overflows, and illegal connections (Figure 7.2).

Figure 7.2: AWWA simplified water balance chart



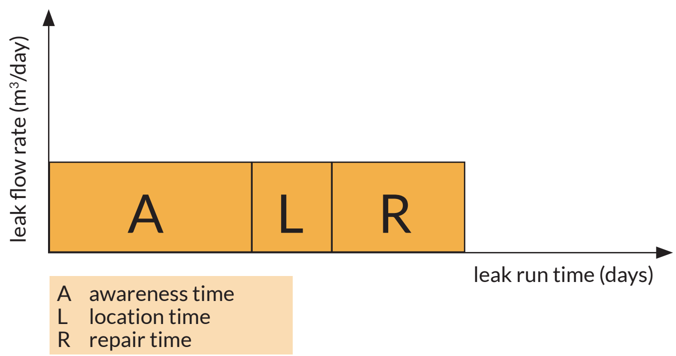
How much water is being lost?

Although it is widely acknowledged that NRW levels in developing countries are very high very little data are available in the literature regarding the actual figures, largely because most water utilities in the developing world do not have adequate monitoring systems for assessing water losses and many countries lack national reporting systems that collect and consolidate information on water utility performance. The result is that NRW data are usually not readily available, and when they are, they are not always reliable because it is common for the management of poorly performing utilities to practice "window dressing" in an attempt to conceal the extent of their inefficiency.

Physical losses can occur along with the entire distribution system, from storage reservoirs and the primary network to the smallest service connections. When people think about leakage, they normally think of big and spectacular pipe bursts. These often cause a lot of damage but are insignificant in volume compared to all the other leaks. Normally around 90% of the water that is physically lost from leaks cannot be seen on the surface. These leaks might eventually become visible after many years, but until then, large volumes of water are lost every year. Sometimes, undetected leaks can be quite large, such as those that run directly into a sewer or a drain. Therefore, a water utility that does not practice a policy of efficient and intensive active leakage control will always have a high level of leakage, except if the infrastructure is new and/or in excellent condition. The volume of water lost from an individual pipe burst does not only depend on the flow rate of the event but is also a function of run time. This is often overlooked. The leak run time consists of three components (Figure 7.3):

- **Awareness time:** time until the utility becomes aware that there is a leak;
- **Location time:** time spent to precisely locate the leak so that a repair job order can be issued; and
- **Repair time:** time between issuing of repair job order and completion of the repair.

Figure 7.3: Computation of water loss through leakages



$$(A + L + R)\ [d] \times \text{flow rate}\ [m^3/d] = \text{water lost}\ [m^3]$$

Source - Author

Why and where are losses occurring?

The most problematic leakages are those that are not visible on the surface. The reason for the leakages can be the below-mentioned reasons or a combination of them:

- Bad quality of equipment like valves, joints, connections and pipes
- Deterioration of the distribution system
- Poor workmanship like bad welding or wrong handling during the laying of the pipes
- Water hammer and poor water pressure management
- Corrosion of material due to acidic soil
- Settings or movements in the soil
- Load from heavy traffic or construction work
- Frost settings in the soil
- Drying out of the soil
- Earthquake
- Illegal connections from water thieves,
- The accidents that are done by contractors during construction work.

7.3 Impact of NRW

Impact on water utility efficiency

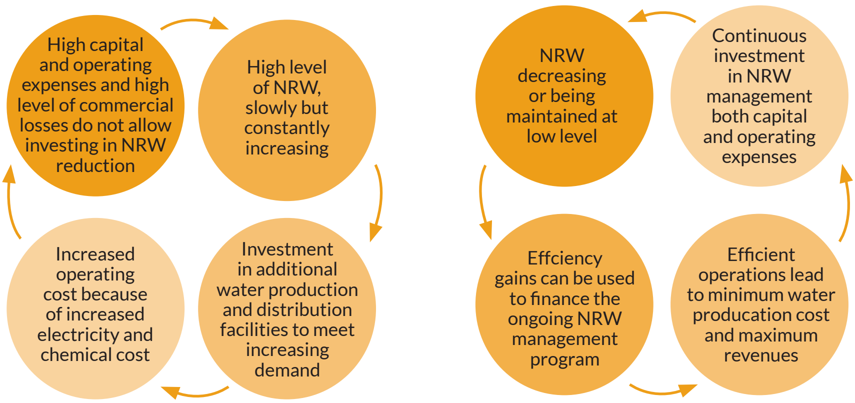
The business in general cannot survive for long if it looses a significant portion of its marketable product, but that is exactly what is happening with many water utilities. High levels of NRW lead to low levels of efficiency. When a utility's product (treated water) is lost, water collection, treatment and distribution costs increase, water sales decrease, and substantial capital expenditure programs are often promoted to meet the ever-increasing demand. In short, the utility enters into a vicious cycle that does not address the core problem. An NRW reduction will naturally reduce the urban water loss and subsequently increase the revenue generation but it can also lead to other important benefits for the water utility and its consumers:

- Reduced stress on the area's water resources, allowing more people to be served by the same water source.
- Reduced energy consumption for abstraction, treatment and distribution while still meeting the same demand for water as pressure is adapted to demand and smaller volumes of water will need to be treated and distributed.
- A more stable water supply as improved performance will provide full pressure distribution 24 hours a day, 7 days a week.
- Better support for decision making and customer service due to new management systems.
- A strong basis for setting up a long-term rehabilitation and investment plan for the network.
- Improved water quality due to optimized water distribution as chlorine content in the distributed water will be better controlled and risk of pollution-related to burst and periods with low pressure or vacuum will be reduced.

The challenge for these utilities is to turn this vicious cycle into a virtuous cycle, which will lead to low levels of NRW and therefore substantially improved efficiency (Figure 7.4). To make such a transformation, political will and the full support of top management is vital. In most cases, technical know-how at the utility level must also be improved. Some utilities may require assistance from outside experts, either through standard technical assistance or more innovative methods, e.g., performance contracts.

In addition to the general reluctance to invest in NRW reduction, there is also a lack of financial incentives. Average tariffs are usually too low and do not encourage water utilities to expand coverage and reduce commercial losses. Also, raw water is in many cases free of charge and environmental costs are not taken into account. If water utilities were forced to pay abstraction charges, the reduction of physical losses would be high on the agenda. Reducing physical losses will not only help postpone capital investments for developing new water sources, but it will also help reduce a utility's electricity bill. Water delivered to customers' taps has a large amount of embedded energy. For the reasons stated above, the level of NRW is one of the best indicators of water utility efficiency. A utility with a high level of NRW either has management who is not aware of the benefits of NRW reduction or is simply not capable of introducing and managing these complex and interrelated activities. A utility with a low level of NRW obviously must be well managed, as NRW management is one of the most complex and difficult tasks of a water operator.

Figure 7.4: Vicious (a) and Virtuous (b) Cycles of NRW



Source - Frauendorfer & Liemberger (2010)

Impact on customers

The main objective of a water utility is to satisfy customer demand. A high level of NRW has a severe and direct impact on the ability of utilities to meet this objective and therefore harms customers. High physical losses often lead to intermittent supply, either because of limited raw water availability or because of water rationing, which may be needed to reduce supply hours (and therefore hours of water leakage) per day. In addition to substandard service, intermittent supply poses a significant health risk, as contaminated groundwater, or even sewage can enter the leaking pipes during supply interruptions and very low-pressure periods. The avoidance of this significant public health risk should be reason enough to reduce leakage to enable continuous supply. High leakages also increase flow rates in the pipe network, which can cause unnecessarily high-pressure losses that affect customers and often lead to supply interruptions during peak demand hours.

Yet another problem is that intermittent supply will leave customers unsatisfied, resulting in low willingness to pay for improved service. This will discourage local governments to approve tariff increases that could help improve the situation, and the vicious NRW management cycle will be reinforced. In the long run, high levels of NRW may lead to unnecessarily high tariffs (if tariffs are properly set). In these cases, high water tariffs can, in effect, represent a subsidy borne by paying customers to cover NRW. If tariffs are not high enough, the water utility will remain financially weak and will not be able to provide appropriate service to its customers. In water systems characterized by unsatisfied demand and limited coverage, a high level of NRW is often the main reason why the system cannot be improved. In many cases, the population is then forced to use alternative water sources, which are often of poor quality and high in cost. There are two reasons for this situation. First, where raw water is limited, the volume of water that is physically lost is often required to supply unserved areas. Second, poor financial performance that results from high NRW makes it difficult to finance distribution network expansion.

The urban poor is often blamed for high levels of NRW, especially due to illegal connections. On the other hand, the poor are significantly affected by high water losses. While theft of water in low-income communities is certainly a reality in many Asian cities, its impact must be put in the proper perspective. The volume of water that is illegally consumed by a poor household is normally quite small, because of the lack of washing machines, flush toilets, garden irrigation, etc. Furthermore, this low level of consumption would nearly always be in the lowest tariff category (if such a category exists). Therefore, the financial impact is even less than the volumetric impact. Experience in many countries shows that water theft by higher-income households and commercial and industrial users can be much more of a problem. Case studies from various Asian cities also indicate that there is very often a high willingness to pay for piped water supply among the poor, as this is nearly always cheaper than water purchased from water vendors. Unfortunately, in many cities, it is illegal to supply water to informal settlements, which automatically leads to the construction of illegal connections. These are nearly always built of inferior quality and at the tapping points the main pipes are damaged, so the physical losses in such areas often exceed the commercial losses caused by the theft of water. In the case of intermittent supply, which is frequently caused by excessive leakage, the urban poor often suffers most, as they cannot afford proper storage facilities and pumps and often have to buy water from vendors during non-supply hours. Reducing physical losses will also make more water available and enable water utilities to increase coverage, including to poor communities.

7.4 Improving the Accuracy of Water Balance

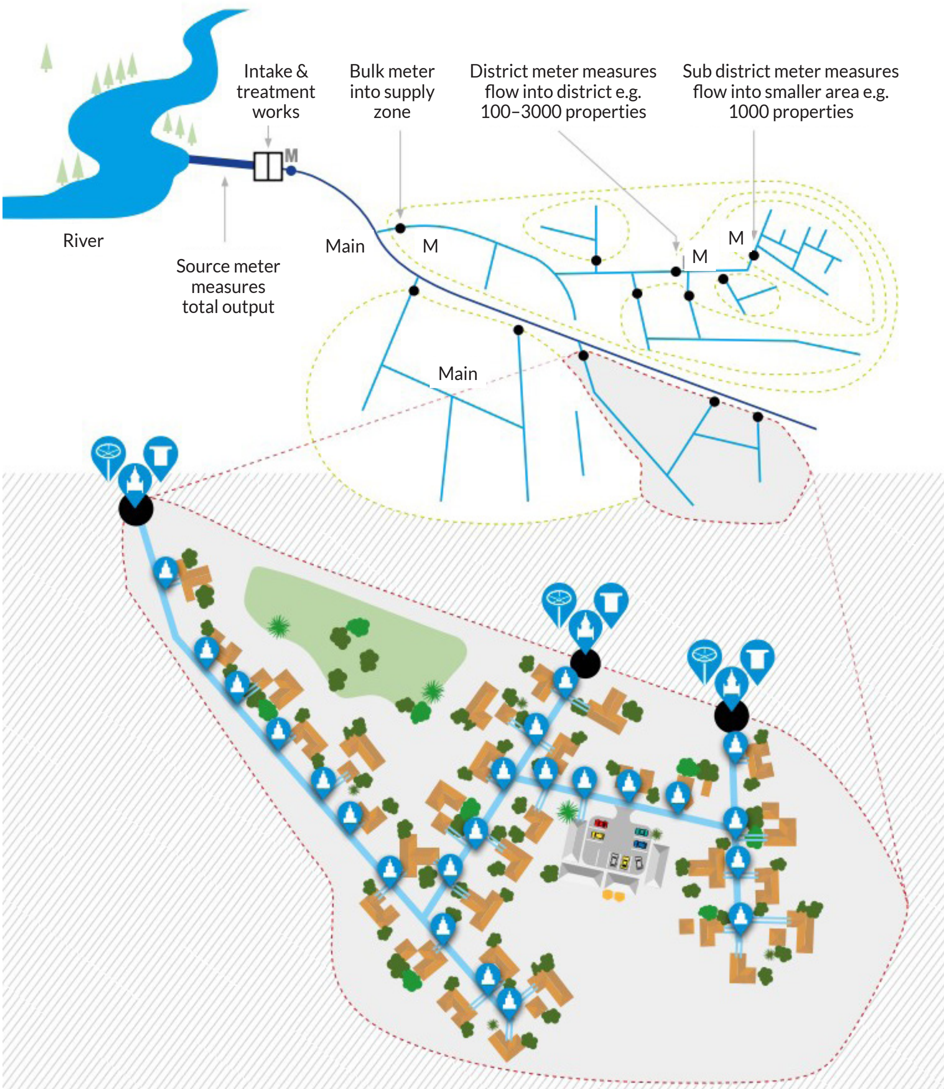
Initially, NRW management was based more on guesswork than on precise science. This has changed dramatically in many industrialized countries, kick-started by the regulatory pressure on UK water companies to cut leakage. Yet, despite some encouraging success stories, most water supply systems worldwide continue to have high levels of water losses. Part of the problem is the lack of a standard approach to defining and quantifying the components of NRW. Surprisingly, few water utilities in developing countries establish a water balance. Even if they do, no standard approach or terminology is used, so they all differ from each other. The first step for any utility aiming to reduce water losses is to prepare a baseline to establish current levels of water losses. This is done by carrying out a water audit that leads to a water balance, which is a prerequisite for designing an NRW reduction strategy. This first step is critical, yet it is often overlooked in the development of many urban water supply projects.

7.5 District Metering Areas (DMA)

Active NRW Management is only possible using zones, where the system as a whole is divided into a series of smaller sub-systems for which NRW can be calculated individually. These smaller sub-systems, often referred to as District Meter Areas (DMAs) should be hydraulically isolated so that utility managers can calculate the volume of water lost within the DMA. Sustainable SMART water management is about monitoring and controlling the supply system, and water authorities and operators often face a series of challenges when monitoring the water volume conveyed by networks and detecting leaks to preserve the water supply.

Dividing a network into sections called district metering areas (DMA) is an effective tool to prevent water loss. A high-quality reliable AVK gate valve is the perfect choice to shut off the flow between the different DMAs completely. Each DMA has one or two inlets on which a bulk water meter is installed to measure the amount of water flowing into the DMA (Figure 7.5). All consumers within the DMA are also supplied with a household water meter to measure how much water is consumed. A negative difference between the water in the DMA and the water used by consumers indicates a leak inside the DMA. However, if the difference is positive, it suggests that water from the neighbouring DMA sends water into this DMA. Even though the latter may not be a direct leak, they are both harmful with managing each DMA individually. So, to control the water distribution system it is of vital importance to install reliable high-quality valves. By choosing high-quality shut-off valves, leakages from the valve itself can be avoided. Gate valves with a high-quality rubber gasket ensure that the valves are 100% drop-tight. Experts and engineers often say that high quality, functional and operational valves are the backbone of any water distribution system!

Figure 7.5: DMA Formulation



Benefits of the DMAs

For each DMA, utility managers should develop a detailed operation manual to assist future teams in managing the water supply. The operations manual includes a schematic of the pipe network; location drawings of the flow meters, pressure control valves, and boundary valves; and a copy of the billing database for the DMA. The manual is a working document and operational data should be continually updated, including information on the following:

- Flow and pressure graphs
- Leakage step tests data
- Leak locations
- Illegal connection locations
- Legitimate night flow (LNF) test data
- Maintaining asset life through pressure management
- Safeguarding water quality
- Enabling continuous water supply

7.6 Developing a strategy for NRW Management

Rehabilitation of distribution systems

Leakage management and high-quality operational valves

High quality, functional and operational valves are the backbone of any water distribution system.

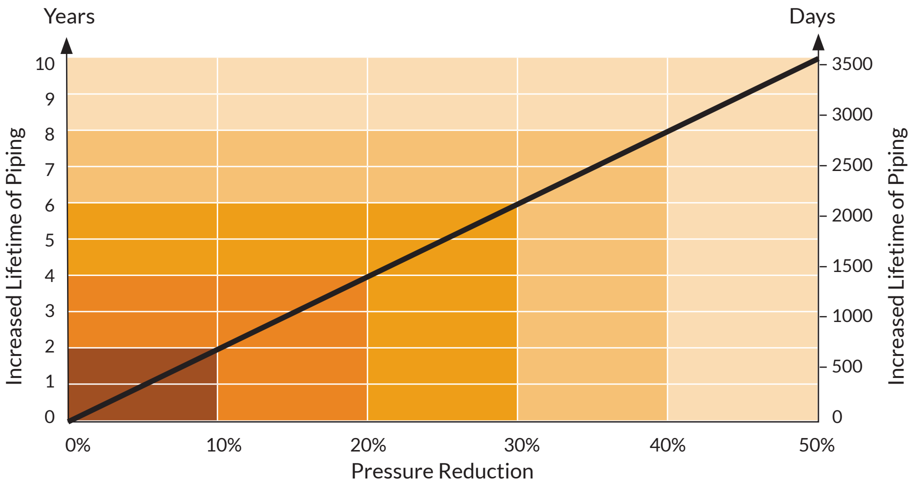
Replacement of ageing infrastructure

Timely replacement and rehabilitation of piped infrastructure is the first key for leakage management and NRW reduction.

Pressure management (pipes -life increment)

Improved pressure control presents dual benefits of reducing leakages and stabilizing system pressures, which increase asset life (Figure 7.6). Most pipe bursts occur not only because of high pressure but rather due to ongoing pressure fluctuations that force the pipe to continually expand and contract, resulting in stress fractures. Installing a pressure control device, such as a pressure reducing valve (PRV), helps to reduce pressure throughout the day, stabilize fluctuations, and reduce stress on pipes. There are several methods for reducing pressure in the system, including variable speed pump controllers and break pressure tanks. However the most common and cost-effective is the automatic pressure reducing valve or PRV. PRVs are instruments that are installed at strategic points in the network to reduce or maintain network pressure at a set level. The valve maintains the pre-set downstream pressure regardless of the upstream pressure or flow-rate fluctuations. PRVs are usually sited at the entrance of a pressure zone, next to the flow meter. The PRV should be downstream of the meter so that turbulence from the valve does not affect the meter's accuracy. It is good practice to install the PRV with a bypass pipe to enable future major maintenance works.

Figure 7.6: Relationship between the pressure in the pipe and the lifetime of piping



7.7 Case studies

State of Goa—Non-revenue water (NRW) reduction project by JICA (2015)

JICA conducted a development study on the augmentation of water supply and sanitation for the Goa state in the Republic of India from March 2005 to November 2006 based on the request from the Government of India (GOI). In the course of the development study, the feasibility study (F/S) was carried out about the priority projects which were identified in the master plan for water supply and sanitation. The target year of the master plan was set as the year 2025. In this development study, many problems regarding the operation and maintenance of waterworks were pointed out.

