Azadi Ka Amrit Mahotsav

Ministry of Housing and Urban Affairs
Government of India

Atal Mission for Rejuvenation and Urban Transformation 2.0

GUIDELINES

FOR PLANNING, DESIGN AND IMPLEMENTATION OF 24X7 WATER SUPPLY SYSTEMS

DRINK FROM TAP

CENTRAL PUBLIC HEALTH AND ENVIRONMENTAL ENGINEERING ORGANISATION
MINISTRY OF HOUSING AND URBAN AFFAIRS
GOVERNMENT OF INDIA

www.mohua.gov.in | www.cpheeo.gov.in

DECEMBER 2021

दुर्गा शंकर मिश्र
सचिव
Durga Shanker Mishra
Secretary

सत्यमेव जयते

भारत सरकार
आवासन और शहरी कार्य मंत्रालय
निर्माण भवन, नई दिल्ली–110011
Government of India
Ministry of Housing and Urban Affairs
Nirman Bhawan, New Delhi-110011

FOREWORD

Clean water is essential for survival, and its absence can impact the health and livelihood of mankind. Unplanned and rapid growth of urban areas of developing countries poses major threat to water supply. Father of our Nation, Mahatma Gandhi Ji encouraged sustainability in water sector by stating that water is not an inheritance and it is an impetus on this generation to rightfully hand it over to the future generations. Universal piped water supply coverage with last mile connectivity was the objective under Atal Mission for Rejuvenation and Urban Transformation (AMRUT) in 500 cities of India.

Honourable Prime Minister launched AMRUT 2.0 on October 1st, 2021 with a vision to make cities water secure and provide universal coverage of water supply services in all the urban areas of the country with major focus on water conservation through rejuvenation of water bodies, reduction of NRW, recycling & reuse of wastewater, roof top rain water harvesting measures and water efficient plumbing fixtures. 24x7 water supply with 'Drink from tap' facility is one of the admissible components in 500 AMRUT cities under AMRUT 2.0

Piped water supply is the safest way to provide potable water to consumers in adequate quantity and recommended quality, but it is a huge challenging task to provide safe and reliable water supply with required quantity and acceptable quality for the urban citizens due to the prevailing practice of intermittent water supply in most of the urban areas. Considering the importance and benefits of 24x7 water supply, it is absolute necessity to transit from intermittent to continuous 24x7 water supply systems which will not only improve overall service delivery standards like coverage, quantity, quality, reduction of NRW, revenue collection, PPP funding etc. but also will improve the quality of life of urban citizens.

The guidelines on planning, design and implementation of 24x7 water supply systems has been prepared by the Expert Committee constituted by the Ministry by incorporating the latest technological advancements and best practices. The objective of the guidelines is to handhold States and Cities to disseminate knowledge and guide them in transitioning from Intermittent to 24x7 water supply systems with drink from tap facility. Integration of GIS which is the need of the hour in planning, design, O & M of water supply and distribution network has been introduced in the guidelines.

I am sure, the guidelines will encourage and empower the State PHEDs/ Water Boards/ Jal Nigams/Urban Local Bodies (ULBs) to suitably use them for effective planning, design and implementation of 24x7 water supply projects.

I congratulate Dr. M. Dhinadhayalan, Adviser (PHEE), CPHEEO & his team and the members of Expert Committee and other Experts who were involved in the preparation of this Guidelines.

(Durga Shanker Mishra)

New Delhi
15th December, 2021

Office Address: Room No. 122 'C' Wing, Nirman Bhawan, New Delhi-110011
Tel.: 011-23062377, 23061179; Fax: 011-23061459; Email: secyurban@nic.in
Website: www.mohua.gov.in

डी॰ तारा, आई.ए.एस.
अपर सचिव
D. Thara, I.A.S.
Additional Secretary

आज़ादी का अमृत महोत्सव
सत्यमेव जयते
भारत सरकार
आवासन और शहरी कार्य मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF HOUSING AND URBAN AFFAIRS
अमृत
Atal Mission for Rejuvenation and Urban Transformation

PREFACE

Urban centres are engines of economic growth of the country and major contributors to the country's Gross Domestic Product (GDP). Unplanned and rapid growth of urban areas poses a major challenge to provide basic water service in any country. India being a water stressed country, severe water crisis, will not only risk urban growth and national economy but also, negatively impact the liveability of cities and quality of life for urban citizens. Therefore there is an urgent need for universal, adequate, reliable, good quality and continuous (24x7) water supply services to urban India to leverage the economic potential of cities.

To meet Sustainable Development Goal (SDG) 6 which ensures availability and sustainable management of water and sanitation for all and to extend ease of living in water supply sector AMRUT 2.0 was launched by Government of India on 1st October 2021 with an objective of making cities 'water secure' by providing universal coverage of water supply to all urban households. Cities are mandated to undertake reforms for water conservation such as reducing Non-Revenue Water (NRW) to below 20%, recycle of treated used water to meet at least 20% of total city water demand and 40% for industrial water demand, rain water harvesting, 24x7 water supply, PPP projects, community involvement etc. 24x7 water supply with 'Drink from tap' facility is one of the admissible components in all 500 AMRUT Cities under AMRUT 2.0 and these projects should cover at least one ward or DMA with at least 2000 households in the contiguous manner. Projects costing up to 20% of the project fund allocation for water supply projects in AMRUT cities may be taken up for 24x7 water supply. Additional funding for such projects will be admissible in form of reform incentive.

To achieve these objectives, there is a need to shift from intermitted water supply system to continuous 24x7 Water Supply Systems. Continuous pressurised water supply system is the solution for achieving improved service levels in the water supply like improving deteriorating water quality, reduction in leakage and control of NRW, financial stability, ensuring equitable water supply, consumer satisfaction etc.

Ministry of Housing and Urban Affairs has constituted an Expert Committee which is entrusted with a task of knowledge dissemination, bringing in latest technological interventions, innovations and document best practice case studies in water supply sector of various cities. The Expert Committee has prepared the **Guidelines for Planning, Design and Implementation of 24x7 Water Supply Systems** after series of consultation with International Experts and field visits made to the Cities of Puri, Pune, Coimbatore and Nagpur that have implemented/are implementing 24x7 Water supply projects. The Guideline provides planning and design approaches to achieve qualitative, quantitative, equitable and sustainable water supply in urban areas. It contains all the information and concepts related to 24x7 continuous water supply systems like Geographic Information System (GIS), hydraulic modelling, methods of demand distribution, operational zone, district metering area, water loss reduction program etc. which are the essential building blocks of 24x7 system.

I express my best wishes and appreciate the efforts of Dr. M. Dhinadhayalan, Adviser (PHEE), CPHEEO & Chairman of the Expert Committee, his team and the members of Expert Committee who are instrumental in preparing this Guideline. I would also like to extend my thanks to GIZ for being the knowledge partner and Experts appointed by GIZ for reviewing the document. I hope it will prove useful to all states/cities to achieve and step by step upgrade their existing intermittent water supply system into 24x7 continuous water supply systems reaping all its benefits.

(D Thara)

Office: 144-C, Nirman Bhawan, New Delhi-110011, Phone: 011-23061444, 23061991
Email: tharad@ias.nic.in, Website: www.mohua.gov.in

Dr. M. Dhinadhayalan
Adviser (PHEE),
CPHEEO
Tel.(O) : 91-11-23061926
Fax : 91-11-23062559
E-mail : adviser-phee-muha@gov.in

भारत सरकार
आवासन और शहरी कार्य मंत्रालय
निर्माण भवन
GOVERNMENT OF INDIA
MINISTRY OF HOUSING AND URBAN AFFAIRS
NIRMAN BHAWAN
नई दिल्ली-110011, तारीख 20
New Delhi-110011, dated the 20

Executive Summary

1. OVERVIEW OF URBAN WATER SUPPLY

Just after independence in 1947, water supply situation in Indian cities was not satisfactory. Only 16 percent of the towns in India had protected water supplies (Environmental Hygiene Committee, 1949) which served 6.15 percent of the total population or 48.5 percent of the then urban population. Since then, the focus was shifted to improve the water supply in the country. As a result, access to improved sources of water has increased significantly from 72% in 1990 to 88% in 2008. In 2015, 88% of the total population had access to at least basic water, i.e., 96% in urban areas and 85% in rural areas.

Distribution of households according to the primary source of drinking water was reported in Census 2011, which is shown in Fig.1. As per NITI Aayog (2019), 93% of India's urban population had access to 'basic water supply'. Universal piped water supply coveragewas the objective under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) in 500 cities of India. The Mission was launched in 2015 by Ministry of Housing and Urban Affairs. 1.18 Crore new tap connections have been provided under the AMRUT as against the target of 1.39 Crores connections.

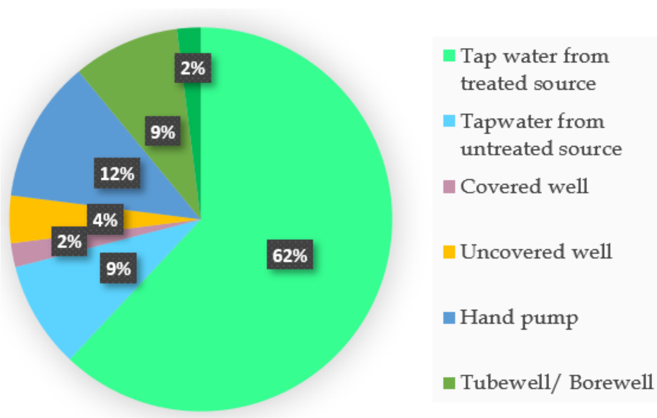


Fig. 1: Distribution of Households according to Source of Water
(Source: Analysis of Census 2011 Data)

One of the main objectives of the recently launched AMRUT 2.0 is to provide 24x7 water supply with drink from tap facility in 500 AMRUT Cities.There lies a great challenge ahead to supply continuous (24x7) drinking water to every household with functional water tap. Challenges faced by ULBs, non-availability of guiding document, approach adopted for present Guideline have been discussed in Chapter 1.

2. CONTINUOUS 24X7 WATER SUPPLY

Continuous pressurised water supply is a solution for improving deteriorating quality problem in the country. Through the leaks in intermittent water supply, outside contaminants enter pipeline during non-peak hours owing to the vacuum that is developed inside pipeline. Thus, water becomes non potable. On contrary, in 24x7 system due to pressure inside pipeline, outside impurities can't enter in and quality of water remains intact.

In most of the developed countries there is continuous water supply. They operate their system by direct pumping with a practice of 100% consumer metering and telescopic tariff. However, in many developing countries like India, water tariff is not volumetric.

Way back in 1949, the Environmental Hygiene Committee constituted by the Government of India recommended to discourage intermittent water supply and promote 24x7 continuous water supply systems in urban areas with the objective to prevent contamination of drinking water in piped water distribution system.

The demerits of an intermittent system and merits of 24x7 system are shown in Box-1.

Box-1: How Superior is pressurized 24x7 water supply system?	
Intermittent	**24x7 System**
1) High health risks 2) Leakage control is passive. 3) No demand management 4) Few meters 5) Flat water rates 6) Wastage of treated water 7) Service level is poor. 8) Service level cannot be measured. 9) Inequitable distribution of water and inadequate pressure 10) Less financial sustainability 11) Large doses of chlorine 12) Capacities underutilized. 13) Valves- wear and tear 14) More manpower- zoning 15) Large sizes of pipes 16) Supply hours affect poor. 17) Storage is required. 18) Pay for pumping for roof top storages. 19) Meters go out of order. 20) Store and throw water	1) Stops contamination. 2) Reduction in medical bills 3) Leakage control is active. 4) Demand management is possible. 5) 100% consumer metering 6) Telescopic tariff 7) Reduces consumption. 8) Equitable distribution and enough pressure 9) Financial sustainability. 10) Life of network increases 11) Better demand management 12) Better service level 13) Consumer satisfaction 14) Water is accessible to poor. 15) Willingness to pay- even in slums. 16) Time for rewarding activities. 17) Attracts industries.

3. APPROACH PROPOSED

The present systems in the country operate on intermittent mode, the goal should be to ultimately achieve the world-class standard of continuous water supply with metered functional tap connections to all households with a smooth transition. The Guideline recommends an approach for planning, design and upgradation of urban water supply system to convert existing intermittent supply to 24x7 water supply system.

4. DECENTRALIZED PLANNING

Decentralised planning system solves the complex problem by breaking it into smaller sub-problems. The city is divided into manageable zones called as operational zones(OZs) which are further divided into sub zones called as District Metered Areas (DMA)s. DMAs are progressively chosen for providing 100% consumer metering and with bulk meter at entry of DMA. Leakages in chosen DMAs are identified, gets quantified and are removed. The leakages in all the DMAs should be stopped and water that otherwise would be lost, is saved which helps in increasing hours of supply. This is the basic principle of converting intermittent systems in to 24x7 systems. Each individual DMA is tackled in this way and their combined success in increasing water supply duration finally converts intermittent system of city to 24x7 water system.

This document provides the detailed procedure for conversion of intermittent system to pressurized continuous 24x7 system. This includes a procedure for determining optimum boundary of operational zone, establishing DMAs with various tests required for making it hydraulically discrete, comprehensive design of transmission main, rational design capacity of service tanks for 24x7 system, retrofitting and rehabilitation of water distribution networks, proper material selection, control valves for 24x7 system.

5. GIS BASED HYDRAULIC MODELLING

It is observed that water supply systems in India are not being planned, designed using Geographic Information System (GIS). Without GIS, it is not possible to assign ground elevations and demands to large number of nodes of distribution system. The Ministry has published Advisory on "GIS Mapping of Water Supply and Sewerage Infrastructures," which may be referred to for the same.

Like GIS, without comprehensive hydraulic model of a city, no reforms can take place in the water supply sector. Hydraulic modelling is an essential tool for conversion to continuous system. Besides this, the basic building blocks of 24x7 system, i.e., operational zones and DMAs need GIS based hydraulic model for design.

It is observed that the technique and sci-art of rational allocation of demands to the nodes of distribution pipe network is not uniformly practiced in the country. This Guideline describes the method for realistic distribution of the total design population/ total design demands in the various wards of the city based on equivalent area, forecasted density and by using GIS technology so that nodal demands are accurately given for hydraulic modelling. Integration of Geographic Information System (GIS) with appropriate network software is also discussed in this guideline.

6. INCLUSION OF DESIGN PROCEDURES FOR 24X7 WATER SUPPLY SYSTEMS

Following design procedures are discussed in this Guideline:

1) As discussed above, design of operational zones and District Metered Areas (DMA)s are included in this Guidelines. Uniqueness of the present decentralised approach is to consider one operational zone for each service reservoir. This is achieved by grouping the reservoirs as per characteristics of terrain which becomes easily possible by use of GIS tool.

2) If the operational zone is not sized properly, it leads to malfunctioning of reservoirs like *emptyin*g and *overflowing*.

3) There are many inappropriate practices existing in distribution systems of the cities in India. For example, in existing distribution system of many cities, it is observed that two or three existing reservoirs are observed to combinedly serve a single excessively large operation zone. This Guideline discusses how to correct such snags.

4) If DMAs within operational zones are not properly established, water audit is not possible. Prioritization of the leak repair program is also not possible in absence of DMAs in the existing distribution system.

5) One of the neglected areas in water supply is the equitable distribution of water in the distribution systems. Equitable distribution of water with designed pressure is the important aspect of 24x7 water supply. It is achieved by *Whole-to-Part* approach, in which two stages are involved- (a)

equitable distribution from Master Balancing Reservoir (MBR) to service reservoirs and (b) equitable distribution from service reservoir to DMAs.

6) Equalization of pressures (residual heads) at Full Supply Level (FSL) of service tanks is also a *grey* area. Equalization of heads helps in effective and equitable supply of water to various service reservoirs in city by the transmission mains.

7) Currently, many cities are being transformed into *Smart Cities*. This Guideline describes the procedure how to economically design pipelines on both sides of the roads by utilizing these roads as boundaries for operational zones and DMAs.

8) Pressure management strategies in Water Distribution Network is important. The methods of pressure management are discussed.

9) NRW computation is an important parameter in 24x7 systems. Estimating physical and commercial losses in the distribution system is an essential component of water balance in NRW reduction program. This Guideline discusses procedure to compute such losses. For this purpose, importance of connecting the meters and flow control valves to the Supervisory Control and Data Acquisition (SCADA) system is also discussed.

10) This guideline recommends to consider a minimum residual head of 17 M at highest spot in the DMA of Class I and Class II cities/towns and 12 M head for Class III-VI Towns. A Peak Factor of 2.50 is recommended for all Cities and Towns irrespective of Population size.

11) The case studies of 24x7 water supply projects for the cities such as Puri, Pune and Coimbatore are included in the guidelines. The per capita cost of the project and other best practices may be referred to in these case studies.

I am confident that guidelines will help State PHEDs/ Water Boards/ Jal Nigams/Urban Local Bodies (ULBs) for effective planning, design and implementation of 24x7 water supply projects in urban areas of the Country.

I express my best wishes and appreciate the efforts of Dr. Sanjay Dahasahasra, Former Member Secretary, Maharashtra Jeevan Pradhikaran and Dr.Rajesh Gupta, Professor & Head, Civil Engineering Department, VNIT Nagpur, Expert Committee Members for providing technical support in preparation of the guidelines. I would also like to extend my sincere gratitude to other Expert Committee members who have reviewed and enriched the document. I would also thank Dr. Ramakant, Deputy Adviser(PHE) & Member Secretary of the Expert Committee, Shri. Vipin Kumar Patel, Smt. Chaitra Devoor, Assistant Advisers, CPHEEO, Special Invitee Dr. Kalpana Bhole, Assistant Chief Engineer, MJP, Nagpur for their untiring efforts in coordinating and reviewing the Guidelines. I would also like to extend my special thanks to GIZ for being the Knowledge Partner and Experts appointed by GIZ. I would also like to thank International Experts who contributed in preparing the Guidelines.

Dr. M. Dhinadhayalan

Table of Content

List of Figures

List of Tables

Abbreviations

CPHEEO	Central Public Health and Environmental Engineering Organisation
CI	Cast Iron
DI	Ductile Iron
DMA	District Metered Area
DPR	Detailed Project Report
DTP	Draft Tender Papers
ESR	Elevated Service Reservoir
FSL	Full Supply Level
GIS	Geographic Information System
GSR	Ground Service Reservoir
GoI	Government of India
HDPE	High Density Polyethylene
HGL	Hydraulic Grade Line
JnNURM	Jawaharlal Nehru National Urban Renewal Mission
LSL	Lowest Supply Level
MBR	Master Balancing Reservoir
MJP	Maharashtra Jeevan Pradhikaran
MoHUA	Ministry of Housing and Urban Affairs
MS	Mild Steel
NRW	Non-Revenue Water
OZ	Operational Zone
PDN	Pipe Distribution Network
WTP	Water Treatment Plant
ZBR	Zonal Balancing Reservoir

Units of Measurement

Ha	Hectare
Km	Kilo Metre
LPCD	Litres Per Capita Per Day
m	Metre
m^2	Square Metres
m^3	Cubic Metres
MLD	Million Litres Per Day

Chapter 1
Introduction

Intermittent water supply systems in developing countries like India, suffer from several deficiencies like inadequate & poor design, operation & maintenance problems, economic stress etc. At many places, water at consumer end has insufficient quantity and sub-standard quality. Though the country has made significant progress after independence, the service level in water sector is not satisfactory. It is estimated that 50% population will live in urban areas by 2050. Providing safe and continuous water supply to the population is a daunting task and great challenge to the water engineers. Currently, all cities are providing intermittent water supply to its population, despite the benchmarks set up by the Government of India (GoI). On the initiative of GoI, in some cities efforts are being made towards converting their existing intermittent water supply system into continuous water supply system to improve the service quality.

1.1 THE CONCEPT OF DECENTRALISED URBAN WATER SUPPLY SYSTEM

It is well known fact that there are several problems in supplying water through distribution system giving rise to inequitable distribution, lack of pressures in higher elevation areas, high rate of Non-revenue Water (NRW) and problems related to quality of water. Most of the cities have clumsy and complicated distribution system. Because such situations were in existence before advent of District Metered Areas (DMAs), leakages were tackled in a passive way, i.e., leaks were repaired only when they were visible.

All the above-mentioned problems can be solved by scientifically designing operational zones and DMAs so that the main problems of high NRW and inequitable distribution can be effectively solved in decentralized manner. The demand management is most important. For demand management, 100% consumer metering with telescopic rate of tariff is required which helps in computation of NRW and subsequent water loss reduction. Elimination of illegal connections and volumetric telescopic tariff will further save water. The saved water is used for extending supply hours and finally converting the scheme in to 24x7.

1.2 PRESENT STATUS OF WATER SUPPLY IN INDIA

The benefits of pressurised continuous piped supply of safe drinking water distributed to households are well known. Environmental Hygiene Committee constituted by Government of India in 1948 recommended 24x7 continuous water supply from Hygiene and public health point of view. However, till today in India, only few cities - Puri, Malkapur and other towns, get continuous water supply. All other cities get water for few hours during the day and in some cases, after 2 to 3 days. A 24x7 water supply is achieved when potable water is supplied for 24 hours in a day for 7 days in a week in adequate quantities with desired pressure, as per guidelines, at consumer's locations with quality assured. Ministry of Housing & Urban Affairs, Government of India has developed service level benchmarks for assessing performance of urban local bodies (ULB) in providing water supply services. Such performance indicators, targeted benchmarks and baseline performance figures are shown in Table 1.1.

Table 1.1: Performance indicator and benchmark for water supply services

S. N.	Performance indicator	Targeted Benchmark	Average values in India
1	Coverage of water supply connections*	100%	70%
2	Per capita supply of water	135 LPCD	114 LPCD
3	Extent of metering of water connections	100%	22%
4	Extent of non-revenue water (NRW)	15%	31 %*
5	Continuity of water supply	24 hours	2.7 hours
6	Quality of water supplied	100%	95%
7	Efficiency in redressal of customer complaints	80%	89%
8	Cost recovery in water supply services	100%	72%
9	Efficiency in collection of water supply-related charges	90%	60%

Source: PAS-SLB data from www.pas.org.in covering 900 cities in 5 States

1.3 DISADVANTAGES OF INTERMITTENT WATER SUPPLY

Intermittent water supply has several disadvantages. In such systems, water is supplied only for few hours in a day or once in few days. Water stored for use during non-supply hours is likely to get contaminated. Water that is stored and remains unused during no-supply period is usually thrown away when a fresh supply begins. Consumers tend to keep taps open during the no-supply period and this results in wastage of water when the supply starts. Bigger diameters of pipes are required to supply full water demand in a short period.

Water mains in non-supply period develop negative pressure at places owing to sucking of surrounding sewage and wastewater (Figure 1.1). This contaminates water supplied in subsequent cycle. Unlike in intermittent supply, in 24x7 water supply system, by definition, pipelines are pressurized and hence outside dirt can't find entry (Figure 1.2) inside pipeline, hence water maintain its quality, as per BIS guidelines.

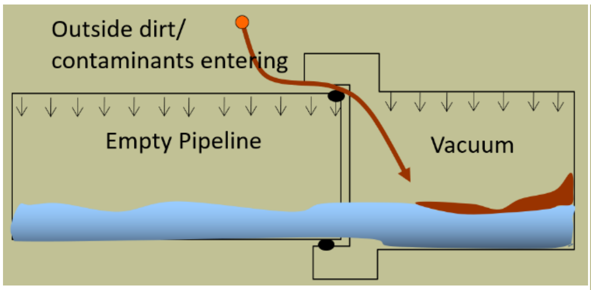


Figure 1.1 Intermittent system- contaminant entering in the pipe

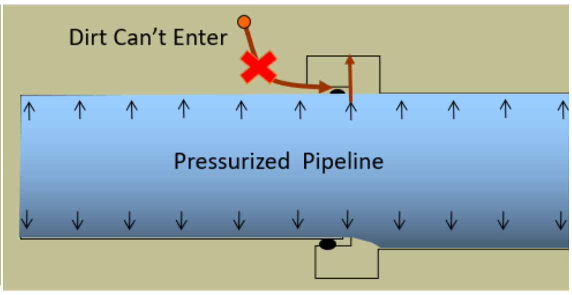


Figure 1.2 Intermittent system- contaminant entering in pipeline during non-supply hours

1.4 REASONS FOR INTERMITTENT WATER SUPPLY

The main cause of concern of intermittent supply are as follows:

- Continuation of Water Distribution System (WDS) beyond its design life
- Pipes are too old and not replaced
- Non-availability of adequate quantity of water at source
- Unexpected or unbalanced growth during design period
- Improper layout
- Unmetered supply
- Improper planning and design of network and poor O&M.
- Heavy leakage losses leading to high NRW

Other Important Reasons are as below:

(i) Low Peak Factor Taking High Flow: Since water is supplied intermittently, and that too for limited hours, lesser diameters (designed for peak factor of 2 or so) with respect to actual requirement, must pass large flow as a result, head loss increases, and the pressures drop. In such situation continuous flow is not possible and the system is then downgraded as intermittent system.

(ii) Haphazard Laying: It is normally observed that as and when existing pipeline cannot cope up high demand, parallel pipelines are provided by ULBs. This gives rise to clumsy network causing inequitable distribution and insufficiency of pressures, thus making system uncontrollable from O&M point of view.

(iii) Cross connections: The ULB's operating staff generally tends to find temporary solutions to the supply problems and opt for cross connecting distribution network pipelines, without any scientific assessment/study and on ad hock basis. No records are generally maintained of these cross connections in most of the cities and towns.

(iv) Adding of Dwarf and Small Capacity ESRs: In many cities, ULB chose a way of adding small capacity and dwarf service tanks. As staging height of these reservoirs is less, it is obvious that the norm of minimum residual head cannot be achieved from these reservoirs of low staging height.

(v) Exceptionally Big Zone: In many cities, excessively big operational zones are provided with a single service tank to serve large population. This causes dropping of pressures and the system is compelled to operate on intermittent system.

1.5 SHIFTING FROM INTERMITTENT TO 24X7 WATER SUPPLY

Urban water sector is facing the challenges of poor quality of water, poor managerial and financial autonomy, limited accountability, weak cost recovery. This has led to poor services to customers across the country. The major challenges are- improving sector governance, institutional arrangements and improving financial sustainability.

In the developed countries, water is provided on 24x7 basis. Intermittent water supply system is practiced only in South-Asian countries like India. Hence, it is the most important challenge to convert existing intermittent water supplies to 24x7 system. When level of water supply service is not satisfactory, people spent money on coping costs like buying plastic overhead tanks, booster pumps and small purification devices like RO filters etc. The household filtration systems is discarded in case of continuous water supply systems.

1.6 NEED OF THE GUIDELINES

Environmental Hygiene Committee Report, 1949 was accepted by the Govt. of India, which recommended, "Intermittent water supplies should be discouraged as far as possible. It results only in dissatisfaction, waste of water, inequitable distribution, and risk of contamination of water by back siphonage or in suction during hours of low pressure. Intermittent supplies are also open to the objection that the flushing of closets is interrupted, and the fighting of fires is impossible during the hours of interruption. It has been demonstrated recently at Lucknow that the water-works authorities can successfully supply water all the 24 hours, educate a community used only to intermittent supply to adapt themselves to continuous supply and reduce consumption." Above recommendations show the long-lasting aim of improving service delivery of water supply to provide pressurised continuous water on 24x7 basis. Even though the present progress in that direction is not tangible, it is time to work to achieve above goal ultimately throughout the country. The recently launched AMRUT 2.0 envisaged to provide 24x7 water supply with drink from tap facility, GIS based master plans of Class-II Towns, target for non-revenue water (NRW) is 20% and incentive based reforms is planning and implementation of projects in PPP mode in water sector in cities with population below ten lakh. All the urban water supply schemes are designed and operated as per the current CPHEEO norms and Service Level Benchmarks (SLBs).

Though the current manual recommends continuous 24x7 water supply with minimum peak factor, important topics such as methodology of operational zones, District

Metered Areas (DMAs), water loss reduction program, which are the essential building blocks of 24x7 system are not mentioned. If the operational zone is not sized, designed and maintained properly, it leads to malfunctioning of storage reservoirs like emptying and overflowing. Moreover, if the DMAs are not properly created (hydraulically discrete and with 100% consumer metering), it is not possible to compute level of Non-Revenue Water (NRW) which is required as first step in the programme of water losses reduction.

Geographic Information System (GIS) and network technology for hydraulic modelling are also discussed. Hydraulic model which simulates entire distribution pipe network has been discussed at length in separate chapter. Using planning tool of GIS, the methodology such as forecasting ward wise population and demand allocation using forecasted population density have been discussed. Apart from this, the scientific art of making equitable distribution of water has been discussed. Thus, this Guideline helps to improve service delivery of water supply system and would help to finally transform existing water supply systems in to 24x7 system.

1.7 PLANNING AND DESIGN

This guidelines recommends planning and design of urban water supply system which can go straight way to upgrade their systems to pressurized continuous 24x7 scheme.

1.7.1 Conversion of Intermittent to 24x7 Water Supply System

Basic principle of conversion is to increase the supply hours of the existing scheme by saving the water. This can be done by 100% consumer metering and by demand management through enforcing of telescopic tariff. Water can be saved by arresting the leakages in the system. Implementation steps that can save water are shown in Figure 1.3.

