Standards for Non-Revenue Water Management in Kenya

Manual

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MINISTRY OF ENVIRONMENT, WATER AND NATURAL RESOURCES
STATE DEPARTMENT OF WATER
MAJI HOUSE, NGONG ROAD
P.O. Box 49720 - 00100
Nairobi, Kenya
T. +254 (0) 20 2716103
F. +254 (0) 20 2727622
E. ps@water.go.ke
I. www.water.go.ke

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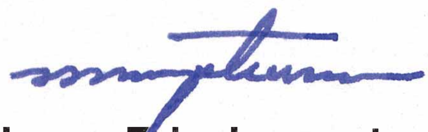
Foreword

Water is an important natural resource to all forms of life and for mankind. It is the backbone of economic growth and a nation's prosperity. Kenya as the rest of the world is becoming more and more water scarce due to deterioration of water sources resulting mainly from global warming and population explosion. Construction of new water schemes to meet the growing demand for water services is expensive, requires more time to develop and comes with new challenges. Alternative sources of water are water re-use, desalination and rain water harvesting. However, reduction of non revenue water is the cheapest way to alleviate the water stress.

The Government of the Republic of Kenya is committed to ensuring sustainability of Water Service delivery in order to realize the aspirations of the Jubilee Coalition of achieving universal access by the year 2020 and to the right to water and sanitation as envisaged under the bill of rights in the constitution. However, among the challenges to achieving the Kenyan dream includes a high level of Non Revenue Water (NRW) which is estimated at an average of 45% of the total water production in the country. The water services provision has been devolved to the County Government and therefore, it is timely to ensure an elaborate mechanism is put in place for the proper management of Non-Revenue Water in the country.

Kenya Vision 2030 recognizes that Kenya is a water scarce country and therefore emphasizes water conservation and prudent use for the limited available portable water. In this regard, the Government of Kenya has instituted specific strategies to raise the standards of the country's overall water supply and resource management among others. The National Water Resources Management Strategy and the National Water Services Strategy aim at ensuring that water resources are conserved and maintained and Non Revenue Water at water supply and Sanitation systems is reduced to acceptable levels. Accordingly, the Ministry of Environment, Water and Natural resources in conjunction with Japanese International Cooperation Agency (JICA) has developed standards for Non Revenue Water management in order to cut down on Operation and Maintenance (O&M) costs and avail more water that could otherwise be lost to consumers.

The Non-Revenue Water (NRW) reduction management standards consisting of manual, guidelines and handbook is meant to provide a practical approach to reduction of NRW in Kenya. The effective utilization of the standards will result in significant reduction of NRW and all the Water Services Boards and Water Service Providers are encouraged to use them.



James Teko Lopoyetum, HSC
Principal Secretary
State Department of Water

Executive Summary

"At current levels of NRW, urban WSPs are losing approximately KSh 9.9 billion annually, slightly less than one third of the sector budget. This not only threatens the financial sustainability of the sector but also wastes funds, which could otherwise be used to increase access and improve service delivery. In short, current under performance on NRW is at the direct expense of the customer and undermines Kenya's aspiration to move towards higher living standards." (IMPACT REPORT NO 6 -2013)

The performance indicator with respect to NRW reduction has improved marginally from 47% in 2008/9, 45% in 2010/11 to 44% in 2011/12. The improvement remains very poor, considering the acceptable sector benchmark of 25% and national target in the national water services Strategy (NWSS 2007-2015) of 30% by 2015.

Out of 66 urban WSPs, 64 or 97% have unacceptably high levels of water losses. With 16 WSPs losing more water on the way than they actually manage to sell. These figures are a clear indication of the lack of professional management and good corporate governance in many WSPs.

High levels of NRW result from poor infrastructure maintenance and, above all, poor commercial practices (corruption). They are detrimental to the commercial viability of the WSP as well as the safety of the water it supplies (where related to leakages). Also, coupled with the overall reduction in water production, they result in less water being available for an increasing number of consumers.

This Non-Revenue Water (NRW) management standard aims to provide a practical approach to reduction of NRW in Kenya. The target group is the Utility Managers, technical personnel and those who are in charge of NRW management in the Water Service Provider (WSP).

The standard is based on experiences in management of NRW from pilot studies in four areas (Meru, Embu, Narok and Kapsabet Nandi) with diverse terrain in Kenya. It aims to provide a basis to address current challenges of NRW management that exist in Kenya and suggest procedures and measures that do not require use of sophisticated equipment, high level of skills and major investments.

The standard is comprised of: **Manual, Guideline, Handbook** and **Case Studies** for NRW reduction. The Manual, Handbook and Case Studies are for use by the WSPs. The Guideline is for use by the WSB in evaluating and guiding the NRW reduction activities implemented by WSPs.