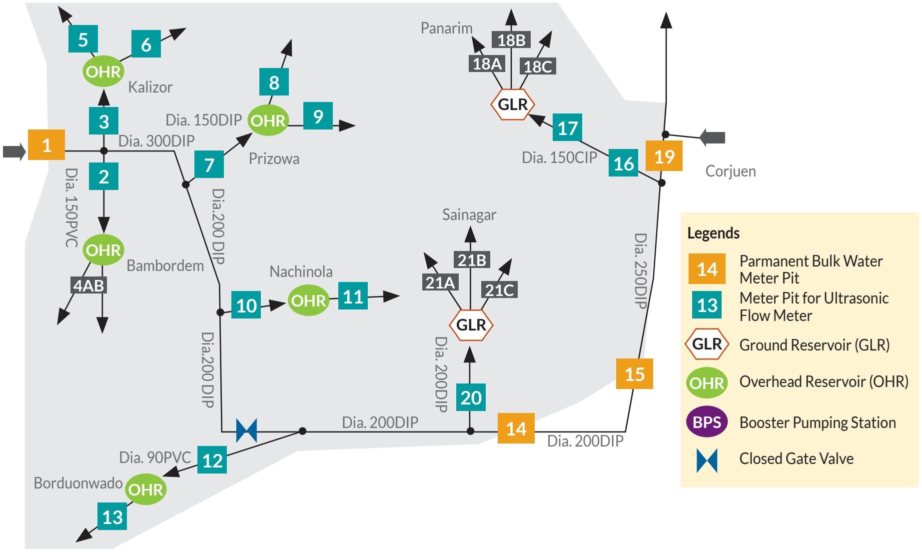
Figure 7.7: Goa state and location of pilot project stations

Team No.	Pilot Project Area (PPA)	Water Supply Scheme	No. of Service Connection	Pipeline Length
3	Curtorim PPA	Salaurim	2,242	78km
4	Khadpaband PPA	Opa	1,538	24km
5	Moira PPA	Assonora	1,979	60km

In particular, high Non-Revenue Water (NRW) (about 50%) was raised as a serious issue. It was also explained in the study that inappropriate measurement system/flow control at water treatment plants or reservoirs, inaccurate pipe network drawings will hinder active NRW reduction activities.

1. **Project Purpose-** Strengthening the capacity of PWD to reduce NRW
2. **Targeted outputs-** The following are the outputs intended out of this project:
   Output 1: NRW reduction in 3 pilot areas
   Output 2: Long-term/ Annual NRW Reduction Plan for the entire state of Goa
   Output 3: Technologies and skills for NRW reduction are shared within PWD for the entire state
3. **Action Plan** (Table 7.1)
   - Formulation of the 5 Working Group teams of PWD officers and engineers
     Team 1 : Current situation investigation
     Team 2 : Planning Long-Term NRW Reduction Plan
     Team 3 : Pilot Project Team for Pilot area 1-Salaurim
     Team 4 : Pilot Project Team for Pilot area 2-Opa
     Team 5 : Pilot Project Team for Pilot area 3-Assonora (Figure 7.8).

Figure 7.8: Pilot Project 3 DMA map



- Series of capacity building workshops for PWD officers and Engineers
- Study and Analysis of the Present State-Wide NRW Situation
- Analysis of Pilot Project Areas and Formulation of Pilot Project Plan
  Aspects for selection of pilot project area, taken into account.
  - The total number of house connections in the pilot project area is about 2,000 (recommended figure by IWA is 500 to 3,000)
  - A rather easy area to collect information of existing distribution pipes
  - Adequate for area isolation (avoid multiple inflows to the area, one or two inflow points are expected)
  - Valves for separation of leak management area are existing or easy to install
  - Continuous and sufficient water supply condition
  - An area that may include a lot of leakages
  - No security problems
  - No ongoing improvement projects
- Preparation of topographical map and pipe network drawings of the pilot project area
- Training on how-to-use leak detection equipment
- Technologies and skills for NRW reduction are shared within PWD for the entire state
- A physical survey in pilot DMAs.

Table 7.1: Activities and the respective targets for the DMAs

Sr. No.	Description	Activities	Targets	Progress vis-à-vis the targets and activities
1	Preparation of topographical map and pipe network drawings of the pilot project area	Based on existing pipe network drawings, valve locations, pipe alignment with diameters and their materials to be collected and added to the existing drawings. At the same time, the customer list in the pilot project area is to be confirmed.	Topographical map and pipe network drawings of the pilot project area are prepared	Since the GIS system developed by the JICA Loan project covers transmission mains and distribution mains, information of house connections and water meters were added by Team 3 to 5 and JET. This added information will be combined with the GIS system in future.
2	Training on how-to-use leak detection equipment	First Fiscal Year: Training issued were • Kind of equipment • Principle of equipment • Characteristics of equipment • How-to-use equipment Second Fiscal Year Training items will be • Review of how-to-use equipment just before application at the project site.	Training regarding equipment is conducted.	Classroom lectures (three times for the respective team, a total of 9 times) regarding equipment handling were conducted. After the classroom lecture, training at the project site was also conducted and actual survey works were commenced.

Sr. No.	Description	Activities	Targets	Progress vis-à-vis the targets and activities
3	Procurement of Materials required for the pilot project	Valve condition should be checked before commencement of fieldwork of pilot project. Malfunctioning valves, which can not be opened or closed should be replaced by PWD. Those valves should be procured by the PWD	Required materials are procured.	Required materials (valves and bulk meters) and civil works were listed up by counterpart members and bidding documents for the procurement were also prepared. However, bidding arrangements were terminated because of the election that was scheduled on March 3, 2012.
4	Isolation of pilot project area	Three pilot project areas were selected from respective Salaulim, Opa, and Assonora water supply schemes. Each pilot project area includes about 2,000.	Pilot project areas are isolated.	Pilot project areas were selected and investigations were conducted.
5	Estimation of NRW ratio of the pilot project area before com-mencement of the pilot project	Investigation of NRW situation in the isolated pilot project area.	The current NRW ratio is estimated and evaluated in the pilot project area.	After procurement of equipment, materials, this activity was conducted.

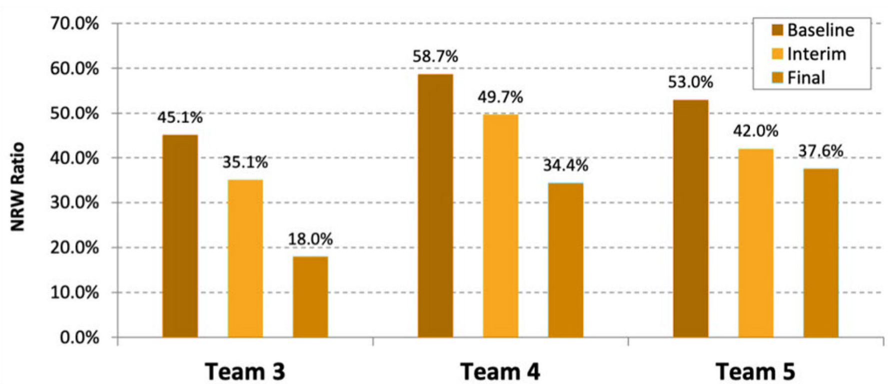
- **Activities at DMA level** (Table 7.2)

Table 7.2: Activities that were executed at the DMA level

Sr. No.	Activity	Description
1	Physical isolation of DMAs and analysis of the present condition	Each pilot area is isolated into leak management zones. The NRW ratios are monitored before the measures are taken.
2	Detection & repair of leakage Replacement of distribution & service connection pipes	Leak detection and repair were conducted. The distribution pipes and service connection pipes were repaired or replaced
3	Repair and replacement of meters	The water meters repaired or replaced
4	Identification and legalization of unauthorized connection	Unauthorized connections to be brought into legal connection
5	Measurement of NRW reduction in each DMA	The NRW ratios after the measures will be estimated. The effects of NRW reduction will be confirmed

- Final NRW Reduction Plan
  - **Long-Term NRW Reduction Plan**- The plan is for the entire Goa State and covers a long period. The plan is the basis of NRW reduction activities of PWD Goa and includes a policy of PWD for NRW reduction, a target of reduction, and various aspects of action plans together with their implementation schedule and preliminary cost estimate.
  - **Annual NRW Reduction Plan**- Although the annual plan is prepared for the one-year activity of 3rd fiscal year of this project, the annual plan will be referred to as the implementation plan of the Long-Term NRW Reduction Plan, especially for DMA activities, year by year continuously after this capacity development project
  - **NRW Reduction Manual** - A Manual is prepared based on the experience of the pilot project. All DMA activities are explained following the order of workflow from setting DMA to final evaluation. When PWD staff implement NRW reduction activities in the field as scheduled by the annual plan, the manual will be an important and useful reference for the PWD staff.
- The final impact on NRW

Figure 7.9: Reduction in NRW for all pilots.
Team 5 is the impact for project pilot 3



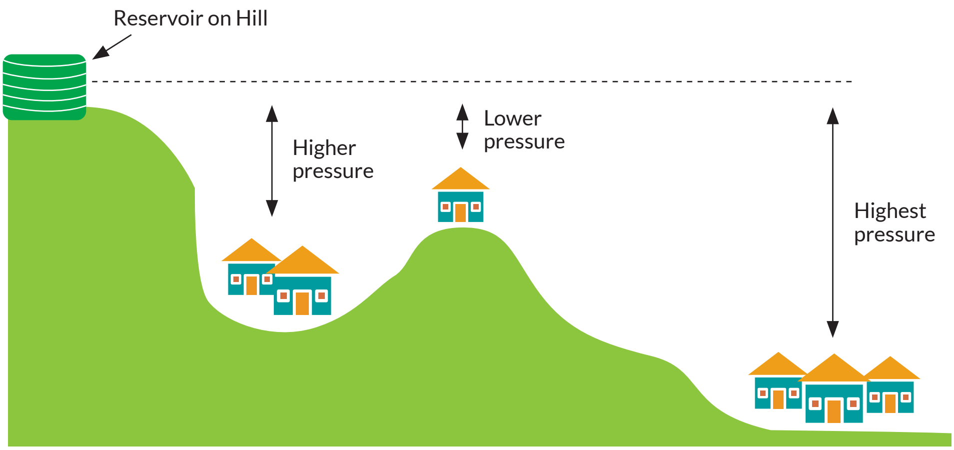
Case of Israel—NRW Management projects in Israel

According to 2010 reports, the average NRW rate in Israel is 12.9% (76.7 million m3 /year): this value is composed of 2% of physical NRW caused by leakages and pipeline bursts and from 10.9% administrative NRW mainly caused by lack of public consumptions registration, inaccurate water meters, lack of water meters and illegal connections to the water supply network leading to illegal consumption (hereinafter 'illegal connections'). In some smaller cities, the picture is more severe up to the level of 30-40% NRW, while in the bigger cities the rates are lower than the national average.

In Israel when the value of NRW in a specific local authority is more than 12%, it is fined because of the lack of efficiency in the system, according to water authority regulations. Only 99 out of 201 local authorities, managed to keep the reasonable value of NRW according to the standards.

1. General inventory of NRW practice in Israel
    - Water meters replacement and installation - The standard water meters are to be replaced in Israel once every five years. Nevertheless, before the establishment of the municipal water corporations, many of these meters were outdated. Two other associated problems are faulty/malfunctioning/broken meters, and lack of metering on many supply connections. The first and basic step in NRW control (mainly administrative) is the replacement of old and broken meters and the installation of meters on all consumer connections.
    - Advanced wireless metering system - This system allows quick identification of water leakages and irregular demand of water in real-time. This system alerts when there is a problem, and allows the water corporation to check the source of the leak close to the discovery time and to fix the leakages quickly.
    - Pressure management system - Dynamic adjustment of the pressure in the water supply system according to the demand in real-time (this system is installed in Haifa which is a mountain city with an altitude variation of 400 meters, and 270,000 population). The system is based on pressure regulating valves which are controlled locally or from the remote control centre, according to the minimal required momentary pressure in each zone to supply the required demand (more details below).

Figure 7.10: Pressure Management



- Combined water meters - These are water meters that are adapted to high and low flow rates having a double mechanism. The relevant meter side is activated according to the actual flow rate. Those meters are designed for industrial and commercial consumers because the range of the flow rate is more varied.

2. Adopted successful techniques
   - Periodic (every 5 years) water meters replacement and installation
   - An advanced wireless metering system
   - Pressure management system
   - NRW survey
   - Combined water meters
   - Control systems
   - Replacing old pipeline
   - Active discovery of hidden leakages
   - Installing instruments to prevent water hammer
   - Enforcing and supervision
   - District Metered Area (DMA)

Israel is coping with NRW issues intensively and now normally accepted NRW level is envisioned at 5-10% compared to actual NRW of 15-40% in various cities until the year 2000.

7.8 Conclusion

NRW is an indicator of water utilities' operating efficiency. Ensuring the accuracy of the NRW calculation is essential in understanding the full problem. The International Water Association standard water balance is an excellent method of breaking down the components of NRW, and tools are available to help utility managers calculate the water balance. Accurate production and customer metering ensure that the true NRW level is measured. The average billing cycle must be factored into NRW calculations to ensure that the period used for the consumption volume measurement matches the production meter volume measurement.

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Exercise

Exercise Number	Description
Exercise 01	Differentiation between UFW and NRW and the effect of poor revenue collection system of water utilities. Arrear management/collection strategies to identify 'actual' NRW.
Exercise 02	Town a has a population of 1 lac. The domestic demand is calculated as 135 LPCD. The commercial and industrial water demand is 10% and 29% of domestic demand respectively. 2% of domestic demand is required to serve the floating population and fire fighting purposes. The NRW of the town is 45%. What would be the total water demand for the town if by certain intervention NRW can be reduced to 20%. If through various physical interventions the distribution network of the town could be reduced to 20%, how much MLD water could be saved in this course?

Chapter 8

Waste Water Reuse

Recap

If a large proportion of water that is supplied is lost, meeting consumer demands is much more difficult. This is a major factor of NRW. The previous chapter discussed in brief the strategies for NRW reduction along with case studies.

Training Objectives

- To understand the urgency/importance of waste water reuse
- To assess the potential areas of waste water reuse
- To adopt the right technology for waste water treatment.
- To identify the feasible economic model for waste water reuse.
- To create policy ecosystem for waste water reuse enhancement and acceptance.

Training Outcomes

- Targeting the potential waste water reuse.
- Adoption of most relevant technology for the city.
- Strong policy and planning backup to waste water reuse.

Chapter Contents

8.1 Benefits of wastewater reuse

8.2 Challenges of wastewater reuse

8.3 Type of waste water reuse

8.4 Ensuring water treatment quality

8.5 Case studies

8.6 Economics of waste water reuse

8.7 Public preference and acceptability

8.8 Policy and planning level interventions

References

Wastewater reuse or water recycling is the use of treated wastewater (or untreated wastewater) for a beneficial purpose. One of the key advantages of recycling water is to protect water resources by reducing water pollution discharges and the need for water to be removed from natural habits. With 80 countries and 40% of the world's population facing chronic water problems and with the demand for water doubling every two decades, these extracts mentioned above merit action. The largest source of reuse resides in agriculture and the equally largest misplaced resource is sewage in the habitations. The government in India suggests the percentage of sewage recycled or reused after appropriate treatment (in gardens and parks, irrigation, etc.) should be at least 20%, to begin with. The availability of a safe and sufficient water supply is inextricably linked to how wastewater is managed. Increased amounts of untreated sewage, combined with agricultural runoff and industrial discharge, have degraded water quality and contaminated water resources around the world. Globally, 80% of wastewater flows back into the ecosystem without being treated or

reused, contributing to a situation where around 1.8 billion people use a source of drinking water contaminated with faeces, putting them at risk of contracting cholera, dysentery, typhoid and polio. Far from being something to discard or ignore, wastewater will play a major role in meeting the growing water demand in rapidly expanding cities, enhancing energy production and industrial development, and supporting sustainable agriculture.

Figure 8.1: Representation of Potable and Waste Water cycle

Source – Author

Therefore, agricultural use of water resources is of great importance due to the high volumes that are necessary. Irrigated agriculture will play a dominant role in the sustainability of crop production in years to come. By the next decade, further reduction in the extent of exploitable water resources, together with competing claims for water for municipal and industrial use, will significantly reduce the availability of water for agriculture. The use of appropriate technologies for the development of alternative sources of water is, probably, the single 'most adequate' approach for solving the global problem of water shortage, together with improvements in the efficiency of water use and with adequate control to reduce water consumption.

Societal and environmental pressures over recent years have led to a growing movement for the industry to reduce its wastewater and to treat it before discharge. Wastewater is now seen as a potential resource and its use, or recycling after suitable treatment can provide economic and financial benefits. Societal and environmental pressures over recent years have led to a growing movement for the industry to reduce its wastewater and to treat it before discharge. Wastewater is now seen as a potential resource and its use, or recycling after suitable treatment can provide economic and financial benefits.

8.1 Benefits of Wastewater Reuse

Reclaimed water is water produced in any part through the treatment of wastewater that may be used for beneficial purposes; because of such treatment, reclaimed water is considered a valuable resource, and is no longer considered wastewater. Reclaimed water use technology has improved greatly in recent decades, and studies show that for water-stressed regions, reclaimed water is a dependable alternative water source. Therefore, water must be carefully managed during every part of the water cycle: from freshwater abstraction, pre-treatment, distribution, use, collection and post-treatment, to the use of treated wastewater and its ultimate return to the environment, ready to be abstracted to start the cycle again. Due to population growth, accelerated urbanization and economic development, the quantity of wastewater generated and its overall pollution load are increasing globally.

Water is a renewable resource within the hydrological cycle. The water recycled by natural systems provides a clean and safe resource, which is then deteriorated by different levels of pollution depending on how, and to what extent, it is used. Once used, however, water can be reclaimed and used again for different beneficial uses. The quality of the once-used water and the specific type of reuse (or reuse objective) define the levels of subsequent treatment needed, as well as the associated treatment costs.

8.2 Challenges of Wastewater Reuse

Treated wastewater (TWW) reuse faces technical, legal, institutional and socio-economic challenges. These challenges could be overcome through participatory approaches. Farmers will utilize TWW reuse based on economic and financial analyses. TWW reuse standards should consider local environmental and socio-economic conditions. Training on environmental, legal, institutional and economic issues is essential for TWW reuse.

8.3 Type of wastewater reuse

Wastewater can be used within the business itself or between several businesses through 'industrial symbioses'. Industrial water consumption is responsible for 22% of global water use. In 2009 many countries consumption by industries was 50% as compared to other developing countries. It is expected that in rapidly industrialising countries, this proportion could increase by a factor of five in the next two decades years. Therefore, there is a strong incentive to use wastewater in-house and locally, based on cost savings alone. Businesses can directly use some wastewater, providing it is fit for purpose. For instance, using process water for cooling or heating, or rainwater from roof collection or concrete aprons for toilet flushing, irrigation or vehicle washing.

Agriculture and aquaculture

On a worldwide basis, wastewater is the most widely used low-quality water, particularly for agriculture and aquaculture. The rest of this chapter concentrates on this type of reuse because of the large volumes used, the associated health risks and the environmental concerns. Other types of reuse are only discussed briefly in the following sub-sections.

Urban

In urban areas, reclaimed wastewater has been used mainly for non-potable applications such as:

- Irrigation of public parks, recreation centres, athletic fields, schoolyards and playing fields, and edges and central reservations of highways.
- Irrigation of landscaped areas surrounding public, residential, commercial and industrial buildings.
- Irrigation of golf courses.
- Ornamental landscapes and decorative water features, such as fountains, reflecting pools and waterfalls.
- Fire protection.
- Toilet and urinal flushing in commercial and industrial buildings.