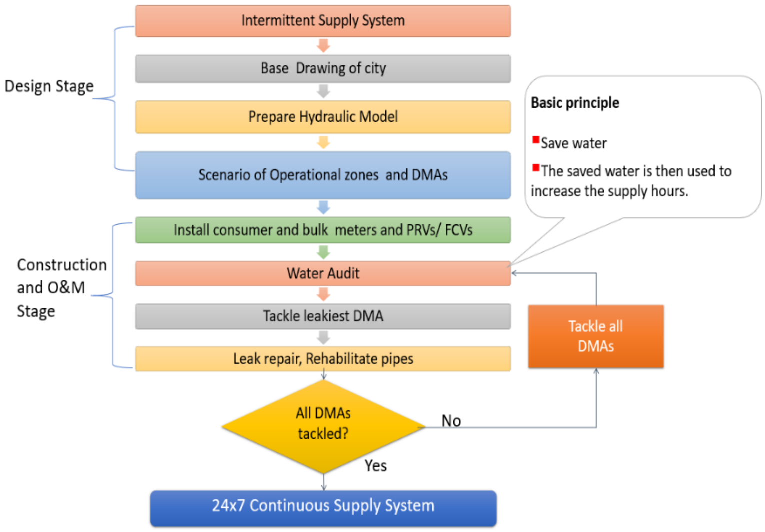


Figure 1.3: Implementation steps

1.7.2 Strategy

Stages required for conversion to 24x7 can be summarized as under:

- Planning and design
- Actual Conversion to 24/7

- Long-term operational stage

The above strategy is summarized as under:

Apart from the technical measures, tariff strategy is required to save water by discontinuation of flat rates and charging on volumetric basis by adopting tariff on telescopic rate structure. Other measures such as organizational, commercial, policy and budget are equally important. Summary of these strategic measures are shown in Figure 1.4.

All the above measures should be taken in to consideration. If technical measures alone are taken but other measures are not taken, then the goal of conversion to 24x7 would not be achieved.

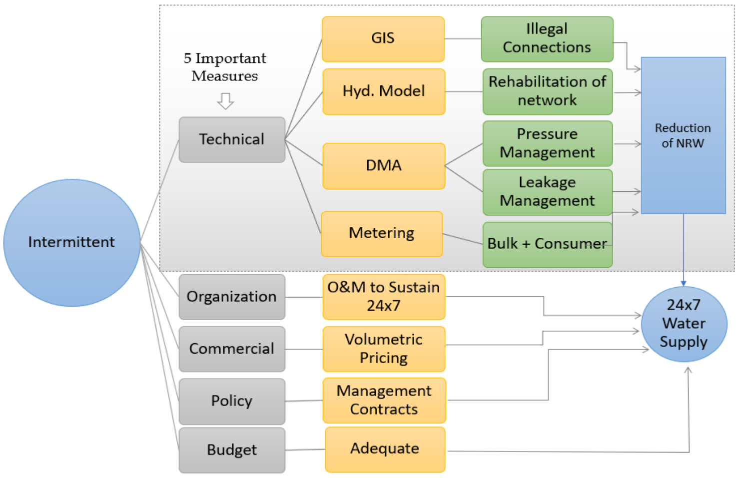


Figure 1.4: Strategic measures

1.8 ACTIVITY CHART FOR CHANGE OF MODE

Common activities necessary for adoption of the 24x7 water supply may be considered by the ULBs which are shown in Figure 1.5.

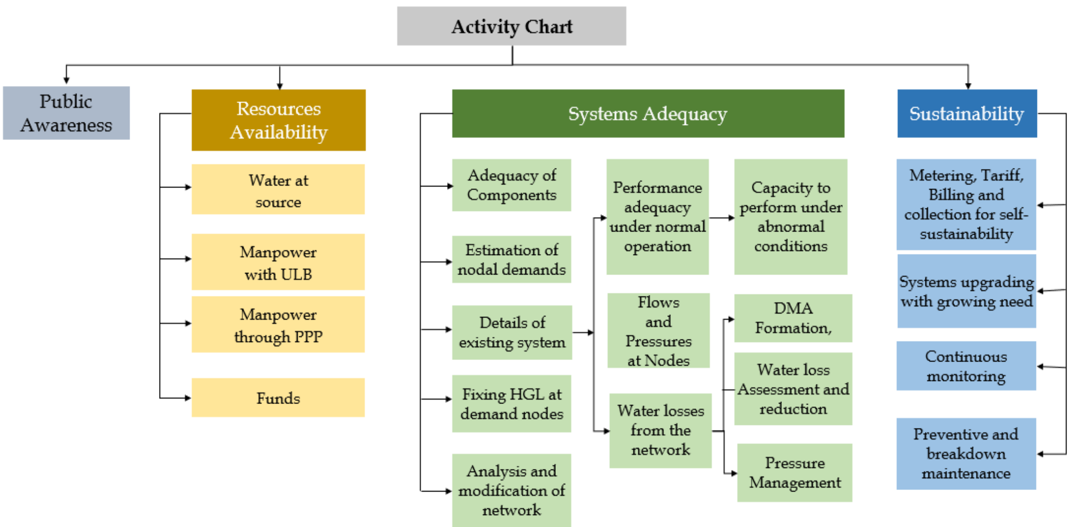


Figure 1.5: Activity chart showing a road map for change of mode

1.9 OUTCOMES

Outcomes of conversion to 24x7 system are as given below:

(i) **Improved health:** With implementation of 24x7 project, incidences of waterborne diseases and infant mortality rates will decrease which will reduce the cost of healthcare and expenditure on resources of hospitals, clinics and local doctors. It will contribute to Human Development Index (HDI) massively.

(ii) **Improved water service quality:** This will increase public acceptability and they would be willing to pay higher water charges. This will open the door to water service providers and the water utility become financially self-sufficient. Thus, government will be relieved for giving operational subsidies.

(iii) **Operation under continuous supply:** Water service providers' efficiency increases.

(iv) **Continuous supply**: It permits service providers to regularly reduce leakage and save the water, thus reducing the need for investment in costly water resource acquisition projects (dams, long transmission pipelines, etc.) or at least, delaying the need for such investment.

(v) **Improved revenue:** It permits service providers to invest in extensions of their networks to serve the poor which, apart from raising their living standards, will help achieving the Sustainable Development Goals for water supply.

(vi) **Improved living conditions**: This will improve living conditions for entire population. The urban land prices and rentals will get enhanced.

(vii) **Gender Issues:** Women and children, particularly the girls from poor households will be immensely benefitted. It will help them undertake gainful education and employment. Their health will improve.

(viii) **Poverty reductions:** The combined effect of water availability, quality and reliability will eliminate shortages in poorer areas and will improve health, education, employment, and skill-training for the poor.

(ix) **Improved conditions for inward investment:** Developed countries' investors will find helpful conditions and social infrastructure for their staff.

1.10 COST OF CONVERSION

The cost of conversion will be city/system specific, will vary from place to place and with various ground conditions viz. source sustainability, existing water supply system, terrain, working conditions, etc. However, the per capita cost of conversion provided in the case studies of Puri, Pune and Coimbatore attached in the document may be referred to.

*****

Chapter 2

Design Parameters

For preparation of 24x7 water supply project, the first step is to prepare the Detailed Project Report (DPR) by adopting following design parameters, as presented in this Chapter.

2.1 DATA FOR DESIGN

2.1.1 General Data

General data required is as follows:

(i) Decade wise census population data
(ii) Daily per capita supply in litres at consumer end (LPCD)
(iii) Supply hours for design of pipelines up to Elevated Service Reservoirs (ESR)s, i.e., for Rising/Transmission mains
(iv) Capacity and staging height for ESR and side water depth (SWD)
(v) Residual nodal head
(vi) Demand management by consumer meters
(vii) Water tariff- a tool for demand management
(viii) Losses in the system
(ix) Valves and meters
(x) Land required for planning.

2.1.2 Collection of Available Data

The implementing Agency/ULB should collect the necessary information/available data which are required to prepare the DPR. In case, the Agency/ULB is unable to collect all relevant data and prepare the DPR, the services for the same may be outsourced. The following information is required:

(i) Technical data and preparing base map,
(ii) Creating base maps using GIS includes- (i) satellite image, (ii) digitization of features, (iii) landmarks, (iv) existing water infrastructure and (v) contours
(iii) Existing valves and its location
(iv) Pumping station details, including principal mechanical and electrical plant infrastructure specifications, i.e., details of pumps, motors, starters, transformers etc of their actual duty details, age, and status.
(v) Reservoir (ESR, GSR and MBR) details, including capacity and validated operating levels including staging height, present life, need to repair. The ground levels need to be validated
(vi) All sources and details of bulk supply of water

(vii) Recorded burst/ leak frequency data – primary and secondary mains, distribution network and connections.
(viii) Ward boundaries with ward wise population of latest census year, population of the census year.
(ix) Status of the statutory clearances.
(x) Permission of land availability.
(xi) Arrangement of financial resources.
(xii) Sustainability of water resources.

2.2 GIS MAPPING

GIS mapping is necessary. It has been discussed at length in the Guidelines of "GIS Mapping of Water Supply and Sewerage Infrastructure," released by the MoHUA in April 2020.

2.3 CUSTOMER'S UNDERGROUND TANK

This guideline recommends to consider 17m residual head for Class I and Class II cities/ towns and 12m residual head for class III towns and below. For the buildings up to 3 storeys, there should be no underground tank at customer's house. If it is there, then after stabilization of 24x7 pressurized supply, such tanks shall be removed subsequently. However, for building with more than 3 storeys, they can have RCC underground tank with waterproof treatment.

2.4 BREAK PRESSURE TANK AND MASTER BALANCING RESERVOIR

Design Methodology of computing volume along with depth and the arrangement of inlet and outlet at bottom of Break Pressure Tank (BPT) / Master Balancing Reservoir (MBR) is given in Appendix A. Computation of sizes of BPT is given in Table A1.

Recommendations and salient features of this guideline for capital works is presented in Table 2.1 and Recommendations and salient features for operation & maintenance of 24x7 water supply systems is presented in Table 2.2.

Table 2.1: Recommendations and salient features of this guideline for capital works.

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
1	**Design period**	Design period for water supply system is considered as 30 years. However, different components of water supply system are designed to work satisfactorily for different period as below: **(a) Units for Intermediate Stage:** Water treatment plants, clear water reservoirs, balancing and service reservoirs, electric motors and pumps should be designed for forecasted population of intermediate stage and land should be kept available for ultimate stage and for future expansion. **(b) Ultimate stage:** All pipelines including raw and treated water transmission mains and distribution should be designed for forecasted demand of ultimate stage, pump house and pipe connections to several treatment units and other small appurtenances. **(c)** Head work should be designed for the forecasted demand of 50 years as it is not possible to construct additional head work in the submergence of the dam/water bodies.	Base year: means proposed date of completion of the scheme. Intermediate: is computed as base year + 15 years. Ultimate stage: is computed as base year + 30 years. ESRs should be designed for the intermediate stage, but as an exception, ESRs for areas of high population density may be of ultimate stage. For such operational zone, increase in population after intermediate stage is very less. This is proposed with due consideration to economical scale factor.
2	**Land Required for Water Supply Infrastructure**	City planners should earmark the land required for water supply infrastructure and its expansion of ultimate stage in the master plan of the city for next 30 years or more.	Land is required for Water Treatment Plants, sumps and ESRs etc. When land for water supply infrastructure and its expansion is not available, the city planners may plan

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
			recreational amenities or parks, stadium, etc. over the water reservoirs.
3	**Population forecast: ward wise forecast of population and population density**	Not only total population of city but its ward wise distribution and computation of ward wise future population density based on equivalent area may be adopted.	This (nodal demand by future population density) has been discussed in Advisory note on "GIS Mapping of Water Supply and Sewerage Infrastructure." along with the case study. After ULB's approval to total future population and its ward wise distribution, then only detailed design should be taken up.
4	**Per capita supply of domestic / non-domestic for design.**	Supply at consumer end for cities/ towns with population less than 10 lakhs should be 135 LPCD and for larger cities having population of 10 lakh or more should be designed for 150 LPCD. Non-domestic demand, bulk supply etc. should be computed as per actual consumer survey. The non-domestic demand should be assigned to the respective demand nodes. Fire demand should be added to domestic demand proportionately.	Supply should be at consumer end. This means losses should be added to the demand. On stabilization of the water supply systems, per capita water supply may be reduced as per the need based assessment in the city.

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
5	**Floating population**	Rate of supply for floating population should be as follows: i) Bathing facilities provided: 45 LPCD ii) Bathing facilities not provided: 25 LPCD iii) Floating population using only public facilities (such as market traders, hawkers, non-residential tourists, picnickers, religious tourists etc.): 15 LPCD.	Figures should be got certified by Chief Officer/Deputy Commissioner of ULB. Data from Tourist Bureau, Check/ Entry Tax points, Mandi associates etc. should be obtained and extrapolated/ projected.
6	**Total demand**	In addition to domestic demand, commercial demands (hotels, lodges, hospitals, market etc.) and institutional demand (schools, colleges, offices theatres etc.) duly extrapolated for different stages should be added as point loads to the respective nodes in distribution system. Total demand should be computed by adding following losses: Total losses in the system should not exceed 15%. Indicative, break up of losses is as below: (a) Head work to inlet of WTP should not be more than 1% (b) In WTP losses should not be more than 3% (c) Outlet of WTP to Various ESRs losses should not be more than 1% (d) In distribution system losses should not be more than 10%	Consumer survey of the city is essential for commercial and institutional establishments and for ascertaining requirement of consumer meters, listing of suspected illegal connections and for shifting of connections from main line. After deciding these values of demands, hydraulic modelling (design of distribution system) should be taken up.
7	**Supply Hours and Peak Factor**	(a)The transmission system for both raw water and treated water including all pipelines up to ESRs should be designed for 23 hours of supply.	On stabilization of the water supply systems, peak factor may reach to the optimum value,

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
		(b)Distribution system should be designed for a peak factor of 2.5 irrespective of population.	based on the internationally established 24x7 water supply system.
8	**Minimum Diameter of Pipe for water distribution**	Minimum of 100 mm for Class I cities and for other cities, 80mm may be provided.	In hilly terrain, 80 mm can be the minimum size of pipe.
9	**Public stand post**	No new stand post should be given. Existing stand posts should be converted to group connection with meter by formulating operational zone wise time bound program by ULB.	Household tap connections are necessary.
10	**Minimum residual head at ferrule**	It is recommended to consider a minimum residual head of 17 m at the ferrule at the highest spot of DMA for Class I and Class II cities/towns. For towns other than Class I and II cities/towns, minimum residual head at ferrule at the highest spot can be considered as 12m. (Ref. Table F1 in Appendix F).	Environmental Hygiene Committee Report ,1949 recommended, “In towns of over 2 Lakhs, or where buildings of 3 or more stories are common, the minimum residual pressure should be 50 feet (15.24 m). Since 1949, number of such cities have grown in large number. In old areas of city, despite pipe material being metallic, many times the joints are weak due to aging specials of jointing of CI/DI pipes. Even in such situations, pressure should not be relaxed. A

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
			systematic pipe replacement program may be carried out stagewise in such cases.
11	**Maximum staging height of Elevated Service Reservoir (ESR)**	Maximum height of staging should be limited to 30 m.	To achieve above minimum head of 17m and to have optimum velocity to achieve economical design of all pipelines in distribution, the staging height of ESR/GSR should be appropriately chosen.
12	**Capacity of ESRs/ GSRs**	Capacity should be determined by mass balance calculations. However, minimum capacity should be 33% of the total demand of the operational zone (OZ) of that ESR.	Side water depth (SWD) if excessively chosen then the ESRs do not work efficiently. The maximum SWD should be as under: • For ESR capacity up to 1 Lakh litres: 3 m. • For ESR capacity up to 10 Lakh litres: 4 m • For ESR capacity > 10 Lakh litres: 5 m
13	**Fire Demand**	Fire requirement should be computed for each operational zone. For the operational zones having population 50,000 or more, the quantity should be computed by, $\textit{Fire}\ \text{requirement}\ (\text{m}^3/\text{day}) = 100\sqrt{P}$ Where P is population of operational zone in thousands. "P" should not be linked up with total population of city/town.	The one third of the quantity computed as above should be provided in container of tank. The outlet of the tank supplying water for normal operation should be kept just above this storage so that the capacity provided for mitigating fire is always available. There should be another outlet at the bottom of tank which can be opened when instance of fire occurs.

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
		If the population of operational zone is less than 50,000 then the quantity required for 50,000 population should be computed and then it should be proportionately reduced.	Location of fire hydrants should be decided in discussion with Fire Department. However, arrangement for filling of vehicles of fire brigade should be provided at each ESR and along important roads, parks, and playgrounds.
14	**GIS Mapping**	It is necessary to use GIS system. GIS mapping of all the existing, proposed and executed infrastructure is required. GIS simulating modelling should be adopted.	Expanse of urban project from source to actual city and spread of the city is large, hence, it is not possible to manually feed the values of ground elevations and demands to hundreds of nodes of large network. Training courses on GIS should be organized for capacity building of ULB's engineers and planners.
15	**Consumer meters**	Distributing water with 100% consumer metering is the need of the hour. Hence, consumer metering is necessary. Water supply to a house begins with connection of the service pipe with water supply mains. Service connection pipe to be laid by consumers & internal plumbing shall conform National Building Code or related IS code. The State Govt/UTs may devise a policy to bear the cost of house service connections including consumer meters so as to ensure volumetric measurement of water required for	Demand management is not possible in case of unmetered water supply at flat rate. Therefore, policy should be adopted for 100% house metered connection by the ULBs. Consumer flow meters shall conform to IS-779 and IS-2373 regarding bulk flow meters.

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
		deciding telescopic tariff with provision for cost recovery from the consumers.	
16	**Water tariff**	Volumetric tariff with telescopic rate structure is mandatory. This method, will help to supply water to urban poor at affordable price, encourage consumers to decrease their consumption and penalise for their luxurious consumption.	It is required for controlling demand and hence it is an important tool for demand management. 100% household is to be supplied water through house metered connection (without public stand-posts), first slab of telescopic tariff structure should be such designed that the urban poor can get drinking water at affordable price.
17	**Hydraulic Modelling**	Hydraulic modelling is the basic tool in designing of operational zones (OZs) and District Meter Areas (DMAs) required for 24x7 system. GIS based hydraulic model should be adopted. GIS enabled water supply systems is more effective in O&M also. Values of elevations and demands must be given to each node using software tools. Only two hydraulic models should be prepared for entire city- (i) for entire distribution system and (ii) for raw/ treated transmission mains. If the city is exceptionally large and is divided into excessively big zones, then the two models as above should be prepared each for the respective very big zone.	Hydraulic model should not be prepared in pieces. If it is done, the contours will not be seamless and the nodes will have incorrect elevations, and this will vitiate the hydraulics of the network. The water demand on nodes shall also be equally distributed. Thus, the assignment of ground elevations and nodal demand should be made by "whole to the part" method and not by the "part to the whole" method. Hydraulic Modelling can be done using various softwares including free available in public domain.

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
18	**Creation of operational zone**	The main principle of decentralised planning is that each service reservoir should have one operational zone (OZ) and each OZ to receive water from only single reservoir. These OZs are further sub divided in DMAs. Each OZ and each DMA should be hydraulically discrete. Such OZs should be created for entire city by following proposed hydraulic parameters of residual head and the respective peak factor.	OZ boundary is determined with help of natural features like the roads, railway line, nalla etc and slope within OZ area. Normally in non-hilly area the slope within OZ should be up to 5m. In case of direct pumping, pressure zones shall be formed using the GIS technology and then the number of OZs shall be computed.
19	**Optimised boundaries of operational zones (OZ)**	If the operational zone is not sized, designed, and maintained properly, it leads to malfunctioning of storage reservoirs like emptying and overflowing. Hence, Boundaries of operational zones (OZ) should be optimised.	In the present (existing) systems, optimum boundaries of operational zones (OZ) are not designed scientifically hence this exercise should be made as described in Chapter 4.
20	**Maximum size of OZ**	OZ should be designed for a population not more than 50,000 or 10,000 connections /families/ flats. For hilly areas, maximum population per OZ should be 10,000.	Oversize OZ will be difficult to operate and maintain, i.e., to provide equitable distribution of water and designed residual head and hence its size be limited.
21	**Design of DMA, its boundary, and Maximum size**	Number of DMAs in one OZ should not be more than 4 and each DMA should be hydraulically discrete. Each DMA should have house service connections (HSC) not more than 3,000. However, the size of an individual DMA may vary, depending on number of local factors and system characteristics. For DMAs in dense urban areas, like inner cities because of the high housing density, the	DMA boundary is determined with help of natural features like the roads, railway line, water bodies, nalla etc and slope within OZ area.

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
		no. of connections may be larger than 3,000 connections. If a DMA is larger with connections more than 5,000 connections, it becomes difficult to differentiate small bursts (like service pipe burst) from night flow data, and it takes longer time to locate. All DMAs should be fed by exclusive pipeline from outlet of ESR in OZ with branches and from these pipelines consumer connections should not be given. Each DMA should have only one inlet. By this arrangement and by limiting the size and boundary of DMAs equitable distribution of water as per designed nodal demands with designed residual head can be achieved.	
22	**Transmission mains**	Design methodology for achieving economy in capital/ pumping cost and equalization of residual head at FSLs of ESRs is mentioned in details in Chapter 6. By this method, velocities in pipes are increased to optimum level, diameters are reduced, pumping head is optimized and every ESR gets just designed quantity of water.	This methodology uses the tool of velocity (m/s), head loss gradient, hf (m/km) prudently as it is used in design of pumping mains.
23	**Design of distribution system**	Design methodology in details is given in Chapters 5. Velocities in pipes need to be increased to optimum level and diameters can be reduced without use of costly software.	
24	**Bulk metering**	Bulk meters shall be installed at head work, inlet, and outlet of WTP and at entry of each DMA.	By observing minimum net night flow through bulk meter at inlet of DMA, Non-

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
			Revenue Water (NRW) can be effectively monitored.
25	**Automatic Meter Reading (AMR) meters**	AMR facility is optional. AMR enabled meters can be installed.	It is recommended that bulk supply connection should have AMR meter installed for conducting water audit. Commercial establishment having connection size greater than 50mm are encouraged to install AMR meters from the revenue generation perspective. AMR enabled meters can be installed for remaining connections.
26	**Control valves** **(i) PRVs** **(ii) FCVs**	(i)PRVs are needed in hilly cities/ areas. PRVs are also needed when some of the DMAs are situated on lower elevations. (ii) FCVs with Solenoid at entry of DMA are proposed.	Control valves such as Pressure reducing valve (PRV), Flow Control Valves (FCV) are vital for equitable distribution of water and equal terminal pressures.
27	**Preparation of contract documents and speedy implementation**	Contract document for capital works need to be clear, unambiguously worded for avoiding litigation/ arbitration/ unrequired payment and speedy execution. This is achieved by formulating standardized (model) DTP and this avoids repetitive and erroneous work.	
28	**Public Private Partnership (PPP)**	PPP may be used for cities with population more than ten lakhs. AMRUT 2.0 also recommends planning and implementation of projects in PPP mode in water sector in cities with population more than ten lakhs.	Reform based incentive may be provided.

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
29	**Break Pressure Tank (BPT) and Master Balancing Reservoir (MBR)**	1) Design Methodology of computing volume along with depth required is mentioned in Appendix A 2) The arrangement of providing inlet and outlet at bottom of BPT/ MBR saves pumping cost and is discussed in Chapter 6.	
30	**Isolation valves**	For enabling effective break down maintenance of leaky pipes in distribution system, adequate number of isolation valves should be provided to isolate the network.	The drawing showing these locations of isolation valves should be readily available with maintenance staff.
31	**Pipe Material**	(1) Distribution system- Provide metallic and non-metallic pipes as per the site and service conditions. (2) Raw and clean water Rising Mains- These are the arteries of water supply projects and they must be laid with metallic pipes lined from inside and non-metallic pipes as per the site and service conditions. (3) Gravity Transmission Mains- a) Inside & Outside city areas - pipes should be based on economical size of the gravity mains	
32	**Laying of Pipelines**	Clear cover for non-metallic pipes should be 0.9 m. If it is not possible due to hard rock, then the pipes in these stretches should be metallic. Laying, jointing and alignment should be made as per the IS code. In the terrain where ambient temperature goes below 0 degree Centigrade, pipes may be protected with proper insulation.	More than 25 mm size connection should be avoided from small diameter such as 80/100 mm. Service connections must not be given from raw, pure water pumping mains, transmission mains, feeder mains and mains feeding DMAs.

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
33	**Pipelines on both Sides of Roads having width 6m and more.**	For the roads having width 6 m or more, pipes are to be laid on either side of the road. This can also be done economically while deciding boundary of DMA.	It is necessary to lay pipelines on either side of the road so that while giving house connection, the road is not required to be cut/ damaged. The method for the concrete roads having width more than 6m is to insert the ducts intermittently in the body of the roads so that service connection pipes can be laid through it.
34	**Customer's Underground Tank**	For the buildings up to 3 floors, underground tank should not be encouraged at the customer's house. If such tank exists, then after stabilization of 24x7 pressurized supply, such tanks shall be gradually removed/abandoned.	This guideline recommends to consider 17 m residual head for Class I and Class II cities/towns. For the buildings up to 3 storeys, underground tank is not recommended at customer's house. If it is there, then after stabilization of 24x7 pressurized supply, such tanks shall be removed/ abandoned subsequently. However, for buildings with more than 3 storeys, they can have RCC underground tank with waterproof treatment to avoid outward seepage and inward contamination. The cleaning of such tanks is mandatory with frequency of once in six months and it should be strictly monitored by the agency responsible for O&M.

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
35	**Flow Computation**	Flow can be computed using Hazen William method or Darcy-Weisbach method.	
36	**Drinking Water Quality**	It shall be as per IS 10500, 2012.	
37	**Express feeder for electric substations**	Express feeder for electric substations at pumping stations at head works and at WTP is mandatary. The work of electric lines shall be got done from corresponding electricity board. Electricity Board shall not give electric connections from the express feeder. The cost of express feeder should be included in the project cost.	Express feeders are necessary for uninterrupted electricity required for pumping water in 24x7 projects. The standby arrangement of generators may be provided.
38	**Consumer Survey**	Door to door consumer survey should be carried out. The consumer meters should be geo-tagged with GIS coordinates and shown on GIS maps of DMAs.	The city shall be divided into grid of suitable size. Survey team should visit all properties in an element of grid. During survey, illegal connections shall be identified.
39	**Physical Survey for generating Contours**	Ground elevations all along the roads in the city should be found out by Total Station method. The instrument should have capability of recording GIS coordinates. The elevation points shall be mapped in GIS and GIS based contours shall be generated. If city terrain is not undulating, the contours can be generated using 3D stereo satellite method. In hilly areas when roads are not seen, “Drones” or other suitable methods may be used to generate contours.	GIS based contours are necessary to assign the ground elevations to the nodes.

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
40	**Identifying Existing Pipelines**	Existing laid Pipelines shall be identified by pipe alignment survey. Trial pits shall be dug at suitable intervals to know pipe material, diameters etc.	A Change Management team shall be formed comprising of ULB engineer, agency's engineer, valve operators etc. They should identify existing pipes by interacting with local people.
41	**City Water Balance**	A City Water Balance considering Integrated Urban Water Resource Management may be computed.	

Table 2.2: Recommendations and Salient Features for Operation & Maintenance

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
1	**NRW control measures (Leakage program)**	Since bulk meter at entry of DMAs and 100% consumer meters are to be installed, Active leakage management program is essential. The NRW values can be computed by (a) knowing quantity of water entering DMA and consumption in DMA); (b) conducting Step tests. (3) NRW should be brought down to at least 15%.	In passive leakage program, only visible leaks are attended and repaired. For leakage identification, modern methods such as detection using inert gas techniques can be used which can be conducted in shorter time compared to the conventional methods.
2	**Creation of NRW cell**	Mandatory for all the Cities and Towns along with Quick Response Teams with Vehicles equipped with necessary tools/ equipment.	Dedicated NRW cell is required which can take stock of situation and continuously monitor NRW levels.
3	**Creation of calibration/repair workshop for domestic consumer meters**	ULB should promote creation of calibration / repair workshop for domestic consumer meters for 15mm to 50mm diameters with immediate testing facility on the lines of electricity board. Minimum stock of common spare part should be ensured for making them commercially viable.	ULB should promote creation of meters repair workshop with testing facility.
4	**Water audit**	Due to provision of bulk meter at entry of DMA, NRW of the OZ can be computed as all consumer connections are equipped with meters. Water audit of rising mains, transmission mains, OZ and DMAs is essential.	In 24x7 system, water audit is a continuous activity. There is an 'economic level' of reducing NRW.

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
5	**Energy audit**	Energy audit is essential as per IS 17482:2020.	In many ULBs, pumps are not replaced even after 15 years. Hence, low efficiency is observed and ULB has to pay more electricity bills.
6	**Eradication of illegal connections**	Step by step illegal connections can be eliminated.	Identification of illegal connections may be made during customer survey and mapped on GIS.
7	**Water quality**	Water quality should be monitored as per IS 17482:2020	Water Quality Testing Facilities should be created
8	**Supervisory Control and Data Acquisition (SCADA)**	SCADA system is essential to monitor the flow and functioning of the water supply systems including night flow and leakages.	All the level controls of tanks, pumps, Bulk meters, FCVs and PRVs should be connected to the SCADA. Software for hydraulic models should be connected to SCADA to monitor real-time values of concentration of residual chlorine in any pipe at any point of time.
9	**Consumer billing and complaint redressal**	Consumer billing and complaint redressal system is essential. Computerised billing systems should be encouraged.	With SCADA/MIS, it is possible to show the redressal of complaints online for compliance of complaint. Complaint redressal cell should be set up.
10	**Special Purpose Vehicle (SPV)**	Special Purpose Vehicle (SPV) may be preferred by the city to handle O&M.	
11	**Public Private**	AMRUT 2.0 recommends planning and implementation	Some of the components like water treatment plant,

S. No.	Parameter	Conversion from present intermittent stage to 24x7 water supply system	Remarks
1	**2**	3	4
	Partnership (PPP)/ O&M through contractor	of projects in PPP mode in water sector in cities with population more than ten lakhs	pumping machinery with transformer, major pipeline, distribution system etc may be undertaken using separate O&M contracts.
12	**Training and capacity building**	Various training modules as discussed in the advisory on "GIS Mapping of Water Supply and Sewerage Infrastructure," may be referred to,	

Chapter 3
Hydraulic Model

3.1 HYDRAULIC MODELLING

A hydraulic model is a mathematical model of a fluid flow system, and used to analyse hydraulic behaviour. Modelling of the water supply system is a critical part of designing and operating water networks. It helps the system to serve reliably, safely, and efficiently in daily operations. Hydraulic model gives commanding knowledge of the water infrastructure and help to take informed decisions. Modelling is defined as a mathematical description of a real-world system (Haested Methods, 2003).