The disadvantages of urban non-potable reuse are usually related to the high costs involved in the construction of dual water-distribution networks, operational difficulties and the potential risk of cross-connection. Costs, however, should be balanced with the benefits of conserving potable water and eventually of postponing or eliminating the need for the development of additional sources of water supply. Potable urban reuse can be performed directly or indirectly. Indirect potable reuse involves allowing the reclaimed water (or, in many instances, raw wastewater) to be retained and diluted in surface or groundwater before it is collected and treated for human consumption. In many developing countries, unplanned and indirect potable reuse is performed on a large scale, when cities are supplied from sources receiving substantial volumes of wastewater.

Often, only conventional treatment (coagulation-flocculation clarification, filtration and disinfection) is provided and therefore significant long-term health effects may be expected from organic and inorganic trace contaminants, which remain in the water supplied. Direct potable reuse takes place when the effluent from a wastewater reclamation plant is connected to a drinking-water distribution network. Treatment costs are very high because the water has to meet very stringent regulations, which tend to be increasingly restrictive, both in terms of the number of variables to be monitored as well as in terms of tolerable contaminant limits.

Industry

The most common uses of reclaimed water by industry are:

- Evaporative cooling water, particularly for power stations.
- Boiler-feed water.
- Process water.
- Irrigation of grounds surrounding the industrial plant. The use of reclaimed wastewater by industry is a potentially large market in developed as well as in developing and rapidly industrialising countries. Industrial reuse is highly cost-effective for industries where the process does not require water of potable quality and where industries are located near urban centres where secondary effluent is readily available for reuse.

Recreation and landscape enhancement

The use of reclaimed wastewater for recreation and landscape enhancement ranges from small fountains and landscaped areas to full, water-based recreational sites for swimming, boating and fishing. As for other types of reuse, the quality of the reclaimed water for recreational uses should be determined by the degree of body contact estimated for each use. In large impoundments, however, where aesthetic appearance is considered important it may be necessary to control nutrients to avoid eutrophication. The overall target to achieve through systematic wastewater management are:

- Reducing environmental impact
- Reduce demands and stress on freshwater supply
- Eliminating the need to transport water
- Improving sustainability
- Avoiding expensive non-compliance fees

8.4 Ensuring Water Treatment Quality

Good water quality is essential to human health, social and economic development, and the ecosystem. However, as populations grow and natural environments become degraded, ensuring there are sufficient and safe water supplies for everyone is becoming increasingly challenging. A major part of the solution is to produce less pollution and improve the way we manage wastewater. A more circular and therefore more sustainable economy requires us to value wastewater for its potential, rather than discard or ignore it. More than just an alternative source of water, safe wastewater management could help protect our ecosystems and give us energy, nutrients and other recoverable materials. The quality standard has to comply with the CPHEEO guidelines and health standards. Wastewater reuse is the most promising alternative to augment water supply and means of alleviating the anthropogenic impacts on the environment- it reduces the volume of wastewater discharged to receiving waters, and its substitution for freshwater leaves more water for the environment.

Wastewater can be reused for a variety of purposes, including agricultural irrigation, heavy industry, urban and landscape irrigation, groundwater recharge, and wetland creation. The wastewater reuse schemes have the potential to extend existing water supplies, lessen the demand on sensitive water bodies, lower the cost of developing new water supplies, reduce disposal costs, lessen the discharge of pollutants to the environment, and provide water to serve a variety of beneficial uses. Wastewater, treated, partially-treated or untreated, is most widely reused for irrigation in an agricultural setting in developing countries as well as the water-scarce regions of the developed countries. There are many ill effects of reusing untreated or partially treated wastewater for irrigation like groundwater pollution, soil contamination, and the adverse effect on farmers and consumers of wastewater products. The environmental impacts of the reuse of highly reclaimed wastewater using advanced or tertiary treatments have only been considered in this section.

The potential environmental benefits of the reuse of highly reclaimed wastewater are as follows:

- Prevention of over-extraction and conservation of freshwater resources: Over-extraction of freshwater resources, mainly for municipal and agricultural activities, has led to significant degradation of rivers, lakes, aquifers, and dependent systems, such as wetlands. Wastewater reuse provides a renewable and alternative source of water supplies for municipal and agriculture purposes and it decreases the pressure on freshwater resources. Liberation of freshwater for the environment through substitution with wastewater reuse has been widely promoted as a means of prevention of over-extraction of freshwater resources and reduction of anthropogenic impacts.
- Pollution reduction of receiving water bodies and associated habitats: another major environmental benefit to be garnered from reusing wastewater is the diminution in pollution of waters receiving the discharge of sewage and the restoration of ecosystem health. The wastewater reuse eliminates the discharge of effluent into surface water

and thereby decreases the associated pollution loads in terms of organics, nutrients and coliforms. Major environmental pollution in surface water bodies such as dissolved oxygen depletion, eutrophication and algal blooms, foaming, fish kills and destruction of floral and faunal biodiversity can be avoided.

8.5 Case Studies

Case of Chennai: Madras Refineries wastewater utilizations (industrial reuse purpose)

Chennai city has perennially finite water resources. Two industries i.e. the Madras Refineries Ltd. (MRL) and the Madras Fertilizer Ltd. (MFL) are the biggest users of water for their process requirements. Both industries commissioned a tertiary treatment plant (TTP) for municipal sewage reuse to become water self-sufficient and to meet increasing process water requirements. Chennai administration considered that the recycled water adds a new, more sustainable water source for the city – one that saves both fresh and desalinated water, is always available and is more reliable than rainfall which can vary from year to year.

Chennai is a city of 9 million population which has some of the highest annual rainfall in India - has taken its water from four major lakes that are replenished by the annual monsoon rains. However, while Chennai needs around 1,200 MLD of water each year, these lakes, in their current condition, are only able to supply between 500 to 800 MLD a year, depending on the volume of rainfall that has occurred. With water demand far outstripping supply, the city has had to turn to other sources to meet its water needs, such as extracting precious groundwater or desalinating water at great expense. Recycled water, therefore, adds a new, more sustainable water source for the city, one that saves both fresh and desalinated water, is always available and is more reliable than rainfall which can vary from year to year. It is also targeted that by the year 2050, Chennai can meet up to 50 per cent of its water needs by recycling and reusing its sewage.

Industrial wastewater reuse in Chennai

Since 1991, Madras Refineries Limited and the Madras Fertilizer Limited started reusing municipal sewage, producing 12 MLD and 16 MLD reusable water. Based on these Tertiary Treatment Plants (TTP), the Chennai Metro Water and Sewerage Board supplied secondary treated sewage (with BOD 120 mg/L even after secondary treatment) and the industries provide the required further treatment depending on their end uses. The TTP that receive secondary treated wastewater from Chennai city at the Madras Refineries Ltd. and the Madras Fertilizer Ltd. consist of the following treatment units. The rejects containing high TDS are disposed to the sea through a submerged outfall. As per the 1991 estimate, the capital cost for building the MRL plant was around Rs. 24 Crores. The treatment costs for the MRL plant are reported to be about Rs. 35/- per 1,000 litres of water, which is much less in comparison to the charge of Rs. 60 per litres for freshwater supplied to industries. The Chennai Metro Water and Sewerage Board also charge a much higher tariff rate of Rs. 5.2/- per 1,000 litres of water to cover its treatment costs up to the secondary stage.

Case of Singapore Water Reclamation (NEWater)

A joint initiative between the Public Utilities Board (PUB) and the Ministry of the Environment (ENV) of Singapore to demonstrate the suitability of using NEWater (advanced treated wastewater) as a source of raw water to supplement Singapore's water supply. Singapore has a population of 4.4 million people on an island with a land area of 700 km^2. Due to its location in lowland areas and high population density, Singapore is considered a water-scarce country. Increased water demand due to population and economic growth, environmental needs, change in rainfall, flood contamination of good quality water and over-abstraction of groundwater are all factors that continue to create water shortage problems. Singapore had a long-term agreement with the Malaysian Government to import water to meet its ever-increasing water demand of 350 MGD (1,3266 MLD) at a price of less than one Singapore cent per 3,785 litres. Due to the conflict related to the price for importing water from Malaysia, Singapore decided to embark on a water reclamation programme to ensure self-sufficiency in water.

Singapore has a unique political driver to ensure that its water consumption becomes self-sufficient by promoting wastewater reuse and will not have to rely on sources from Malaysia. To become self-sufficient in water and to promote wastewater reuse as an alternative source of raw water, The Public Utilities Board (PUB), a Government-owned utility for managing the country's entire water cycle in association with the Ministry of the Environment (ENV) of Singapore initiated a Water Reclamation Study (NEWater Study) in 1998. The NEWater Plant is a 10,000 m^3/d advanced water reclamation plant employing state-of-the-art dual-membrane (microfiltration and reverse osmosis) and UV disinfection treatment process train. The NEWater Plant treatment process train is shown in Figure 8.2.

Figure 8.2: Treatment Process Flow Diagram of the NEWater Reclamation Plant, Singapore

This NEWater plant was built on a compact site downstream of the Bedok Water Reclamation Plant (WRP) (formerly known as Bedok Sewage Treatment Works) as the Bedok WRP receives more than 95% of its wastewater from domestic sources and commenced its operation in May 2000. The secondary effluent is first subjected to micro-screening (0.3 mm) followed by microfiltration (MF) (pore size: 0.2 µm) for removal of fine solids and particles, and then demineralization in two parallel 5,000 m^3 /d (5 MLD) reverse osmosis (RO) trains fitted with thin-film aromatic polyamide composite membranes configured for 80 to 85%

recovery in a three-stage array. The RO permeate is disinfected by ultraviolet irradiation using three UV units in series equipped with broad-spectrum medium pressure UV lamps delivering a minimum design total UV dosage of 60 mJ/cm^2 as the final step. To control the rate of biofouling in the membrane systems, chlorine is added at two points before and after MF. The product of the reclamation plant is called NEWater.

NEWater is considered to be safe for potable use as it is evaluated by the comprehensive Sampling and Monitoring Programme (SAMP) and meets the stringent requirements of the United States Environmental Protection Agency's National Primary and Secondary Drinking Water Standards and the WHO's Drinking Water Quality Guidelines. In addition, the findings from the HETP confirms that exposure to or consumption of NEWater does not have a carcinogenic (cancer-causing) effect on the mice and fish or estrogenic (reproductive or developmental interference) effect on the fish. The average unit power consumption at NEWater Plant varies in the range of 0.7 to 0.9 kWh/m^3. The successful operation of the NEWater Reclamation Plant is a good example of the unique political will and the government's initiative to drive and promote wastewater as an alternative source of water to address the country's water scarcity challenge. The outcome of the NEWater Reclamation Plant led the PUB to embark on new initiatives to supply NEWater to industries for non-potable use. Towards the new initiatives for wastewater reclamation, the PUB in association with Vivendi Water Systems Asia set up a 40,000 m^3/d dual-membrane high-grade water reclamation plant (HGWRP) at Kranji, Singapore and the plant started operation in December 2002.

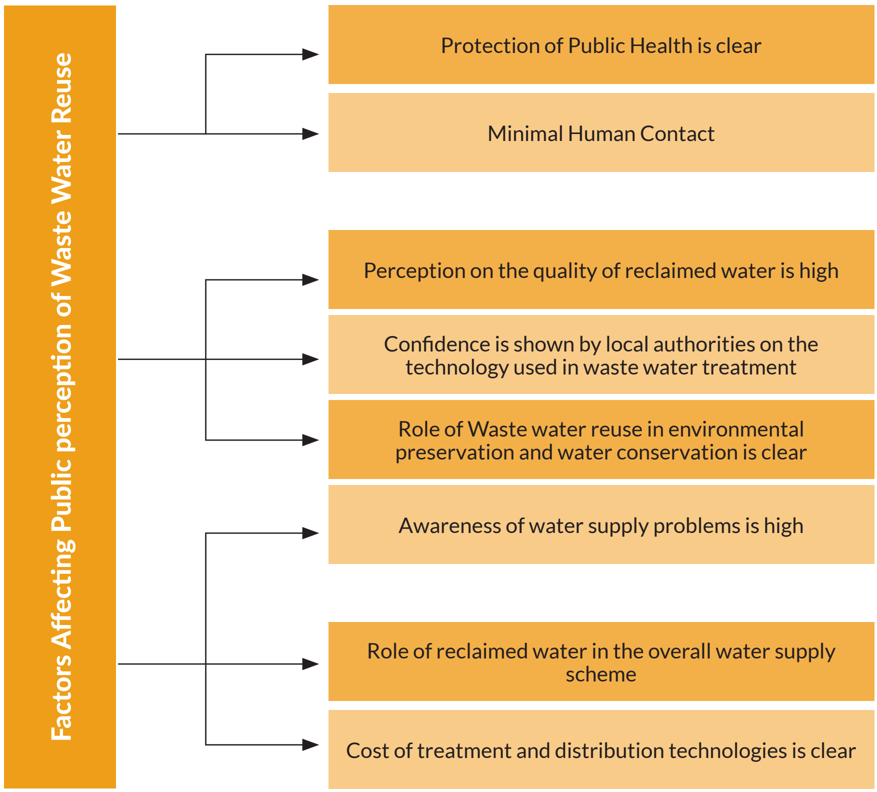
8.6 Economics of Waste Water Reuse

Land application of wastewater is an effective water-pollution control measure and a feasible alternative for increasing resources in water-scarce areas. The major benefits of wastewater reuse schemes are economic, environmental and health-related. During the last two decades, the use of wastewater for irrigation of crops has been substantially increased due to the following:

- The increasing scarcity of alternative water resources for irrigation.
- The high costs of fertilisers.
- The assurances that health risks and soil damage are minimal if the necessary precautions are taken.
- The high costs of advanced wastewater treatment plants needed for discharging effluents to water bodies.
- The socio-cultural acceptance of the practice.
- The recognition by water resource planners of the value of the practice.

The Economic benefits can be gained by income generation and by an increase in productivity. Substantial increases in income will accrue in areas where cropping was previously limited to rainy seasons. A good example of economic recovery is associated with the availability of wastewater for irrigation, where agricultural income increases from almost zero to millions when wastewater was made available to the region. The practice of excreta or wastewater fed aquaculture has also been a substantial source of income in many countries such as India, Bangladesh, Indonesia and Peru. In India, the East Calcutta sewage fisheries in India, the largest wastewater use system involving aquaculture in the world produces 5-10 T/Ha fish, which is supplied to the local market. Economic benefits of wastewater/excreta-fed aquaculture, therefore, are very high and cities and local bodies can get additional revenue from wastewater reuse for various use as discussed above.

Figure 8.3: Factors that affect the public perception of reusing treated wastewater



8.7 Public Preference and Acceptability

Key drivers for the acceptance of reclaimed water are the possession of positive perceptions about the treatment process and reclaimed water itself, and the extent to which other people might influence a person's decisions about the way STP functions. Therefore, personal communication channels (i.e., family, friends, and colleagues) must share messages of the benefits of using recycled water instead of focusing primarily only on the issues and challenges of operating an STP, which is often the case with the majority of apartment residents. The marketing strategies used by the water board and even private land developers should be devised attractively.

Wastewater has been reused in an unplanned way in many parts of the world for centuries. For example, wastewater that is discharged to streams, or infiltrates groundwater systems without deliberate management activities are often reused for other purposes. There are many examples of river water being used for municipal purposes, discharged (often treated to some extent) back to the river, and later withdrawn for water supply for cities further down the same river. There are also many places, particularly in Asia, where wastewater is used to irrigate crops for human consumption without any treatment or administrative oversight. All these occurrences are termed unplanned reuse. In this chapter, we are primarily concerned with planned wastewater reuse, where the water is diverted to specific use in a controlled way, including management of water quality. Unplanned reuse can sometimes act as an impediment to planned reuse because water managers argue that there is no need to invest in wastewater treatment and management when unplanned reuse is already occurring. However, the unplanned uses may not be the most efficient uses of the discharged water, particularly when environmental impacts are considered. There can also be obvious health and environmental implications from unplanned activities.

However, the public acceptance of the use of wastewater or excreta in agriculture and aquaculture is influenced by socio-cultural and religious factors. In many countries, there is a strong objection to the use of excreta as fertiliser, whereas, in some areas of Asia, the practice is performed regularly and regarded as economical and ecologically sound. In most parts of the world, however, there is no cultural objection to the use of wastewater, particularly if it is treated. Wastewater use is well accepted where other sources of water are not readily available, or for economic reasons. Wastewater is used for the irrigation of crops in several Islamic countries if the impurities are removed. This results, however, from economical need rather than cultural preference. The practice of reuse is accepted religiously provided impure water is transformed to pure water by the following methods self-purification, the addition of pure water in sufficient quantity to dilute the impurities, or removal of the impurities by the passage of time or by physical effects. Due to the wide variability in cultural beliefs, human behaviour and religious dogmas, acceptance or refusal of the practice of wastewater reuse within a specific culture is not always applicable everywhere. A complete assessment of local socio-cultural contexts and religious beliefs is always necessary as a preliminary step to implementing reuse projects.

8.8 Policy and Planning Level Interventions

The use of wastewater constitutes an important element of a water resources policy and strategy. Many areas in arid and semi-arid regions have adopted (in principle) the use of treated wastewater as an important concept in their overall water resources policy and planning. A judicious wastewater use policy transforms wastewater from an environmental and health liability to an economic and environmentally sound resource. Governments must be prepared to establish and control wastewater reuse within a broader framework of a national effluent use policy, which itself forms part of a national plan for water resources. Lines of responsibility and cost-allocation principles should be worked out between the various sectors involved, i.e. local authorities responsible for wastewater treatment and disposal, farmers who will benefit from effluent use schemes, and the state, which is concerned with the provision of adequate water supplies, the protection of the environment and the promotion of public health. To ensure long-term sustainability, sufficient attention must be given to the social, institutional and organizational aspects of effluent use in agriculture and aquaculture.

The planning of wastewater-use programmes and projects requires a systematic approach to support the characterization of basic conditions and the identification of possibilities and constraints to guide the planning phase of the project. Government policy on effluent use in agriculture has a deciding effect on the achievement of control measures through careful selection of the sites and the crops that may be irrigated with treated effluent. A decision to make treated effluent available to farmers for unrestricted irrigation removes the possibility of taking advantage of a careful selection of sites, irrigation techniques and crops, and thereby limiting the health risks and minimizing the environmental impacts. However, if crop selection is not applied but a government allows unrestricted irrigation with effluent in specific controlled areas, public access to those areas can be prevented (and therefore some control is achieved). The greatest security against health risk and adverse environmental impact arises from limiting effluent use to restricted irrigation on controlled areas to which the public has no access. It has been suggested that the procedures involved in preparing plans for effluent irrigation schemes are similar to those used in most forms of resource planning, i.e. following the main physical, social and economic dimensions.

The following key issues or tasks are likely to have a significant effect on the ultimate success of effluent irrigation schemes:

- The organizational and managerial provisions were made to administer the resource, to select the effluent-use plan and to implement it.
- The importance is attached to public health considerations and the levels of risk taken.
- The choice of single-use or multiple-use strategies.
- The criteria adopted in evaluating alternative reuse proposals.
- The level of appreciation of the scope for establishing a forest resource.

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Chapter 9

Project Management Tools for Enabling Water Management

Recap

The previous chapter presents an overview of wastewater reclamation and reuse in India with the focus on its rationale, current practices and challenges, potential and future scope. Urban local bodies and municipalities have implemented reclaimed water reuse projects in many water sensitive cities in the country.

Training Objectives

- To understand in brief the aspects considered while planning for disasters.
- To understand various models of financial sustainability in water services.
- To understand ecosystem services and its linkage with water supply.
- To understand the role of IEC and utilise it in better management of water supply.
- To familiarise oneself with the requirements of appraising a DPR.