Hydraulic model is useful in planning, execution, operation & maintenance (O&M) phases of the 24x7 water supply project. At many places, conventional manual methods of designing are being used, as a result the demand allocation is not accurate which vitiates the hydraulic performance of network in terms of economy, sustainability, and equitable distribution of water.

3.2 REQUIREMENT OF HYDRAULIC MODEL

Hydraulic model is an important tool required for conversion to the 24/7 water supply system. Without GIS based hydraulic model, activities (shown under red polygon in Figure 3.1) such as creation of Operation Zone (OZ), formation of District Metering Area (DMA), water audit, pipe rehabilitation, replacing consumer pipe, NRW Reduction are not possible.

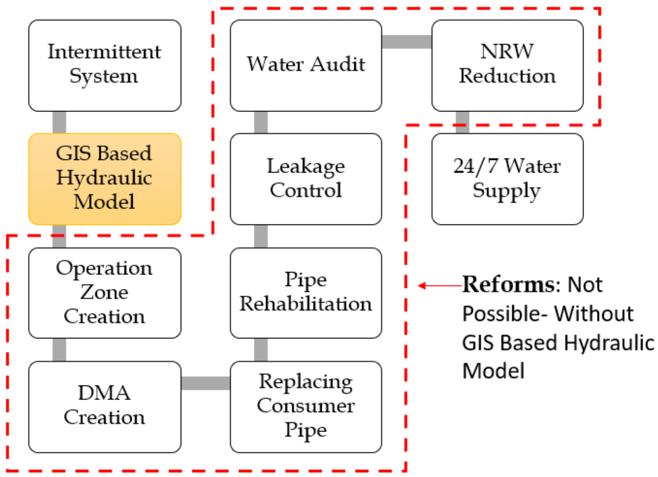


Figure 3.1: Hydraulic model required for carrying out reforms

3.3 HAPPENING INSIDE HYDRAULIC MODEL

Hydraulic Model is a mathematical model of fluid dynamics. Network flow involves two basic principles - conservation of mass and conservation of energy. The principle of conservation of mass involves the continuity equations which means at any node, the flow coming in must be equal to the flow going out. Principle of conservation of energy is used in forming energy equations in which frictional head loss between the two nodes is computed which is then used to compute hydraulic grade level (HGL) of the downstream side node. Continuity equations are of linear nature whereas energy equations are non-linear. Therefore, the convergence methods such as Hardy-Cross Method, Linear Theory Method, Newton- Raphson Method and Global Gradient method are evolved. Amongst them, Global Gradient method is widely used in the computation engine of all the software.

3.4 INTEGRATION OF GIS WITH HYDRAULIC MODEL

Geographic Information System (GIS) and network software like EpaNET (freeware) or any other free software or any appropriate software can be used to create the hydraulic model (Figure 3.2) by using combined capabilities of both the software.

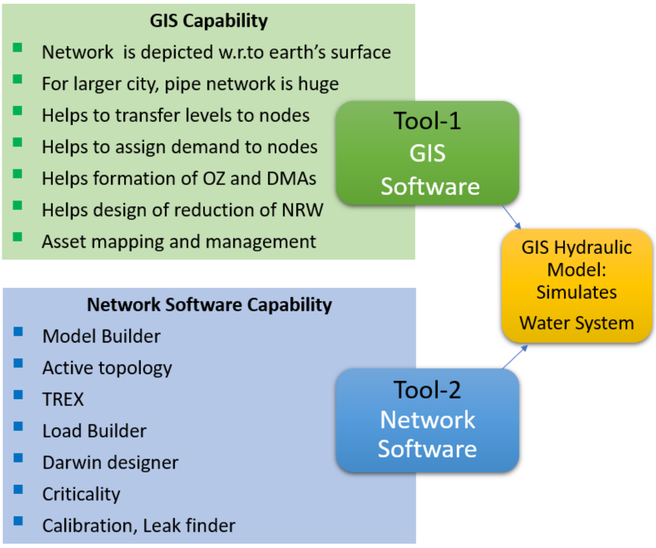


Figure 3.2: Tools used in the hydraulic model

Integration of GIS with hydraulic model involves two components- (a) GIS part and (b) Network software part.

3.4.1 Creation of GIS Base Map and Existing Infrastructure

GIS part involves - (a) Creation of Base Map, (b) Locating existing infrastructure on base map.

3.4.1.1 Creation of base map

Base map consists of (i) Satellite image, (ii) Digitization of water supply components, (iii) Landmarks, (iv) Contours and (v) Consumer geo-coding. Creation of base map is necessary because it is used as background map of hydraulic model, which is discussed in the "Advisory for Mapping Water and Sewerage Infrastructure", published by CPHEEO, MoHUA.

Base Map: The base map consists of the shape files of digitised road edges, water bodies, footprints of household properties etc. GIS based contours are generated by conducting the survey along the roads of the city and then making the shape files of the points which have values of ground elevations besides the values of Eastings and Northings of all such points. Shape files of all these points are then added to the GIS software. Using GIS techniques contours are generated. Most important advantage of such GIS contours is that the nodes (or junctions) of the pipe network can be easily assigned the values of ground elevations. Other methods of generating GIS contours are using 3D-Stereo satellite image method, or by Light Detection and Ranging (LIDAR) method or by Drone technology.

3.4.1.2 Locating existing infrastructure on base map

Adding Reservoirs: Location of existing reservoirs are marked on Google and the KMZ (Keyhole Mark-up language Zipped) file is created which is then converted to the shape file in GIS software. Alternatively, these reservoirs can be easily located in the online service of GIS software which are then converted to the shape files along with its attributes such as diameter, staging height, minimum and maximum water elevations in tank.

Existing Pipelines: For creation of hydraulic model, we need the maps of existing pipelines, and all other relevant data such as existing valves and their status whether they can be used further. Two cases may crop up - (a) data of pipelines is available and (b) data is not available.

(a) Data of pipelines available: Some Urban Local Bodies (ULBs) maintain their network data satisfactorily, but it is available in AutoCad format. In such cases, the pipelines along its attributes are georeferenced (Figure 3.3). Georeferencing is the process of assigning real-world coordinates to each pixel of the raster image. After georeferencing, the shape files of the pipelines are created. If the data is available only in the hard copy format, then the hard copy of the map showing the pipelines is scanned and its Joint Photographic Experts Group (JPEG) file is created. The JPEG file is added to the GIS software, and it is georeferenced and then converted to the shape files. The data of pipe attributed in this case may be assigned manually.

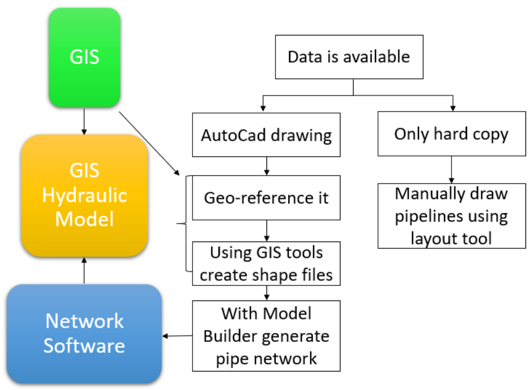


Figure 3.3: Creation of hydraulic model

(b) Data of pipelines not available: If maps of alignment of existing laid pipelines are not available, then the task becomes difficult. In such situation, data of existing laid pipelines is obtained by conducting pipeline alignment survey. The survey team should comprise of the ULB's engineer, meter readers, valve operators and contractor's staff. Using the Global Positioning System (GPS) instrument, the alignment should be marked on GIS map. In this case, the team should visit the site of pipe alignment and interact with the customers residing in the area. After discussion with them, alignment of pipes is identified. The trial pits should be taken at suitable intervals so that the team can understand and note the attributes of actual pipes laid. These attributes such as pipe material, diameter, and the year of laying of pipelines are then marked. In this way the existing pipes and valves are marked on the GIS maps.

3.4.2 Network Software Component

As discussed above, the shape files of the existing pipelines are available. The first task in creation of the hydraulic model is to add the existing pipelines to the active topology of the model.

Model Creator: Model creator is generally add-in facility of any network software. The role of the model creator is to convert the shape files into active topology of the pipes. The nodes are automatically added into the active topology by the model creator. Node of pipe network is the junction where another pipe is added as T-junction or the junction where two pipes of different diameters meet. Similar to the pipes, the shape files of reservoirs are also added to the active topology. So, active topology of the basic network is ready. The model is prepared using following methodology.

3.5 BUILDING A MODEL

Distribution pipe network consists of components such as pipe, junction (nodes), reservoirs, reservoir, pump, isolation valves, Pressure Reducing Valve (PRV) and Flow Control Valve (FCV) etc.

It is required to create a model comprising of all these components. Initially, a network of pipes and junctions is created using "Model Creator" facility of the network software. Once the existing and new pipes are added, the shape files of the pipes are used in process of building the model. One such small model is shown in Figure 3.4, in which water is supplied by gravity from dam (which is represented by the reservoir, R1) to Water Treatment Plant (WTP), Clear water sump of WTP is denoted by a tank, T1. From the Tank T1, water is supplied to various junctions J-1, J-2, J-3, J-4 which are the demand nodes. Demand is given to the demand nodes. Pipes are represented as P-1, P-2, P-3, P-4, P-5 and P-6.

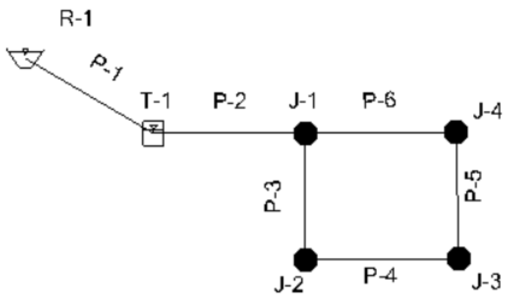


Figure 3.4: Small network created by the Model Builder

Data: Data to be given are (a) Levels to reservoir, tank and all the junctions; (b) demands to the junctions; (c) pipe attributes like diameter, material, C-value etc. Each demand node (tank) supply water to respective operational zone. Hence demand of operational zone is assigned to such demand nodes.

Since the model is to be prepared using GIS, the data of lengths of pipelines need not be given as they are automatically scaled out, however the data can be given manually too. Most important job is to assign levels and allocate the demands to the hundreds of junctions in distribution network. To accommodate the 10% minor losses, for computation purpose only the lengths may be increased by 10%. However, in drawings actual length shall be shown.

3.5.1 Combining Existing and New Pipes

New pipes are added in the area where they are required for making 100% coverage. Care should be taken to add new pipes only in the areas where they are needed. For example, there can be reserved areas like cantonment area, industrial area etc. where they have their own water supply system. In such areas, pipes need not be shown in such areas in the model. Once the shape files of the existing and new pipes are available, they are combined.

3.5.2 Assigning Elevations and Demand to Nodes

Using GIS, values of ground elevations are assigned to each node of distribution system automatically by using facilities of Elevation Assigner and demand builder available in the Network software.

3.5.3 New Reservoirs

Boundaries of the operational zones of the existing service reservoirs should be decided utilizing the logic as discussed in the Chapter 4. However, after marking the optimised boundaries of the existing reservoirs, there remain some of the areas that are unserved by any of the existing tanks. In such unserved areas, new service tanks should be proposed.

3.6 CREATING OPERATIONAL ZONES AND DMA

Hydraulic model should be capable of designing future operational zones and DMAs within planning area/ metropolitan area and development area. Creation and fixing boundary of operational zones and detailing of DMAs is detailed in Chapter 4.

3.7 ADDING ISOLATION VALVES

Location of isolation valves: GIS and Network software help to decide location of isolation valves which are used to make segments in distribution system (Figure 3.5). Segments allow O&M team to repair any damaged pipe by closing the respective isolation valves.

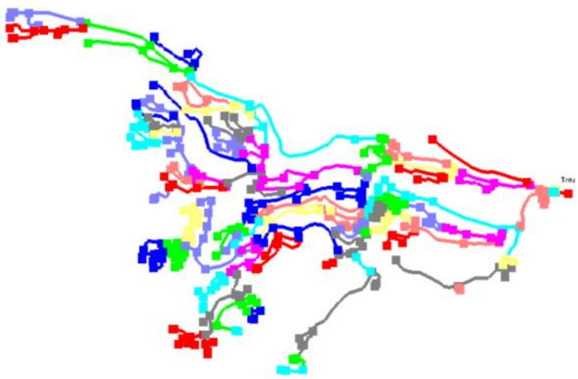


Figure 3.5: Segments in operational zone

For enabling effective break down maintenance of leaky pipes in distribution system, adequate number of isolation valves should be provided. They should be such located that a segment not exceeding 50 to 250 connections gets isolated for the purpose of repairs and at the same time, rest of the connections remain unaffected. Optimization of number of isolation valves is possible and recommended to operate the scheme on continuous supply basis. The drawing showing these locations of isolation valves should be readily available with maintenance staff.

3.8 SCENARIO MANAGEMENT

Scenario management: The concept of Scenario management is important. With scenario management, we can create scenarios of normal water supply and behaviour of distribution system when pressures are deficient. It is observed that there is a practice of creating many hydraulic models for a single city/town (separate model for each Operational Zone). Distribution system should not be modelled in pieces. Instead of creating multiple number of models, a base scenario of distribution system of entire city should be created, and operational zones should be created as child scenarios.

Only two hydraulic models should be prepared for entire city- (i) for entire distribution system and (ii) for raw/ treated water transmission mains. If the city is exceptionally large and is divided into big zones, then the two models as above should be prepared each for the respective big zone.

3.9 METHOD OF ANALYSIS

There are 3 types of analysis of pipe network: (a) Steady-State, (b) Extended Period simulation and (c) Pressure Dependent Analysis.

(a) Steady state method: This method represents behaviour of the system for a specific case or at a given point of time. It is used to assess the adequacy of the pipe size for the ultimate stage, i.e., for the demand of 30 years.

(b) Extended period simulation (EPS): This method is more rational and realistic to the real world when the behaviour of the network is observed/ checked with respect to the varying time of levels. Some of the types of system behaviours that can be analysed using an EPS model include- how tank levels fluctuate, when pumps are

running, whether valves are open or closed, and how demands change throughout the day.
When the model is run in EPS mode, the behaviour of system is different at different points of times. Say, at peak hours, the demand is maximum in comparison with demands in non-peak hours. Pipes must pass maximum flow through them and at the same time, pressures are dropped. Whereas, at other points of times, system behaves differently. This type of behaviour is modelled by the EPS function which is a continuous function. Steady state represents behaviour of the system for a specific case or at a given point of time. If we want to express both in layman's view, EPS is like taking film of any incidence continuously whereas steady state means snapping it at a specific time.

(c) Pressure dependent analysis (PDA): This method is used when the supply to distribution system reduces, and pressure deficient conditions are formed. For example, in some of the cities, the supply is reduced every summer. City's water supply remains close for a day in every week. When supply restarts, pressure deficient conditions are formed. PDA method of analysis is used in such situations to observe simulation of the system.

3.10 MODEL CALIBRATION

Hydraulic model must be synchronized with the ground realities. For this purpose, the model is calibrated using special utility in network software. The flow is measured at the outlet of the tank and simultaneously, the pressures are measured at nodes situated at some key locations. Based on the input data of flow and nodal pressures, the model is calibrated on the values of C-values.

3.11 USE OF SIMULATED GIS HYDRAULIC MODEL IN RETROFITTING

If required residual nodal heads are not achieved, then the corrective measures should be taken as discussed in Appendix E.

*****

Chapter 4

Operational Zone and DMA

4.1 OPERATIONAL ZONE (OZ)

Operational zone (OZ) is the jurisdiction of each tank to serve water supply. Performance of distribution of water depends on size of operational zone of tank. A schematic of the operation zone with DMAs is shown in Figure 4.1.

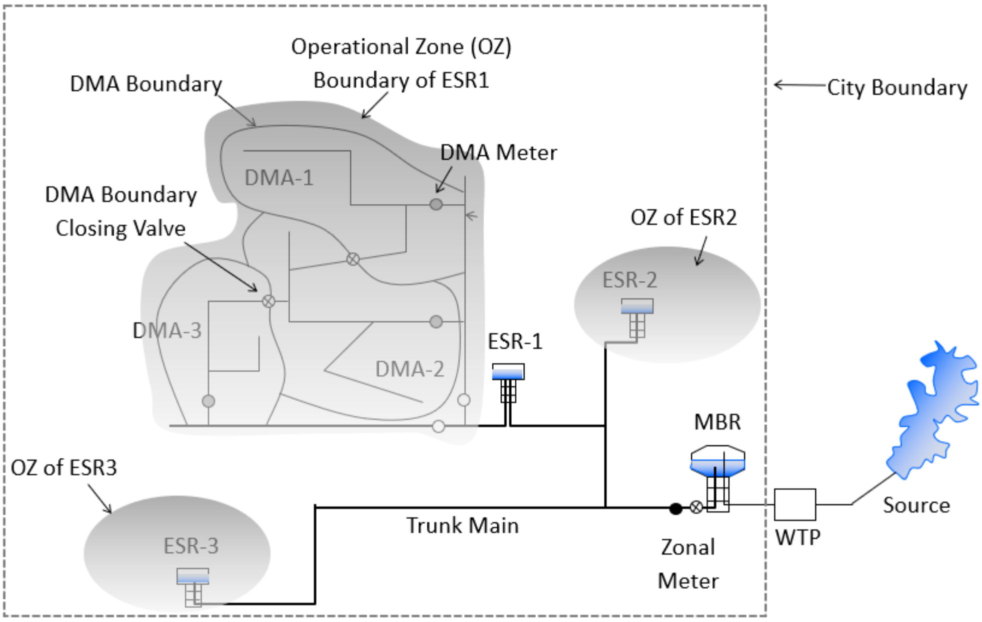


Figure 4.1: Operational zone with DMAs (Source: “Water Loss Reduction”, Bentley Publication)

4.2 DESIGN CRITERIA FOR OPERATIONAL ZONES

For the approach of 24x7 system, following are design criterions for operational zones to supply water equitably and with required pressure:

1) Compute optimum demand that a tank can serve and based on that, extent (boundary) of an operational zone should be determined so that when in full operation, the tank should not get empty, or will overflow.
2) The minimum nodal pressures are fulfilled.

4.3 COMPUTATION OF OPTIMUM DEMAND THAT A TANK CAN SERVE

For existing reservoirs, (based on the diameter, water column in tank and capacity) optimum demand that a tank can serve should be computed. Its logic is shown in Figure 4.2.

Level of water for every hour in Excel sheet is computed by an equation,

$$L_t = L_{t-1} + \frac{Q_{t-1}}{A} \qquad (4.1)$$

Where,

L_t = Level of water in tank at time, t

L_{t-1} = Level of water in tank at time, t-1

Q_{t-1}= Surplus or deficit of water in tank at time t-1

A = Area of cross-section of tank

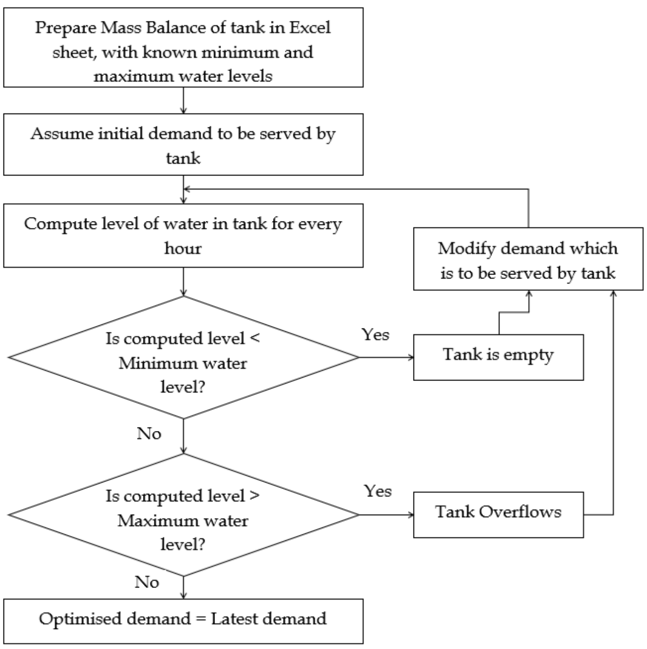


Figure 4.2: Logic for computation of optimized demand of tank

To begin with, approximate demand is assumed that a tank can serve, and the tank is checked for boundary conditions- empty or overflowing. The iterations are carried out till boundary conditions of tank are satisfactory and, in that iteration, optimum demand of a tank is calculated.

4.3.1 Fixing Boundary of Operational Zone

Generally, tank's size and volume are determined by making mass balance calculations in excel sheet. It is expected that the tank would not overflow or get empty. To achieve this, a logic is developed as shown in Figure 4.3. This logic needs to be adopted in Excel sheet of mass curve calculations.

4.3.2 Mapping Operational Zone Boundary in Hydraulic Model

To begin with, it has to be borne in mind that if excessive capacity of existing ESR remains unutilized, then increase the spread of OZ. Try to add area with lower elevations. Finally arrive at optimum boundary of OZ and the optimum demand that can be served by the existing tank. Steps involved are:

(1) Commanding elevation of ESR = Lowest Supply Level (LSL) of ESR which is equal to Minimum residual nodal head + 5 m for head loss in OZ. Below this commanding elevation, all nodes will receive water with required head. The figure of 5m can be lowered or increased by the designer with his experience/prudence considering location and slope in OZ.

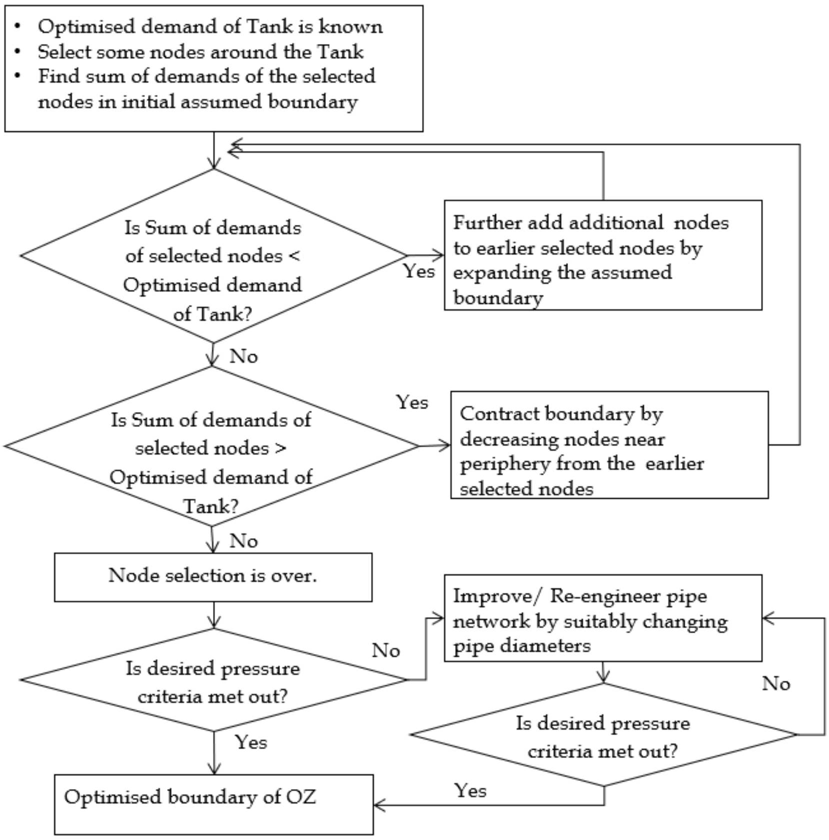


Figure 4.3: Logic for fixing boundary of operational zone of Tank-1

(2) With an intention to use the maximum capacity of existing ESR, decide the boundary of OZ considering natural boundaries like road edges, stream, railway line etc.
(3) Find out the total of the demand of the nodes in the chosen boundary of OZ. As a rule of thumb, it should not be more than three times capacity of that ESR. If the total of demand is much less that means capacity of ESR is unutilised and expansion of the boundary of OZ is required.
(4) Above iterative process should be carried out by the designer, then the optimum boundary of OZ and optimum demand that an ESR can serve is computed.

The details are explained with following exercise:

A hydraulic model is created using the existing pipe as well as the new pipes as explained in Chapter 3. Suppose the network comprises of the existing reservoirs: Tank-1 and Tank-2. Objective is to decide and fix the operational zones of these tanks. The network is shown in Figure 4.4.

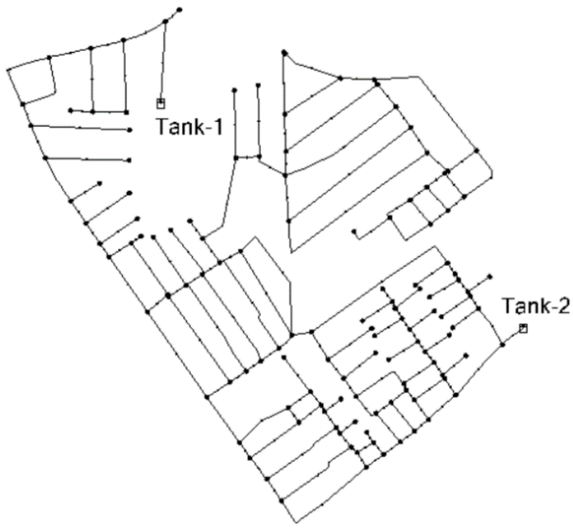


Figure 4.4: Network whose operational zones are to be fixed

Suppose there are 130 nodes in this network and demand to each node is given by the Network software. Total demand of all the nodes put together is 3 MLD. There are two existing tanks, Tank-1 and Tank-2 having capacity to serve respectively the optimum demands of 0.5 MLD and 1 MLD. Objective is to determine the optimised boundaries of operational zones of Tank-1 and Tank-2 so that the tanks do not get empty or overflow. After fixing boundaries of Tanks 1 and 2, find the nodes of the network which are unserved by the existing Tanks 1 and 2 and suggest a new tank to take care of the unserved area.

Fixing boundary of tank-1: Logic of fixing boundary of operational zone of Tank-1 is shown in Figure 4.3. It is an iterative process. Boundaries of the operational zones and its DMAs are so located topographically that its spread remains within normally available topographical features such as rivers, lakes, railway track, bigger width roads etc. Logic of fixing the boundaries is shown in Figure 4.5. In the first iteration (Figure 4.5), some nodes are selected (shown red) and sum of its demands (say, 0.34 MLD) is compared with the value of optimum demand (0.5 MLD) of a tank. Since, the sum of the selected nodes is less than the optimum demand of Tank-1, the nodes in the selection are increased further and again the sum of newly selected nodes are compared with the optimum demand of the tank-1. The process is iterated till the sum of the demands (0.495 MLD) of the selected nodes in the third and final iteration (Figure 4.6) is approximately equalling that of the optimised demand (0.5 MLD) of the Tank-1.

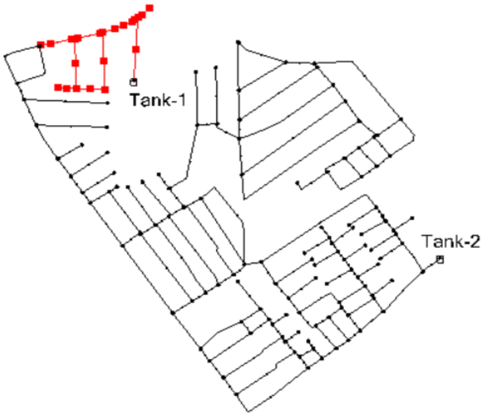


Figure 4.5: Selection of nodes in first iteration

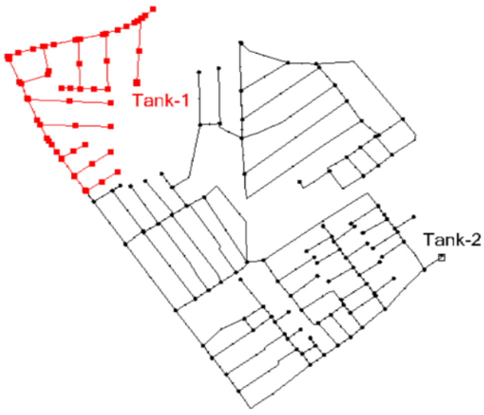


Figure 4.6: Selection of nodes in third & final iteration

Boundaries of the operational zones of Tank-1 and Tank-2, thus fixed by the above logic are shown in Figure 4.7.

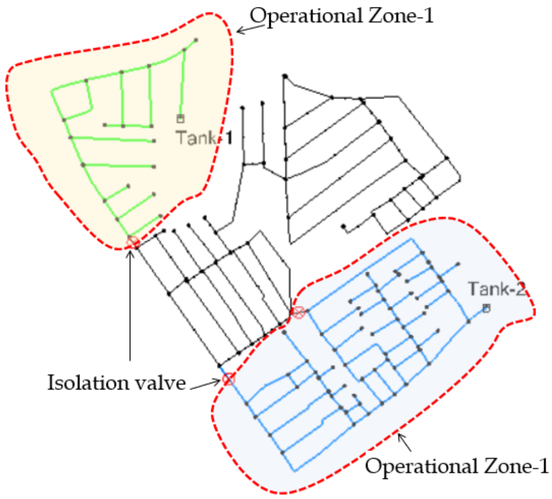


Figure 4.7: Operational zones 1 and 2 are fixed for tanks 1 and 2, respectively

Pipes in operational zone 1 are shown in green colour and that of pipes in operational zone 2 are shown in blue colour. After fixing boundaries of Tank-1 and Tank-2, isolation valves are installed as shown in Figure 4.7. The pipes which are unserved by the Tanks 1 and 2 are shown in black colour. New tank should be inserted at suitable location to serve the unserved nodes.