Training Outcomes

- Gain an understanding of infrastructure resilience and ways to do so.
- Gain an understanding of improving water upply using the project management tools.
- Awareness regarding important aspects of preparing a water balance chart.

Chapter Contents

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9.1 Preparing for Disasters – Urban Flooding, Drought, Water Scarcity

Drinking water and sewerage systems are exposed to both natural and manmade hazards that are common in every part of the world. Earthquakes, hurricanes, floods, landslides, drought, volcanic eruptions, vandalism, and accidents involving hazardous materials are part of the wide variety of events that cause death, injury, and significant economic losses for the countries affected. Disaster preparedness refers to measures taken to prepare for and reduce the effects of disasters. That is, to predict and, where possible, prevent disasters, mitigate their impact on services & vulnerable populations, and respond to and effectively cope with their consequences. Disaster preparedness for any urban city is as important as managing other basic services. All the services in the city are affected by natural and manmade disaster for which planning is important while designing a water supply system for the city (de Veer, 2002).

The following are the components of the water supply system in the city that may be adversely affected by the disaster:

- **Raw Water storage** — Surface or groundwater: Cracks in dams, dry storage during drought, deposition of silt, accumulation of debris and damage of machines and equipment due to flooding of water.
- **Raw water conveyance system** — Breach of embankments of canals, dislocation of joints, washing away of pipes and deposition of silt etc.
- **Water Treatment facilities** — Excess turbidity, contaminants, inundation of equipment, pumps and damage due to seismic pressure.
- **Primary filter water storages** — Infiltration/ exfiltration due to cracks, mixing of contaminants.
- **Rising mains/ pressure mains** — Dislocation of joints, washing away of pipes and vandalism.
- **Regional water storages/ secondary storages** — Infiltration/ exfiltration due to cracks, mixing of contaminants.
- **Tertiary or colony-level storage reservoirs** — Infiltration/ exfiltration due to cracks, mixing of contaminants.
- **Water distribution system** — dislocation of joints and mixing of contaminants.

All the above components of the water supply system are affected differently by natural catastrophes i.e. urban flooding, earthquakes and draught etc. Accordingly, the mitigation measures are different for the different components. Manmade catastrophes are also a major threat to the water supply system like sabotage, mixing of contaminants (chemical, biological and radiological) in raw or filtered water, which may affect the entire population using that water.

Everyone knows how vital water supply and sewerage systems are for the health and development of any community. This makes it a priority for such services to operate optimally at all times since a significant degradation of their quality can affect most of the population. The main objective of water supply and sewerage companies, therefore, must be to maintain systems that qualitatively and quantitatively meet the needs of the population so that interruptions in the supply of drinking water and/or the collection, treatment, and disposal of wastewater are as brief as possible. Given the negative effects that different phenomena may have on water supply and sewerage systems—such as the rupture and dislocation of mains and distribution pipes, the contamination of springs or damage to treatment facilities—mitigation and prevention is very important. Moreover, it has been proven that it is always less expensive to invest in prevention than to pay for rehabilitation after a disaster.

While acknowledging that it is impossible to achieve 100% disaster-safe systems, both public and private firms in the sector must be capable of resolving, in the best fashion and the shortest time possible, the problems that may arise during and after the impact of some of the hazards mentioned above. Experiences with emergencies and disasters in the last decade of the twentieth century prove the need to prepare for such contingencies.

Disasters are mostly caused by natural phenomena, even if many of their consequences must be attributed to human actions or negligence. To control or minimize natural hazards, it is essential to know the characteristics of common adverse natural phenomena and how they impact our environment. The study and proper management of such hazards is also a prerequisite for developing operational, planning, training and simulation programs. These actions comprise several stages:

- Becoming familiar with, analyzing, and assessing the presence of natural hazards and their effect on the equipment and infrastructure of the area under study, based on the vulnerability associated with such phenomena;
- Estimating the potential impact of natural hazards on routine as well as longer-term development activities, and on the components of water supply and sewerage systems;
- Devising and adopting measures to reduce vulnerability and mitigate the effects of hazards;
- Programming emergency operations.

Effects of natural disasters on water supply system and its measures

Earthquakes

Dislocations in the earth's crust, the main cause of earthquakes, deform the rocks below the earth's surface and build up energy that is suddenly released in the form of seismic waves that shake the surface. Earthquakes are one of the most serious hazards, given their enormous destructive potential, the extension of the areas affected, and the impossibility of forecasting their occurrence.

The main effects of an earthquake, depending on its magnitude, are:

- Fault lines along rocks and below the surface;
- Sinking of the surface;
- Avalanches, landslides, and mudslides;
- Liquefaction.

Earthquakes are classified according to their magnitude and intensity. Seismic magnitude refers to the amount of energy released, which is usually measured using Richter's logarithmic scale. The significance and type of damage related to the magnitude of the earthquake and the area covered the degree to which buildings and infrastructure are seismic-resistant, and the quality of the soil where structures are located. An earthquake has a specific magnitude, but its intensity varies depending on the location of the area under study concerning the epicentre, the geological characteristics of a site, as well as materials used for structures. Following are some of the types of damage that an earthquake can inflict on the water supply:

- Total or partial destruction of intake, transmission, treatment, storage, and distribution systems;
- Rupture of transmission and distribution pipes and damage to joints between pipes or tanks, with consequent loss of water;
- Interruption of electric power, communications, and access routes;
- Deterioration of the water quality at the source due to landslides and other phenomena;
- Reduction in yields from groundwater sources and flow in surface water sources;
- Changes in the exit point of groundwater or the phreatic level;
- In coastal areas, inland flood damage due to the impact of tsunamis. The introduction of saltwater into coastal aquifers will affect the quality of water.

Landslides

Landslides are the result of sudden or gradual changes in the composition, structure, hydrology or vegetation of sloping terrain. They are often closely linked to primary hazards such as earthquakes or water saturation caused by hurricanes or intense rainfall. In urban areas, they are also associated with human actions such as providing drinking water services to communities located on slopes with unstable soil. Leaks in these systems lead to excessive moisture in the soil and can result in landslides. The situation can be critical when drinking water is supplied without providing proper sewerage at the same time. The magnitude of the impact of landslides depends on the volume of the mass in motion and its speed, as well as the extension of the unstable zone and the disintegration of the mass in motion. Landslides can often be predicted since they can be preceded by cracks and undulations in the terrain.

The most common effects of landslides are the following:

- Blockage or damage to roads along slopes;
- Changes in the normal flow of surface waters, such as rivers and streams, may result in dams or accumulations of water. Rupture of the dam can cause the violent discharge of great volumes of water or mud;
- Soil may sink or be displaced altogether, affecting houses, schools, roads and other structures.

Effects of landslides in areas where water supply and sewerage system components are located include:

- Changes in the physical or chemical characteristics of intake water, which will affect treatment;
- Total or partial destruction of the works, particularly intake and transmission components in the path of active landslides;
- Contamination of the water at surface intakes located in mountainous areas;
- Indirect impacts due to the blocking of roads and the disruption of power and communications;
- Blockage of sewage systems due to a build-up of mud and stones.

Floods

Floods are the result of excessive rainfall, unusually high sea levels, or the rupture of dams and dikes. Increasingly, floods result from the human activity causing environmental degradation, deforestation, and inappropriate land use. On the other hand, some floods are the result of the geomorphology and climatology of water catchment areas. The magnitude of the effects of floods is related to the level reached by the water, its speed, and the geographical area covered. Other significant factors are the design quality of the installations and the type of soil on which they are built. The usual impacts of floods on water supply are the following:

- Total or partial destruction of river water intakes;
- Contamination in water catchment areas;
- Breach in Carrier canal/ disruption/ dislocation of raw water conduits;
- Siltation in the carrier system due to mud;
- Damage to Water Treatment facilities or disruption of treatment process due to excessive turbidity;
- Damage to pumping stations close to flooding waterways;
- Blockage of components due to excessive sedimentation;
- Rupture of exposed pipes across and along rivers and streams;
- Power cuts, road blockages, and disruption of communications;
- The intrusion of saltwater into continental aquifers, contaminating or reducing the availability of groundwater.

Drought

Droughts are prolonged dry periods during natural climatic cycles, caused by a complex set of hydrometeorological elements that affect the soil and the atmosphere. They do not necessarily start when it stops raining, since enough water might have been stored in dams or in the ground to maintain the hydric balance for some time. Among the effects of drought are the following:

- Reduction of surface water due to lack of rainfall, putting agriculture and animal husbandry at risk;
- Changes in the fauna where waterways are affected;
- Changes in the standard of living due to the negative impact of drought on the economy,
- Loss or reduction of surface- and groundwater sources and deterioration of water quality;
- A decline in water levels at intake points and in storage facilities;
- The need to distribute water with water trucks, affecting quality and increasing costs;
- Damage to the system due to lack of use.

The disaster cycle

The disaster cycle includes different stages, which can be summarized as three phases or periods:

- **Before the disaster**: which may be a period of calm or a declared state of alert depending on the event being analyzed;
- **During the disaster**: a stage that may be very brief or very long depending on the characteristics of the phenomenon;
- **After the disaster**: in which the focus is on recovering from the impact of the disaster, and which may be a short, medium or long-term endeavour.

Planning for emergency operations

Also known as preparedness which involves designing a series of activities that, if properly executed, should make it possible to prepare in advance for a disaster and respond promptly once it occurs. It is important to identify the activities to be carried out at each stage of the disaster cycle, particularly those involving the stage before the event, and the response stage, which must include the uninterrupted operation and maintenance of water supply and sewerage systems. In planning for emergencies and disasters, the stage before an adverse event is the most important. It is then that one can anticipate the performance of the company and the physical components of water supply and sewerage systems. Three sets of activities before the occurrence of a disaster or emergency are required:

- Prevention
- Mitigation
- Preparedness

After the disaster

After the disaster has occurred it is time for response activities, which may involve search and rescue, relief, and aid to the victims. Water supply and sewerage companies and agencies must respond quickly and effectively by implementing the emergency plan, and by trying to maintain the largest possible volume of water in the storage tanks until the actual condition of the systems can be verified. The following set of activities is required after the onset of a disaster:

- Response
- Rehabilitation
- Reconstruction

The rehabilitation of water supply and sewerage systems is of crucial importance since the speed with which these services can be restored will have a significant impact on the health of the population. With reconstruction, the essential thing is for the company to incorporate prevention and mitigation measures when designing the new construction or retrofitting plans, to prevent the same weaknesses the systems had before the disaster.

Vulnerability analysis

The following is a summary of the steps that must be taken to carry out a vulnerability analysis. Although reference is made to the drinking water supply system, the steps are also applicable to sewerage systems.

- Identify the relevant national or regional disaster reduction institutions, as well as the legislation and standards regarding emergencies and disasters.
- Describe the area under study: location, climate, urban infrastructure, public health services, geological, geomorphologic and topographic data, level of socio-economic development, etc.
- Identify and describe each of the components of the system and their subcomponents.
- Identify and provide a functional description of the system (flow volume, level, pressure, quality of the service).
- Identify the system's operational aspects (capacity, demand, deficit or surplus volume).
- Identify and describe the administration and response capacity of the company or agency responsible for the system under study.
- Determine hazard parameters and hazard assessment, taking into account the likely impact on the system.
- Estimate the system's vulnerability based on the determination of the likely effects of the emergency on the system's components.
- Quantify the capacity of each component and subsystem to operate in certain conditions, bearing in mind quantity, quality, and continuity **(operational vulnerability)**.
- Identify the critical and vulnerable components of the system that may be Emergencies Water Supply, capacity to meet basic demand, and of the priority points of supply **(physical vulnerability)**.

- Estimate the organizational response capacity (**organizational vulnerability**).
- Determine the mitigation, preparedness and emergency measures required to reverse the impact of the hazard on the system's components in administrative, operational, and physical terms.
- Determine the minimum demand of the population in priority supply points, both during and after the impact of a disaster.
- Draft the final report and vulnerability maps. Several reports can be produced to cover the various hazards that can affect the system.
- Develop the Emergency Plan and the Prevention and Mitigation Programs.

For each of the hazards, steps 7 through 13 should be repeated. The vulnerability of a drinking water supply or sewerage system is analyzed from three points of view:

- **Physical**: Estimation of the possible damage to infrastructure components;
- **Operational**: Assessment of the surplus or remaining capacity to provide the needed services, including an estimate of the time required to rehabilitate the systems.
- **Organizational**: Determination of the institutional or company response capacity, bearing in mind the organization, its expertise, and its other resources.

In some cases, it may prove necessary to consider the cultural and socioeconomic characteristics of the community that benefits from the water supply and sewerage services, since improper use of the systems contributes to their vulnerability. Each vulnerability analysis is related to a specific hazard, and this determines the structures and equipment that are susceptible to direct damage (for instance, the flooding of a pumping station) or indirect damage (failures in the power supply). The internal features of the company that support operations and maintenance (for instance, transportation, communications, and the supply of materials) must be analyzed, as well as features outside of the company (electrical power, telephone services, fire-fighters, and so on).

Precautions before setting up water infrastructure

Similarly, advances in information management, technological resources such as geographic information systems (GIS), must be incorporated into emergency and disaster management to have the best possible information available for effective decision-making. Proper planning and appropriate organizational development that facilitate a speedy response to an emergency must be one of the priorities of any water supply and sewerage agency or company, whether private, public (national, municipal) or mixed. This calls for the total commitment, involvement and support of the key decision-makers in the sector, so that the necessary material, human and logistical resources can be made available to ensure an appropriate response. The urgent need for disaster reduction planning by water supply and sewerage systems administrators has been stressed repeatedly in recent years. It is also important to make sure that such efforts will have a long-lasting effect and, even more importantly, that they will be reinforced with the knowledge and involvement of a significant number of the agency's or company's technicians and professionals.

Geographical

The location of installations must be away from the water streams. But, we have to compromise between the costs of infrastructure *versus* vulnerability of the structure due to natural catastrophes e.g. Water Treatment Facilities are generally set up near the water source (river) to reduce the cost of Raw water mains. But to avoid the damage from the floods, the Water Treatment Facilities must be set up away from the Flood plain. Similarly, no structure should be constructed in seismic Zone-IV. But, it depends upon the availability of the land and the locality of water supply. Underground reservoirs and booster pumping stations are set up near the point of water supply. We cannot select the corridor for laying pipelines away from the vulnerability zone. The water line is the continuous structure that has to pass through various zones which cannot be avoided.

Structural safety

While designing the water infrastructures, the vulnerability of the natural and manmade disaster must be kept in mind and the structure must be safe enough to withstand those e.g. if a water treatment plant is set up near the flood plain areas of the river where chances of liquefaction or raising of the water table are there, the foundations of the components must be designed accordingly. The depth of the foundation must be decided keeping in mind the scour depth if the structures are prone to flood. Similarly, the plinth level of the structure and the approach roads level must be kept much above the high flood level.

If the water source is surface water, then a temporary intake structure can be created by building a small weir made of bags filled with sand. The end of the inlet pipe needs to be covered with some kind of filter (netting) and positioned in the river directly upstream of the weir. The pumping equipment can be whatever is commonly available in the country; straightforward technology gives the best chances for reliable functioning. A source caretaker is required to make sure that the pump does not operate when the water level is too low. Advantages of simple intake structures are that the materials required can be easily obtained locally or flown in quickly. Its construction requires little time and can be done without highly skilled technicians, is easy to manage, costs are low and the structures can be dismantled easily. Upgrading of the system may involve the use of floaters attached to the inlet. In case the water level rises, small diversion structures are used to cope with flow variations in the river.

Pipes

The quickest response is achieved by using pipes that are locally available even if they are not an ideal solution.

Flexible hoses are suitable for such purpose. They usually have to be brought in from abroad but can be flown in and are easily transported overland, can be installed on-site very quickly (rolled out) and connect easily to other types of pipe. However, flexible hoses are more expensive, more vulnerable and less durable than other pipes. Some flexible hoses, though, can resist quite large pressures. Two types are distinguished: lay-flat hose made of canvas or PVC material (collapsed when not in use, making it easy to handle and transport), and PVC suction and delivery hose made of flexible smooth bore PVC, reinforced with a semi-rigid PVC spiral.

Polyethene (PE) pipes are suitable for survival supply due to the ease of jointing and the flexibility of the pipe. Jointing can be done through fusion welding or push-fit or mechanical couplings. All these jointing options are easy and quick and give very strong joints that can withstand end loading. They, therefore, do not need thrust blocks at points where the direction of the pipeline changes. Several couplings also allow connection to galvanised iron (GI) pipes and low-pressure applications can screw PE pipe onto GI threaded pipe and fittings. The flexibility of PE makes it possible for smaller-diameter pipes to be delivered in long coils. This way only a few joints are required and pipe can be laid very quickly. Even in freezing conditions, PE remains flexible and can be laid easily. It also slows down the freezing of the water in the pipes due to its thick wall and low thermal conductivity. Even if the water does freeze, the pipes will not break easily. Transport of the coils can sometimes be difficult because they require quite a bit of space. PE is often locally available. PE can initially be laid overland if necessary because it is quite robust and not very sensitive to sunlight (use the black pipes, not the blue ones). If laid over land, it is of course more vulnerable to damage by people walking over it and vandalism – and this danger should not be underestimated. Pipes should therefore be buried in trenches as soon as possible.

Water treatment

In disaster/emergencies, water treatment complicates the water delivery process and should therefore be minimised and always be simple. It is better to look for a water source supplying water of safe quality wherever possible. When treatment is found to be necessary, deciding which treatment system is most suitable depends not only on the raw water quality but also on the availability of construction materials and chemicals. Simple water treatment systems include the following:

Sedimentation

Sedimentation using a large OXFAM or other types of tank.

Coagulation/Flocculation

Often used where no time is available to wait for the construction of filtration units and where the required chemicals (usually aluminium sulphate) can be made available. The system can be operated as a batch or continuous system. Staff should be well instructed and be monitored on their performance.

Multi-stage filtration (two coarse material filtration systems followed by slow sand filtration)

These filters can be constructed fairly quickly (within a week) if use is made of OXFAM tanks and if the required coarse gravel and sand can be found nearby. If the turbidity of the water is not too high, large amounts of water can be effectively filtered. A well-trained and supervised crew is required.

Chlorination

It is recommended always to chlorinate the water in disaster/emergency response operations. In a piped water supply system this is usually done as the last step of the treatment process. For survival water supply a batch system is the easiest: two small OXFAM tanks (of about 10 m^3 each) are filled with water and the required amount of chlorine is added. The chlorinated water should stand for 30 minutes before it is released into the distribution system. The most suitable chlorine solution is hypochlorite dissolved in water.

Public stand posts

In most disaster/emergency response operations, water distribution is through public stand posts. Private connections are not common unless existing systems are used. Special connections will be needed for public facilities such as field hospitals and health posts, feeding centres and market places. These facilities have their water requirements, which should be included in the calculation of the total water demand and the design of the water supply. For public stand posts, usually push taps, also called self-closing taps, are used. These are robust taps that close automatically under their weight after a user stops pushing the weight up. The taps help in this way to diminish water wastage if users do not close the taps due to negligence. Sometimes people do keep the taps open on purpose by attaching a piece of rope between the weight and the pipe above.

Wherever possible, the water catchment area should be protected to minimise the risks of pollution. Human settlement, agricultural and livestock activities should be prevented as much as possible anywhere near or upstream of the intake. Part of the source assessment should be the identification of present or potential pollution sources upstream of the intake. If pollution threats are found, then the intake may have to be positioned further upstream (beyond the polluting source), or another reliable and safe water source needs to be found, or the people need to be settled elsewhere.