4.3.3 Achieving Required Minimum Nodal Pressures In Operational Zones Of Existing ESRs

There are five alternatives-

1. Separate out part of OZ of Existing tank for nodal pressure < 17m
2. 17m head created by newly proposed ESRs
3. By getting rid of dwarf existing ESRs
4. On-line boosting on outlet of tank for entire OZ having nodal pressures < 17m
5. On-line boosting on branch line to area having nodal pressures < 17m

A detailed procedure is explained in Appendix E.

4.3.4 Bad practice establishing very large OZ

In the existing distribution system of many cities, it is observed that two or three existing tanks are in one premises and they serve a single excessively large operation zone. In such situations, while refurbishing/ reengineering, care should be taken so that each tank serves one operational zone by subdividing large operational zone.

4.4 DISTRICT METERED AREA (DMA)

A district metered area (DMA) is defined as a discrete area of a water distribution network usually created by the closure of isolation valves in which the quantities of water entering and leaving the area are metered. Such DMA with boundary closure valves is shown in Figure 4.8. In other words, DMA is sub-division of large network, created by closing isolation valves interconnecting the surrounding network and thus isolating area, called DMA. DMA receives water from separate pipeline coming from ESR and supplies continuous water through 100% metering of consumers.

4.4.1 The Need of DMA

We know that there are many problems in supplying water through distribution system giving rise to inequitable distribution, lack of pressures in higher elevation areas, high values of NRW and problems related to quality of water. This is because in many water supply systems, pipe networks are clumsy. Because such situations were in existence before advent of DMAs, leakages were tackled in a passive way, i.e., leaks were repaired only when they were visible.

To overcome this problem, total distribution network is divided into small segments. As the boundary is limited, minimum pressure does not fall and can handle variations in ground levels effectively because the DMA boundary is so chosen that the difference in minimum and maximum ground level is kept reasonable, say 5m. Effect of problem, if any, is limited to a small area of DMA and so the problem can be resolved effectively in O&M.

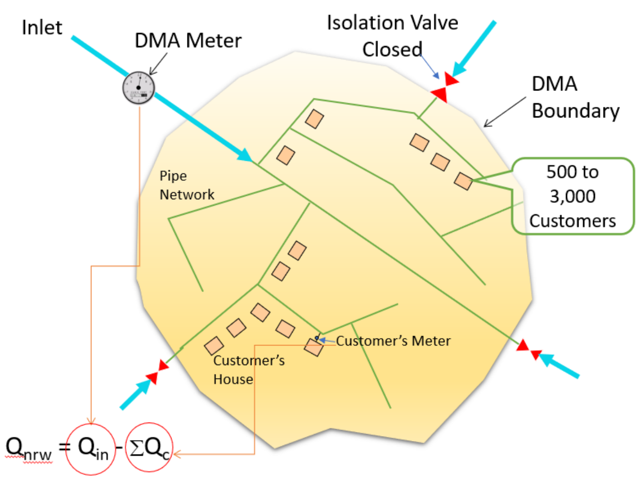


Figure 4.8: A typical DMA

To get rid of passive leakage management, the DMA concept was first introduced to the UK in early 1980's. With advent of DMA, flow is measured to quantify the level of leakage. Computing Non-revenue Water (NRW) in DMA converges the scope of identification of leakage area and hence, we can determine (DMA Management Manual, 2006) more precisely where and when it is most beneficial to undertake leak location activities. With smaller sub-zones, an active leakage control is possible. NRW can be computed easily for DMAs. Thus, with DMAs, water utility can better target NRW reduction program, isolate water quality problems, and better manage overall system pressure to allow for 24x7 water supply throughout the network.

To attain 24x7 in totality, each operation zone is further divided into number of DMAs. A typical DMA is shown in Figure 4.8. DMA is thus a subsystem of the entire water distribution network with well-defined boundaries. Design of DMAs involves fixing of its boundaries which is a challenging task for a large network. As shown in Figure 4.8, there is only one entry to the DMA. Entry of water from the adjoining DMAs is restricted by installing and closing isolation valves at boundary of DMA, by doing this, the DMA becomes hydraulically discrete. From the inlet, quantity of water coming into DMA is measured by the bulk meter (which is called as DMA meter). The summation of quantity of water measured by consumer's meters, gives the total value of quantity of water consumed in the DMA. The difference of the two indicates the NRW of the DMA. Thus,

DMA NRW = Total DMA Inflow- Total DMA Consumption

4.5 DESIGN CRITERIA FOR ESTABLISHING DMA

4.5.1 Size of DMA

DMA size is expressed in the number of properties. As per BIS IS 17482:2020, the size of a typical DMA in urban areas varies between 500 and 3,000 properties/metered connections. The size of an individual DMA may vary, depending on several local factors and system characteristics, such as:

a) the required economic level of leakage
b) geographic area and the /demographic factors (like, urban or rural, residential, commercial, industrial areas)
c) previous leakage control technique (like, ex-waste meter districts)
d) individual water Agency/ Board preference (like, discrimination of service pipe bursts, ease of location survey)
e) Hydraulic conditions.

DMAs in dense urban areas, like, inner portion of cities, may be larger than 3,000 properties/metered connections, because of the high housing density. If a DMA is larger than 5,000 properties/metered connections, it becomes difficult to discriminate small bursts (like, service pipe bursts) from night flow data, and it takes longer to locate it. However, large DMAs can be divided into two or more smaller DMAs by temporarily closing the valves so that each sub-area is fed in turn through the DMA meter for leak detection activities. In this case, any extra valves required shall be considered at the DMA design stage.

4.5.2 Design of DMA

Several factors shall be considered when designing a DMA, such as:

a) the required economic level of leakage:
b) size (geographical area and the number of properties):
c) variation in ground level:
d) drinking water quality considerations.

Topography: DMA boundary is so fixed that it remains within normally available natural topographical features such as rivers, lakes, railway track, roads etc.
Hydraulically Discrete: DMAs should be isolated from other adjoining DMAs for precision in measurements. For this, each DMA should have a single inlet for water and a district meter should be placed to monitor the inflow into it.
Isolation can be achieved using the Isolation Valves. These valves should be initially set as closed and can be opened during any emergency/ pipe break cases etc.
Cost of setting up DMAs: Cost of establishing DMAs will primarily depend upon the cost of isolation and metering equipment required. DMAs should be formed in such a manner that, there will be minimum cost.
Slopes and elevation: DMA should be set up on uniform terrain. If a DMA has lot of uneven terrain conditions, supplying water would be difficult.

4.6 DMA CATEGORY

DMAs are categorised into four different types- single inlet DMAs, multiple inlet DMA, cascading DMA and Pressure managed DMA. These four types are shown in Figure 4.9.

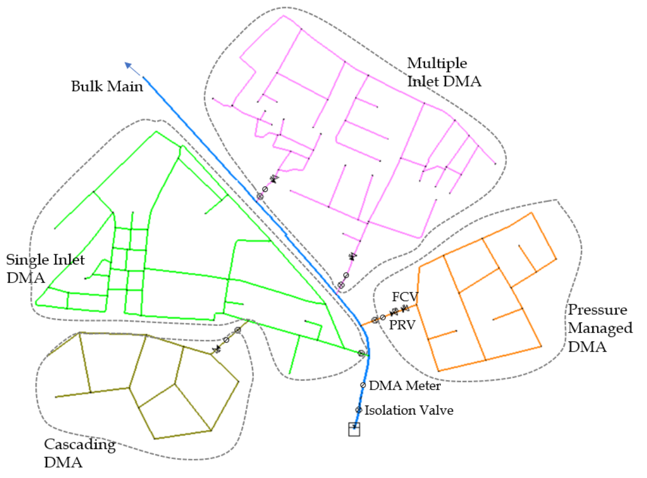


Figure 4.9: Types of DMA

(a) Cascading DMA: Sometimes due to topology of the network, a DMA is fed through bulk meter by other DMA.
(b) Single inlet DMA: In this type there is only one inlet meter. Errors are minimum as there is just one meter.
(c) Multiple inlet DMA: Sometimes in situations like pressure or system redundancy one meter is not possible and unavoidable multiple inlet meters are to be installed. This arrangement is only suitable when the width of DMA is less, and length is more and hence pressure drop along the length is excessive. However, this involves

extra cost due to providing of second inlet with necessary isolation valve, bulk meter, PRV and FCV.

(d) Pressure managed DMA: As shown in Figure 4.9, if the DMA is situated at low elevation, PRV is introduced to dissipate excess hydraulic pressure. It may be noted that PRV is not an essential feature and is not required to be provided for DMAs on flat terrain.

4.6.1 Establishing DMA Based on Number of Connections

GIS helps in measuring number of connections in operational zones and DMAs. For operational zone, the procedure is explained in Box-1. In the similar way number of connections can be counted in DMAs. Or alternatively the number of connections in DMA can be counted from the attribute table of OZ, in which the name of DMA is mentioned in separate column. The number of connections can be summarised on that DMA.

Box-1: Counting the no. of connections in OZ using GIS
Suppose, we have two GIS layers- (a) 'connections' as target layer and (b) and 'OZ boundary layer as source layer. In spatial selection method, we need to select that target layer features "have their centroid in the source layer feature." Then the selected layer ('connections') should be exported. After opening the attribute table of the exported layer, the no. of connections is known.

Knowing the number of connections, number of DMAs in each operational zone can be determined. GIS also helps in fixing location of Flow Control Valves (FCV). The FCVs may be installed at the entry point of the DMAs. Knowing the quantum of water, coming into DMA (by bulk meter installed at entry points) and quantity of water consumed (from consumer meters), value of NRW is computed.

4.7 EQUITABLE FLOW AND PRESSURE

4.7.1 Whole-to-Part Approach

Design of operational zone and DMA is made by the approach of whole-to-part and is coupled with demand management by 100% consumer metering and telescopic tariff. Whole-to-part approach is explained below with use of PRVs and FCVs, however, PRVs should be used only when required. PRVs are mainly required in hilly cities like Shimla or where the operational zone or DMA is at lower elevations. Maximum head that comes on pipes in the distribution system is the difference between FSL of ESR and minimum ground elevation in the OZ of that ESR. Class of pipe should be so chosen that working pressure of that pipe is more than the maximum head coming on the pipes in that OZ.

Equitable distribution of water with equal pressure is a need of 24x7 System. It is achieved by Whole-to-Part approach, in which two stages are involved- (a) from MBR to ESRs and (b) from ESR to DMAs

(a) From MBR to ESRs: In this stage, Master Balancing Reservoir (MBR) supplies water to different ESRs as shown in Figure 4.10. Inlet of each tank should be provided with isolation valve, bulk meter and then Flow Control Valve (FCV)/ Pressure Reducing Valve (PRV). In normal case FCV is sufficient because while controlling the flow, the pressure is proportionately reduced. However, in the situations having steep slopes such as in Shimla city, both the PRV and FCV are required. In such situations, the sequence in the direction of flow would be isolation valve, bulk meter, PRV and then FCV (Figure 4.10). Precaution should be taken to locate the bulk meter prior to PRV and FCV. The FCV is so set that the inflow to tank would be as per the demand of the operational zone served by that tank.

FCV with level controller should be installed on the inlet of tank. FCV with level controller ensures that the tank does not overflow and thus eliminates the physical loses due to overflowing of tanks in the water balance. The sensor for the overflow shall be away from the inlet so that the turbulence which is near inlet will not interfere with the work of sensor. Detail method of design of transmission main and achieving equal residual head at FSLs of ESRs has been discussed in the Chapter 6. By that method, every ESR draws water as per designed demand of that ESR. For avoiding physical loss of water due to overflow, the overflow pipe should be connected to distribution main on downstream of outlet valve.

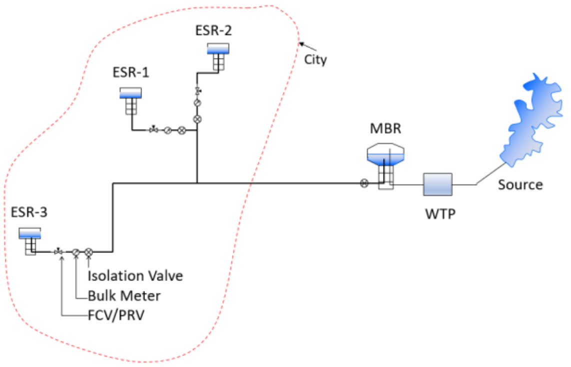


Figure 4.10: Equitable flow from MBR to ESRs

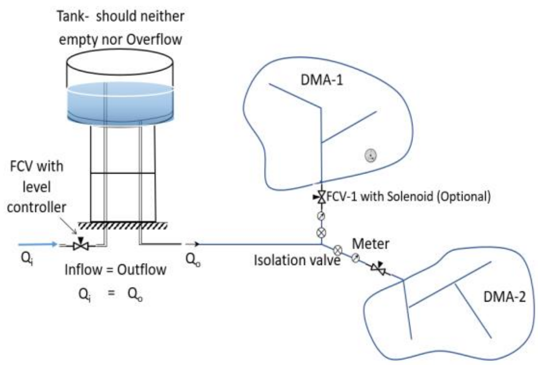


Figure 4.11: Equitable flow from ESR to distribution network through DMAs

(b) From ESR to DMAs: In this stage, ESR supplies water to different DMAs as shown in Figure 4.11. Bulk meter and FCV are required for DMAs, the sequence of the valves should be as discussed above. FCV with solenoid may be installed at the entry point of the DMA. FCV with solenoid is provided at the entry point of each DMA. There is inherent mechanism like router (Transmitter) which is connected with the Programmable Logic Controller (PLC) of the supervisory control and data acquisition

(SCADA). This arrangement automatically adjusts the flow during peak and non-peak hours.

4.8 ONE INLET FOR EACH DMA

If separate inlet to DMA is not provided, then the distribution network becomes complex, and lot of difficulties are faced in O&M of the system. This is the main reason for inequitable distribution of water. It is suggested to have multi-outlets (one for every DMA) from the ESR for efficient design and smooth O&M of distribution system. For having better hydraulic balancing within DMA, ESRs of distribution system should have more than one outlet and each outlet should feed 1 to 3 DMAs depending upon the availability of location of ESR. It should be decided on following considerations: (a) higher elevation within OZ so that staging height required is less, (b) central location so that DMA's can be planned in different directions and length of bulk line to DMAs reduces and (c) availability of land.

If centralised place with high elevation is available and the OZ is having 3 DMAs, then 3 outlets, one for each DMA should be provided. Normally two outlets are sufficient for ESR capacity up to 1 ML.

Equitable distribution of water is possible when separate inlets are provided for each DMA. This can be done by providing different branches from the main line coming from the outlet of tank. Such arrangement of branch main providing exclusive inlet to each DMA is typically shown in Figure 4.12.

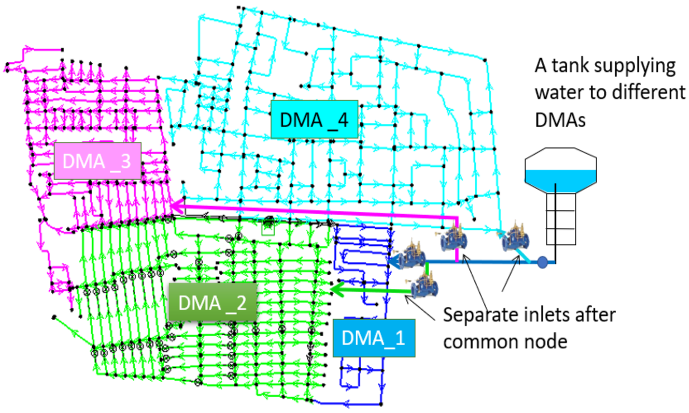


Figure 4.12: Separate inlets for each DMA

4.8.1 Equitable Pressures within DMA

The topography of DMA should be normally flat which will ensure equitable pressure distribution within the DMA. For this purpose, the lowest and highest elevation points should be found out. The elevation difference between these two points should not be normally more than 4 to 5m.

4.9 PIPELINES ON BOTH SIDES OF ROADS

Currently, many cities are being transformed into Smart Cities. Smart city requires smart roads which can monitor the traffic and signals. However, not only the smart roads but the concrete roads having width of 6m or more also need water pipelines on both the sides. Boundaries of the operational zones and its DMAs are so located topographically that its spread remains within normally available topographical features such as rivers, lakes, railway track, bigger width roads etc. Selection of the boundaries is also governed by the methodology as explained above in this chapter. This exercise of planning the pipeline on both sides of the smart roads can be done using GIS and the network software.

It is necessary to lay pipelines on either side of the concrete road so that while giving house connection, the road is not required to be damaged. The method for the concrete roads having width less than 6m is to insert the ducts intermittently in the body of the roads so that service connection pipes can be laid through it. For the concrete roads having width 6 m or more, pipes are to be laid on either side of the road. This can also be done economically while deciding boundary of DMA.

4.10 PRESSURE MANAGEMENT

Pressure management strategies in water distribution network include reduction of water losses that causes additional head loss and controlling of outflows. Water loss assessment and its reduction have been covered separately. Herein, we discuss about controlling of outflows.

4.10.1 Pressure Zone of Tank

The pressure in the network is generated by the height of water column at the tank/ ESR. It is, therefore, necessary that there is sufficient water depth in ESR to maintain supply pressure. Thus, storage capacity of ESR plays an important role. Capacity of storage at ESR should be sufficient to take care of fluctuation in consumer demand.

4.10.2 Layout of the Network

Layout of system is important from pressure control point of view. Usually, branched type of systems is observed in old networks. However, such networks have their own disadvantages and in urban city usually a combination of branched and looped network is provided. Loops in the network helps in maintaining more equitable pressure. Therefore, the layout should be such that main pipelines form loops. Direct consumer connections through these mains should be avoided. Secondary smaller diameter branched networks (called as rider) originating at different points from this main loop network should be used for providing service connection. This branched network, if possible, should follow ground topography.

4.10.2.1 Layout in hilly areas

Pressure management in hilly areas is most challenging. It is illustrated by taking example of the hilly city. Three pressure zones at hilly city are shown in Figure 4.13.

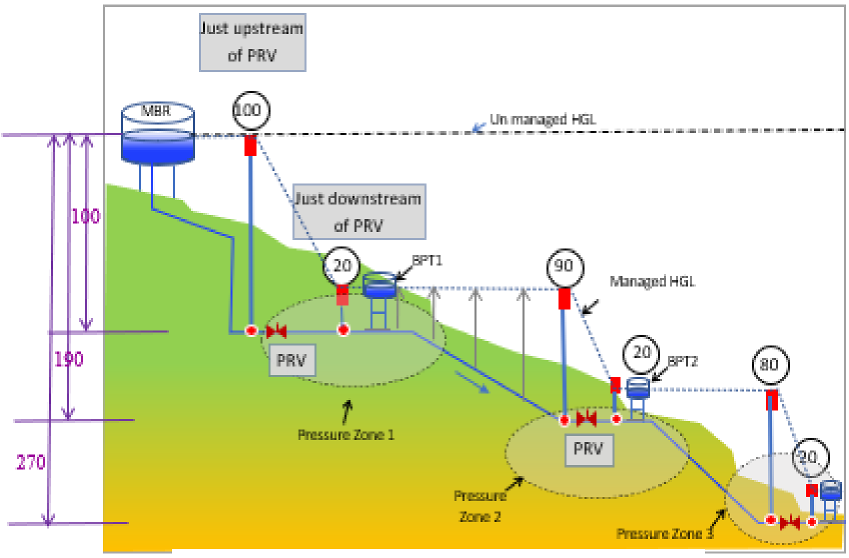


Figure 4.13: Pressure zones in hilly city

Such pressure zones at different ground elevations can be formed using GIS technology. Break pressure tanks- BPT1 and BPT2 are serving the function of service reservoir for pressure zone 1 and 2, respectively. In one such hilly city, the elevation difference between MBR and Pressure Zone 3 is 270 m. It is required to bring down pressure to 20m for each pressure zone. Hence, three Break Pressure Tanks (BPT) are provided- one for each pressure zone. Just upstream of each BPT a Pressure Reducing Valve (PRV) is installed which is set to limit the zone pressure to 20m. Thus, the residents in each pressure zone should get water with required residual nodal pressure of 20m (which is mentioned as mandatory condition in the Tender of the city). Direct-acting PRVs can be used to limit pressures up to 20m.

4.11 DISTRIBUTION OF WATER BY DIRECT PUMPING

Bigger cities require large number of operational zones and hence, large number of the service tanks. It is a common observation that land is not available for construction of tanks and hence, in some of the cities like Ahmedabad and Chennai, water is distributed by direct pumping.

Smart Pumps: Another reason is that generally residual nodal pressures in the existing distribution system are less than 12m or 17m as the case may be. In such situation, direct pumping is proposed. The direct pumping can be through the smart pumps. The characteristics of the smart pumps are as follows:

(i) Demand based pumping using the smart pumps may be designed for an efficient water distribution network.

(ii) At the pumping station, the controller should control the pump speed based on actual flow rate and pressure. To optimise the proportional-pressure curve used by the controller, remote sensors should be installed at critical points in the distribution network, i.e., where a stable pressure is required.

(iii) The remote sensors should log the pressure throughout the day and send the logged data to the controller as text messages once every 24 hours. Every day the controllers should automatically adapt its proportional-pressure curve, ensuring a stable pressure at the critical points. When the water demand is low, the controller lowers the discharge pressure at the pumping station to save energy and to reduce leakages and wear of the pipes.

(iv) Automatic Adoption function should automatically optimise the proportional-pressure curve using the logged pressure data from remote sensors and ensures a constant pressure at consumers or critical points. The pressure at the pumping station will vary depending on the usage-pattern at the critical points.

Components: The components may be-

a) The control system should include the Pump with Variable frequency Drive, and other related Hardware for 24x7 Water Distribution The controller of suitable rating, with Modbus RTU on RS485 for SCADA integration.
b) 24x7 System Controller must be designed specifically for controlling two to six pumps in water supply pumping stations. The Controller can also be integrated to most SCADA systems via a range of different communication protocols embedded to the control hardware.

Measures to be taken: Following measures are suggested-

- The cities in which present water supply is by pumping should prepare GIS maps of the entire pipe network. Condition assessment of the pipes and appurtenances should be shown on GIS maps.
- GIS based hydraulic model should be prepared,
- Pumps to be used should be of variable frequency drive.
- Exercise for maximum negative pressure (cavitation) of metallic pipes should be made. The minimum negative pressure line should be above ground elevation to avoid cavitation.

*****

Chapter 5

Optimization of Diameters of Pipes

Major portion of the capital cost of the project is that of the cost of pipes which is about 70%. Therefore, many researchers have developed and studied different optimization techniques to optimize the cost of pipelines ensuring that various hydraulic design constraints like pressure, velocity and head loss gradient are satisfied. Mathematical algorithms either run on an independent program or on the top of hydraulic models. Optimization techniques that have been studied include methods such Genetic Algorithms, Linear Programming, Non-Linear Programming etc.

Optimization is defined as “the action of making the best or most effective use of a situation or resource.” In design of distribution system, optimization aims at selection of a “best” element with regard to some criteria. In the design of distribution system, the optimized or the best diameter of pipe needs to be selected with respect to criterion that the nodal pressure shall not be less than the design norm, and that the velocity shall not exceed say, 2.1 m/s. Optimization of pipe diameters is required whenever new pipes are to be designed in operational zones of the distribution system.

5.1 NOVEL METHODOLOGY

Some of the network software have a built-in facility of optimizer tools. Many designers face difficulty in understanding and using this tool while designing their projects for pipeline optimization. They often complain that the tool results in non-telescopic pipe diameters that faces rejection from designers and the utility engineers. Besides this, some of the software do not render true and fully optimised results as they fail to observe the basic criteria of minimum velocity, say 0.3 m/s. Few of the pipes in the output of these software depict very low velocity of even less than 0.1 m/s which indicates that these pipes have unduly large diameter. Objective is, therefore, to discuss a novel methodology of designing pipes by using only the hydraulic model without any optimizer software.

5.2 BASIC PLANNING PRIOR TO OPTIMIZATION

Following planning procedure should be carried out:

1. After forecasting of ultimate population of the entire city/ town, its ward wise distribution is forecasted. The demands are assigned to the nodes using future ward wise population density method as described in the advisory on “GIS Mapping of Water Supply and Sewerage Infrastructure”, published by CPHEEO, MoHUA. This method makes the nodal demands realistic. Appropriate peak factor should be used for arriving at nodal demand.

2. Create hydraulic model as described in Chapter 3.
3. Fix boundaries of OZs and boundaries of DMAs as discussed in Chapter 4.
4. By the above method, the distribution system also becomes economical. DMAs and operational zones thus designed, become the building blocks of Conventional or 24x7 water supply system.

5.3 DESIGN PRINCIPLES FOR OPTIMIZING DIAMETERS

While designing network for operational zone/ DMA, designer assigns the required data of lowest supply level (LSL) of water in ESR, pipe data such as diameter, material and C-value and the junction data like the ground elevation, nodal demands etc. The parameter of giving Lowest Supply Level of water of ESR is based on following:

1) Achieving higher velocity reduces the diameters which reduces capital cost.
2) Optimally reduced diameters mean less volume of water in the network within operational zone and DMA, it takes less time to build up pressures after starting water supply on every cycle of suppling water.
3) Optimally reduced diameters mean, easy, less time taking and less cost for repairs/ replacement of pipes.
4) Provide appropriate staging height of ESR to achieve above.
5) Even though it is ideal to provide ESR at higher elevation and at centre of operational zone fulfilling both conditions, this type of arrangement is seldom possible. Try to fulfil them to the extent possible.
6) Lowest supply level of water of ESR should be equal to highest ground level in operational zone + minimum residual head + head loss for getting desired velocity.
7) Velocity should not be less than 0.3 m/s in all diameters above 80/100mm.
8) The minimum diameter in the distribution system of city/ town should be 100 mm for class I & II cities and for others it should be minimum 80mm.

5.4 THE NEW TECHNIQUE

All calculations performed in the computation engine of network softwares are based on either Darcy- Weisbach or the Hazen-Willum's equation which is,

$$V = 0.849C\left(\frac{D}{4}\right)^{0.63}\left(\frac{hf}{L}\right)^{0.54} \quad \text{(Eq. 5.1)}$$

In which,

D= Diameter (m)
V= Velocity of flow (m/s)
C=HW C-value, for example 140 for internally lined DI/MS pipes and HDPE pipes
hf= Frictional head loss (m)
L= length of pipe between two nodes (m)

Now consider single 1000-meter length of pipeline, considering DI pipe, after putting values in Equation (5.1),

$$V = \frac{0.849(140)D^{0.63}hf^{0.54}}{(4)^{0.63}(1000)^{0.54}} = 1.19052\ D^{0.63}hf^{0.54} \qquad \text{(Eq. 5.2)}$$

Using relationship between V (m/s), D (m) and hf (m) as above, Values of velocity and hf may be computed.

Principle: It is experienced that if we can manage to get the velocity around 1 m/s and correspondingly increase in the head loss gradient to a value around 5 m/Km in as many pipes as possible, we get the optimized diameters.

The methodology is explained here by studying following illustrative example.

Illustrative Example:

The network under study is shown in Figure 5.1. The pipe and junction data and the results before optimization are shown in Table 5.1.

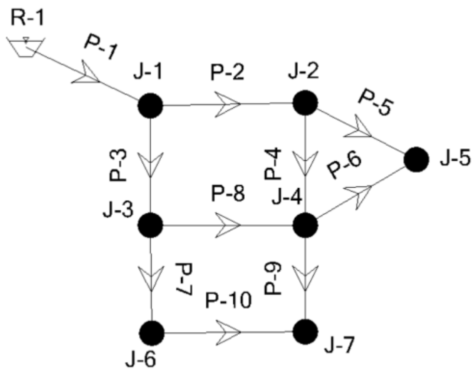


Figure 5.1: Network

Table 5.1: Before optimization- pipe and junction data and the results

Pipe Data					Pipe Results				Junction Data			Junction Results	
Label	Material	Diameter (mm)	Length (User Defined) (m)	Hazen-Williams C	Flow (Absolute) (ML/day)	Velocity (m/s)	Headloss Gradient (m/km)		Label	Elevation (m)	Demand (ML/day)	Hydraulic Grade (m)	Pressure (m H2O)
P-1	DI	700	500	130	5	0.15	0.038		J-1	85	0.5	99.98	15
P-2	DI	600	300	130	2.3	0.09	0.019		J-2	80	0.5	99.98	20
P-3	DI	600	200	130	2.2	0.09	0.017		J-3	86	0.5	99.98	14
P-4	DI	400	200	130	1.04	0.1	0.032		J-4	80	0.5	99.97	20
P-5	DI	300	100	130	0.76	0.12	0.071		J-5	80	1	99.97	20
P-6	DI	300	100	130	0.24	0.04	0.008		J-6	82	0.5	99.97	18
P-7	DI	500	200	130	1.23	0.07	0.015		J-7	83	1.5	99.95	17
P-8	DI	300	300	130	0.46	0.08	0.028						
P-9	DI	300	200	130	0.77	0.13	0.072						
P-10	DI	300	300	130	0.73	0.12	0.067						

It can be seen that the velocities in pipes before optimization (Table 5.1) are too less and can be increased to such extent that minimum nodal pressure is 12m or more. According to above methodology (Age-old Prudence method), the diameters of the pipes whose velocity was less are decreased and the results after 4th iteration are shown in Table 5.2.