High alert & security for water infrastructures

Safety and Security audit of the water infrastructures must be conducted periodically and accordingly, the measures must be taken according to the security threats.

Alternatives during emergency

The provision of drinking water by tankers is a solution for survival supply when time is very limited and other systems cannot be realised within the time limits. Water supply by tankers is only possible when certain requirements are fulfilled. Usually, these requirements can be met locally. Otherwise, trucks, repair facilities, etc. have to be brought in by road or air from elsewhere. Water supply by tankers is almost always planned and managed by specialised external agencies because of the complexity of its management and the high costs. This is not, therefore, a solution for longer-term water supply, although examples exist, where large water tanker operations have continued for many months. Water tankers are also often used to supplement other water services. The water utilities must preserve the alternative resources of water supply during such emergencies i.e. water tankers to arrange drinking water from a nearby source away from the affected areas.

Water tanker requirements

Water tankers are normal trucks or trailers with storage vessels mounted on them. If hiring or purchasing water tankers or storage tanks locally, one must know what they have been used for. Before use, rigorous cleaning and disinfection (super chlorination) is needed. Regular cleaning/disinfection during operations is also a good practice.

- The water source must have adequate yield and water of sufficient quality (biological contamination is usually not a direct problem because the water will be chlorinated). The place should allow for pumping into the water tanker. Permission will be needed to be obtained from the owner and water rights from the authorities.
- Water pumps are needed at the source and perhaps at the delivery location; a pump to empty the tanker quickly can save a lot of time.
- Water storage capacity and some tap stands need to be provided at the delivery location.
- Fuel and lubricants need organising for the trucks.
- A sufficient supply of chlorine has to be available for chlorination of the water;
- There must be enough truck drivers.
- O&M facilities include mechanics and tools, equipment and spare parts.
- Road access has to be available between the source and the beneficiaries (check road conditions, bridges, permission to use the road from local authorities, owners or those in power in the area).
- It may be necessary to equip the trucks with communication equipment, especially where security can be a problem or where the situation can change very quickly.
- Managing the water tankering operation properly demands professional skills and experience.

Interconnectivity of water treatment plants and water storage reservoirs

The water treatment plants and primary water storage reservoirs should have connectivity so that in case of closure of one facility, the water supply can be switched over to the affected areas in case of emergency.

Geographic Information System

The water utilities must have a perfect GIS platform which can demonstrate the affected area due to natural catastrophes and alternative route for restoring the water supply.

Evacuation

Every water facility must have an alarm system and space for evacuation during emergencies.

Prevention and mitigation measures

The correct application of prevention and mitigation measures requires strong corporate or institutional will to support emergency planning. The effects of a hazard cannot be reduced without allocating the necessary resources. Even a modest, but continuing, the budgetary allocation can produce significant results. After carrying out the vulnerability assessment, the next step is to identify the most effective prevention and mitigation measures. This will make it possible to program the necessary actions to reduce the potential impact of any given hazard on the system. Such measures must include devising emergency operations, signing agreements with other institutions, preparing and carrying out the necessary training activities, allocating material and other resources, and choosing the most important retrofitting projects to reinforce the current system components.

Setting up an early alarm system

The water utility must set up an early alarm system to know the possible disaster in advance i.e. water level fluctuations in Dams & reservoirs, coordination with the metrological department, frequent water sampling at a raw water source, CCTV cameras surveillance etc.

Setting up the Emergency Operation Centre

24x7 Emergency operation centre must function to coordinate with the metrological department, emergency response operational staff, public complaints, hospitals and District Disaster Management Authority (DDMA).

Setting up the Disaster Management Resource Centre

The water utilities must set up Disaster Management Resource Centre in all zones containing all manpower, material & tools for repair of water lines, D.G. Sets, contact details of expert agencies to call in an emergency, nearest hospitals & police department.

Capacity building and advance training for the stakeholders

The water utility must impart training to all employees and other stakeholders related to disaster recovery, conduct mock drills periodically to utilize in emergencies.

Community participation

The people residing near the facilities are the first responders. Hence, the community residing nearby and the beneficiaries must be involved in a training program.

9.2 Planning for Financial Sustainability of Water Services

In every city, population growth is inevitable which requires continuous expansion of water supply and sanitation services. Water is considered to be the basic need for human being and every livestock. Hence for every water utility, providing water supply and sanitation (WSS) is a major business that needs to have a sound financial basis. The sums involved in setting up and operating & maintaining services and infrastructure, expanding their coverage and upgrading them to meet current social and environmental expectations are huge. Yet most systems are underfunded, with dire consequences for WSS users, especially the poorest. Some projects fail due to poor funding, non-availability of water master plan for future or wrong selection of business models.

Sustainable water infrastructure is critical to providing the public with clean and safe water and to help ensure the social, environmental, and economic sustainability of the communities that water utilities serve. Utilities must plan and effectively manage their infrastructure and operations to ensure sustainability and develop and maintain the necessary technical, financial, and managerial capacity to do this planning.

A sustainability policy should be developed, in such a way that utility infrastructure investments throughout the water sector could best be influenced through the planning that takes place in the project development phase before infrastructure solutions are selected and designed. This planning is relatively low cost and can reduce long-term infrastructure costs. Such planning helps ensure that funded projects are financially sustainable over the long term and that they support the environment and other relevant sustainability goals. Water utilities typically have a long-term planning horizon and long-term infrastructure operation and maintenance commitments. The costs and potential benefits of investment decisions will be realized over a long period. Accordingly, Sustainability Policy calls on drinking water and wastewater systems to undertake “robust and comprehensive” planning to ensure that water infrastructure investments are cost-effective over their lifecycle, resource-efficient, and consistent with other relevant community goals. The important relationship between utility and community sustainability must be emphasized. The core mission of water sector utilities is to provide clean and safe water in compliance with all applicable standards and requirements at an affordable price in order protect public health and enhance the economic, environmental, and social sustainability of the communities they serve.

Many water infrastructure decisions share interdependencies with housing, transportation, and other infrastructure, requiring collaboration or pursuit of coordinated strategies to optimize these investments. A system-wide approach involves utilities looking "beyond the fence line" to include community institutions and the implementation of projects outside the utility's direct span of control. There is also an opportunity to discuss collaborative partnerships with other municipal departments and with neighbouring utilities to share information and services or to plan on a regional basis.

Benefits

Several utilities are also facing challenging and sometimes competing infrastructure priorities driven by regulatory requirements (Rao, et al., 2015). Utilities that effectively incorporate sustainability considerations into planning can expect to achieve many benefits, including:

- Minimizing costs by optimizing investment choices, operating water and wastewater systems more efficiently, and pursuing cost-effective investment and management strategies, such as collaboration and partnering with neighbouring systems to leverage resources and improve efficiency. Water utility planning that leads to the adoption of energy-efficient operational practices and technology can save utility money. Water and wastewater energy costs are often 30-40% of a municipality's total energy bill. They are also often the largest controllable cost for these utilities. Hence, the location of water infrastructure must be selected in such a manner that requires minimum power consumption. Gravity-fed water lines are preferred over pumping-mains. Using non-conventional power i.e. solar & hydel power may be cheaper than conventional energy.
- Maximizing results of investments to ensure a continuing source of water, treatment, and discharge capacity, as well as financing capability. Selection of upgraded technology instead of conventional one may give more productivity at the same cost.
- Improving the ability to analyze a range of alternatives, including (as appropriate) both traditional and non-traditional infrastructure. Nowadays, the O.H. tanks are not constructed as the VFD pumps give the same results thus saving the cost of the project.
- Alternatives, such as green infrastructure and/or decentralized systems, and selecting the option or mix of options that best meet the needs of the utility and the community it serves.
- Engendering greater support for the utility by recognizing community values and sustainability priorities.
- Ensuring that financial and revenue strategies are adequate to finance, operate, maintain, and replace essential infrastructure throughout its operational life, while appropriately considering the needs of disadvantaged households.

Elements of Financial sustainability

For successful completion of the projects, the following are the elements of financial sustainability:

- Assessment of need of the project/O&M, i.e. if water utility is unable to provide adequate water supply in a particular area, setting up of sewerage infrastructure in that area will not be advisable.
- Selection of appropriate technology – One must to make a balance between the cost of land and the cost of technology and its output. In most metro cities, there is no choice of the land or the cost of land is huge. In such a situation water utility must select the option of technology that require fewer footprints and have more productivity.
- The projection for the budget for the entire projects scattered throughout completion including O&M.
- Availability of funds for the entire projects – The flow of funds must be ensured for the successful completion of the project.
- Availability of resources (i.e. land, manpower, material and managerial staff etc.) is required for successful completion of projects.
- Selection of Business Model for projects or O&M: E.P.C., D.B.O.T., DBFOT, lease, annuity – full annuity or part annuity, PPP & complete asset management, etc. These are discussed in detail in following sections.
- Environment Impact Assessment – The impact of the project on the environment during and after completion of the project should be considered.
- Community Participation – Involvement of beneficiaries is crucial for the sustainability of any project.

Business models

The financial sustainability of the project largely depends upon the business model selected for the capital works or the O&M work. The business models along with their merits and demerits are described as under.

Engineering, Procurement & Construction

Engineering, Procurement, and Construction (EPC) is a type of contracting arrangement used in some industries where the EPC Contractor is made responsible for all the activities from design, procurement, construction, to commissioning and handover of the project to the end-user or owner. In this model, the water utility invites the tenders for the award of work to the agency quoting the lowest rates for construction of the project on the design provided by the utility. The agency constructs and hands over the project to the client after a one-year defect liability period. The agency is not responsible for the success of the project, as it has constructed the project as per the process and design provided by the client itself. Often, the quality of works is found to be sub-standard. O&M is the responsibility of the client. This contract can be further classified into two models, as under.

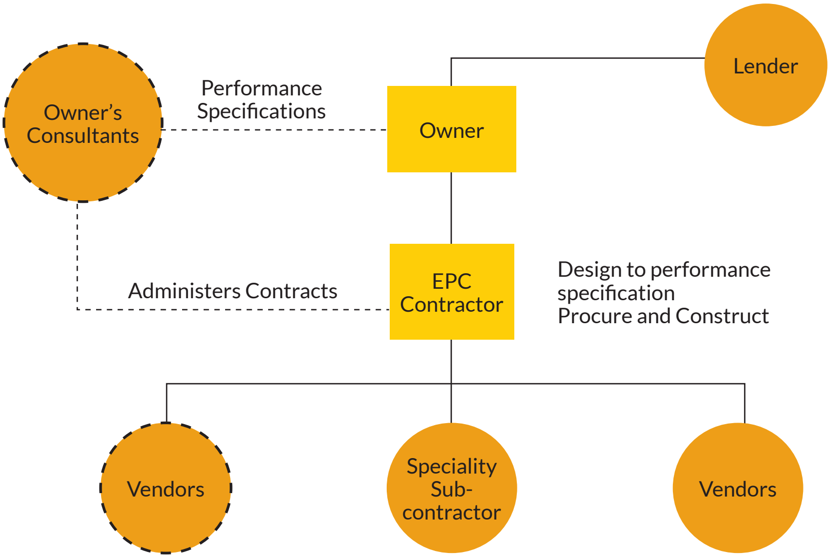
Integrated design-build model

In this model, the client appoints a consultant for designing, preparation of tender/ contract conditions and supervision of the project as described in Figure 9.1.

Non-integrated design-build model

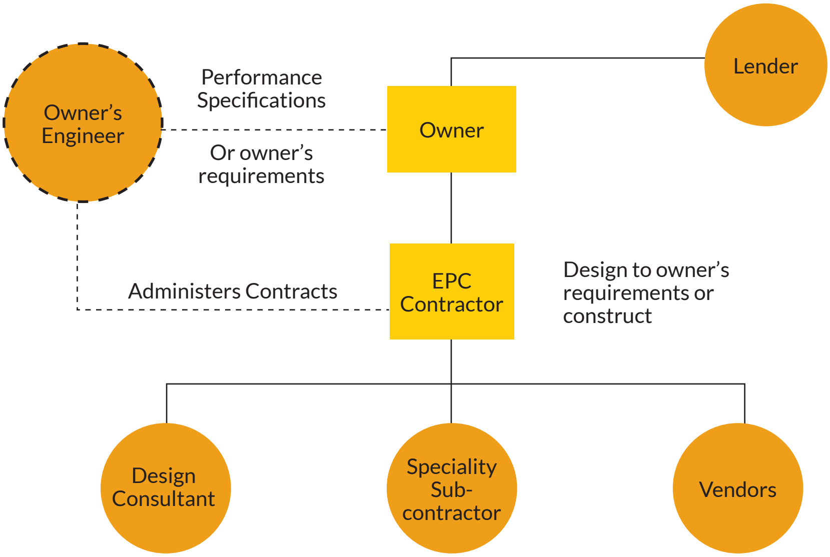
In this model, the contractor appoints a consultant for designing, while a consulting engineer is appointed by the owner, and is responsible for the preparation of tender/ contract conditions and supervision of the project as described in Figure 9.2.

Figure 9.1: Integrated Design-Build Model



Source – Author

Figure 9.2: Non-integrated Design-Build Model



Source – Author

- At the outset of the procurement process that whether both integrated and non-integrated design-builder will submit proposals.
- It can impact questions to ask in the Request for Quote (RFQ) process.
- It can impact the allocation of risk, caps and liabilities under the contract.
- It can impact remedies available to the owner for default, particularly the owner's ability to obtain access to the design documents required to complete the project.

Advantages

- It provides a single-point responsibility
- Opportunity for innovation and faster project delivery
- Efficiency (design & construction expertise together)
- Fitness for purpose
- No real alternative for proprietary technology
- Fewer changes and implementation simplified
- Often reduction of claims (or number of claims)
- Increased flexibility to address changed conditions
- The reduced administrative burden for the owner
- Cost savings and more certainty of the final price
- Improved risk management for owner
- Greater ability to evaluate contractors on factors other than cost

Disadvantages

- Loss of control and reduced owner involvement in the design
- The cost of tendering (to all parties) is known
- Difficulty/time comparing different designs
- Cost of risks and contingencies
- The danger of Design-Build becoming Build-Design
- Environmental/regulatory processes
- Limited pool of qualified Design-Builders
- QA/QC largely in the contractor's hands
- Disputes tend to be larger and more complex
- Management of long term risks
- Some lack of project definition before contract award
- Consequences of default more drastic than for Design Bid Build (DBB) model.

Design, Build, Operate & Transfer (DBOT) or Turnkey project

Many EPC project failed due to poor design, non-availability of funds for maintenance of the facility or less skilled maintenance staff of water utility. Hence, to avoid such failures, the water utilities adopted this model of DBOT in which, the agency has the entire responsibility of designing the process and the structures, its constriction and post-maintenance for certain years as provided by the client. After completion of the O&M period, the agency transfers the complete asset to the client for further maintenance. In general, this O&M period varies from 5 years to 15 years. The merit of this model is that the agency is very conscious about the quality of work and efficacy of the process and structural design as he has to operate the faculty for a long period and the payment is linked to the required result of the product i.e. If, a Water Treatment Plant is constructed by an agency on this model does not perform as per the desired standard, the agency will not be entitled to the payment towards O&M during the period till the required standards are met. However, the demerits of this model are that often the agency quotes the rates of Capital works and O&M smartly, regarding which, the utility has to be very cautious. The agencies' interests are to acquire maximum profits from the capital works , and are seldom interested in the O&M. The client does not have much control over the agency and is left with the option to rescind the contract. However, many agencies are interested in long term gains, even after capital works.

Advantages

- The contractor is solely responsible for the efficacy of design, quality of work, execution of all works required for completeness of the project and sustainability of long term performance of the project.
- The contractor tries to introduce innovative and updated technology into the project
- Since the contractor has to operate the system, he will be very cautious about the process and design.
- The client doesn't require strict supervisory control during the execution of the work
- Since key performance parameters are predefined, the agency uses standard operating procedure during O&M and tries to achieve desired results.
- The project is financially sustainable.
- Since it is a turnkey project, the contractor has to execute all the components of the work which are required for completing the project. Nothing has to be paid by the client.
- The contractor imparts training to the clients' employees before the transfer of the assets.

Disadvantages

- The cost of the project is generally high as the contractors inbuilt the risk cost and lump-sum provisions for unforeseen components which are not listed in the contract.
- To save the cost of construction, the contractor tries to manipulate the design of various components of the work. Hence, the client has to be very cautious about the design submitted by the contractor.
- The precise justification of rates is difficult to work out to compare the overall cost of the lowest tenderer.
- Generally, the O&M period of the plant is taken as 15 years. By the time the contractor transfers the ownership and management of the plant to the client, the useful lives of the electrical and mechanical (E&M) equipment are almost over. In such a scenario, the client has to get the plant revamped again incurring a huge cost.

Design, Build, Finance, Operate & Transfer (DBFOT)

Sometimes, water utilities run short of funds for a particular project. In such circumstances, the water utility intends to get the project partially funded initially by an agency. This model is similar to DBOT, with the addition of financing the project by the agency to some extent. This can be recovered during capital work and O&M.

Lease contract (short term & long term lease) or Privatisation

This model is also known as Privatization. In this model, the water utility hands over the entire asset to the agency for maintenance for a short or long term lease. The agency has the responsibility of creating the infrastructure and maintaining the old and new infrastructure, with the consent and agreement of the water utility and the beneficiaries upto required standards. The agency recovers the entire capital and maintenance cost from the revenue generated during this period. Many times, these models have failed since water is considered to be a basic need and the agency is not given the complete liberty to recover the revenue as per their terms and conditions. In such a situation, if the provision of Viability Gap Funding (VGF) is not made, the agency generally withdraws or abdicates the contract. In some cases, a part of the revenue is passed on to the client in case of revenue surplus. However, in the water sector, such events are rare.

Public-Private Partnership (PPP)

A lease agreement is considered to be privatisation and is generally objected to by the employees of the water utility and the consumers this is because the entire management is in the hand of the private operator who mostly tries to collect as much revenue as possible to meet their expenditure of O&M and capital investment. To achieve this, they may increase the tariff also. To avoid such complications, this model came into force. In this model, the entire asset is handed over to the private partner for management, in turn he is paid a Management Fee. If the operator suggests some modification, alteration or addition in the existing infrastructures, the client will pay for the entire capital works at the pre-decided rate contract. The Operator has to meet the basic parameters or KPIs for a certain period of contract varying from 10 to 25 years after completion of all capital works such as :

- Converting intermittent water supply into 24x7 or increasing the overall duration of the water supply.
- Reducing power consumption cost.
- Reducing Non-Revenue Water (NRW).
- Ensuring the quality of water supplied to the consumers to the extent of 98%
- Increasing collection efficiency i.e. to the extent of 95%
- Extension of water supply and increasing number of consumers.
- Redressal of consumers' grievances.

In the above key performance parameters, reduction of NRW and power consumption are measurable and the remaining are qualifying parameters that make operators entitled for payment.

Annuity (part or full)

When, a water utility is unable to invest a heavy amount of funds in a big-budget project instantly, but is in a position to invest over a longer period, this model is preferred over others. In this model, the water utility provides only the land to the agency for creating infrastructure. The agency invests the entire capital cost on the project. After successful completion and commissioning of the project, the client repays his capital investment along with the O&M cost annually or bi-annually as pre-decided in the contract. In this model, the project cost is high as the agency will try to charge the interest on the capital investment and risk cost too.