Table 5.2: After optimization (Iteration no. 4) - pipe & junction data and results

Label	Material	Diameter (mm)	Length (User Defined) (m)	Hazen-Williams C	Flow (Absolute) (ML/day)	Velocity (m/s)	Headloss Gradient (m/km)		Label	Elevation (m)	Demand (ML/day)	Hydraulic Grade (m)	Pressure (m H2O)
P-1	DI	300	500	130	5	0.82	2.334		J-1	85	0.5	103.8	19
P-2	DI	200	300	130	2.31	0.85	4.032		J-2	80	0.5	102.6	23
P-3	DI	150	200	130	2.19	1.43	14.77		J-3	88	0.5	100.9	13
P-4	DI	100	200	130	0.74	1.09	14.41		J-4	80	0.5	99.74	20
P-5	DI	100	100	130	1.07	1.58	28.29		J-5	80	1	99.79	20
P-6	DI	80	100	130	0.07	0.16	0.53		J-6	80	0.5	98.7	19
P-7	DI	100	200	130	0.64	0.94	10.87		J-7	83	1.5	98.51	15
P-8	DI	150	300	130	1.05	0.69	3.79						
P-9	DI	150	200	130	1.36	0.89	6.142						
P-10	DI	100	300	130	0.14	0.2	0.638						

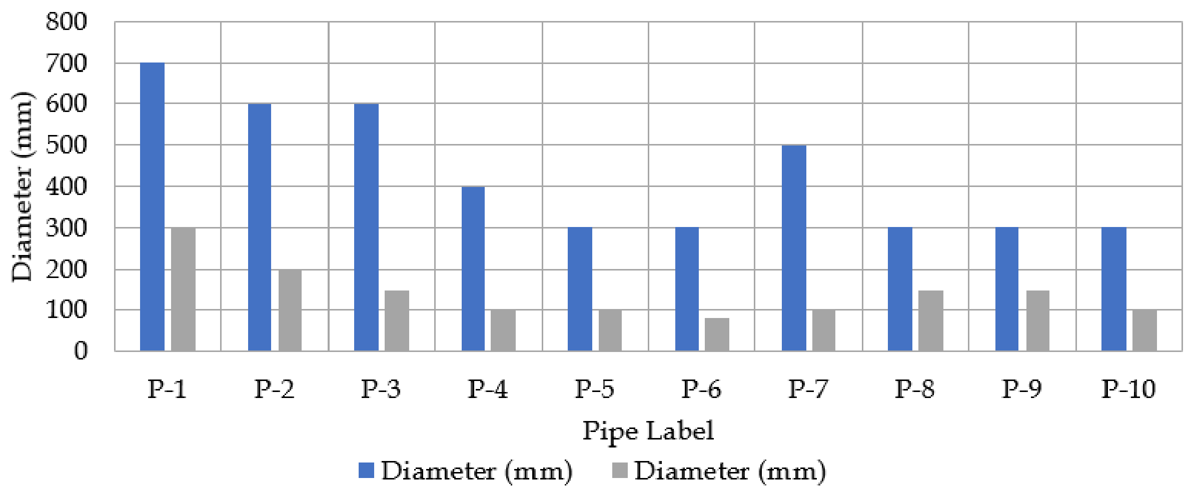


Figure 5.2: Pipe diameters before and after optimization

5.5 STAGING HEIGHT OF ESR

With the above concept of decentralised planning, head loss gradient up to 5 m/km can be achieved with reasonable staging height of ESR. Presently 10 to 12 storey buildings are quite common and construction technology is quite modernised, the maximum staging height can be considered as 30 m.

The Lowest Supply Level of water in ESR shall approximately be equal to highest ground level in operational zone + required as minimum residual head + 5m for head loss. It becomes possible to locate ESR centrally with reference to spread of operational zone, the figure of 5m can be further reduced. Another approximate criterion can be available head at entry of DMA. It should be equal to highest ground elevation in DMA + required as minimum + 3m for head loss.

For achieving equitable distribution, no connection should be given from pipelines feeding DMAs and higher diameter pipelines forming loops within DMAs.
In general, ESR should have 8 hours capacity, i.e., one-third of the total demand of the operational zone including 10% losses in distribution. However, it should be designed by the mass-curve method.

5.6 THE METHODOLOGY

Hydraulic modelling is a computer software exercise for analysing and designing of pipe diameters of distribution system. For analysing and designing large number of pipelines, computer software is required.

The network software is to be fed data in terms of diameter of pipes, materials, C-value and elevations and nodal demands to junctions and Lowest Supply Level (LSL) of ESR and by running the model, velocity in pipes and residual head at nodes are observed for optimizing the diameters.

The hydraulic model should be prepared for the entire city using any suitable software. A designer may have to work on two types of design models, viz., operational zone in distribution system and transmission mains. Further, there may be possibilities that the distribution network is to be designed as new and another possibility is that of an already existing network, which is to be reengineered by changing the boundaries of earlier operational zones and DMAs and by adding new pipes. In the optimisation exercise, diameters of new pipes are optimised by utilizing capacity of existing pipes to the extent possible. In short, the diameters of existing pipes are not to be changed in the hydraulic model. This is discussed in following sections.

5.6.1 Optimization of Pipes in all Operational Zones

In most of the cases, some pipes in distribution system are existing and all operational zones are to be reengineered with increased nodal demands, peaking factor and revised norm of residual nodal head.

The steps to be followed are as under:

a) GIS based hydraulic model of the city/ town under consideration is prepared. Since, the model is based on GIS, the pipe lengths between the nodes are automatically scaled out, and therefore there is no need to assign the data of lengths to pipes separately. So also, the pipes and junctions' labels are automatically assigned by the network software in its flex table. The default values of pipe material and its HWC-value are changed to actuals. LSLs of ESRs are assigned. The required diameters are assigned to each pipe, as per the experience and judgement of the designer.

b) While preparing hydraulic model, the existing pipes are shown in colour code and the new pipes are added to increase the coverage to 100%. So, the model contains both the existing as well as the new proposed pipes.

c) It is to be ensured that the boundaries of all operational zone are designed optimally, i.e., ESRs/GSRs do not get empty or get overflowing.

d) The elevations are assigned to each node using GIS based contours and the demands are also assigned to all the nodes using the method of 'Future population density method' as discussed in the advisory on "GIS Mapping of Water Supply and Sewerage Infrastructure" published by MoHUA.

e) In hydraulic model, initially a base scenario is created for the entire city's distribution system. The scenario management has already been discussed in Chapter 3. We need to iteratively run the hydraulic model for each of the operational zone.

f) Run the model. In each iteration, observe pipe diameters, velocity and hf (m/km) in the pipe table and nodal pressures in junction table (Figure 5.3).

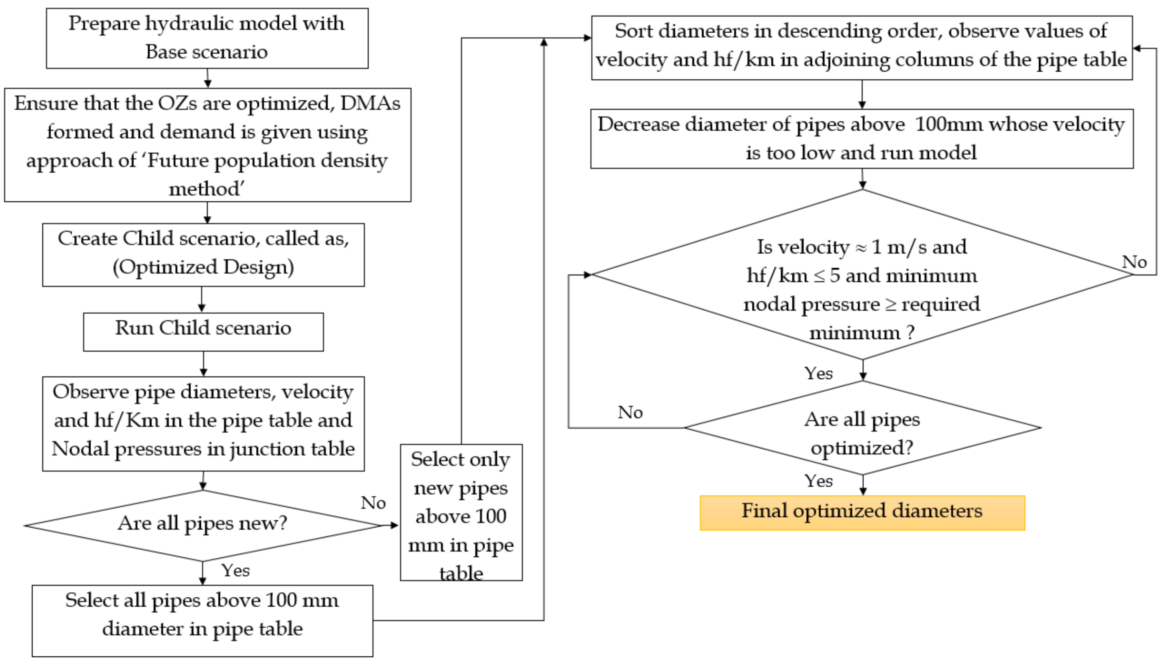


Figure 5.3: Iterative process of optimizing diameters.

g) Select only new pipes in pipe table. Following steps are taken for new pipes keeping existing pipes undisturbed.

h) Sort diameters in descending order, observe values of velocity and hf (m/km) in adjoining columns of the pipe table.
i) Decrease diameters of the pipes in which velocities are too low and whose diameter > 100mm and again run model.
j) Observe the values of velocities in the pipe table. If velocity is less than 1 m/s and hf (m/km) is also less than 5 m/Km, and minimum nodal pressure is also more than or equal to residual nodal head as per norm, the steps are repeated. (Sometimes diameter needs to be increased).
k) The process is repeated for all the new pipes whose diameters are more than 100mm, till we get all optimized diameters.
l) It can be easily seen that the diameters of existing pipes are retained and only the new pipes are optimized.

*****

Chapter 6

Transmission Mains

6.1 OBJECTIVES

After proper grouping ESRs and after designing with optimized diameters, the exercise of equalization of residual heads at FSLs of ESRs is carried out. Equalisation of residual head at FSLs of tanks ensures that only designed quantity of water is supplied to the ESRs and thus, O&M gets simplified. Most important advantage is that all the tanks are filled simultaneously in the minimum required time and there is equal distribution of water to all the service tanks. In short, with proper design of diameters of exclusive branches feeding individual ESRs, residual heads at FSLs of individual ESRs become nearly equal to designed residual head and thus they receive water equal to the design requirement. This helps to set timetable of closing inlet valves of ESRs which becomes possible without emptying any part (length) of transmission main. Removal of excess residual head by decreasing diameters, pressure in other segments remains well developed and the ESRs with high FSLs get designed inflow.

Objective of this chapter is to discuss design methodology to achieve- (i) optimization of diameters, i.e., capital cost, (ii) optimization of cost of pumping and (iii) equalization of residual heads at full supply levels (FSLs) of ESRs/ GSRs. This chapter further introduces, and discusses a novel methodology, called here as “moving node method,” which is required to achieve equal residual head of about 3m at FSLs of all the service tanks. The exercise can be carried by using any software by which we can prepare hydraulic model. By achieving equal residual heads at service tanks, use of pressure reducing valves (PRVs) can be avoided. The hydraulic model to be used should preferably be GIS based.

Cost of transmission main constitutes major cost of large sized urban/ rural water supply systems. For optimization of capital cost, following methodology is recommended.

6.2 GENERAL PRINCIPLES IN DESIGN OF TRANSMISSION MAINS

In general, following principles are to be adopted in design of transmission mains by gravity:

1. After deciding boundaries of operational zones (OZ) of existing and new tanks, the lowest supply levels (LSL)s of all tanks is known. By adding side water depth (SWD) of 5m to LSLs, we get Full Supply Levels (FSL)s of all ESRs. Transmission main shall be designed to give minimum residual head of 3 m at FSLs of every service tank which are to be fed by the transmission main. The residual head should be as

close as possible to 3m so that quantity of water supplied to the service tank is nearly equal to the demand of the operational zone that the service tank is serving.

2. Grouping high level and low-level service tanks (ESR)s in the city should be done, preferably by use of Inverse Distance Weighted (IDW) surface.
3. Lower-level group of ESRs should be fed from low level master balancing reservoir (MBR) and higher-level group of ESRs should be fed from high level MBR, through separate transmission networks so that only needed quantity is pumped to high level MBR. This arrangement makes substantial saving in monthly recurring energy bills on account of pumping.
4. Designer shall assign diameters from his experience along with other data such as assigning elevations at junctions. After assigning node elevations as FSLs of ESRs, ultimate stage demand to the nodes and after assuming LSL of MBR, analyse the assumed scenario by running the hydraulic model on any software. If it gives low values of velocities (m/s) and hf (m/km), it means chosen diameters are high and the cost of transmission main is more. Then by increasing the LSL of MBR, decrease the diameters of relevant pipes and increase the velocity in such a way that the computed head loss gradient is between 4 to 5 m/km. In short v (m/s) and head loss gradient (m/km) are the tool to be used prudently. For this purpose, velocity criteria as under is recommended for usage.
5. The diameter of transmission main on downstream of MBR should be little more than that of the inlet diameter of the pumping main (on upstream side of MBR) feeding the MBR.
6. If assumed diameters after analysis indicate that many ESRs get negative residual head, the MBR level needs to be suitably increased.
7. From the main network there is an exclusive branch to feed the ESR at its end and increasing or decreasing diameter of that branch does not involve tangible capital expenditure and hence diameter of that branch can be increased or decreased for making the network hydraulically efficient.
8. If in a large network of transmission main, if only one or two ESRs, that are yet to be constructed, show negative residual head then for such ESRs provide online pump on its outlet or provide pump on the pipeline leading to the inlet of pressure deficient DMA.

   This arrangement is more economical than increasing the level of MBR and pumping total water to high elevation or increasing the diameter in long lengths of the network. If the height of any of those ESRs is needed to be decreased too much, then it is better to go for a sump and pump house. From the sump, water could be pumped to ESR of that operational zone or directly pumped into the distribution system of that OZ.
9. If the main line of the transmission network goes down the slope and again rises, then the ESRs on branches in lower level will have high and unrequired residual head. This scenario in branch line feeding group of ESRs in lower level is an indicator that the pumping energy is being wasted. On the other hand, while proposing alignment of main line along a road on high contour, care should be taken that the top of pipeline is below HGL by 1 m at least at critical place. This type of

critical place also gives signal for providing sump and pumping to downstream ESRs on high locations. It also indicates for providing a zonal balancing reservoir (ZBR) and pumping water to it, for gravitating water to high level ESRs. To ascertain this aspect, it is necessary to add nodes showing elevation of ridge points.

6.3 PUMPING MAINS

A typical pumping main (Figure 6.1) are designed with well-known method of economical diameters (Figure 6.2). In this method, the logic is based on minimization of total cost which comprises of costs of pumping main, cost of pumping machinery, capitalised cost of pumping expenditure based on consumption of electricity. For this exercise, instead of taking subsidised cost of electricity, actual unit cost of electricity needs to be considered.

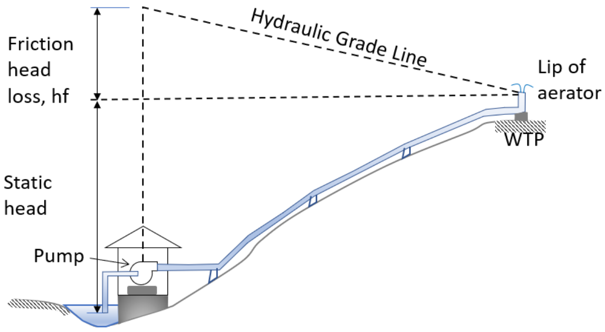


Figure 6.1: Typical pumping main

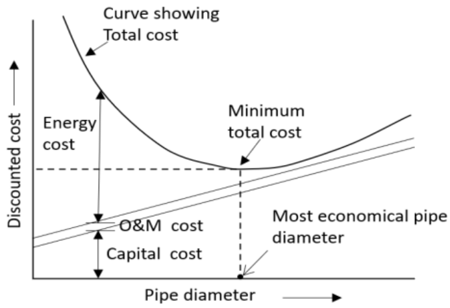


Figure 6.2: Determination of most economical pipe diameter

Equalization of residual heads: After optimization of pipe diameters, the residual heads at FSLs of each ESR are observed. If they are more than 3m to 5m, then equalization of residual heads is achieved using the “Moving Node Method,” applied to branch pipes of main pumping main. This proposed method is discussed in this chapter.

6.4 TRANSMISSION GRAVITY MAINS

In both urban and rural water supply systems, there are number of service tanks. Transmission mains feeding to these service tanks are generally larger diameter pipelines which are designed to move large quantities of pure water by gravity from the MBR to various Elevated Service Reservoirs (ESRs) in the city. A typical gravity transmission main is shown in Figure 6.3, which supplies water to the various tanks.

The tanks are generally situated at different elevations. If they are not properly grouped and if the main pipeline of gravity transmission network, on its alignment goes down the slope and again rises, then the ESRs on branches in low level will have high and unrequired residual head beyond the requirement of 3m. It is an indication that the energy is being wasted by pumping unrequired quantity to high level MBR. One such example of incorrect practice and solution thereof is illustrated below.

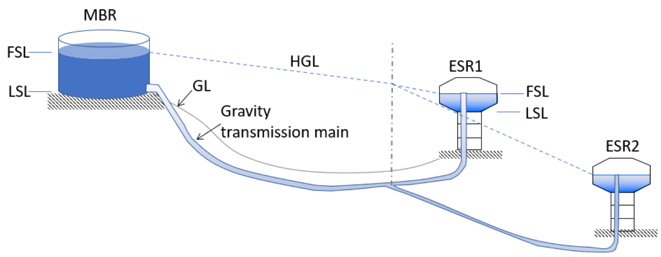


Figure 6.3: Typical gravity transmission main

6.4.1 Incorrect Practice and Its Solution

The Aurangabad city (Maharashtra) is getting water supply from the source of dam of 'Jayakwadi' major irrigation project. Water from the dam is pumped to WTP and after treatment it is again pumped to the MBR at one hillock. Before 2003, old transmission network (which is shown within circumscribing the area with dotted red line in Figure 6.4) was supplying water by gravity. Water was supplied from the existing MBR at LSL of 632m. This old transmission main touches the lowest level of the city, as may be seen in the darkest green area at RL 538 m. Part of the water was being pumped from the lowest point (Kranti Chowk) to the high level ESRs. Eventually, ESRs located in eastern side of city covering CIDCO and surrounding area, having higher elevations were the sufferers till the year 2003. The practice of bringing total quantum of water to the city centre and then to distribute it further without consideration to topography and optimization of energy cost may not be adopted.

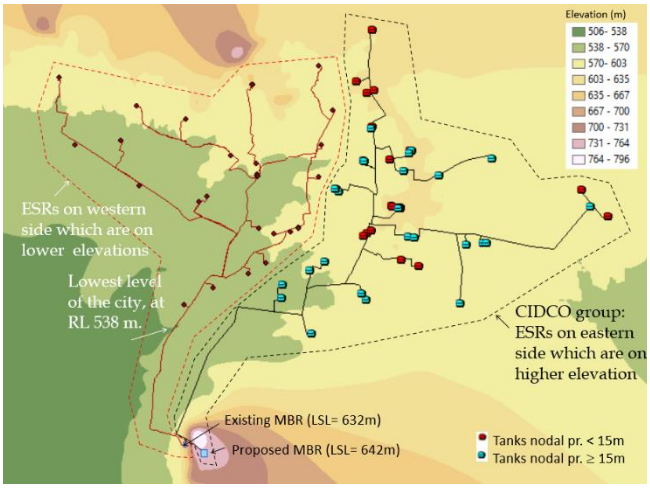
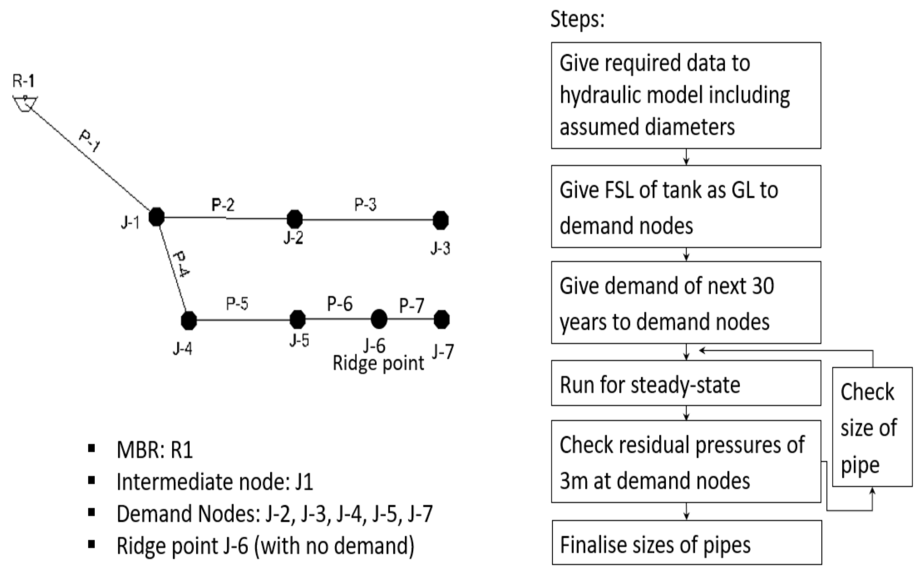


Figure 6.4: Old transmission network in red and new transmission network (2003) in grey colour

New scheme was commissioned in 2003 to mitigate the growing demand of water and to redress the problem of ESRs located in higher elevation area shown by circumscribing with black dotted line as shown in Figure 6.4, by laying separate transmission main along higher contour called as Beed-bypass Road.

6.5 OPTIMIZATION OF CAPITAL COST OF TRANSMISSION MAINS USING HYDRAULIC MODEL

Transmission mains are lifelines of urban water supply schemes or regional water supply projects. The design can be made using GIS based hydraulic model. Master Balancing Reservoir (MBR), R1 supplies water to the five demand nodes (ESR)s. The steps involved are shown in flow chart shown in (Figure 6.5), in which J-2, J-3, J-4, J-5 and J-7 are the demand nodes representing the service tanks and J-6 is the intermittent junction on ridge with no demand.



In the hydraulic model, elevations to be given at junctions J-2, J-3, J-4, J-5 and J-7 are the FSLs of respective ESRs, whereas ground elevations are given to the junctions J-1 and J-6.

Figure 6.5: Iterative design of pipe diameters of Transmission mains

Normally assumed diameters, lengths (in case of non-GIS), pipe material, Lowest Supply Level (LSL) of MBR and Full Supply Level (FSL) and ultimate stage demands are fed to the demand nodes as data. After assigning data, the hydraulic model is run. Required iterations are carried out by way of changing assumed diameters suitably by using above general principles.

Software analyses the data and computes the residual head at the inlets (FSLs) of each ESR to be served by that MBR. Thus, the economy to be achieved depends upon the diameters assumed, i.e., the personal expertise of designer.

6.6 OPTIMISATION OF ENERGY COST BY OPTIMIZATION OF LSL OF MBR

The pumping energy is to be saved by keeping the LSL of MBR as less as possible. The LSL is governed by the highest FSLs of few of the ESRs. Say, if there are 6 ESRs, to be fed by transmission main network then one or two ESRs have their FSLs remarkably high. For bringing down LSL of MBR, it is necessary to lower down FSLs of these ESRs. These ESRs are termed as “Pressure Problem ESRs”. For bringing down FSLs of these ESRs, following steps are necessary:

(a) Every ESR has an exclusive branch from the transmission main network. Head loss in this exclusive branch of "Pressure Problem ESR" should be minimised by increasing its diameter. This procedure is possible for existing as well as new ESRs.

(b) Increase the diameter of inlet pipe (Figure 6.6) from the outlet of ESR to DMAs in operational zone (OZ) to reduce head loss in that inlet pipe so that residual nodal heads in distribution pipe network of OZ are increased more than the stipulated minimum residual head. Increase beyond a minimum residual head is not necessary and to that extent the LSL of that ESR can be lowered. This procedure is to be followed for new and "Pressure Problem ESRs" only

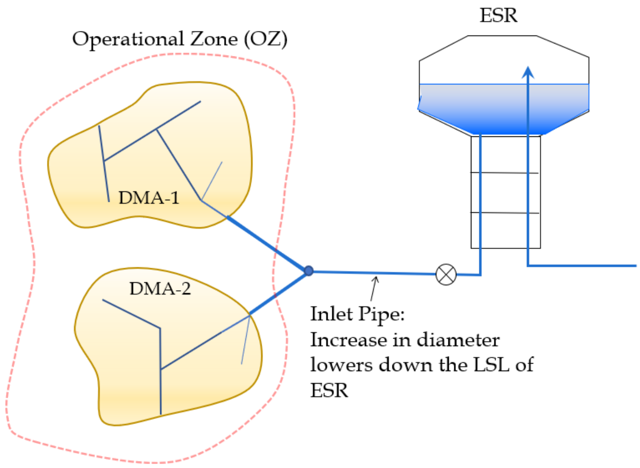


Figure 6.6: Inlet pipes to DMAs

(c) Side water depth (SWD) of "Pressure Problem ESRs", if they are not yet constructed, should be decreased by 1m. This will also lower down the LSL of MBR by 1m. This can be done by increasing plan area of container by keeping the capacity unchanged but increasing the diameter. For example, for a capacity of 1 ML ESR, decreasing SWD from 5m to 4m, the plan area of container increases by 20%, i.e., from 16 m diameter to 18m diameter. As the capacity remains the same, increase in cost is nominal.

(d) If LSL of MBR is reduced by say 2m using above exercise and head on pumps for inlet side is say 50m, it amounts to 4% reduction in energy cost per month perpetually.

It needs to be pertinently noted that the total exercise of transmission main as discussed above in terms of iterative procedures, focusses on increasing velocity by increasing LSL of MBR and thereby decreasing diameter and cost of total pipes of transmission main network; while above Paras (a) and (b) are an exception to it and are advocating decreasing head loss by increasing diameter for achieving decrease in the cost of pumping. Hence, striking balance between increase in cost of pipes verses capitalised cost of saved energy bills is the tool of optimisation.

6.7 OPTIMISATION OF ENERGY COST BY INLET-OUTLET AT BOTTOM OF MBR

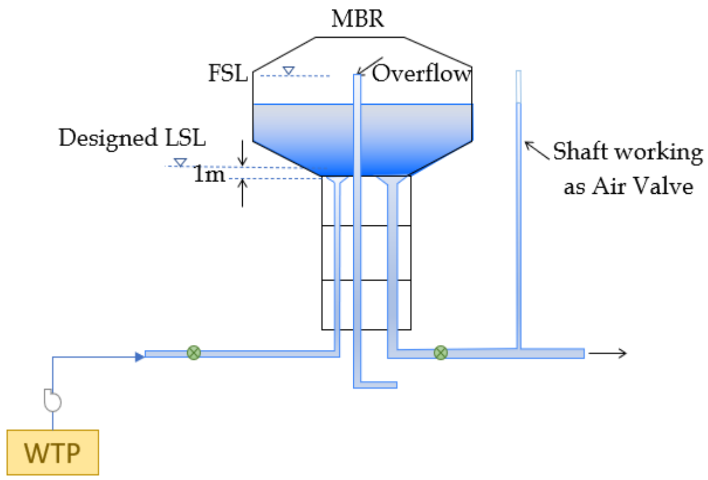


Figure 6.7: Inlet, outlet arrangement of MBR

Normally, the side water depth of MBR is 5m and inlet is at FSL and outlet is at LSL. However, this Guideline recommends invert levels of inlet and outlet at same level and at bottom of MBR. LSL of MBR is lowered down to the extent possible by using principles in explained above. Bottom of MBR is placed further 1m below the designed LSL of MBR as shown in Figure 6.7. This arrangement saves energy. We can save energy cost of pumping head perpetually, i.e., every month.

In case rising main to MBR leaks, then wastage of water due to emptying of MBR can be saved by shutting the pumps and closing the valve at inlet. In case of MBR, if located on hillock, i.e., on ground level, then outlet of MBR should be with a bell mouth embedded below bottom so that full capacity is available for use and MBR can be cleaned during maintenance. It is necessary to have all season road to MBR/ BPT. Overflow pipe from FSL should discharge water at a place away from MBR and then that discharge should find its way to natural stream.

6.7.1 Level of Bottom of MBR for Optimization of Energy Cost

The logic of various steps involved in computation of optimum LSL of MBR are shown in flow chart which is shown in Figure 6.8.

Every design including hydraulic modelling has always factor of safety. In design of pipeline, the factor of safety terms of slightly higher designed LSL to MBR. Design LSL is of course not to be lowered down but unnecessary pumping cost can be saved. This can be done by providing bottom of slab at an elevation lower by 1 to 2m below design LSL (Figure 6.8). In the steady state of operation, i.e., inflow equal to outflow, the water level will not climb up to designed LSL but will remain at a level lower than that and the pumps will operate for this decreased head. This yields in saving of electricity bills due to decrease in head on pump by more than 5m. Decrease in head due to this arrangement compared to inlet at FSL is 5 to 7m. This is an extra saving over and above saving. If head on pump on inlet pipe is 50m, then saving is about 10 to 14%.

For lengths of transmission mains up to 10 kms, provide bottom of MBR at 1m below design LSL and for more lengths bottom of MBR should be 2m below designed LSL.