Complete asset management – One city One operator

This model is almost similar to the PPP model with the difference that the water assets of the entire city are handed over to the agency for maintenance only. The agency is responsible to maintain the entire water supply system of the city right from intake to WTP up to household connections of the consumers. However, the revenue collection remains with the water utility itself. A water utility may assign to the operator the task of meter reading and distribution of bills to the consumers. Also the agency can modify the existing infrastructures only to make them functional and to achieve the desired results. If any new structure is required, the operator will give requisition to the water utility. The water utility will award the work separately and hand it over to this operator after successful commissioning. This operator, if eligible, may participate in the tenders.

Case study — Experience of various business models in water utilities

In Delhi Jal Board (DJB), around two decades back, all the works of the Water & Sewage Treatment Plants and other infrastructure were being awarded on the Engineering, Procurement, and Construction (EPC) model. But, later on, the quality of the works and the performance of the infrastructure was not found up to mark and huge expenditure was incurred in its restoration.

To avoid demerits of the above business model, DJB started adopting the Design, Build, Operate and Transfer business model. Initially, the response to this model from Indian companies was very limited. However, an additional clause was introduced in the tender conditions allowing foreign agencies to participate in collaboration with Indian companies. Thereafter, the responses from the agencies for this business model was very encouraging. The latest technologies were imported and implemented for new projects e.g. rehabilitation of trunk sewers through trenchless technology. Thus water and sewerage treatment plants were constructed within the limited available land. The Sonia Vihar water treatment plant, and Delhi Gate, Kapashera and Chilla sewerage treatment plants are examples of this model. The advantage of this business model is that the agencies are very cautious about service level benchmark which are built in the contract agreement.

In 2012, the PPP model was adopted by the Delhi Jal Board for awarding the water management contracts in three areas *i.e.* (1) the water asset management of the area under the command of Malviya Nagar Underground Reservoir & Booster Pumping Station, (2) water asset management of Vasant Vihar and Mehrauli area, and (3) Command area of Nangloi Water Treatment Plant. Under these contracts, the agency had to first carry out a pre-feasibility survey, execute some capital works for the improvement of the water supply. After completion of all capita works, the agency was to manage the water supply assets to achieve key performance indicators (KPIs) as indicated in section on Public Private Partnership on page 159. The agency has to spend some percentage of equity for carrying out the capital works, which will be reimbursed for achieving all KPIs in various instalments. All these contractors were awarded to the foreign agencies in collaboration with the Indian partners.

Challenges in these contracts:

- The capital works were to be completed within 2-3 three years, however due to the delay in obtaining the approvals and permissions from various departments for allotment of land, road excavation, removing trees etc., the capital works could not be completed on time, resulting in a delay in achieving KPIs and consequent revenue loss.
- Due to poor assessment of existing assets at the time of preparation of Detail Project Report (DPR), the estimate for capital works was on the higher side. When these capital works were executed, it amounted to approximtely 50% saving in the capital works was found. This resulted in inflated budget provision.
- There was a dispute on some issues of KPIs which were achieved before completion of capital works for example, in the Nangloi case, the agency reduced power consumption by closing down one of the pump houses.

Achievements:

- 5-10% NRW was reduced in Malviya Nagar.
- In three colonies intermittent water supply was converted to 24x7.
- Revenue increase by improving collection efficiency and increasing the duration of the water supply.
- Capital works carried out without passing through the mammoth procedural formalities of red-tapism.

Recently, Ghaziabad Municipal Corporation has awarded the work of entire asset management to M/s Vatech WABAG on one city and one operator basis. This is a successful model in the maintenance of the sewerage system of the entire city. With the success of this model, the Delhi Jal Board has initiated adopting a similar model in Delhi for water and sewerage system dividing Delhi into various districts.

Conclusion

Incorporating sustainability considerations into water and wastewater utility planning can produce substantial benefits. It can help utilities:

- Reduce lifecycle costs by operating more efficiently, pursuing cost-effective investment strategies and optimizing investment choices.
- Optimize social, environmental, and economic benefits by selecting projects through a systematic process of setting sustainability goals and objectives that also support community priorities.
- Increase community support through upfront dialogue with community members and active consideration of other community priorities as alternatives are considered.
- Balance assessment of a range of traditional and non-traditional infrastructure alternatives using consistent criteria.
- Increase fiscal sustainability by analyzing the full lifecycle costs of investments, developing low-cost financing strategies, and ensuring that revenue needs are accurately assessed to support maintenance, renewal, and replacement of infrastructure while meeting all regulatory requirements.
- Provide information on sustainability benefits for making replicable, consistent, and transparent decisions and for explaining decisions to board members, local elected officials, the public, and others.
- Increase customer support through clear rate expectations (and avoided "rate shocks"), increased system reliability, and increased responsiveness when disruptions occur.
- Enhance the technical, financial, and managerial capacity of the utility.

Utilities applying this guidance and these tools should utilize the identified processes on an iterative basis, refining them over time. This will help support the sustainability and responsiveness of the planning process.

As the practice of planning for sustainability evolves, more effective practices will emerge. These resources can help utilities over time and further optimize their infrastructure and operational decisions.

9.3 Ecosystem Services and Models for Water Management

Ecosystem services are defined as the benefits that people obtain from ecosystems and the direct and indirect contributions of ecosystems to human well-being. The concept of ecosystem services is relevant for connecting people to nature for its improvement and not for destruction. It makes visible the key role of ecosystem functioning and biodiversity to support multiple benefits to humans. Understanding the linkages between the natural and socio-economic systems can lead to improved and more sustainable management of ecosystems.

Ecosystem service concepts can offer a valuable approach for linking human and nature, and arguments for the conservation and restoration of natural ecosystems. Despite an increasing interest in the topic, the application of these concepts for water resource management has been hampered by the lack of practical definitions and methodologies.

In 2010, the parties of the Convention of Biological Diversity adopted a revised Strategic Plan for Biodiversity including the Aichi Biodiversity Targets, a reinforced action to halt the loss of biodiversity and ensure ecosystems are resilient and continue to provide essential services.

Aquatic ecosystems (rivers, lakes, groundwater coastal waters, seas) support the delivery of crucial ecosystem services, such as fish production, water transport, water provisioning and recreation.

In the past 3 decades, all the static and flowing water bodies in the capital city of India i.e. Delhi have been polluted completely due to unplanned growth and poor urban planning. The groundwater was also overexploited resulting in lowering of groundwater table and pollution of groundwater due to infiltration from the contaminated source i.e. nearby polluted water bodies. The people, on one side, polluted these water bodies and on the other hand, kept them aloof from the natural water and water bodies which has resulted in a reduction of key surface and groundwater resources for them. Over time, people realized the scarcity of water resources and again started connecting with water bodies for their rejuvenation. Creation of water Biodiversity within the flood plain was the first step to revive the ecosystem for water management.

Key ecosystem services are also connected to the hydrological cycle in the river basin, for example, water purification, water retention and climate regulation. Most of these water-related ecosystem services can be directly appreciated by people and quantified, but some, especially regulating and maintenance services, are less evident. All ecosystem services have to be considered for the sustainable use and management of water resources.

Method

This method proposes a practical and flexible approach relevant for water resource management. The use context of the approach is the study of the relationship between multiple pressures, ecological status and delivery of ecosystem services in water systems.

The focus of the analysis is on inland waters and the spatial scale of interest ranges from the water body to the catchment/river basin. While for water bodies the main focus is on specific ecosystem functions that support ecosystem services, and their alteration under different stressors, the catchment is the appropriate scale to observe and quantify processes related to the water cycle, and to implement monitoring and management plans to reduce multiple-pressures. The assessment and valuation of ecosystem services at the European scale allows us to address regional trends, identify hot spots in the delivery or degradation of services, test the effectiveness of regional policies and conduct scenario analysis at a large scale.

The approach that can be developed is organised in four building steps:

- Definitions and scoping
- Framework (relations between pressures, ecological status and delivery of ecosystem services)
- Biophysical assessment of ecosystem services
- Economic valuation of ecosystem services

Approach for assessing and valuing water ecosystem services

Water-related ecosystem services

A large variety of ecosystem services have been addressed by assessments such as Millennium Ecosystem Assessment, the Economics of Ecosystems and Biodiversity. The services can be related to the following ecosystems: lakes, rivers, transitional waters, coastal waters, groundwater, freshwater wetlands, coastal wetlands, riparian areas, floodplains. Providing a list of ecosystem services can support the practical implementation of the methodology, but of course, the list is not to be considered exhaustive and more services can be included, especially hydrological services relevant for river basin planning and decision making.

Framework – Linking pressures, ecological status and ecosystem services for water

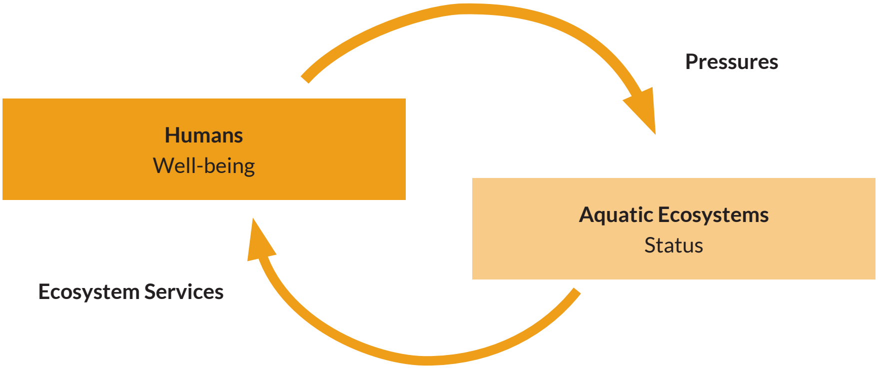
Understanding the relationship between anthropogenic pressures and ecological status is the basis of the River Basin Management Plan (RBMP), to devise cost-effective measures to achieve good ecological status for all water bodies. In particular, for planning sound restoration actions, it is necessary to consider the complex links between pressures combinations and the ecological response of aquatic systems. Overall, the main pressures affecting the aquatic ecosystems can be summarized as alterations of water quantity and quality, and changes in the physical habitat and the biological components, as shown in the Table 9.1.

Table 9.1: Changes and alterations in the ecosystem

Alteration of	Changes / Stressors and Pressures
Water quantity	Flow modifications (hydrological alterations): • Quantity and frequency (dams, water abstractions, irrigation, transfers) • Groundwater abstractions • Changes in precipitation and temperature • Changes in runoff
Water quality	Diffuse and point pollution: • Nutrients • Chemicals (pesticides, endocrine disrupting compounds, nanoparticles, etc.) • Metals • Pathogens • Litter • Groundwater salinization • Sediments, increased turbidity and brownification
Habitat	Hydromorphological alterations (physical alteration of channels, bed disruption, dams)
Biota and biological communities	Alien species, other changes in biological communities

Source — Adapted from Grizzetti, et al., (2016) Human activities are the major drivers for generating multiple pressures (Figure 9.3). Pressures affect the biodiversity and the status of the aquatic ecosystem, which can result in a change in the ecosystem services and their economic value. The excessive exploitation of ecosystem services can turn into pressure for an ecosystem. For this reason is important to consider the resilience of the system and to introduce the notion of sustainability when assessing the delivery of ecosystem services (Figure 9.3). The interest of River Basin Management Plans is to quantify the changes in the components of this system under remediation measures and scenarios of pressures.

Figure 9.3: Interactions between Humans and Aquatic Systems



Source – Adapted from Grizzetti, et al., (2016)

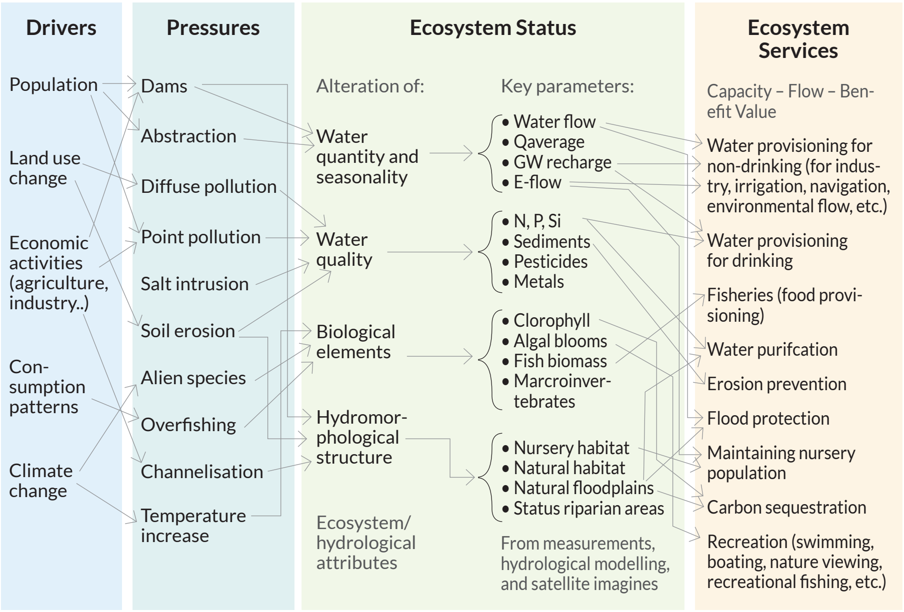
To support the analysis of these linkages, a conceptual framework for the integrated assessment of water-related services has been developed. In the framework, one can identify the main pressures affecting aquatic ecosystems and the possible links to the alteration of four ecosystems/hydrologic attributes:

- Water quantity (including seasonality);
- Water quality;
- Biological quality elements;
- Hydro morphological & physical structure.

In the integrated assessment framework for analyzing the links between pressures, ecosystem status and ecosystem services, the list of pressures and the arrows describing the relationships are not exhaustive; the users are invited to develop the specific relationships at stake in their case study (Figure 9.4).

The purpose of this framework (Figure 9.4) is to support the users in describing the relationships between pressures and ecosystem services, and design a conceptual scheme of the assessment and scenario analysis. The arrows are examples. Each user can select the relationships under analysis and complete and adapt the framework to the specific case under study. The idea is to think about the links between the selected services and specific stressors. Figure 9.5, which presents expected qualitative effects of stressors/pressures on different ecosystem services, could inspire this reflection.

Figure 9.4: Integrated Assessment Framework for analysing the link between pressures, ecosystem status and ecosystem services



The list of pressures and the arrows describing the relationship are not exhaustive, the users are invited to develop the specific relationships at stake in their case study

Source – Grizzetti, et al., (2016)

Biophysical assessment

Tools

The biophysical methods include spreadsheet/GIS approaches. These methods apply to all ecosystem services, not specifically to water ecosystem services. Most of them rely on the spatial mapping of the ecosystems and land use.

Figure 9.5: Expected qualitative effect of stressors/pressures on different ecosystem services.

Ecosystem services		Flow modifications	Diffuse and point pollution	Groundwater Salinization	Erosion/ Brownification	Hydromorphological alterations	Alien species	Overfishing
Provisioning	Fisheries and aquaculture	high	high	low	high	medium	high	high
	Water for drinking	high	high	high	high	medium	low	low
	Raw (biotic) materials	medium	high	low	medium	high	high	medium
	Water for non-drinking purposes	high	high	high	high	medium	low	low
	Raw materials for energy	high	high	low	low	high	medium	low
Regulation & Maintenance	Water purification	high	high	medium	high	high	low	low
	Air quality regulation	high	high	low	low	medium	low	low
	Erosion prevention	high	low	low	low	high	medium	low
	Flood protection	high	low	low	low	high	medium	low
	Maintaining populations and habitats	high	high	low	medium	high	high	high
	Pest and disease control	high	high	low	medium	high	high	high
	Soil formation and composition	high	medium	low	high	high	low	low
	Carbon sequestration	medium	low	low	medium	high	medium	low
	Local climate regulation	high	low	low	low	high	low	low
Cultural	Recreation	high	high	low	high	high	medium	high
	Intellectual and aesthetic appreciation	high	high	high	high	high	high	high
	Spiritual and symbolic appreciation	high	high	high	high	high	high	high

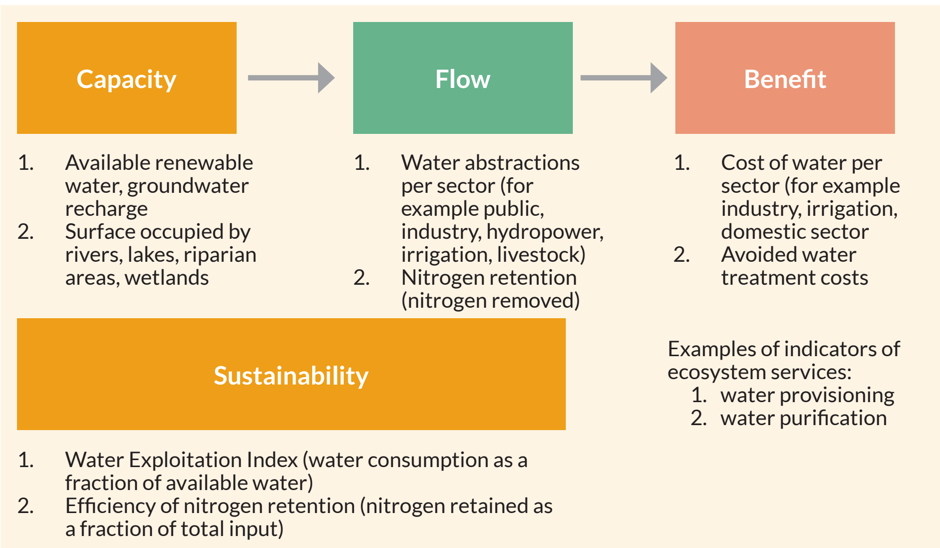
Legend: Expected impact of each pressure over the ecosystem service: ● *high,* ● *medium,* ● *low.*

Source – Grizzetti, et al., (2016)

The water quantity and quality, and the water-related ecosystem services, are affected by the complex interactions of climate, topography and geology, land cover and management, and other anthropogenic modification of the landscape. Incorporating water-related ecosystem services in the decision-making process requires the capacity to predict the effects of land use and climate changes on the water resources, which can be offered by the hydrological models. Hydrological and biogeochemical catchment models are appropriate tools for dealing with water-related ecosystem services). They can represent the dynamic of the river basin (resilience) and the temporal (lag time) and spatial distance between beneficiaries and impacts, and they can be used in scenario analysis of multiple stressors. They also allow describing physical relationships between stressors, status and services as presented in the integrated assessment framework.

Indicators

Figure 9.6: The conceptual framework to classify indicators of water ecosystem services. Some examples of indicators for the ecosystem services of 1) water provisioning and 2) water purification are reported



Source – Grizzetti, et al., (2016)

To support the correct understanding and appropriate use of the indicators for ecosystem services, and more generally to structure the assessment, we have to analyze which dimension of the ecosystem service is captured by the indicators. To this purpose, a simplified conceptual framework for structuring the analysis and the classification of indicators of water ecosystem services is proposed. The framework includes the capacity of the ecosystem to deliver the service, the actual flow of the service, and the benefits. Capacity refers to the potential of the ecosystem to provide ecosystem services, while the flow is the actual use of the ecosystem services. The capacity relies on biophysical data, while flow requires the acquisition of socio-economic data. Benefits are associated with human well-being and the value system. Services are often associated with high exploitation of the ecosystem; the risk is an unsustainable use of nature. For this reason, we are interested in looking at the sustainable flow of services. This is considered in the conceptual framework by including indicators informing about the sustainability, i.e. indicators combining capacity and flow (an example could be the Water Exploitation Index). In many cases, the information on capacity and flow is lacking, or the full capacity of the ecosystem is unknown or unaccountable. In these cases, we can try to collect indicators about the efficiency of the processes (for example the removal rate of a pollutant per unit of input).