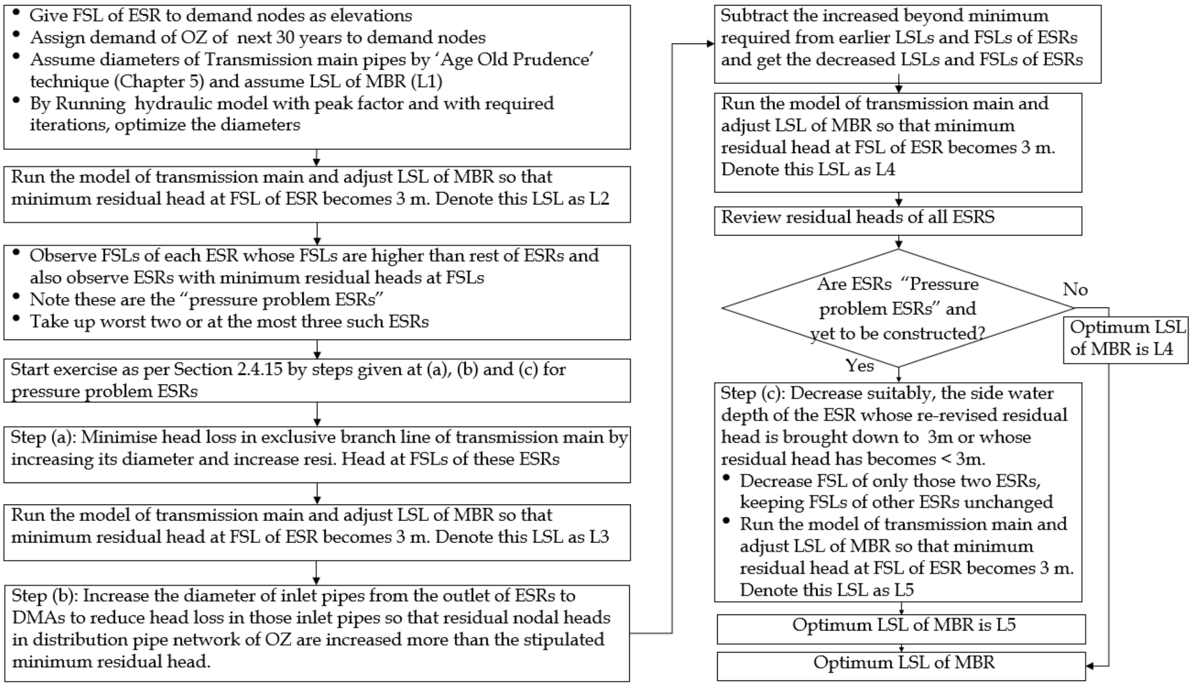


Figure 6.8: Logic of computing optimization of LSL of MBR

6.8 EQUALISATION OF RESIDUAL HEADS AT FSL OF ALL ESRS

Diameters of transmission mains are so adjusted that the residual head is around 3m. The junction table of hydraulic model is then seen for the residual heads at each of the tank. After running the hydraulic model, as above for achieving a minimum residual head of 3m, compare the residual heads available at FSLs of all ESRs. If variation is large, the ESRs with excess residual heads on their inlet side, can draw more water than they are designed to draw and supply to operational zone. Hence, extra residual head needs to be dissipated. This is achieved by the new method of "moving node," (IWWA, January 2021).

6.8.1 Moving Node Method

From the main network of transmission main, every ESR/GSR has an exclusive branch feeding that ESR. The velocity and hf (m/km) in this branch are to be increased by decreasing diameters for dissipating excess residual head. For this purpose, the length of branch main should be divided (Figure 6.9) in two segments, say L1 and L2 by providing an extra node at meeting point of (junction) of L1 and L2. By assigning decreased diameters to one or both segments and by adjusting length of each segment by moving node at the junction of L1 and L2, the residual head is brought down in the range of 3 to 4m. Increase in velocity up to 3m/s in a small length does not cause any problem as some extra margin is available above the criteria of minimum 3m residual head. This extra margin can be dissipated by throttling the valve on inlet side. For dissipation of large extra head which normally is in case of existing small and dwarf ESRs, 80 mm diameter segment on branch pipeline may have to be used if velocity in it is less than 3m/s. Otherwise the minimum criteria of 100 mm shall be adhered to. Another method of dissipating extra head is to provide an orifice plate with a scour valve on its upstream side. If length of the exclusive branch is less, then above method of dissipation of excess residual head is not possible. In only such exceptional case, pressure reducing valve (PRV) is required to be installed.

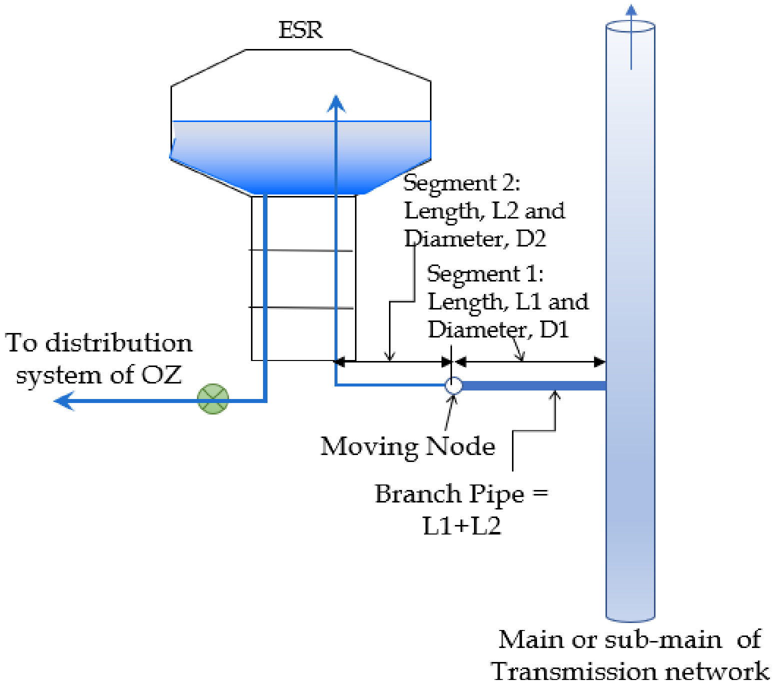


Figure 6.9: Branch pipe with two segments

Due to equalised residual head by bringing it to 3 to 4m, feeding of all ESRs in nearly equal time becomes possible. Hence, enforcing timetable of closing inlet valves of ESRs becomes possible without emptying transmission main. Removal of excess residual head by decreasing diameters, pressure in other sections remains well developed and the ESRs with high FSLs get designed inflow. The logic of this process is shown in Figure 6.10.

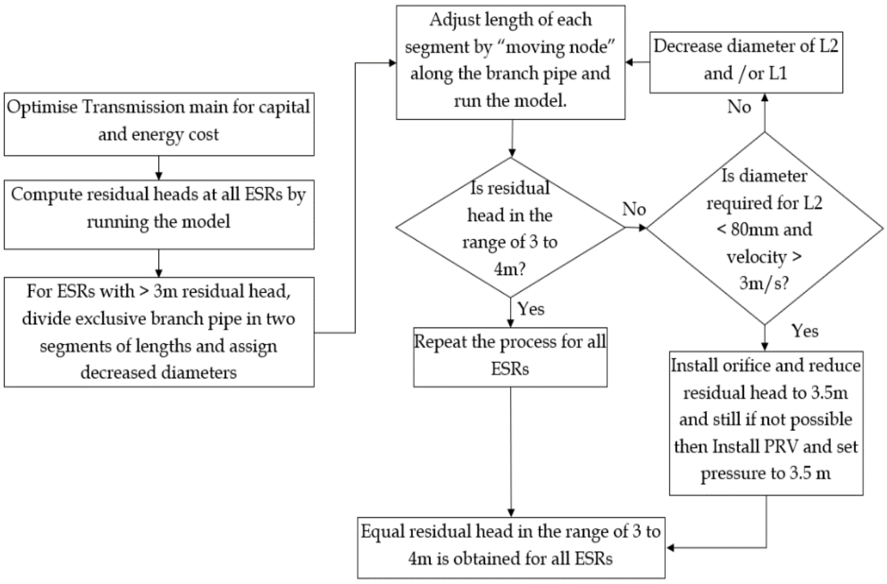


Figure 6.10: Logic of making equalization of residual pressures for ESRs other than "Pressure Problem ESRs."

6.8.2 Design of Branched Pumping Main - Optimization of Diameters

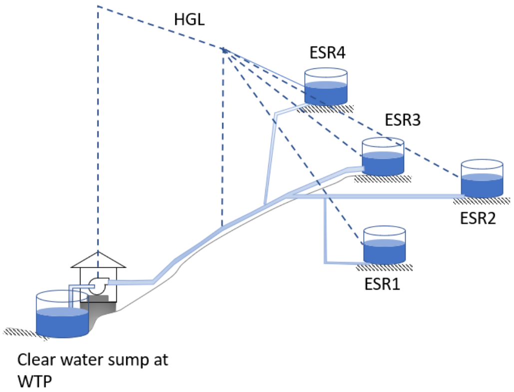


Figure 6.11: Branched pumping main

It may not be possible to feed all ESRs by gravity from MBR/ clear water sump at WTP.

In that case, it is necessary to locate the sump at appropriate place and pump water to needed ESRs (Figure 6.11). First preference should be given to pump water by separate pumps to separate ESRs by separate pumping main, if ESRs are in different directions from sump. In this case diameters of pumping main works out to be less. If this arrangement is not possible, then branched pumping main as shown in Figure 6.11 is the option. Branched pumping main should be designed with following methodology:

(i) Assume MBR of high height and design gravity transmission main to ESRs on the principles of gravity transmission main discussed above.

(ii) Instead of assumed MBR, provide pump with head = FSL of hypothetical MBR-LSL of sump.

(iii) Provide water hammer control devices on main pipeline and branches.

(iv) It is better not to provide inlet valves at entry of ESRs.

6.9 SURGE PROTECTION FOR TRANSMISSION MAINS

Transmission main should be checked for water hammer analysis by any established software. A sample results of one of such analysis is shown in Figure 6.12.

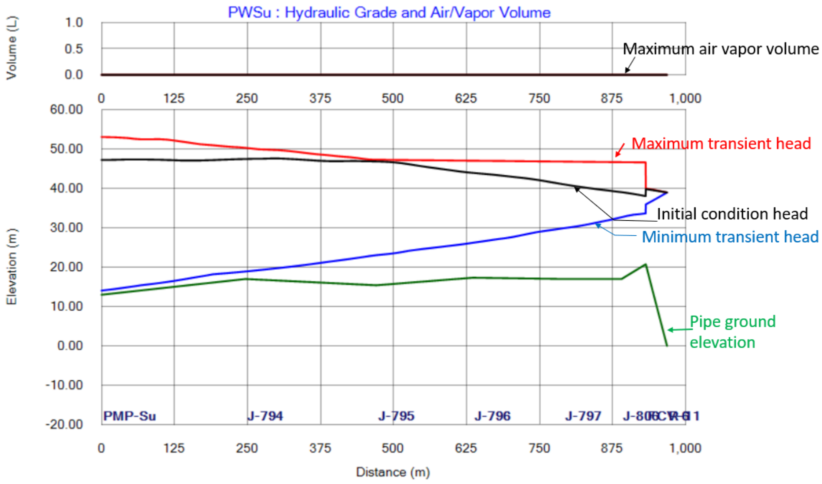


Figure 6.12: Sample result of water hammer analysis of a pumping main

It is to be observed that the minimum transient headline (shown in blue colour) must be above the ground elevation line (shown in green colour) of the pumping main which indicates that the pumping main is safe from cavitation. Pipe class should be such that it sustains maximum transient head shown in red colour. If minimum transient headline (blue colour) happens to be below that of the ground elevation line (green colour) then the pipeline is unsafe. In such situation water hammer protective equipment should be designed.

*****

Chapter 7

Reduction of NRW

7.1 REDUCING NON-REVENUE WATER

The maximum leakage occurs in the distribution system and house service connections which is around 80% of the total leakages in the system while the remaining percentage covers the loss at source, transmission system, treatment plants and service reservoirs. NRW is usually taken as the measure of efficiency of a water supply system. It is defined as:

$$NRW = \frac{\text{Water put into system - Total water billed}}{\text{Water put into system}} \text{ x } 100$$

The reduction of NRW is a crucial step to improve the financial health of water utilities and to save scarce water resources. The percentage of physical losses is influenced not only by the deterioration of piped network, but also by the total amount of water used, system pressure, and the degree of supply continuity. The percentage of administrative losses depends on the degree of effort exerted in identifying illegal connections and in repairing meters. To a large extent, the level of NRW is an indicator of how well a utility is managed. Figure 7.1 shows NRW values of various cities in India. Many cities have NRW values more than the national average of 31%. They should target to lower NRW and accordingly chalk out the program for it.

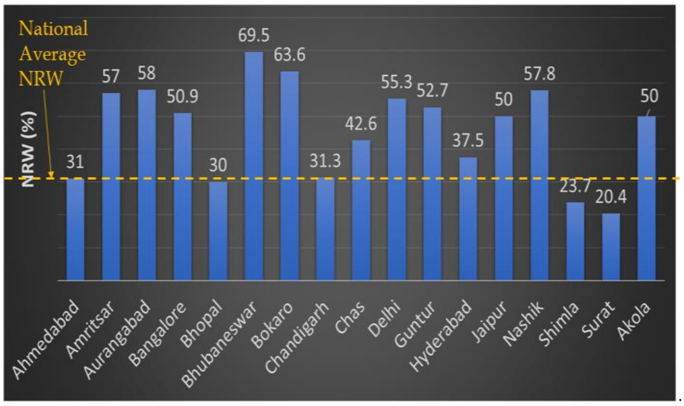


Figure 7.1: NRW values of different cities in India

Continuous supply system may result in increase in NRW; however, installation of district flow meters, functioning of domestic meters on consumer connections will indicate areas where quantum of NRW is high and efforts to minimize NRW can be concentrated.

7.2 IMPACTS OF NRW

In many water utilities, there are high levels of NRW (Figure 7.1) which leads to low levels of efficiency in terms of financial economy and redressal of complaints. When a utility's product (treated water) is lost, water collection, treatment and distribution costs per unit of volume increases, water sales in terms of volume and amount decreases, and to resolve this situation substantial capital expenditure programs are often promoted to meet the ever-increasing demand. In short, the utility enters a vicious cycle (Figure 7.2) that does not address the core problem.

The challenge for these utilities is to turn this vicious cycle into a virtuous cycle (Figure 7.3), which will lead to low levels of NRW and therefore substantially improved efficiency.

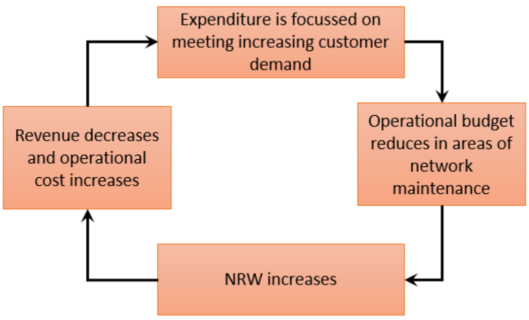


Figure 7.2: Vicious circle of NRW

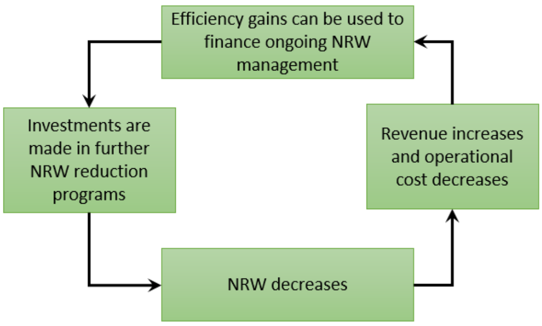


Figure 7.3: Virtuous circle of NRW

7.3 WATER AUDIT

For effective control of water losses, NRW of every DMA is to be determined by dividing operational zones. A city is divided into number of operational zones (OZs) which are further divided into number of sub zones called as District Metered Areas (DMAs). Each DMA is then critically studied for different demand patterns, leakages and unaccounted for water. Thus, the problem is divided into sub-problems and effective control measures are taken to provide effective solution for each sub problem to solve the problem in total.

Water audit identifies how much water is lost and the loss of revenue against the same. The objective of water audit is to help the utility select and implement programs to reduce distribution system losses. Water audits should be performed annually to help managers to adjust priorities, monitor progress, identify new areas of system losses, and establish new maintenance goals. A water audit followed by leak detection program can help water utilities reduce water and revenue losses and make better use of water resources.

7.4 WATER BALANCE

Effective water management scheme aims at understanding the standard water balance and minimizing/avoiding non-revenue water. A standard water balance is shown in Table 7.1.

Table 7.1: Standard Water Balance

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorized Consumption m^3/year</td><td rowspan="2">Billed Authorized Consumption m^3/year</td><td>Billed Metered Consumption (Including water exported)</td><td rowspan="2">Revenue Water m^3/year</td></tr>
<tr><td>Billed Unmetered consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption m^3/year</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water m^3/year</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses (NRW) m^3/year</td><td rowspan="2">Commercial Losses m^3/year</td><td>Unauthorized Consumption</td></tr>
<tr><td>Metering Inaccuracies and Data handling error</td></tr>
<tr><td rowspan="3">Physical Losses m^3/year</td><td>Leakages on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakages and Overflows at Utility’s Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

Total input of water in a water distribution network can be divided into two parts, (a) Revenue water and (b) non-revenue water.

7.4.1 Components of Water Balance

(a) Authorized Consumption: It includes the volume of metered and/or un-metered water taken by registered customers. Authorized consumption includes water required for firefighting and training, flushing of mains, street cleaning, watering of municipal gardens, public fountains, building water, etc. These may be:

- **(i) Billed Authorized Consumption:** It includes consumption of the consumers who are metered and billed and are producing revenue. It also includes billed unmetered consumption
- **(ii) Unbilled Authorized Consumption:** Though consumption, in this category, is legitimate but it is not billed and therefore do not produce revenue. These also include unbilled unmetered consumption.

(B) Water Losses: Water losses comprises of the commercial losses and physical losses.

(i) Commercial Losses: These include unauthorized consumption such water theft through illegal connections. It also includes inaccuracies associated with customer metering as well as data handling errors made by the meter readers and computation error at the time of billing.

(ii) Physical Losses: It comprises of leaks on transmission mains, losses due to overflow in tanks and leaks on service connections especially at the ferrule point.

7.5 COMPUTATION OF NRW BY STEP TEST

Step test is generally used to compute NRW within DMA. This technique, is usually undertaking during the night hours in order not to interrupt the regular supply of water to the customers. The minimum night flows are evaluated against expected and calculated legitimate usage within that DMA. If there is certainty that there is sufficient leakage for that DMA, Step Testing will be performed within that DMA to localize any leakage potential. After each section closure, re-evaluation of the recordable night flows is conducted to see if the amount of estimated leakage is found. This allows for quick and immediate decision making by the client in order to control the costs of the leakage survey. Estimated leakage potential within each isolated DMA and each subsection within that DMA will be known.

7.6 METHODS FOR REDUCING UNACCOUNTED FOR WATER (UFW)

7.6.1 By 100% Consumer Metering and Telescopic Tariff

100% Consumer metering and telescopic tariff based on volumetric measurement curbs wastage of water as excess and unnecessary consumption becomes costly for consumer. Thus, demand management is achieved which reduces NRW.

7.6.2 Leak Detection

The leak detection involves identification of actual leak points without carrying out any excavation. The main principle of these methods is to identify the location of each leak and magnitude of each leak’s severity, expressed in litres per second, in buried pipes. The principle includes a generated noise from the point of leak in the buried pipelines.

7.6.2.1 Methods of leak detection

The common methods used for leak detection includes followings:

(a) Finding leaks by visual inspection of surface: Visual indication of leakage in pipes like dampness and stagnant water are noticeable in cases of large leaks, or even small leaks of pipelines located just below the surface depending upon the soil condition.

(b) Detection of hidden leaks through leak locators: The usual way to detect leaks in buried pipes is using acoustic data loggers, correlators, listing sticks, or smart sensor methods. The sound generated by the leaks is detected through standard sounding rod or electronic leak detectors. The detection procedure follows the steps as below.

- Zone measurement
- Pre-location and
- Pin-point location

Shortcomings: As leak detection equipment work on the principle of locating the source of leak noise, thus noise generated in the system due to running of borewell pumps, customer usage, movement of traffic and other such interferences affects the efficiency of the method.

(c) Detection of hidden leaks through non-acoustic leak inspection: Leaks are detected in buried pipes using electric current or electro-magnetic smart sensors. These sensors have been developed to overcome the shortcomings of listening to leaks to provide greater locational accuracy, leak measurement, and remaining pipe wall thickness.

The detection procedure follows the steps as below.
• Identification of high priority DMAs
• Pipe insertion of sensor through existing valves, meter boxes or hot-taps and
• Pin-point location and leak quantification

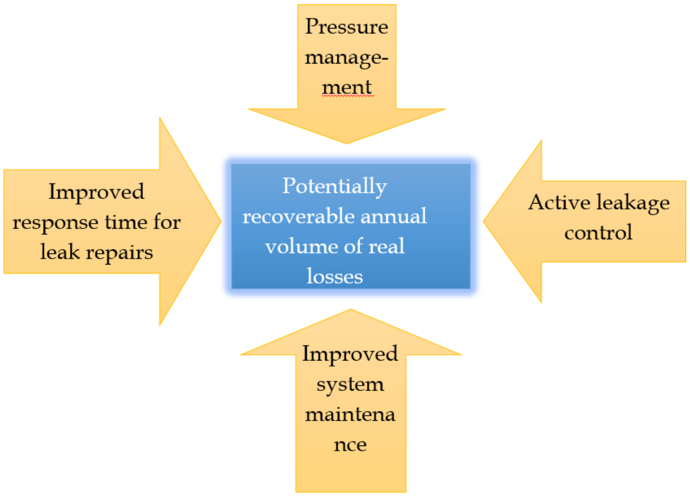


Figure 7.4: Flowchart for reduction in real losses of water

(d) Detection by Helium Gas: For leakage identification, modern methods such as detection using Helium gas techniques can be used which can be conducted in shorter time compared to the conventional methods.

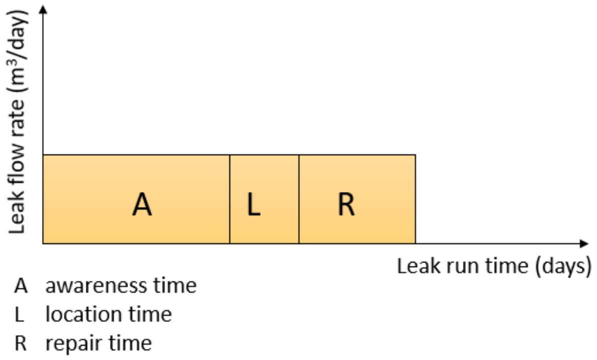
7.7 LEAKAGE REDUCTION MEASURES

Principally, the measures for reduction of both apparent and real leakages in the water distribution networks are shown in Figure 7.4. As shown in Figure 7.4, various Leakage Reduction Measures are Pressure management, Active leakage control, improved system management and improved response time for leak repairs.

7.8 RESPONSE TIME

Physical losses can occur along the entire distribution system, from storage reservoirs and the primary network to the smallest service connections.

When utilities think about leakage, they normally think of big pipe bursts. These often cause a lot of damage but are insignificant in volume compared to all the other leaks those do not come to the surface. Normally around 70% - 80% of water that is physically lost from leaks (medium and small leaks) cannot be seen on the surface. These leaks might eventually become visible after some time, 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 instead of coming on surface.



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

Figure 7.5: Water loss computation

The water volume lost from a pipe burst depends on both the flow rate and the leak run time as shown in Figure 7.5.
The leak run time consists of three components:

1) Awareness time: time until the utility becomes aware that there is a leak
2) Location time: time spent to locate the leak so that a repair job order can be issued
3) Repair time: time between issuing of repair job order and completion of the repair

7.9 ESTIMATING LOSSES

Once DMA is established by fixing flow meter at entry point of each DMA, it becomes a tool for monitoring the NRW. NRW has two components, physical and commercial losses. Both of these components can be monitored. NRW in DMA is computed by the following equation,

DMA NRW = Total DMA Inflow- Total DMA Consumption

7.9.1 Estimating Physical Losses

With bulk meter installed at the entry point of DMA, total DMA inflow is measured. If 100% metering is made within DMA, total DMA consumption would be summation of consumer meters measurements for the period in which calculations are made.

Physical losses within DMA are due to the leaks on main pipes and leakages through the consumer house connections. Leaks from the main pipes would be continuous for the whole 24 hours of the day; whereas leaks from consumer connections fluctuate due to consumer's demand at peak hours and are minimum at night. Therefore, leakages during night should be monitored. A flow pattern in a typical DMA is shown in Figure 7.6.

Inflow to DMA is measured continuously by the bulk meter which is installed at the entry point of DMA resulting the curve shown in blue in Figure 7.6. Its Minimum Night Flow (MNF) is noted which is at night.

If the Legitimate Night Flow (LNF) is subtracted from the MNF, Net Night Flow can be computed which is as below,

$$NNF = MNF – LNF$$

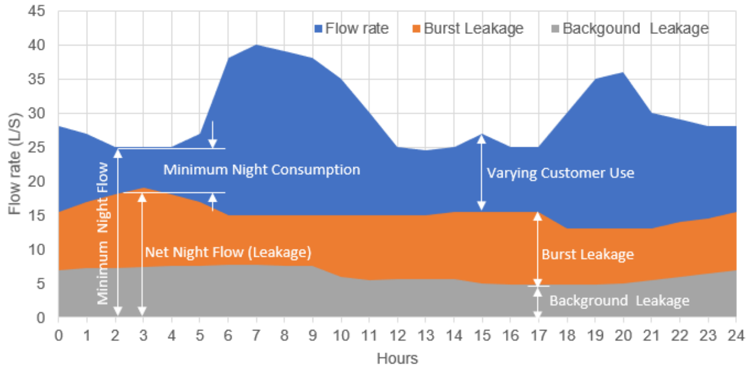


Figure 7.6: Flow pattern in a typical DMA

7.9.2 Estimating Commercial Loss

Since, Total NRW = Physical Loss + Commercial loss, Commercial loss is computed by,

$$\text{Commercial losses} = NRW – MNF$$

7.10 LEAK REPAIR PROGRAM

Bursts can be identified by the variation in minimum night flow over longer period, say 180 days. A typical such variation in a DMA is shown in Figure 7.7. These variations in night consumption can be observed and then can be identified and repaired.

Reported bursts are visible leaks and are also removed in reasonable time by ULB. However, small leakages do not come to surface and cause increase in NRW and contamination. These invisible leakages appear and are shown as background leakages in Figure 7.7. Unreported bursts can also be detected. Such one unreported

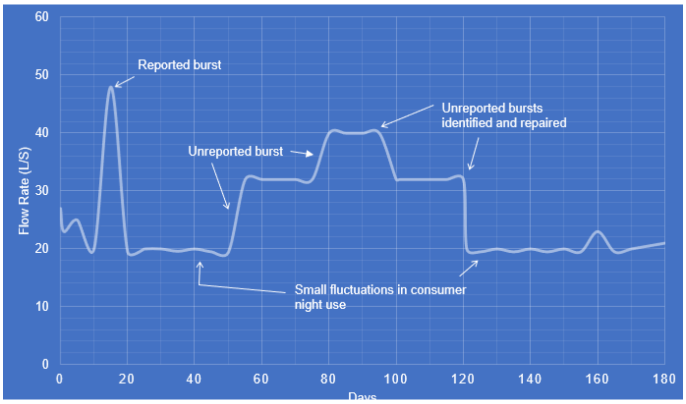


Figure 7.7: Fluctuation in minimum night flow over 180 days

burst is appearing on day 45, since it is not removed, the losses are continued and again another unreported burst occur on day 67. When both the unreported bursts are removed, NRW level is brought down as shown in graph. This is the advantage of SCADA and monitoring work carried out.

7.11 SCADA ATTACHED TO DMA

DMA meter should be connected to the Supervisory Control and Data Acquisition (SCADA) system. SCADA systems when connected, are used to monitor variation in minimum night flow and hence can be used to identify the leaks and bursts in the system.

7.12 DMA MANAGEMENT

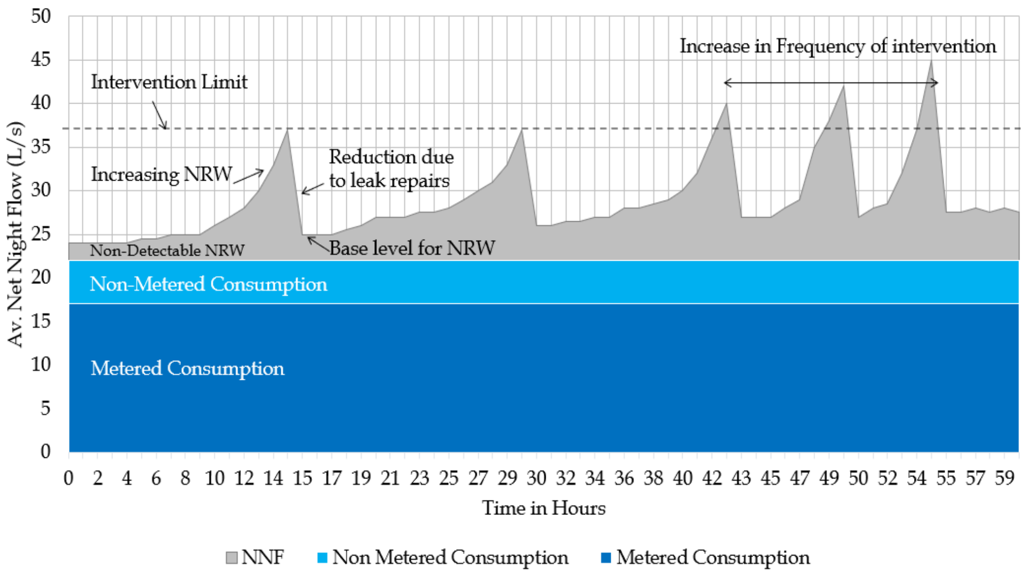


Figure 7.8: Variation NNF with respect to time

As soon as DMA is established initial values of NRW, net night flow (NNF) should be recorded. As shown in Figure 7.8, NRW values generally increases with time. Operator should fix the Intervention limit. When NRW reaches this limit, the task of NRW reduction is taken up. NRW is lowered to its base level. As time moves on, value of NRW again increases. Operator has to again bring NRW to its base level. If frequency of intervention increases rapidly, then the pipe replacement should be made.