Economic valuation

Several methods are available in the literature to estimate the economic values of freshwater ecosystem services. There are three categories of approaches: cost-based, revealed preferences and stated preferences approach. Cost-based approaches consider the costs that arise about the provision of services. Revealed preferences approaches refer to techniques that use actual data regarding an individual's preferences for a marketable good which includes environmental attributes. Stated preferences approaches refer to methods based on structured surveys to elicit individuals' preferences for non-market environmental goods. Another practical way to value ecosystem services under the non-availability of site-specific data or funding constraints is the benefit transfer approach. This approach consists of using economic estimates from previous studies to value services provided by the ecosystem of interest. For the economic assessment, the first step consists of identifying the benefits provided by the ecosystem service to be valued.

Economic valuation at the water body/catchment scale

The choice of the primary valuation method depends on the ecosystem service to be valued and on the beneficiary population.

Table 9.2: Ecosystem Services and their valuation methods

Ecosystem services	Category[a]	Value type	Valuation method[b]	Examples of economic good provided
1-Fisheries and aquaculture	Provisioning	Direct	MP, RC	fish catch
2-Water for drinking	Provisioning	Direct	MP, CV	water for domestic uses
3-Raw (biotic) materials	Provisioning	Direct	MP, RC	algae as fertilizers
4-Water for non-drinking purposes	Provisioning	Direct	MP, PF	water for industrial or agricultural uses
5-Raw materials for energy	Provisioning	Direct	RC	wood from riparian zones
6-Water purification	Regulation	Indirect	RC, CV	excess nitrogen removal by microorganisms
7-Air quality regulation	Regulation	Indirect	RC	deposition of NO_x on vegetal leaves
8-Erosion prevention	Regulation	Indirect	RC	vegetation controlling soil erosion
9-Flood protection	Regulation	Indirect	RC, CV	vegetation acting as a barrier for the water flow
10-Maintaining populations and habitats	Regulation	Indirect	RC	habitats use as a nursery
11-Pest and disease control	Regulation	Indirect	RC, CV	natural predation of diseases and parasites
12-Soil formation and composition	Regulation	Indirect	RC	rich soil formation in flood plains
13-Carbon sequestration	Regulation	Indirect	RC, MP	carbon accumulation in sediments
14-Local climate regulation	Regulation	Indirect	RC, MP	maintenance of humidity patterns
15-Recreation	Cultural	Direct	CV, TC, DC, HP	swimming, recreational fishing, sightseeing
16-Intellectual and aesthetic appreciation	Cultural	Non-use	CV, DC	matter for research, artistic representations
17- Spiritual and symbolic appreciation	Cultural	Non-use	CV, TC, DC	existence of emblematic species
18-Raw abiotic materials	Extra abiotic	Direct	PF, MP	extraction of sand gravel
19-Abiotic energy sources	Extra abiotic	Direct	PF, MP	hydropower generation

a. Provisioning, Regulation and maintenance, Cultural, Extra abiotic services
b. Contingent valuation (CV), Hedonic price (HP), Market price (MP), production function (PF), Replacement cost (RC), travel costs (TC).

One of the main difficulties in the economic valuation is to decide on the size of the benefiting population (beneficiaries). Aggregate benefits depend on estimates of both individual benefits and of the number of beneficiaries. As a general rule, the beneficiaries should be the households/persons aggregated at the relevant geographic scale and should include both users and non-users impacted by the ecosystem service considered (except for services of only local importance). Also, for some services (for example recreational services), when spatially aggregating individual benefits, it is usually considered that the willingness to pay (WTP) decreases with the distance from water body providing ecosystem services, as the opportunities of the ecosystem service provision are expected to decrease with the distance, and concurrently the existence of possible substitutes is assumed to increase. Generally, a distance decay function is adopted to take into account the decrease of the willingness to pay with the distance from the water body providing the ecosystem services. This distance determines the boundaries of the geographical area, or so-called economic jurisdiction, over which the individual WTP-values can be aggregated over the population of beneficiaries to calculate the total economic value of a proposed scenario of environmental change.

Discussion

The entire concept of Ecosystem and Integrated water management is understood from the live example of the Yamuna River basin after Hathni Kund Barrage, where, the priority of water supply overrides the Ecosystem. The entire water coming from the glaciers and runoff arriving from upstream of Hathni Kund Barrage is collected at this dam and diverted one-third of its quantity to Uttar Pradesh and two-third towards Haryana through Eastern and Western Yamuna Canal respectively, leaving no discharge of freshwater into the River course during the nine months of non-monsoon. This water is drawn completely for irrigation and drinking and distributed among the basin states i.e. U.P., Haryana, Delhi and Rajasthan. The distribution of water is regulated and control by the Upper Yamuna River Board (UYRB) under the Ministry of Jal Shaki (previously Ministry of Water Resources), GoI. Hence, it may be comfortably said that there is less river water downstream of the Hathni Kund Barrage which implies simply that the ecosystem of the river is compromised on the downstream of this Barrage till Delhi. The River water which creates and sustains the ecosystem i.e. flora & fauna, water transport, human recreation etc. has been missing. The residents habitated on the banks of river worship and take care of the river till it is alive. However, in this stretch, the people or even the public authorities are careless in disposing of the solid & liquid waste. There is a huge issue of open defecation in and around the river bed. During the small rainfall or release of water from Hathni Kund Barrage, the entire waste deposited in the river bed flushes out and mixed with fresh raw water which is released in the river few kilometres upstream of Delhi from the western Yamuna canal, resulting in a sudden increase in ammonia and nitrate level in the raw water which is untreatable at the water treatment plants in Delhi. Ultimately, there is a crisis of drinking water due to the shut down of the water treatment plants. This crisis not only results in water scarcity in central and south Delhi but also wastes a huge quantity of freshwater which is required to dilute this contamination and flushed out through Wazirabad Barrage till it attains the permissible values of the Ammonia and Nitrate which can be treated at these plants. Of course, consumers also face difficulties during this crisis.

To revive and maintain the Ecosystem of the Yamuna River, many NGOs approached the Apex Court of India. The Hon'ble Supreme court. Supreme Court of India took SUO MOTO Case on an article published in the newspaper titled "QUIET FLOWS A MAILY YAMUNA under CW(P): 725/1994. Various departments of the Government of India and the Government of NCT Delhi were made part of this matter. Besides, various important and historical directions, the Hon'ble S.C.I. directed Haryana Govt. to release at least 10 Cumec freshwater from Hathni Kund barrage in the river course to maintain eco-flow.

Though, this quantity was released by the Government of Haryana in river course, but the quantity of this water is so small that it is absorbed within a few kilometres of the river stretch. Now, the matter is before the Hon'ble National Green Tribunal which has directed the National Institute of Hydrology of IIT Roorkee to work out the optimum quantity of fresh water to be released in the river throughout the year to revive and maintain the river ecosystem.

Another example of compromising the ecosystem with water supply management is the overexploitation of groundwater in Delhi. As everyone knows that Delhi's population is growing manifold which has reached almost 22 million as of now and likely to be 23 million by the end of this year. Due to the failure of the land development and housing department in providing an adequate planned house in Delhi, and also a failure on the part of regulating authority i.e. Revenue and the Police department, there has been unplanned growth in Delhi. A large part of agricultural land has been converted into habitation due to which groundwater is overexploited from two sides, by the residents on one hand, and on the other hand, by the public water utility to arrange water for the residents. The water table went down to that level, the Govt. declared 6 districts out of 8 districts as a red zone and had to ban the exploitation of groundwater. Due to overexploitation, besides the water table receding, the quality of water also got deteriorated due to infiltration of contaminated water from the nearby polluted water bodies. The water utility i.e. Delhi Jal Board is incurring huge expenditure on re-boring of tube wells due to excessive lower down of water table, especially in South Delhi. Many Ranney wells have been shut down due to the infiltration of polluted water from the river.

The above example reflects how water supply affects the ecosystem of water bodies and groundwater. Disturbing the ecosystem has affected the socio-economic pattern and also resulted in increased expenditure on water supply management.

Strengthen the connection between human and nature

River Basin Management Plans are based on the principles of Integrated Water Resource Management (IWRM). IWRM is "a process which promotes the coordinated development and management of water, land and related resources, to maximize the resultant economic and social welfare equitably without compromising the sustainability of vital ecosystems". Before the ecosystem service approach, IWRM already stressed the need for connecting the environment and human well-being and proposed the integration of multi-disciplinary knowledge from different sectors and stakeholders in water management. The ecosystem services approach has significant similarities with IWRM. Both aim at the management of natural resources that optimizes the economic and social welfare and contemporary ensures ecological sustainability, integrating the knowledge of stakeholders and multiple disciplinary perspectives. Ecosystem services and IWRM both share the goal of negotiating the trade-offs between different human and ecosystem needs while supporting sustainability, and require the involvement of stakeholders for making explicit the whole range of values (not only economic values).

To address current sustainability challenges the recognition of the dependency of human well-being on natural capital is necessary. Integrative frameworks such as the ecosystem service approach allow the incorporation of natural components in the system analysis. The concept of a human-ecological system advocated by the ecosystem service approach is powerful in linking biophysical processes and human benefits and allows ecosystem services to be valued and integrated into the river basin decision making process.

Conclusions

The method proposed to assess and value water ecosystem services provides some knowledge basis for the enrichment of water management. In particular, it proposes a more holistic view to the implementation of multiple pressures, ecological status and delivery of ecosystem services. Under this perspective, the analysis of cost-effective and remediation measures can be improved including all hidden benefits and beneficiaries from water ecosystem services.

One important and novel point is to assess also some sustainability (or efficiency) index that estimates the flow of service that can be sustained with a certain capacity. This could avoid the overexploitation of certain services. The proposed method includes also the economic valuation of the aquatic ecosystem, providing a list of techniques for each service and the spatial scale of application. Valuing water ecosystem services could highlight hidden benefits for society and could raise awareness among users and stakeholders. Even if monetary values are probably the most appealing arguments for water management, they can be advocated and described as the advantages of using a plurality of values. Overall, the proposed approach can be used for assessing the benefits of conservation and restoration of aquatic ecosystems in the implementation of the water policy. There are opportunities by adopting the ecosystem services approach to capture and integrate all the effects (economic, environmental and social) associated with new water plans and investments.

9.4 IEC and Community Engagement

Definition

Information, Education and Communication, abbreviated as IEC, is a strategy to spread awareness through communication channels to a target audience to achieve a desired positive result. It is a strategy of sharing information through the broadcast or the print media, or interpersonal communication in a manner, appropriate to the target group's culture and values. It is intended to instil positive knowledge for appropriate behaviour in the community which will promote preventive health measures and development. These channels of communication or IEC materials are either printed or broadcasted media such as posters, flyers, leaflets, brochures, booklets, radio broadcast or TV spots. The means of community participation may be physical interaction with the target audience, Nukkad Natak and plays etc.

Why Information Education and Communication (IEC)?

IEC is a proven powerful tool for bringing social change and development. These strategies are research-based consultative processes designed for addressing knowledge, attitudes and practices to bring positive changes in the behaviours and attitudes of the target groups. They define a community's needs, create awareness, promote health education and guide them on how to exercise their rights in the planning of the project and other activities of O&M of the services beneficial to them.

An individual's behaviour is shaped by the social, cultural, economic and political systems. With well-defined strategies and participatory practices, these strategies of communication sustain and encourage positive behaviour, eliminating social disparities. Hence, for the success of a project to become a customer or community-oriented project, IEC plays a vital role. Many projects though are conceived by the department but are not implemented due to lack of awareness about the project among their beneficiaries. There are more examples where, projects were conceived, implemented and commissioned, but could not be sustained due to the reluctant behaviour of the community for which these projects were implemented. Hence, the involvement of the community in the planning of the project, its execution and afterwards maintenance is essential to make the beneficiaries feel the ownership of the implemented project.

Objectives of IEC

Any water utility is not just about creating water infrastructure, but must also aim at building capacities of different stakeholders especially local communities, responsible and responsive leadership to own, manage, operate and maintain water supply systems. Therefore, IEC strategies, planning and effective implementation will be the key to the success of the project.

The water utilities must undertake IEC activities such as Inter-Personal Communication (IPC), Behavioural Change Communication (BCC) and all other related communication activities. The utility must lead IEC/ BCC plans and should be responsible for the embedding of such interventions across the State.
Annual plan/ calendar of activities for IEC, HRD, training, capacity building can be prepared by the water utility and be part of the project.

The objectives of the IEC activities are to:

- Drive positive behavioural changes among stakeholders concerning judicious use of water, safe handling and storage, ownership of water supply system, etc.;
- Create awareness and motivate people to take up affirmative action for the protection of drinking water sources and against the misuse of water;
- Create awareness and motivate people to conserve water resources;
- Promote behaviour change towards health and hygiene aspects;
- Have effective communication strategy involving all stakeholders;
- Inculcate a sense of responsibility to manage, operate & maintain their water supply systems to ensure service delivery;
- Encourage community contribution towards the capital cost to instil a 'sense of ownership';
- Encourage the community to measure water and promote water tariff/ user charges;
- Recognize the performance of various stakeholders.

Beneficial Attributes of IEC

Variety of Channels

IEC programs engage in different channels of communication, which is exceedingly advantageous for the dissemination of message to varied target groups.

Cost-Effective

Printed IEC materials are cheap and inexpensive, thus are suitable for low budget programs. Messages intended for the masses are conveyed on a broadcast medium like television, which is effective in disseminating the information to a large audience.

Building Capacity

IEC programs ushers in information, skills and knowledge to the target groups which is essential for positive health measures.

Target Specific

The participatory nature of IEC programs provides a sublime opportunity to engage with the local communities, establish good rapport and to define their specific needs. This enhances the effectiveness of the programs, provides an ambient environment for evaluation, improvement and sustenance.

Feedback

IEC programs have feedback which is vital for clarifying questions, reinforcement and solving issues.

External Support

These programs can avail support from other counterparts, government, community leaders, opinion leaders, and local support groups which are tremendously helpful in monitoring, sustaining and achieving success of the programs being implemented.

Logos and symbols

Certain IEC campaigns have established outstanding logos and symbols, which has helped sustain their movements and campaigns. The ‘Red Ribbon’ and the ‘White Ribbon’ logos are instrumental in spreading awareness about HIV and AIDs and elimination of violence against women.

Entertainment

Messages catering to the needs of the individuals and groups can be conveyed through the channels in an entertaining manner captivating the attention of the audience. Jingles in radios, bulletins in televisions, or pictures and graphics are also entertaining.

Role of IEC

The government and social organisations, coupled with the health agencies, have extensively used IEC as an integral medium for social change and development. IEC has become an effective medium for bringing awareness, providing information, eradicating mythical beliefs, and championing the cause for health and development.

Health Sector

In the health sector, IEC has played a pivotal role in spreading awareness and taking preventive measures. Through radio jingles, phone-in programs, TV slots, and printed materials, people have been made aware of swine flu, malaria, and infectious diseases. Awareness of hygiene and sanitary, nutritional diets and programs have been generated among the vulnerable sections in the rural areas through the IEC materials. Polio vaccination and immunization programs are widely posted and distributed in public spaces for spreading awareness. One of the most remarkable achievements of the IEC strategy is the campaign against the stigmatization of HIV affected patients. Through the IEC programs, the government and health service agencies have orchestrated a much-needed campaign about the condition and its vulnerabilities, which is instrumental in eliminating preconceived notions and quenching rumours.

Water Sector

In the water sector, IEC and community participation has played an important role in the distribution of water supply rationally. The water supply in slums and water deficit area is generally managed through public stand posts fed through tube wells or water network and water tankers. There could be fights due to overcrowding for fetching water from these sources. There were many such cases of fights that were reported and went to the extent of murder. But after the introduction of IEC and community participation, the water supply through these means was managed successfully. The latest example of a success story of IEC and community participation was Managing water supply in water deficit areas through water ATM as explained in the following section.

Case Study – Delhi Jal Board

Delhi Jal Board (DJB) and Piramal Water Private Limited came together to design a pilot project for testing out Sarvajal Water ATM units for safe water delivery in slum communities within the framework of DJB's water tanker delivery system in a slum community having no water supply and less than 2000-3000 households. Additionally, the community so chosen shall have sufficient sources for procuring water for non-potable, non-drinking purposes. Despite DJB's commendable efforts at setting up an exhaustive network of tankers for water delivery, it is improbable to ensure equitable distribution and scheduled delivery of water across all the slum clusters. This situation causes long queues at the site of water distribution, petty fights over the distribution of water and skipping work for water collection for daily use.

Figure 9.7: Ring structured Water ATM Unit

This project proposes to set up a network of automated water vending units through the installation of 10 Sarvajal Water ATM units at a slum community. This shall ensure 24x7 access at multiple locations within the community. Drinking water shall be available on a pay-per-use basis through RFID enabled Water ATM cards. Additionally, in-built remote monitoring capabilities shall enable real-time tracking of all user transactions for accountability and monitoring purposes.

These are solar-powered, RFID-enabled, cloud-connected automated water dispensing devices. These enable 24x7 access to clean water, the quality of which is closely monitored through embedded quality sensors. Furthermore, user tracking enables the stakeholders to determine how much water is purchased when, where, and by whom. This granular and unprecedented method of tracking water usage enables sophisticated demand forecasting, an easy gathering of consumer data and proactive maintenance management.

Ring structured Water ATM units [Dimensions – 10ft high, 5ft diameter], comprising of a vending unit and a 500-litre water tank enclosed within concrete rings shall be used within the purview of this project. The concrete reinforcement ensures that the structure is durable and resistant to vandalism. Each unit shall require 30 sq. ft. space for installation.

Implementation Plan: A Step by Step Approach

Pre-Installation

- DJB selects a slum community for the proposed pilot. Representatives from DJB and Sarvajal carry out a feasibility survey for finalizing the community.
- Based on the feasibility survey, locations for the installation of 10 Water ATM units are selected.
- DJB seeks permission from a relevant government authority (say DUSIB) for the installation of Water ATMs, which requires 30-40 sq. ft of space per ATM unit. A cemented foundation is prepared at all 10 locations for Water ATM installation.

Installation

- DJB selects a water tanker for Water ATM compatible design modification. Sarvajal provides design inputs and assists in vendor selection.
- Transportation and installation of ring structured Sarvajal Water ATM units at all 10 locations.
- Upon completion of water tanker design modification, Sarvajal provides training to driver-cum-operator (hired by DJB) for filling/ re-filling the Water ATM tank.
- Sarvajal locates and trains Water ATM card vendors within the community who shall create, top-up and recharge Water ATM cards.

Project Launch

The project was objected to by the local community with the mindset that the Govt. is privatizing the water supply system and the vendor will charge them very high prices of water.

- Sarvajal & DJB organized a series of the community engagement drives, using written, audio and visual aids to create awareness regarding safe water practices.
- Special training sessions were organized to train the community members in using Water ATMs and mentioning the water fee and balance deduction mechanism.

Figure 9.8: Stakeholder engagement in a slum

Operations and Maintenance

The mechanism of operation of water supply was explained to the community as under:

- DJB shall be responsible for ensuring safe drinking water availability for the tanker to carry it to each Water ATM daily.
- Sarvajal shall be responsible for tracking the water tanker and ensuring all Water ATMs are filled as per schedule.
- Sarvajal shall be responsible for providing regular maintenance services, scheduled tank cleaning, emergency maintenance visits and component/ part replacement at all Water ATMs throughout the project tenure.