****

Appendix A

Break Pressure Tank (BPT)

A BPT is generally provided on highly slopping pipelines laid in hilly areas. BPT is also required for long lengths of gradually slopping gravity mains. Another requirement is to provide BPT at the junction of pimping main and gravity main. This type of BPT is discussed here. The purpose of BPT is to dissipate the excessive pressure from the pumping main and thus break the HGL at the end of pumping main and bring it down to water level inside BPT. By inserting BPT, pumping main is converted to gravity main.

A typical BPT on hillock is shown in Figure A.1. BPT on plain terrain is shown in Figure A-2. BPT is provided on long pipeline to reduce pressures in the pipeline. In short by inserting BPT, the pipeline downstream side of BPT acts as gravity main.

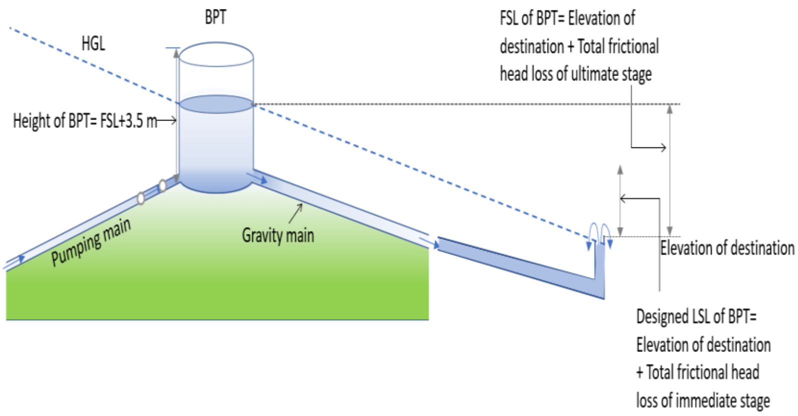


Figure A1: Arrangement of Break pressure tank

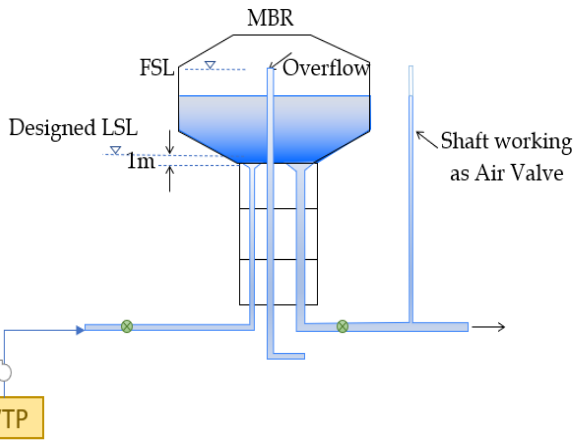


Figure A2: Arrangement of Break pressure tank on plain terrain

The diameter of the raw water pumping main is designed for thirty years, i.e., the economical diameter is suitable for intermediate and ultimate stage. Pumps are designed for intermediate stage (Base year + 15 years), i.e., pump characteristics are suitable for demand and head requirements of intermediate stage. Diameter of gravity main by thumb rule is one or at the most two sizes more than the economical diameter of rising main.

Common Observation: It is observed that in the absence of guidelines, often the size of BPT is arrived at, from consideration of volume required to store water at steady design discharge for an arbitrary period. The arbitrary period is decided based on experience of the designer, which could be wild guess like five minutes, ten minutes or fifteen minutes. Because of the fear that the size may become inadequate, BPT's size much larger than required are provided at various locations.

Categories of pipeline on downstream side of BPT: The pipeline on downstream side of BPT can be classified into three categories depending upon the characteristics of pipeline which include longitudinal profile of pipeline, average slope of pipeline and slope of energy grade line (EGL).

(a) When average slope is greater than the slope of EGL, pipe will always run partially full and BPT will remain empty for all the time. Providing large size BPT in this case is not required and BPT with nominal size is enough.

(b) In another case, average slope of is less than the slope of EGL, longitudinal profile of pipeline is such that during no flow, pipeline remains empty as the water is drained out due to continuous downward slope after stopping inflow into BPT. In this case when the inflow to BPT starts, water enters pipeline and process of filling up of pipeline begins and water level in the pipeline starts rising. Simultaneously, velocity of water in pipeline increases gradually. Thus, water level will reach its Steady State position gradually and will remain stationary at that position. In this case large size BPT is not required, nominal size is enough.

(c) In third case average slope of pipeline and slope of energy grade line (EGL) but longitudinal profile is in the form of inverted siphon as shown in Figure A1.

Deciding Lowest Supply Level (LSL) of BPT: Outlet of pumping main and inlet of gravity main shall be kept at the same level and should be at bottom of BPT as shown in Figure A1.

This will save additional head on the pumps which otherwise would have come if the outlet of pumping main is kept above FSL of BPT. By this arrangement, the advantage is that water level in the BPT can rise to such a level that driving head is just sufficient to negotiate the frictional losses occurring in the gravity main for immediate stage. This will save energy cost for immediate stage. In the ultimate stage also, water will increase to rise just to required level and the energy cost can be saved.

Initially, driving head required to pass the intermediate stage (base year+15) flow through the gravity main is required to be computed which is equal to the elevation of destination, in this case elevation of lip of aerator plus the total frictional head (including minor losses) of intermediate flow as shown in Figure A1. Care should be taken that while working out the frictional head loss, C-value of new pipe (maximum C-value) should be taken. Thus, the LSL of BPT is decided.

Deciding FSL and Height of BPT: Initially the frictional head loss (including minor losses) for the ultimate flow that the gravity main can pass should be computed. Care should be taken that while working out the frictional head loss, C-value of old pipe (lowest C-value) should be taken. FSL of BPT is then elevation of destination plus the frictional head due to ultimate flow (including minor losses). Considering safety of 3m against overflowing, the height of BPT is then computed as,

Height of BPT = FSL + 3.5 m (including free board of 0.5)

Area of cross-section of BPT: Professor R. N. Ingle (V.N.I.T., Nagpur) has developed Guidelines for sizing Break Pressure Tank. Based on the equation of continuity and equation of motion he developed equation for cross-sectional area of BPT which is

$$A_T = \frac{4AL}{F^2 V_0^{\ 2} g}$$

Where: A_T= Cross-section area of BPT; A= Cress-section area of downstream gravity pipe;

D= Diameter of gravity pipe; F=fL/(2gD) = friction loss coefficient; g =gravitational acceleration; L=length of pipeline; V_0= Steady state velocity in the pipeline. $Hf=FV_0^2$

Or, $F = \frac{Hf}{V_0^{\ 2}}$

Here Hf can be computed using the Hazen William Formula.

Illustrative Example: To illustrate the application of the criteria developed, data of the water supply scheme of one city is considered.

Data: The gravity raw water main is from BPT to aeration fountain. The gravity main is prestressed concrete pipeline of length 30,900 m and internal diameter 1500 mm.

The outlet of gravity main (elevation of destination) is in the form of lip of aeration fountain kept at RL of 396 m. Computation is shown in Table A1.

Table A1: Computation of sizes of BPT

SN	Parameter	Formula	Immediate stage	Ultimate stage
1	D = Diameter of pipe (mm)	Data	1500	1500
2	L = Length of d/s gravity pipeline (m)	Data	30,900	30,900
3	Elv_D= Elevation of destination (Lip of aerator)	Data	396	396
4	A= Cross-sectional area of gravity pipe, (m2)	$A = \frac{\pi}{4} D^2$	1.767	1.767
5	HW C-value	Data	145	140
6	Q_{MLD}= Flow (MLD), Q_{MLD}	Data	110	150
7	Q=Flow (M^3/s)	$Q = \frac{Q_{MLD} * 1000}{(24 * 3600)}$	1.273	1.736
8	V_0=Velocity in gravity pipe (m/s)	V_0=Q/A	0.720	0.982
9	hf =Frictional Head loss (m)	$hf = \frac{10.67L}{\left(C^{1.852} D^{4.87}\right)} Q^{1.852}$	7.111	13.478
10	H_f= Total Frictional Head loss + minor losses (m)	Hf = 1.1 (hf)	7.822	14.826
11	LSL of BPT	LSL of BPT= ElvD + Hf (of immediate)	396+7.822= 403.822	
12	FSL of BPT	FSL of BPT= ElvD + Hf (of ultimate)		396+14.826= 410.826
13	Bottom RL of BPT	LSL-0.5	403.822- 0.5=403.322	
14	Top RL of BPT			410.826+3.5=414. 3 m
15	F = Friction constant	$F = \frac{Hf}{(V_0)^2}$	15.070	15.361
16	A_T= Cross-sectional area of BPT(m^2)	$A_T = \frac{4AL}{F^2 V_0^2 g}$	188.872	97.767
17	D_{BPT}= Diameter of BPT	$D_{BPT} = \left\{\frac{4A_T}{(\pi)}\right\}^{0.5}$	15.51	11.16
18	Volume of BPT	A_T (FSL-Bottom RL)	1417.217	733.603
19	Retention time (minutes)	Volume/ Q	18.5	7.04

Inference: From above Table A1, diameter of BPT is 15.5 m and retention time is 18.5 minutes.

**

Appendix B

Case Study of Pune 24x7 Water Supply

BRIEF OF PROJECT

The present population of Pune city is about 40 lakhs, and the area of jurisdiction is 243 Sq km. The present coverage with house service connection is 94%. The existing average per capita supply is 194 LPCD and the proposed per capita water supply is 150 LPCD till the ultimate design period of 2047. There are three sources of water supply to the five areas of the city. Out of 5, 4 packages are with L&T and one package is with Jain Irrigation who was terminated due to slow progress.

Presently, the demand of the city is 1496 MLD, hence 499 ML storage is required. Existing operative 83 tanks have storage capacity of 328 ML. Hence to cater the balance demand, new tanks have been planned by the PMC. Entire city is proposed to be divided in 141 operational zones and 328 District Metered Areas (DMAs). PMC proposed to lay clear water pumping main and clear water gravity main in different zones. The total existing length of distribution system is 2,544 KM, of which 218 KM will be retained. New pipe network of 1,400 Km will be added. The work was started in the year Feb 2018 and proposed to be completed by March 2023. The health department of the PMC is carrying out enough Orthotolidine Tests to check the residual chlorine in drinking water, which is satisfactory.
PMC has proposed to take up the following activities.

- Revamping of Transmission System
- Pump House
- Construction of Service Reservoirs
- Revamping of the entire Distribution system
- Full City Smart metering
- SCADA
- Volumetric Billing
- Consumer Awareness
- Intermittent to Equitable Water Supply
- Equitable to 24X7 Water Supply
- Reduction of NRW to 15

Demo DMA

Demo DMA at the Ganesh Nagar area is shown in Figure B1. Currently, water is supplied only for 1 hour in a day in Ganesh Nagar Demo DMA. The population residing in this DMA is about 6000 and 680 connections are existing. All connections are with AMR meters (Figure B2), but these meters are not yet operationalised. Residents take water from PMC's pipeline to their underground tank (Figure B3).

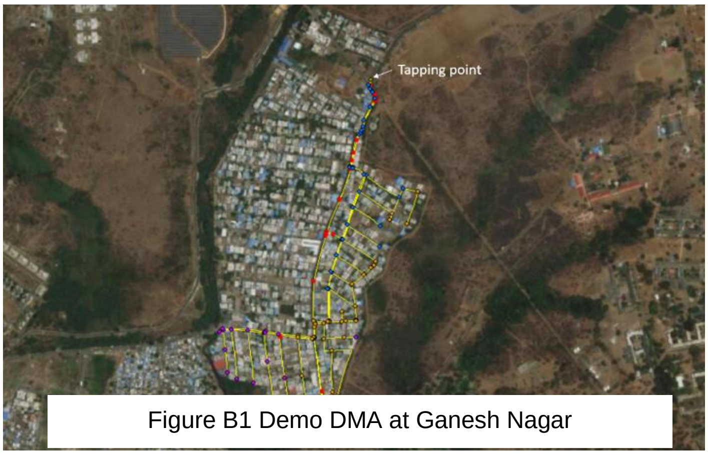


Figure B1 Demo DMA at Ganesh Nagar

Figure B2: AMR meter at Ganesh Nagar

Figure B3: Underground tank of a resident at Ganesh Nagar

BULK METER AT ENTRY OF DMA

The Electro Magnetic bulk meter (Figure B4 and B5) is installed at the entry of this DMA.

Figure B4: Bulk meters with sensor at entry of DMA

Figure B5: Bulk meters reader and transmitter

TAKE AWAYS

The water sources of the Pune city are found adequate for 24x7 project. The city will get water at the rate of 150 LPCD.

1. At present there are 103 service reservoirs, and new service tanks are being constructed to form 141 operational zones.
2. PMC is providing about 3.15 lakhs of AMR meters to all the connections and ensuring 100% consumer metering which is essential for 24x7 water supply project.
3. PMC is developing the dashboard for these AMR meters. All the AMR meters shall be geo tagged which can be seen on the GIS. Walk-by-system is provided to record the water consumption readings.
4. 328 DMAs are planned in 141 operational zones in the city. It is advisable that the pressure loggers should be installed in these DMAs so that the sudden drop in pressure can indicate the likely leakage spots.
5. PMC has proposed to introduce AMI (Automatic Metering Infrastructure) for automatic meter reading without manual interventions.
6. Supervisory Control and Data Acquisition (SCADA) is applied to headworks, water treatment plants.
7. PMC will integrate live SCADA data with a calibrated hydraulic model, to compute real-time conditions throughout water networks. By doing so, flow through any pipe and nodal pressure at any junction can be known at any point of time.
8. PMC proposed to reduce the NRW from 40% to 20%. The water supply system implemented in Pune city will lead to effective demand management and control of NRW to less than 15% or the economic level of NRW whichever is higher.
9. To achieve NRW reduction, it is important to compute NRW in each DMA that are commissioned. The bulk meter installed at entry point of each DMA and aggregation of the consumption recorded by the AMR meters will help computing the NRW.
10. PMC has engaged L&T for their O&M partner for a period of 10 years after implementation of the project in 2023. However, PMC should ensure self-sustainability of the project by introducing differential tariff structure and by improving service level.
11. Predictive Operational Analytics will be carried out by PMC. For this, Asset Management System driven by the end-user will be made operational with intelligence platform that provides real-time predictive behaviour of the system, especially that of the distribution system.

*****

Appendix C

Case Study of Coimbatore 24x7 Water Supply

BRIEF OF PROJECT

Present population of Coimbatore city is about 15.95 lakhs, and the area of jurisdiction is 246.8 Sq. km. There are 100 wards in the city. But the project area for consideration of implementation of 24x7 project is 105 Sq. km with population of 10.61 lakhs residing in the 60 wards. The city gets water supply from the four sources, namely, Siruvani, Pillur, Aliyar and Bhavani. Siruvani source is monsoon dependent and other three sources are perennial. Total sustained supply from these sources is 187.1 MLD which will be augmented by 178.3 MLD by 2035 and reaching a total of 318.2 MLD by the turn of 2050. Overall, the sources of the city are sufficient for 24x7 water supply project. Per capita availability is 120 LPCD and after commissioning Pillur-3, it will increase to 370 LPCD which is more than the design norm.

Study Period of the project was 1 Year and works to be completed in 4 years. O&M period will be for 25 years including the works Period. The works under the Project Scope are: (1) Design, Rehabilitation and Implementation of Water supply infrastructure including Feeder mains, Service Reservoirs, Distribution network, HSCs, Meters, valves, etc.; (2) O&M of distribution system with conventional KPI objectives – Reduction of NRW, maintaining water quality at consumer level and (Expand)CRM and (3) Meter reading, Billing and Collection. Project funding.

SCOPE OF WORK

There are 36 Service Reservoirs with storage capacity of 386.5 Lakh litres. During construction period, the Concessionaire has to build 32 new service reservoirs with the storage capacity of 686.30 Lakh litres. Hence there are 68 operational zones which are being divided into 99 District Metered Areas (DMA)s. About 625 kms of new distribution network has to be laid down and about 1115 kms of the network shall be replaced with retention of 130 kms existing network.

In addition, the Concessionaire has to make/replace 150,000 Connections with 100% metering. In addition, Concessionaire has to design and create SCADA and Instrumentation for Flow meters, Level transmitters, Pressure transmitters, Pressure data loggers and Water quality instruments. The parameters of minimum water head (7m) at ferrule point, treated water quality at user taps, extent of resolution of user complaints, reduction of NRW (20% from 5th to 10th Year; 15% after 10th year) and Collection Efficiency (80% from 5th to 10th Year; 90% after 10th year) are incorporated in the tender document.

Though reduction of NRW (20% from 5th to10th Year; 15% after 10th year) is mentioned, the base line NRW level is not mentioned by the PMC.

GIS Application

GIS work of the project is satisfactory.

Existing Pipe Network

Coimbatore Municipal Corporation (CMC) mentioned that the some of the existing pipelines are being used in the present project. These pipes have been identified and mapped after consultation with the staff that laid these pipes, and the condition assessment survey has been undertaken.

GIS Based Consumer Survey

Project Management Consultant (PMC) informed that they have conducted consumer survey and each connection is Geo-tagged. This activity is important to make 100% bill collection.

Boundary of Operational Zones

Total demand of the city is 318.2 MLD. Hence the storage required is about 106 ML. Presently, the existing and proposed tanks together shall have a storage of 107.3 ML. Hence, capacity of the existing and proposed tanks together seems to be sufficient.

District Metered Areas (DMAs)

DMAs are the building blocks of any 24x7 pressurized water supply project. PMC explained that total 99 DMAs are designed.

Consumer Meters

PMC informed that there are 150,000 water connections, and 100% consumer metering is being done. 30% of the existing meters are not working. They informed that all the meters are being replaced.

SCADA

Supervisory Control and Data Acquisition (SCADA) shall be used for headworks, water treatment plants to control the water in distribution system of the city.

PILOT OPERATIONAL ZONE

Figure C1: Operational zone of the R.S. Puram

There are two DMAs in this operation zone. DMA1 caters to high level areas and DMA2 caters to low level areas.

In DMA1 total house service connections (HSC) to be replaced is 2464 and in DMA2 it is 3352. So, in the operational zone total HSC shall be 5816. One of the operational zones is shown in the Figure C1.

TAKE AWAYS

1) The 24x7 water supply scheme is being implemented satisfactory with minimum water pressure (7m) at ferrule.
2) To achieve NRW reduction, it is important to compute NRW in each DMA that are commissioned. The bulk meter installed at entry point of each DMA and aggregation of the consumption recorded by the consumer meters will help computing the NRW.
3) CMC has engaged PMC for their O&M for an operational period of 25 years for implementation of the project. However, CMC shall ensure self-sustainability of the project by introducing differential tariff structure and by improving service level.
4) Predictive Operational Analytics shall be carried out by CMC. For this, Asset Management System driven by the end-user shall be made operational with intelligence platform that provides real-time predictive behaviour of the system, especially that of the distribution system.

***

Appendix D

Case Study of Puri 24x7 Water Supply

INTRODUCTION

Intermittent water supply systems in developing countries like India, suffer from several deficiencies like inadequate & poor design, operation & maintenance problems, economic stress etc. At many places, water at consumer end has insufficient quantity and substandard quality.

Way back in 1949, Govt. of India aspired 24x7 continuous water supply systems by approving report of the “Environmental Hygiene Committee Report” of Government of India. The report states ‘It has been demonstrated recently at Lucknow that the water-works authorities can successfully supply water all the 24 hours, educate a community used only to intermittent supply to adapt themselves to continuous supply and reduce consumption’. This shows the long-lasting aim of improving service delivery of water supply by providing pressurised continuous water on 24x7 basis. The merits of 24x7 system and demerits of an intermittent system are shown in Box-1.

Box-1: How Superior is pressurized 24x7 water supply system?	
Intermittent	**24x7 System**
1) High health risks	1) Stops contamination
2) Leakage control is passive	2) Reduction in medical bills
3) No demand management	3) Leakage control is active
4) Few meters	4) Demand management is possible
5) Flat water rates	5) 100% consumer metering
6) Wastage of treated water	6) Telescopic tariff or billing as per water tariff
7) Service level is poor and cannot be measured	7) Reduces consumption.
8) Inequitable distribution of water and inadequate pressure	8) Equitable distribution and sufficient pressure
9) Less financial sustainability	9) Better service level
10) Large doses of chlorine	10) Financial sustainability
11) Capacities underutilized	11) Life of network increases
12) Valves- wear and tear	12) Better demand management
13) More manpower- zoning	13) Consumer satisfaction
14) Large sizes of pipes	14) Water is accessible to poor
15) Supply hours affect poor	15) Willingness to pay- even in slums
16) Storage is required	16) Time for rewarding activities
17) Pay for pumping for rooftop storages.	17) Attracts industries
18) Meters go out of order	18) System operates in quasi-steady state reducing wear and tear
19) Store and throw water	

Though the country has made significant progress after independence, the service level in water sector is not satisfactory. It is estimated that 50% population will live in urban areas by 2050. Providing safe and continuous water supply of required quantity and acceptable quality to the population is a formidable task and huge challenge to the administrators and engineers. Currently, all cities are providing intermittent water supply to its population. Some cities are making efforts towards converting their existing intermittent water supply system into continuous 24x7 water supply system to improve the service quality.

In the present scenario of intermittent water supply system, in most of the cities/towns, the NRW is about 45-55% and the water is bacteriologically contaminated due to entry of wastewater/ sewage into water supply pipelines during non-supply hours. The NRW can only be controlled with the application of continuous (24x7) water supply in the cities in a phased manner. NRW reduction is only possible by creating number of District Metered Areas (DMA)s and operational zones under continuous (24x7) water supply system.

THE CHALLENGE

Drinking Water Supply in Urban Odisha had been facing severe challenges since decades and the water supply infrastructure could not cope up with the pace of increasing urbanization. Poor service coverage, poor water quality, intermittent supply and high-water losses were the predominant water supply challenges that were required to be addressed to solve perennial water woes.

To ensure a more qualitative, equitable, efficient and sustainable urban water supply system, the Principal Secretary of Government of Odisha has put more thrust on improving the level of urban drinking water services in the state for universal coverage with adequate quantity and acceptable quality of drinking water supply, with easier and equitable access of the services to all categories of people in the society.

Strong Leadership and committed mandate at all levels, right from the top level of Hon'ble Chief Minister, to provide piped drinking water to each home round the clock, enabling policy interventions and dedicated execution of works resulted in transformation in the Drinking Water Supply Scenario in Odisha and especially in the Puri city.

Upon achieving the universal coverage across the state, the Government of Odisha moved into higher orbits in the Drinking Water Supply with the Mission Drink from Tap. The Mission is a dream project of the Hon'ble Chief Minister, Government of Odisha, Shri Naveen Pattnaik.

MOTIVATION BY STRONG LEADERSHIP

As per constitution of India, water is the subject under the state list. After adoption of 73^{rd} & 74^{th} constitutional amendments, the local bodies have been empowered by decentralization, hence the State Governments have taken up number of schemes entrusted to Municipal Councils or Corporations which are financed under Central Assistance.

Odisha is one of the pragmatic states, implementing the “Drink from Tap Mission.” 24x7 continuous water supply schemes, are being contemplated under this program under the “5T” Governance Mantra of Government of Odisha, which takes Transparency, Technology, Teamwork and Time, and combined them to bring about Transformation.

To accelerate this program, the Principal Secretary of Odisha strengthened and deployed his State Government’s water wing. In line with the requirements of 74th Amendment Act, Water Corporation of Odisha (WATCO) a ‘not-for-profit’ company has been established by the visionary and dynamic Principal Secretary, UD with the mandate to provide water and wastewater related services on sustainable basis in many municipal areas including Puri. Gradually, the services of WATCO are being extended to other Urban Local Bodies (ULBs) of Odisha. The objective of creating the corporate entity (WATCO) is to encourage corporate governance & efficiency, functional autonomy and customer centric service culture in the Water Supply Service Delivery.

With motivation and inspiration from the Principal Secretary, WATCO initiated new ideas, innovative techniques, latest technology, GIS mapping, hydraulic modelling etc. WATCO is successful in completing project in Puri, especially proudful to create third Party Quality surveillance, reducing NRW from 55% to 15%, and self-help women group for public participation. Puri being a famous pilgrimage centre where Lord Jagannath temple is situated, WATCO got prepared Preliminary Report, DPR, BOQ tender etc. within 14 months (costing Rs. 46 Crores) and then converted the prevailing intermittent water supply system into 24x7 Water Supply in record time of only 9 months with driving force of the Principal Secretary.

It is pertinent to mention that Puri has already implemented 24x7 water supply for the entire city. The Members of the Expert Committee of CPHEEO for the revision of water supply manual (supported by GIZ, German Development Cooperation) visited (Figure D1) Puri during 21-22 Oct 2021 to understand the successful implementation of 24x7 water supply.

Besides Puri, Pune and Coimbatore are also implementing 24x7 water supply projects for covering 100% urban population. Ministry has also introduced continuous (24x7) water supply in 500 AMRUT cities in the recently released operation guidelines of AMRUT 2.0 as part of reforms so as to achieve the reform of NRW below 20% and also to ensure drinking water quality as per Indian Standards IS:10500. The 24x7 continuous water supply will attract more PPP funding, financially sustainable and also improve service level in the cities.

Figure D1: Visit of Expert Committee members

Objective of this report is to highlight the efforts taken by the Principal Secretary, Odisha and Engineers of WATCO towards the transition of intermittent water supply to pressurised 24x7 continuous water supply system so as to drink water directly from the tap by the population of Puri city.

DRINK FROM TAP MISSION

The ‘Drink from Tap’ Mission, launched by the Government of Odisha during October 2020, is an aspirational and ambitious, first of its kind program in the country. This program is undertaken by the Govt of Odisha to supply ‘Drink from Tap’ Quality piped drinking water to citizens on a 24x7 basis.

‘Drink from Tap’ aims to ensure that the water received at the consumer tap can be directly used for drinking and cooking purposes without any need for further filtration/boiling/treatment. With this Mission, Govt of Odisha aims to match the service delivery standards of the developed country to make piped drinking water available at the household level across the state.

The Mission aims at availability of quality water round the clock (24x7) in each house, elimination of household level storage (sump), efficient pumping and treatment, water conservation through metering, reduction in NRW & cost of production, quick resolution of issues/complaints, and above all real-time data sharing on water quality levels to enhance public perception and trust in the service delivery of WATCO. The Mission objectives are:

1) Drink pure water straight from the Tap: Conversion of intermittent water supply systems to continuous (24x7) water supply systems to reduce the health risks for users that are likely to be caused due to contamination of water pipelines through joints and damaged segments in intermittent supplies when a system is not under pressure.
2) Equitable, sustainable and people-centric service provision with focus on the urban poor.
3) Water Supply Management through Community Partnership (Self Help Groups) – “Jalsaathi” (Figure D2).
4) 100% coverage of households with piped drinking water in adequate quantity and with quality as per recommended standards.
5) 100% metering of house connections to eliminate non-revenue water (NRW) due to leakages and wastage for full cost recovery.
6) Adoption of innovative, state-of-the-art technology & management techniques, both during construction and operation & maintenance.
7) Quality Assurance through Third Party Quality Monitoring & PPP Laboratories (Figure D3).

Figure D2: Interaction with Jalsaathis

Figure D3: Mobile Laboratory for Water Quality monitoring

MISSION IMPLEMENTATION IN PURI

The water supply infrastructure in Puri was mainly augmented under JNNURM and AMRUT schemes until 2019. The water was supplied from groundwater sources on intermittent basis.

Under the ‘Drink from Tap’ Mission, comprehensive assessment of infrastructure gap was carried out and zone wise Detailed Project Reports (DPR)s were prepared for conversion of Intermittent Water Supply into Continuous Water Supply and migration to surface water source (Bhargavi River) followed by execution of work, installation of household connections and meters.

PROJECT BRIEF

After successful running of 24x7 in pilot zones for about a year, especially supply to slum/low income group areas, WATCO upscaled it to entire Puri city covering a population of 2.5 lakhs and having 32,300 house connections spread across 32 wards including 64 slum areas covering 66,000 slum populations. All these are spread over an area of 16.84 Sq. Km. In addition to this, Puri being a world-famous pilgrimage city has been visited by nearly 2 crore people annually adding to the challenge of supplying drinking water to this large population.

A comprehensive survey/ planning was conducted before embarking upon the mammoth task of converting intermittent supply system to 24x7 supply with arduous task of achieving 'Drink from Tap', thus ensuring drinking water quality at all times and in all places in Puri City.

The Key Information

Key Information of Puri city is as follows:

- Population: 2.5 Lakh (approx.)
- Source: River Bhargavi
- Slum Population: 66,000
- No. of Households: 32,017
- Water Treatment Plant (WTP): 42 MLD
- Total Water Demand: 38 MLD
- No. of Ground Service Reservoirs (GSR)s: 5
- No. of Elevated Service Reservoirs (ESR): 19
- No. of Water Testing Laboratory: 1
- Operational zones (OZ): 19
- No. of DMAs: 19 Nos, one per operational zone with 1000 to 2000 connections
- Length of Water Distribution Pipelines: 275 Kms
- Clear Water Rising Main: 46 Kms
- Raw Water Rising Main: 800 Meter

Distribution System

There are 19 District Metered Areas (DMA)s in Puri city as shown in Figure D4. The jurisdiction of each service tank has been considered as the service area of the DMA. This means one tank serves one OZ/DMA, thus making the decentralized control of supply and demand. Thus, there are 19 tanks and 19 OZ having 1 DMA each (19 DMAs) in the entire city. Peak factor of 2.5 has been considered in the design of distribution system.

Figure D4: Total 19 DMAs in Puri

Project Cost

Project cost of schemes under various programs is shown in Table D1. As can be seen, the State Government has judiciously built up the required infrastructure over many years using both Central as well as State funds.

Table D1: Project cost of schemes (Crores)

Program	Centre	State	Total	Remarks
JNNURM	72	18	90	Centre: State- 80:20
AMRUT	44	44	88	Centre: State- 50:50
Sujal (Drink from Tap)	0	46	46	State Funding (House Connection plus metering, control valves, Bulk flow metering & Ultrafiltration - WTP)
Total	116	108	224	

The per capita cost for formation of DMAs, flow control valves, bulk flow meters, pressure reducing valves and replacement of house service connections (HSC) with water meters (mechanical meters) is Rs. 1840/. The overall per capita cost considering the project cost incurred for creating infrastructure under JNNURM and AMRUT with all DMAs formation is about Rs. 8,960/-

Duration: It took about 14 months for survey, investigation, planning, design and tendering for the implementation of “Drink from Tap Mission” to convert from intermittent to 24x7. But execution for 24x7 WS was carried out in just 9 Months, indicating that a very detailed survey and careful planning is essential in faster implementation of the project. It also needs to be noted that once the planning was done, there was no deviation thus ensuring proper and successful implementation of the scheme. Earlier to this, JNNURM and AMRUT schemes funds were used to build the basic infrastructure for over a period of 5 years.

Site Visit

On 21st Oct 2021, team of the Expert Committee, constituted by the Ministry of Housing and Urban Affairs, Govt. of India, visited three DMAs (Figure D5) in Puri city.

Figure D5: Vist of the team to DMA & ESR.

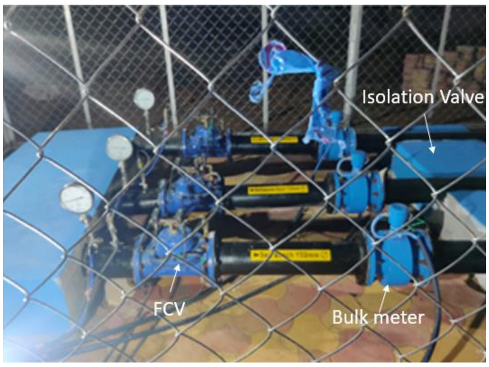


Figure D6: Outlet arrangement of ESR

Equitable Distribution of Water

The Team observed at site of DMA that on the outlet of ESR, isolation valve is installed followed by bulk meter and then the Flow Controlling Valve (FCV). This arrangement is shown in Figure D6. The proposed guideline on 24x7 proposed the similar arrangement that "all DMAs need to be fed by exclusive pipeline from outlet of ESR with branches and consumer connections should not be given from these pipelines. Each DMA should have only one inlet. This arrangement provides equitable distribution of water as per designed nodal demands with designed residual head." It was also explained that in case of emergency, there are mechanisms to let in water into DMAs which are isolated either by neighbouring DMAs or by supplying water through tankers. The Team expressed satisfaction on these arrangements.

POLICY INTERVENTIONS

a. Inclusivity Approach: Water Supply Services to the Urban Poor: The State Urban Water Policy envisions "RIGHT to WATER" for everybody. Providing Water & Sanitation Services to the Slums is one of the top priorities of the mission. It is mandated to cover the entire slum households/populations across the state under the mission in a phased manner. Convergence of the Mission with the various ongoing urban poor development programs of Government such as JAGA Mission ensured greater reachability.
b. Government of Odisha implemented enabling policy interventions which are as follows:
    1) Right to water
    2) Execution of connection by PHED/WATCO as public works
    3) Household need not bother to obtain road cutting permission for connection
    4) Easy instalment on connection charges

5) Explicit component of community participation now with 100% coverage

c. The administration has relaxed house connection norms for the poor which are as below:
   - Water connection with indemnity bond
   - Waiver of connection fee
   - Providing house connection with two taps at Govt. cost under AMRUT for the slums
   - Covering all uncovered slums under AMRUT and now under State Plan
   - Shift from hand pump, tube wells to Piped Water Supply - equity in water distribution

COMMUNITY LED WATER DISTRIBUTION

In 2019, with inspiration from state level administration, the City Administration and WATCO started community lead novel water supply management by partnering with Self Help Groups (SHG)s, called as "Jalsathi." Jalsathi (Figure D7). The 'Jalsathis' have acted as bridge between customers and WATCO. Their partnership is based on incentives for women of SHGs. The Jalsathi's get 5% of water supply revenue collected from the consumers, Rs. 100 for new domestic house connections, Rs. 300 per new commercial connections and Rs. 20 for each water quality tests at consumer end.

The roles and responsibilities of Jalsathi are as below:

1) Facilitating new connections, identifying illegal connections and regularizing them
2) Reading water meters, distributing water bills, and collecting user charges
3) Field water quality testing
4) Support in consumer complaint redressal
5) Sensitizing people on water conservation

Figure D7: Jalsathi women group at Puri

Currently, 32 Jalsathis are working on the mission in Puri, achieving 97% efficiency in revenue collection.

SALIENT FEATURES

Some of the salient features of the scheme are as below:

24x7 Interactive Voice Response (IVR)s based Customer Care

The Centralised Customer care centre is provided with the facility of IVRS based automatic complaint logging, transfer to concerned staff for action and online real-time tracking of redressal.

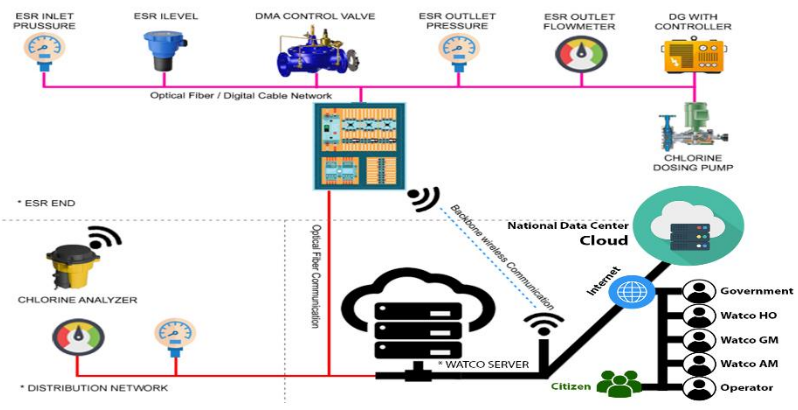
GIS Mapping of Assets and Consumers

Both assets and consumers in the entire city including slums pilot areas have been Geo Mapped on the GIS platform and real time data is obtained from the PLC (Programmable Logic Controller) /SCADA (Supervisory Control and Data Acquisition) to a central server.

SMART Water Management

To achieve real-time data capture, analysis, decision making and public reporting, the “Smart Water Management System under “Drink from Tap Mission” was conceived and has been implemented initially in 4 pilot zones of Puri City. Some of the unique aspects of this project include.

a) Real-time Quality Surveillance (Figure D8) to ensure Drink from Tap Quality Water at every home
b) Real-time data analysis and decision making (Figure D9) resulting in uninterrupted and consistent water supply service delivery
c) Data capture for preventive maintenance of Water Supply Assets
d) Reduction of Non-Revenue Water through leakage detection and control
e) Efficient Incidence Management (Figure D10) and quick resolution of problems
f) Efficient consumer complaint redressal for enhancing consumer satisfaction



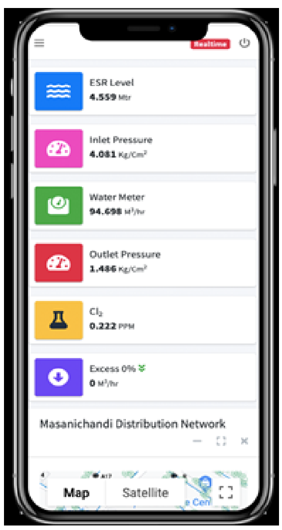


Figure D 8 & 9: Flow and Pressure Monitoring Dashboard

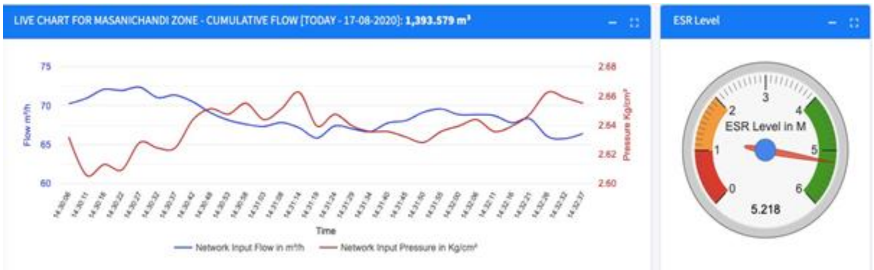


Figure D10: Abrupt Changes in Supply & Pressure (Pipe Burst/Leakage)

Quality Assurance through Third Party Quality Monitoring Laboratories

The State Government has established one State Level and 8 Divisional Level Laboratories on PPP mode for continuous testing and monitoring of water and wastewater quality. The highlight of testing is that it is fully independent of WATCO and is carried out by independent laboratories. Following programs have been initiated-

Figure D11: Digital display board at public places

(1) "Pure for Sure" Campaign: This IEC exercise has been started to create public confidence in public water supply system, so that people can drink from tap rather than relying on existing supply systems. Real-time online water quality data displayed in public places on LCD screens (Figure D11), in order to build confidence in users.

(2) Empanelment of Plumbers: Plumbers are being empanelled (including returning migrant workers) and are trained for installation of household connections as per pre-defined standards to avoid faulty connections and leakages.

(3) Lab on Wheels: Mobile van laboratories have been deployed (Figure D12) for on the spot quality testing for improved water quality surveillance of vital parameters and efficient incident management.

(a) Lab assistants in van

(b) Turbidity apparatus in van

(c) pH meter and DO apparatus in van

Figure D12: Lab on wheel in Puri city

(4) NRW Control Cell: Non-revenue water reduction has been the major challenge. An exclusive cell has been created with dedicated crew members for leakage reduction. With focused implementation on NRW reduction. The NRW has come down to less than 15% compared to previous 54%.

(5) Quick Response Team: Exclusive Mobile Crews (Figure D13) have been set up for immediate maintenance of the leakages and quick response to water supply related incidence management.

Figure D13: Quick response team and Lab on Wheels

IMPACTS AND BENEFITS

1) 100% household level coverage has been achieved.
2) The consumers have water in their taps round the clock directly coming from the public distribution network.
3) Absence of the need for personal storage of water (sump) which is a boon in the urban poor settlements.
4) Lifting the water to roof level storage tanks as well as need of installation of further treatment/filtration systems at home such as RO is eliminated.
5) 100% metering and volumetric billing have helped to reduce the leakages and wastages in water supplies. WATCO has replaced the house service connections (HSC) with compression fittings with saddles and household meters (mechanical meters). This cost is included in the project cost.
6) Hassle free execution of household water supply connections for the consumer with the service at doorstep.
7) Quick resolution of issues and complaints of the consumers enhanced the confidence of the public/communities in WATCO.
8) Use of Technology and tools helped better service delivery.
9) Jalsathis helped in transformation of field situation with enhanced confidence of the people in public water supply system.

10) Each Jalsathi's woman is earning between Rs. 10,000/- to Rs. 12,000/- per month as incentives.

KEY CHALLENGES AND LEARNINGS

The WATCO overcome following challenges:

1) Non-availability of existing infrastructure assets information (digitally) and creation of the same
2) Non-availability of consumer information (digitally) and creation of the same
3) Achieving 100% House Connections including 100% Metering
4) Ensuring adequate Raw & treated Water Source to achieve 24x7 supply
5) Data collection, real time monitoring and control
6) Ensuring quality of water supplied is as per IS: 10500
7) Turning around the lack of public confidence and distrust into highly dependable one
8) Substantially reducing the lag in complaint redressal
9) Eliminating power interruptions
10) Huge manpower required for meter reading, bill distribution and revenue collection was handled through highly reliable and efficient Jalsathis
11) Overcoming Public resistance in eliminating public stand posts, household pumping and storage
12) NRW rate was more than 50% which affected the sustainability of 24x7 Water Supply, which was a challenge. Activities for reduction of NRW was taken on a mission mode. House connection ferrule points were observed as the potential leaking points and almost all house connection ferrules are replaced with saddle and compression fittings. NRW equipments were procured and continuous training of staff for carrying out NRW activities were carried out. An exclusive Non-Revenue Water (NRW) Cell was established in WATCO. All these actions led to reduction of NRW to 15%
13) Interdepartmental coordination
14) Execution of works in concrete roads
15) Executing the works in slums

COMPARISON WITH PUNE and COIMBATORE

Pune and Coimbatore have restricted the terminal pressure to 10 m and 7m, respectively. It means, water will not reach to third floors in Pune. Puri water supply system was designed with a pressure 14m. Comparison is made in Table D2.

Table D2: Comparison of Puri, Pune and Coimbatore on 24x7 Projects

SN	Parameter	Puri	Pune	Coimbatore
1	Population (Lakhs)	2.5	40	15.95
2	PPP model	WATCO Govt. owned company	Concessionaire agreement	Concessionaire agreement
3	Name of SPV	WATCO	L&T	Suez
4	O&M period	WATCO will continue	10	25
5	Project cost for 24x7 WS	Combined cost of JNNRUM + AMRUT + Sujal = Rs 224 Crores. (GoI: Rs 116 Cr; State: Rs 108 Cr)	Rs.3,000 Crores	Rs.646.71 Crores
6	Base line NRW value	54% brought down to 15%	40% to 50% which Concessionaire must bring down to 20%	Base line NRW level has not been measured by Corporation/ Concessionaire. (This is big lapse in tender)
7	Minimum residual nodal pressure	14 m	10 m	7 m
8	Replacement of existing pipelines	Most of the pipes have been laid new since 2015	1618 kms new pipes being added	1744 Kms
9	Customer meters	32,017+ (471 in slum)	3.15 lakhs AMR meters 100% consumer metering is being done	150,000 new meters 100% consumer metering is being done
10	DMAs	19 DMAs (19 OZ)	328	99
11	House service connections to be added	32,017 work already done	3,15,000	150,000
12	GIS maps	GIS adopted	Not seen	GIS adopted
13	Hydraulic model	Prepared	Prepared in pieces	Prepared in pieces
14	Peak factor	2.5	2.5	2.5
15	Customer's underground sumps	Many customers removed sumps	Almost all the houses have sumps	Almost all the houses have sumps

SCOPE FOR FURTHER IMPROVEMENT

1) Pipe network with GIS needs strengthening
2) Hydraulic model should be recreated with GIS and should not be in bits and pieces
3) STEP test shall be carried out for NRW computation
4) In field it was demonstrated as 14 meters with water reaching the third floor without pumping.

CONCLUSIONS

1) 24x7 water supply project has been implemented successfully in Puri City and has been declared as World Class city. The case study may be replicated in other cities so as to have more such world class cities in the country.
2) Motivation from the administration, especially from the Principal Secretary is one of the important reasons of success. Therefore, administrators heading water supply departments may be proactive and lead the 24x7 water supply projects in their respective states as mandated under AMRUT 2.0 Guidelines.
3) The ‘Drink from Tap’ Mission is initiated and water received at the consumer tap could be directly used for drinking and cooking purposes without any further need for filtration/boiling/treatment. The water quality has been maintained as per BIS standards (IS:10500) in Puri city. NRW has been reduced from 54% to 15% which clearly demonstrates that the water required in 24x7 water supply is less than that of intermittent supply systems.
4) A multi-pronged, people-centric approach with conversion of intermittent water supply to continuous (24x7) water supply, 100% household coverage with piped water supply and metering, focus on the urban poor, NRW reduction, innovative, state-of-the-art technology & management techniques, third-party quality monitoring and quality assurance was key to success of the program.
5) Community partnership in water supply management through women SHGs (Jalasathis) have bridged the gap between the communities and WATCO.
6) GIS Mapping of Assets and Consumers etc. are some of the key components of this program.
7) Building institutions like WATCO under the Companies Act helped achieve the desired goal.
8) All Class I & II Cities are required to plan and design the water distribution network with the recommended terminal pressure of 17m as prescribed in the water supply manual so that water will reach up to 3rd floor which will result in gradual delinking of ground level sumps by the households as these sumps are sources of contamination. For residential or commercial building having more than three storeys, sumps may be permitted with frequent cleaning of sumps. Small towns (population up to 50,000) having two storeyed buildings

predominantly may adopt 12m as residual head during planning and design of water distribution network.

9) Cities should mandatorily replace the house service connections (HSC) with compressor fittings and household meters (mechanical meters). This cost may be included in the project cost.
10) Cities should start community led water supply management by partnering with Self Help Groups (SHG)s, called as “Jalsathi” The ‘Jalsathis’ shall act as bridge between customers and ULB. Their partnership is based on incentives for women of SHGs.
11) Availability of quality water round the clock (24x7) in each house, elimination of household storage, pumping and treatment, hassle-free house connections, water conservation through metering, reduction in NRW and cost of production, quick resolution of issues/complaints, and above all end-to-end services delivered at the doorsteps have enhanced the confidence of the public/communities in administration as well as WATCO.
12) In Puri, the per capita cost for providing 24x7 continuous water supply is around Rs.8960 by considering the project cost incurred for creating infrastructure which was funded under JNNURM & AMRUT. The cost also includes the per capita cost for formation of DMAs, flow control valves, bulk flow meters, pressure reducing valves and replacement of house service connections (HSC) with water meters (mechanical meters), i.e., around Rs. 1840. Therefore, 24x7 continuous water supply system can be implemented in all Class-I cities where infrastructure has already been created under JNNURM & AMRUT.

*****

Appendix E

Measures to Increase Residual Nodal Pressure

The objective of this chapter is to identify the areas in operational zones in which the nodal pressures are less than the norm (Say, 17m) and then explain the procedure how to increase the pressure.

How to achieve 17m nodal pressure?

There are four scenarios-

1. Separate out part of OZ of Existing tank for nodal pressure < 17m
2. Using newly proposed ESRs
3. By getting rid of dwarf existing ESRs
4. On-line boosting on outlet of tank for entire OZ having nodal pressures < 17m
5. On-line boosting on branch line to area having nodal pressures < 17m

Illustrative Example 1:

Scenario 1: Some nodes in one DMA have nodal pressures less than 17 m.

Consider one operational zone (OZ) from the Aurangabad city which is shown in Figure E1 with two DMAs. Pipes in DMA1 are shown in pink colour and pipes in DMA2 are shown in blue colour. Demand of water in this OZ is 2.8 MLD. One Elevated Service Reservoir (ESR) shown as T1 in Figure E2 supplies water by gravity to this operational zone. On running the hydraulic model, the nodal pressures are computed which are shown in Figure E3. It can be observed that in DMA1, some nodes have nodal pressures less than 17m which are shown in red colour.

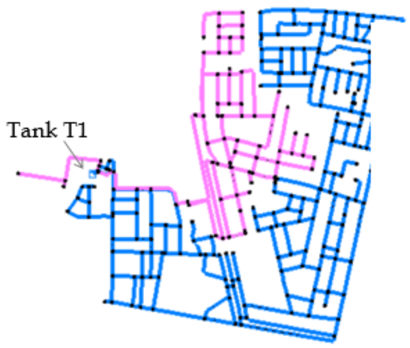


Figure E1:Operation zone with DMA1 (Pink) and DMA2 (Blue)

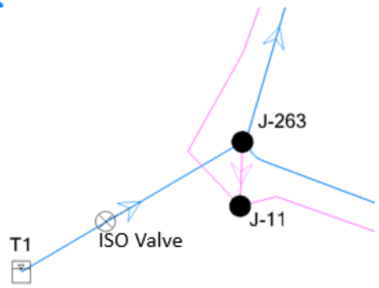
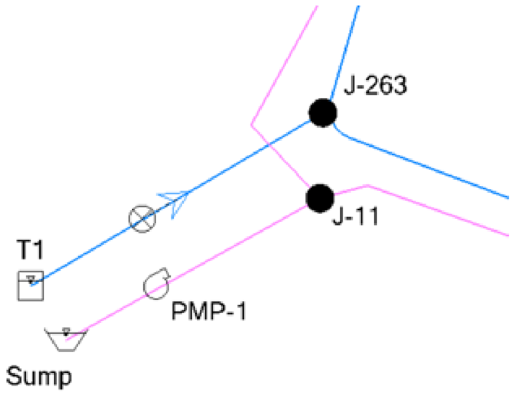


Figure E2: Tank T1 supplies water by gravity

Figure E3:
- DMA1: Pressure < 17m
- SMA2: Pressure ≥ 17m



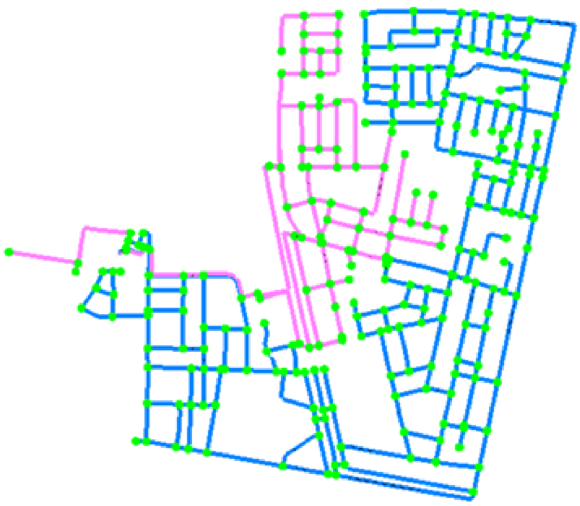


Figure E4: Separate sump and pump are provided to increase nodal pressures in DMA1

Figure E5: With sump and pump, all nodal pressures ≥ 17 m

Solution: Objective is to increase nodal pressure more than 17m. As nodes in DMA1 have nodal pressures less than 17m, it is contemplated that water should be pumped in this DMA. The arrangement is shown in Figure E4 in which one sump is constructed near thetank. It can be seen (Figure E5) that now all the nodes in this operational zone have pressures equal to or more than 17m. Thus we can increase nodal pressures by pump.

Caution: Surge analysis should be made to avoid the negative pressures that cause cavitation.

Illustrative Example 2:

Scenario 2: 17m head created by newly proposed ESRs

The staging height of the newly proposed ESRs can be easily determined to get 17m residual pressure.

Illustrative Example 3:

Scenario 3: By getting rid of dwarf existing ESRs

In this case a separate sump and pump house should be constructed as discussed above. Pump of appropriate duty points is proposed. Pumps shall be Variable Frequency Drive (VFD). The pipes in the area which are being supplied water by direct pumping should be checked for water hammer pressure. The network shall be checked for the cavitation effects also. Negative pressure Cavitation shall not be more than (-)0.9 Bar.

Illustrative Example 4:

Scenario 4: On-line boosting on outlet of tank for entire OZ having nodal pressures < 17m

In this case a pump is installed (Figures E6 and E7) on the outlet of the ESR. With very little flow and head, Nodal pressures more than 17 m can be achieved.

Figure E6: Network of OZ of of Kotla ESR

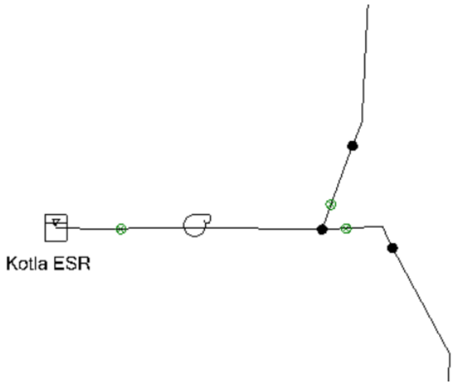


Figure E7: Pump installed on outlet of Kotla ESR

Illustrative Example 5:

Scenario 5: On-line boosting on branch line to area (Figure E8) having nodal pressures < 17m

In this case the pump is installed on the branch (Figure E9) which supplies water to area where pressures are less than 17m. Now the nodal pressures are > 17m.

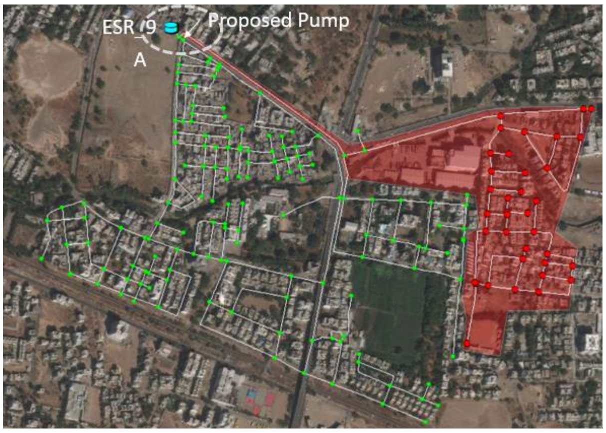


Figure E8: Area where pressures are less than 17m

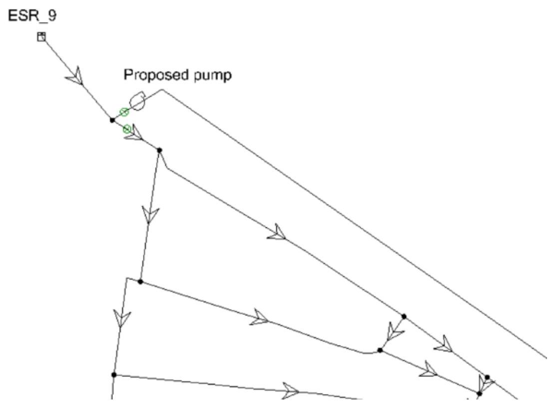


Figure E9: Details at A in which pump is shown installed on branch pipeline which supplies water to area where pressures are less than 17m

Inference: Based on the situation, any one of the above methods can be used to supply water where the nodal pressures are less than 17m.

*****

Appendix F

Information of Pressure in Other Countries

It is to be noted that the countries which provide 24x7 supply, maintain minimum pressures which are as shown in Table F1.

Table F1: Pressure Standards Based on Review of Guidelines and Regulations [m (psi)]

Country	Region	Minimum pressure				
		Condition				
		During fire flow	During maximum hourly demand	During normal conditions	During all conditions	Maximum pressure
Canada	British Columbia	14 (20)	28 (40)	—	—	70 (100)
	Alberta	15 (22)	35 (50)	—	—	56 (80)
	Saskatchewan	14 (20)	35 (50)	—	—	70 (100)
	Halifax	15 (22)	28 (40)	—	—	63 (90)
	Manitoba	14 (20)	21 (30)	—	—	Not specified
	Other provinces	14 (20)	—	28 (40)	—	70 (100)
USA	Louisiana	—	—	—	10.5 (15)	Not specified
	Connecticut, Oklahoma, Delaware	—	—	—	17.5 (25)	
	Michigan	14 (20)	—	24.5 (35)	—	
	Other states	—	—	—	14 (20)	
United Kingdom and Wales		—	—	—	10 (14)	Not specified
Brazil		—	—	—	15 (22)	
Australia		20 (29)	—	—	—	
New Zealand		10 (14)	25 (36)	—	—	
South Africa		—	—	—	24 (34)	
Netherlands		—	—	—	20 (29)	
Hong Kong		—	—	—	20 (29)	

Source: Vali Ghorbanian, “Pressure Standards in Water Distribution Systems,” J. Water Resource Planning and Management, 2016, 142(10).

******

Bibliography

1. Abdul Shaban and R N Sharma , “Water Consumption Patterns in Domestic Households in Major Cities,” Economic and Political Weekly June 9, 2007
2. Alcubilla, R. G., Lund, J. R. (2006). “Derived willingness to pay for household water use with price and probabilistic supply”, Journal of Water Resources Planning and Management, 132(6), 424-434.
3. CPHEEO Manual (1999). Manual on Water Supply and Treatment. Ministry of Urban Development, Government of India, New Delhi.
4. Dahasahasra, S. V. (2007). “A model for transforming and intermittent in to a 24x7 water supply system.” www.geospatialtoday.com, August, 34-39.
5. Dahasahasra, Bhole and Tembhurkar, "Design of Operational Zones of Distribution System for 24x7 Continuous Water Supply Systems," IWWA, 2012.
6. DMA Management Manual, published by IWA, 2006
7. Environmental Hygiene Committee Report, 1949, Available at http:// www.worldcat.org/ title/ report-of-the-environmental-hygiene-committee-october-1949
8. Gupta, R., and Bhave, P. R. (2000). “Changing mode of water supply from intermittent to continuous in water distribution systems.” Proc. International seminar on Intermittent Water Supply System Management, IWWA Mumbai Centre, Mumbai, 7-11.
9. Haestad Methods, 2003, available at https://www.researchgate.net/publication/221936180_Advanced_Water_Distribution_Modeling_and_Management
10. Ingle, R. N., “Development of Guidelines for sizing Break Pressure Tank,” Afro-Asian Conference II.
11. NITI Aayog’s Composite Water Management Index (CMWI), 2019
12. R S Mckenzie & W. Wegelin, “Implementation Of Pressure Management In Municipal Water Supply Systems,” Available at https://www.semanticscholar.org/
13. PAS-SLB data Available from www.pas.org.in
14. PAS, “Road Map of 24x7 projects in Maharashtra,” A report of CEPT University Ahmedabad, 2013
15. R S Mckenzie & W. Wegelin, “Implementation of Pressure Management in Municipal Water Supply Systems,” Available at https://www.semanticscholar.org
16. “Water Loss Reduction”, Bentley Publication
17. WSP, report, “The Karnataka Urban Water Sector Improvement Project 24x7 Water Supply is Achievable”, 2010.
18. WHO Manual, “Leakage Management and Control - A Best Practice Training Manual,” 2001.
19. Guidance Notes for Continuous Water Supply (24-7 Supply),” WSP, 2011.
20. Vali Ghorbanian, “Pressure Standards in Water Distribution Systems,” J. Water Resource Planning and Management, 2016, 142(10).
21. PAS-SLB data from www.pas.org.in covering 900 cities in 5 States
22. “Water Loss Reduction”, Bentley Publication

*****