- Sarvajal shall be responsible for online monitoring of each ATM unit and management of data services and generation of periodic water data reports detailing consumer transactions for selected representatives in DJB.

Finances

The Community was also explained about the pricing of water supply which will be filtered and potable. In lieu of these services as explained above, Sarvajal shall be charging 10 paise per litre of water dispensed which is highly subsidised as compared to the market price.

Figure 9.9: Water ATM in Delhi

The community was also aware of the complete cost of the project as explained under.

Capital expenditure, recurring expenses and other miscellaneous expenses of the project are detailed in Table 9.3, Table 9.4 and Table 9.5 below.

Table 9.3: Capital Expenditure of DJB for Sarvajal

Component	Borne By	Price (in INR)	Details
Sarvajal Water ATM Units (Ring Structured)	DJB	INR 12,50,000	Inclusive of taxes and 12 month component warranty @ INR 1,25,000 per ATM unit
Design Modification in Water Tanker [Motor, inverter and piping fitting]	DJB	Approx. INR 1,50,000	Drawings, design and vendor selection to be done by Sarvajal
Transportation and Installation of Water ATM Units	Sarvajal	INR 50,000	-
Community Engagement Drive, Vendor Training, Consumer Training	Sarvajal	INR 50,000	5 man days per Water ATM unit
Total Cost to Delhi Jal Board		INR 14,00,000	

Table 9.4: Recurring expenses of DJB for Sarvajal

Component	Borne By	Price (in INR)	Details
Driver Salary	DJB	Already being borne by DJB	
Diesel and Tanker Maintenance Expenses	DJB	Already being borne by DJB	
Sarvajal Service Fee	DJB	10 paisa per litre	Includes coordination of project activities, community engagement, regular and emergency maintenance visits and periodic water data reports
Suggested Price to the Consumer		20 paisa per litre	

Table 9.5: Miscellaneous expenses of DJB for Sarvajal

Component	Borne By	Price (in INR)	Details
Yearly component replacement cost (effective from 2nd year)	DJB	INR 15,000	Per annum cost for component replacement beyond the warranty period. Payable in 13th, 25th, 37th and 49th month from installation.

Governmental Schemes and Rights Awareness:

The IEC programs are one of the inevitable ways of taking government policies to the grass-root level. They are pivotal in spreading awareness regarding various programs and policies to the beneficiaries, especially in the rural areas. Welfare programs undertaken by the government requires extensive participation of the rural masses. This is possible only through extensive dissemination of the message. The importance of IEC lies in its consultative and specific research on the target groups, thus comprehending their needs and requirement. Many welfare programs undertaken by both the State and Central governments such as the PMGSY scheme for rural road connectivity, MGNREGA for 100 days of employment, Pradhan Mantri Awas Yojana for rural housing are widely circulated through the IEC materials. Besides, information for safe drinking water, hygiene and sanitation is done extensively through various IEC programs.

The real goal of IEC & community participation in the advancement of knowledge and the dissemination of truth.

9.5 Project Evaluation – DPR evaluation and Appraisal (MoUD, GoI)

The Detailed Project Report (DPR) is an essential building block in creating infrastructure and enabling sustainable quality service delivery. The DPR is to be prepared carefully and with sufficient details to ensure appraisal, approval, and subsequent project implementation in a timely and efficient manner. The major sections of DPR are as follows:

- Sector background context & broad project rationale
- Project definition, concept and scope
- Project cost
- Project institution framework
- Project financial structuring
- Project phasing
- Project O&M framework and planning
- Project financial viability/sustainability
- Project benefits assessments

The appraisal process generally concentrates on the following aspects.

- Market Appraisal – Focusing on demand projections, adequacy of marketing infrastructure and competence of the key marketing personnel.
- Technical Appraisal – Covering product mix, Capacity, Process of manufacture engineering know-how and technical collaboration, Raw materials and consumables,
- Location and site, building, plant and equipment, manpower requirements and breakeven point.

- Environmental Appraisal – Impact on land use and micro-environment, a commitment towards natural resources, and Government policy.
- Financial Appraisal – Capital, rate of return, specifications, contingencies, cost projection, capacity utilization, and financing pattern.
- Economic Appraisal – Considered as a supportive appraisal it reviews the economic rate of return, an effective rate of protection and domestic resource cost.
- Managerial Appraisal – Focuses on promoters, organization structure, managerial personnel, and HR management.
- Social Cost-Benefit Analysis (SCBA) – Social Cost-Benefit Analysis is a methodology for evaluating projects from the social point of view and focuses on the social cost and benefits of a project. These often tend to differ from the costs incurred in monetary terms and benefits earned in monetary terms SCBA may be based on the UNIDO method or the Little-Mirriles (L-M) approach. Under this method, the net benefits of the project are considered in terms of economic (efficiency) prices also referred to as shadow prices.

As per the L-M approach the outputs and inputs of a project are classified into:

- traded goods and services
- Non traded goods and services; and
- Labor.

All over the world, including India currently, the focus is on Economic Rate of Return (ERR) based on SCBA assumed importance in project formulation and investment decisions.

Once the projects are appraised and the investment decisions are made a Detailed Project Report (DPR) is prepared. It provides all the relevant details including design drawings, specifications, detailed cost estimates etc.

The DPR needs to provide information covering the following areas:

1. Existing status of the physical infrastructure (brief description)
2. Baseline information in terms of user coverage & access (by different user categories/ segments including urban poor)
3. List of various projects proposed for the sector in the City Development Plan (CDP) and confirmation /explanation of how this project is aligned with stated CDP priorities
4. List of other capital expenditure projects supported by other schemes for the sector (sanctioned projects that have yet to commence as well as ongoing projects)
5. Existing tariff and cost recovery methods and extent of cost recovery :
    - Past five year trends
    - Existing per unit cost; existing per unit service delivery price (in absolute terms and also on per capita basis)

6. Existing areas of private sector/community participation in the sector for design, construction, project management, and/or O&M services (including billing & collection)
7. Any other qualitative information (*e.g.* list of key issues that are of importance to this sector and project; the importance of the project to the sector, extent to which the project would address key issues/problems of the sector etc.)

Project definition, concept and scope

The proposed project needs to be demarcated in terms of all its constituent sub-components (Several project DPRs specify only the "to-be-constructed" infrastructure component which does not represent the complete project) The project concept comprises several sub-components /elements including:

1. Land – Total quantum of land required and being provided for the project. Confirmation that the required land is owned /already purchased by the ULB/parastatal; the land title is to be clear and unencumbered.
2. Physical infrastructure components – The physical infrastructure of each project/ DPR can be considered in terms of specific components. These would be unique for each project and would also vary across sectors. The design, detailed engineering and drawings as applicable for the components are to be included in this section. These project components can also serve as a reference for "packaging of contracts" either individually, in parts, or through combinations.
3. Environmental compliance/protection measures/improvement measures:
    - Environment impact assessment, and
    - Environment management plan
4. Rehabilitation and Resettlement
5. Specialised procured services for design, independent supervision, and quality assurance
6. Other information:
    - Details of surveys and investigations required to be carried out (site, customer, etc.),
    - Assessment of requirements related to utility shifting, and
    - List of clearances and agencies from which these are to be obtained.

Project cost

The project (construction) cost should cover distinct elements, including but not limited to the specific components listed below:

1. Land acquisition/site development
2. Physical infrastructure component-wise cost
3. Environmental compliance cost
4. Rehabilitation & resettlement cost (to be borne by ULB/ parastatal/ state government)
5. Cost of surveys & investigations

6. Cost of shifting utilities
7. Cost of consultancy services:
    - Design
    - Supervision
    - Quality Assurance
8. Other statutory compliance costs if applicable & Contingency or any other Lump sum provision of unseen underground services
9. Finance/interest cost during construction

Project institution framework (for construction)

The DPR needs to specify the institutional arrangement details, including the information requested below:

1. Roles of different institutions involved in the construction phase of the project:
    - A Roles/responsibility matrix could be a convenient option to present this information.
    - The relationship between ULB on the one hand and parastatal or state government agencies on the other are to be made explicit. Innovative approaches to providing for improved coordination and/or working arrangements can be highlighted.
2. Manner of undertaking construction works:
    - In-house through one of the Govt. agencies/parastatals' staff OR
    - By being tendered out under the supervision/management of the ULB/parastatal OR
    - Through a separately established legal entity/project implementation company such as a Special Purpose Vehicle (SPV)
3. Involvement of the construction entity in the subsequent O&M activities.
4. Areas of involvement of the private sector in the construction phase.

Table 9.6: Areas of involvement of the private sector

Sr. No.	Item
1.	Project Feasibility Study
2.	Project Engineering Design
3.	Specialized survey
4.	Construction works
5.	Supervision consultants (Project Management Consultants)
6.	Quality assurance consultants (Like third party assessment)
7.	Equipment

Additional information regarding the above can be provided in brief, if required.

Construction 'packages' for works construction

Brief description of the strategy for the overall works programme including information on indicative packages for tendering as per the following format.

Table 9.7: Format for package tendering

Project implementation planning: Package-wise contracting relationships		
List: tender packages Cost		Cost
Package No.	Package Description	Estimate
1.		
2.		
3.		
4.		
		Total

Within 30 days of DPR approval, a more detailed format is required to be submitted covering break down by tender packages, contract type, and corresponding estimates for cost, tendering time frame, and package-wise completion schedules.

Project financial structuring

The project financial structuring examines the sources and composition of funding for the project. For this section, the DPR needs to provide the overall financial structuring of the project. In this regard, the DPR should include information as per the table given below.

Table 9.8: Format for charting out the project financial structure

Sr. No.	Level of Government	Project contribution Source	Amount Rs. In Lac	% share by a specific source	% share by Govt. entity	Remarks
1.	Central grant	ACA				
2.	State	Grants towards its share in the project				
3.		Any loan taken by the State Government for the project				
4.	ULB/ Parastatal	Devolved funds				
5.		Own surplus resource				
6.		Own/ Term Loan taken from State Govt.				
7.		Own/ Term Loan taken from Bank				
8.		Debt from accessing the capital market				
9.		Private equity/ community resource funding				
			Total amount	100%	100%	

Project phasing

Planned schedules (as a part of the DPR) need to be prepared for the following types of activities (other activity heads can be included as per the requirement of the city planners/ project preparation team).

1. Schedule for tendering/selection for procurement of services:
    - Construction contractors: Can be given in indicative terms in the DPR. This has to be firmed up and given in more specific detail within 30 days of Central Sanctioning and Monitoring Committee (CSMC) approval--as per the package-wise contract implementation
    - Consultants/firms for supervision and quality assurance
    - Consultants/firms for any other specialized activities that have to be carried out to fine-tune DPR/ undertake CSMC directed inclusions based on in-principle project approvals (eg: additional surveys, design activities etc. as applicable)
2. Schedule for bringing in State level and ULB level contributions to the project: Can be given in indicative terms in the DPR. This has to be firmed up and given in more specific detail within 30 days of CSMC approval.
3. Schedule for obtaining all clearances (along with a list of major clearances)
4. Schedule for shifting utilities
5. Project infrastructure component-wise implementation – The implementation schedules/work plan can be presented in a simple bar chart / Gantt Chart every quarter.
6. The Program Evaluation and Review Technique (PERT) chart provides a further detailed breakdown of activity tasks and milestones and the inter-relationship between tasks. The PERT and Critical Path Method variation (CPM) would be useful for the ULBs/ parastatal both for project planning and subsequently for project management.

Project O&M planning

Institution framework (organization & operations) strategy

The DPR is to incorporate/include information relating to the following five areas:

1. The institution to be engaged in the O&M of the created infrastructure asset/enhanced infrastructure assets.
2. A brief outline of the existing method of billing & collection (including user/customer-segment wise differentiated strategy, if any)
3. Select performance metrics regarding billing & collections (for the most recently completed financial year, and if possible, for the current quarter of the ongoing financial year)
    - the billing/billable ratio (in terms of physical and financial units separately)
    - cost of billing & collection (in absolute terms; as a percentage of the total cost; and details of the cost break up)

    The basis, assumptions and method of calculations concerning the above are also to be provided.

4. Brief description/analysis of the key issues and obstacles regarding O&M (including billing/collection issues) and proposed countermeasures to overcome them for the sector in general and the project in particular
5. The scope for private entity/community /NGO to be involved in defined aspects of O&M for any specific/all components of the infrastructure asset.
   - Private entity/ community entity/NGO can participate through a variety of models for performance-based O&M (even without participating in the infrastructure construction; in this context, contract periods can be of shorter duration since the capital cost has not been borne by the private entities and to prevent service delivery complacency on the part of the contracted entities)
   - The ULB can aim to promote competitiveness among an empanelled group of such entities and distribute geographical regions (eg identified ward areas) among a limited number of selected private/community based/NGO entities. This would enable comparisons of performance.
   - The DPR should explicitly define the requirements of manpower, energy, spares and consumables etc. for O&M on an annual basis giving details of existing usage, norms and proposed additional requirements.

Tariff and user cost recovery

Regarding tariff and user cost recovery, the DPR is to provide:

- The tariff (revenue) model for each customer/user group for the sector (including underlying assumptions) and forecast growth of customer/ user groups over the next 20 years.
- The unit cost of service and unit price (existing year and forecast for the next 20 years)
- Outline plan to restructure the tariff system to any or all categories of user groups to comply with MoA requirement (institution of full cost recovery user charges). In this regard, cross-subsidization requirements/ strategy if applicable are to be explicitly specified and addressed.

Project financial viability & sustainability

The project viability assessment will be based on a combination of multiple perspectives as given below:

1. Overall project perspectives — The DPR is to provide financial analysis for (Net Present Value) NPV and Internal Rate of Return (IRR) defined in the following two ways:
   - NPV & IRR (overall) — examines overall project viability, including finance cost and asset replacement cost
   - NPV & IRR (O&M) — examines only O&M viability: The complete supporting project cash flow projections along with underlying assumptions have to be presented. The Project financial assessment should explicitly state the cost of capital considered and calculation method to arrive at the same

2. ULB level perspectives and financial situation assessment — The DPR is to provide the following information:
    - ULB cash flow — This includes a complete cash flow covering the last 5 years on an actual basis and projections for the next 20 years. The underlying assumptions for the projections also need to be mentioned.
      An assessment of the annual impact of the project on the ULB's finances (i.e. revenue receipts, revenue expenditure, capital receipts and capital expenditure) for the Mission Period is to be provided showing the impact being high/medium/low (more than 20 %; between 20% and 5%; less than 5% respectively). The base year to be considered for this exercise is the last completed financial year. A format for providing the impact is given below:
    - Debt situation assessment — This includes:
        - Debt schedules and terms for all debt taken
        - Debt service coverage ratio (DSCR)
        - The debt-equity ratio for the project and the ULB
3. Other financial information:
    - Has the ULB been credit rated? If yes: provide the name of the rating agency, type of rating and existing rating details.
    - In the case of Special Purpose Vehicle (SPV) or Joint Venture (JV) as a separate legal project implementation entity, the Profit & Loss (P&L) Statement and Balance Sheet forecasts for the next 20 years shall be provided.

Project benefits assessment (Social Cost-Benefit Assessment)

The DPR is to provide the following:

1. A list of benefits from a societal perspective (both social and economic) supported by:
        - Explanation or description in qualitative terms
        - Quantification of these benefits to the extent possible (or wherever possible) along with underlying assumptions.
        - Benefits are to be focused on project outcomes (in the context of the project outlays made) and especially on their impact on citizens/user segments covering elements such as:

Table 9.9: List of elements that must be considered while assessing the costs and benefits

Access	Supply continuity	Time savings
Coverage	Safety	Environment improvement
Service quality	Cost savings	Employment
Improved efficiency	Improved efficiency	Improved quality of life, etc.

The above are illustrative only with the type of benefits being specific to a project/sector/region.etc.

1. A list of "negative externalities" (ie adverse impacts) from a societal perspective (both social and economic) supported by:
   - Explanation or description in qualitative terms
   - Quantification of these negative/adverse impacts to the extent possible (or wherever possible) along with underlying assumptions
   - Examples of negative/adverse impacts include:
     - pollution; environmental distortions
     - reduced green cover
     - reduced access to any specific user segments
     - supply interruptions (especially during project construction phases) etc
     - displacement of inhabitants
     - disruption in livelihood /reduced employment/ labour redundancy
2. Economic Internal Rate of Return (EIRR) (for projects above Rs. 100 crores or otherwise designated as considerably complex by the State Level Nodal Agency) For projects above Rs 100 crores (or otherwise designated as considerably complex by the State Level Nodal Agency), structured estimation of the Economic Internal Rate of Return (EIRR) would be prescribed as a part of the Social Cost-Benefit Assessment. The EIRR would incorporate monetization of the identified (quantifiable) social benefits and adverse impacts and additionally provide for social perspective corrections to the costs and benefits considered for financial viability assessments. For projects where the EIRR is found to be less attractive or is a borderline case, and at the same time the project planners deem that there are substantial intangible benefits, then the project EIRR analysis is to be supported by detailed descriptive statements and assessments on such benefits.

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3. *MoUD, GoI, n.d. Detailed Project Report: Preparation Toolkit for JNNURM. New Delhi: Ministry of Urban Development, Government of India.*
4. *Rao, K., Hanjra, M. A., Drechsel, P. & Danso, G., 2015. Business Models and Economic Approaches Supporting Water Reuse. In: P. Drechsel, M. Qadir & D. Wichelns, eds. Wastewater. s.l.:Springer, pp. 195-216.*

Glossary

Integrated Urban Water Management – Integrated Urban Water Management is an approach that seeks to develop efficient and flexible urban water systems by adopting a diversity of existing technologies, management, and institutional practices to supply and secure water for urban areas. The focus of this approach is the integration of planning, management, and stakeholder participation across institutions at each stage.

Water Sensitive Urban Design – Water Sensitive Urban Design is the process of integrating water cycle management with the built environment through planning and urban design. It is an interdisciplinary cooperation of water management, urban design, and landscape planning.

Water Audit – Water Audit is an approach to accounting water to map the complete availability of water resources available to a city vis-à-vis the functions and operations that utilise water to identify issues in the water supply system and suggest best management practices.

Water Balance – Water Balance is a process to map the total amount of water that is available for consumption, total supplied water, amount of water billed etc. within a system.

Urban Water Cycle – Urban water cycle includes components such as water treatment, distribution, stormwater drainage, wastewater drainage, wastewater treatment, recycling or disposal. This consists of an interaction of the natural water cycle with the social water cycle.

Best Planning Practice – Best Planning Practice refers to the site assessment and planning component of WSUD.

Best Management Practice – Best Management Practice refers to the structural and non-structural elements that perform the prevention, collection, treatment, conveyance, storage or reuse functions of a water management scheme.

Non-revenue Water – Non-revenue water is the amount of water that does not earn revenue to the water utility. It is computed as the difference of system input volume and revenue water.

Apparent Loss — Apparent losses include all the amount of water that the utility supplied but has not been paid or accounted for. This is computed as the sum of amount of water lost due to discrepancy in measurement or payment at the user end, and all the water used by unauthorised connections.

Closure — Closure is a measurement tool that measures the water entering in the audit domain and the water output of the domain. Such a measure is useful to determine preliminarily the losses in the system or the audit domain. Closures are calculated after conducting the audit.

Notes:

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