Each WSP should prepare its own NRW Reduction Plan, based on the information and practical guidelines as enumerated in the standards. The WSPs should take into consideration the characteristics and conditions of its service area to ensure that procedures and measures established in the Reduction Plan prepared in this manner will be "custom made" and therefore best suited to reduce NRW most effectively.

The effective utilization of the standards will result in significant reduction of NRW in Kenya. This will further contribute to the progressive realization to the right to water and sanitation as envisaged under the bill of rights in the Constitution of Kenya (CoK-2010)

The standard is structured with a view to creating understanding of the basic concepts of NRW management through a diagnostic approach, quantifying NRW and then developing strategy to address it. The following is a brief outline of the standard.

a) Manual

Chapter 1: This seeks to impart the Basic Concept of NRW Management, the overall picture of NRW reduction is explained, and basic knowledge of NRW reduction is provided.

Chapter 2: Before embarking on any NRW reduction measures, it is necessary to determine the **volume of water that is being lost**. In Kenya, many utilities lack necessary data or necessary devices such as flow meters. This chapter explains how such utilities could begin to estimate the volume of water being lost.

Chapter 3: The chapter explains the causes of Physical Losses, methods of measuring volume of leakages, methods for detecting underground leakages, and the methods of reducing leakages etc.

Chapter 4: The Chapter explains the significance of Commercial Losses in NRW. Explanations are given on the causes and methods for reducing commercial losses. It is possible to bring the NRW ratio down to approximately 30% by just reducing Commercial Losses.

Chapter 5: This chapter explains what need to be done to manage effectively NRW reduction. NRW reduction activities implemented in a Pilot Area are explained. Thereafter, the most suitable measures for the entire service area are determined.

Chapter 6: It explains the mechanism of meters and the importance of maintaining customer meters in order to maintain accuracy and efficiency of meters.

Chapter 7: This chapter explains the importance of good quality construction work and supervision of construction work. Unless good quality construction is assured, replacing pipes will be pointless, as new leakages from poor construction will occur.

Chapter 8: It explains the importance of zoning in order to closely manage NRW. However, zoning requires significant funds, and therefore many utilities may not manage to implement zoning all at once.

Chapter 9: Managing water pressure is one of the most effective methods of NRW management. Water pressure is a common problem seen in utilities located around the Mt. Kenya region. This chapter provides explanation on how to manage water pressure. In the Pilot Project implemented in Embu WSP, positive results were obtained through managing water pressure.

Chapter 10: GIS: This chapter is provided as the next step forward to those utilities that are already implementing some level of NRW reduction measures. It is not necessary to immediately implement activities in these Chapter, but to improve effects of NRW reduction; these will be necessary activities to implement in the future.

Chapter 11: Cost-Benefit Analysis : It is important for water utilities to consider conducting Cost-Benefit Analysis when they are trying to determine the scope of the NRW reduction measures that should be implemented. Cost-Benefit Analysis will show the effects of the invested cost by comparing the benefit obtained with the cost invested.

Chapter 12: Provides the procedures necessary to make a Plan. The purpose of a NRW Reduction Plan is to determine the most suitable measures to reduce NRW and to use the available budget effectively.

b) Guideline

This Guideline is intended for use by WSB in assessing and evaluating the WSP and giving direction and guidance in the utilities' implementation of Non-Revenue Water (NRW) reduction activities. This Guideline is structured as follows:

Chapter 1: The Self-Assessment Matrix proposed in this Guideline will help each utility to understand its current situation of NRW, and assist the WSB prioritize NRW activities to implement in order to reduce and manage NRW. The focus of the WSB should be on policy direction, leadership and providing necessary materials, equipment and funding for selected activities.
Therefore to use this guideline effectively, the first requirement of the WSB is to request all WSP under its jurisdiction, to conduct a Self-Assessment

Chapter 2: The basic information will be used in calculating the Performance Indicators (PI). This involves the collection, correlation, analysis and summarizing of the basic information of each WSP. This collected data is vital as it will form the basis on which important decisions will be based, including those related to capacity building.

Chapter 3: The Performance Indicators (PI) are indicators that evaluate NRW reduction activities. Using the "Process Benchmarking Method", which is the continuous monitoring of the PI, the importance of each indicator, the relationship between the indicators can be understood and it will also help to clarify problems and issues.
The Performance Indicators will also allow comparisons of WSP, eventually leading to the improvement of the water service, increasing efficiency and strengthening operational fundamentals and providing a basis for better planning for the future.

c) Handbook

This is a simplified NRW reduction manual with many illustrations in the form of diagrams and photographs. The handbook is intended for all staff contributing to NRW management in the WSPs and specifically, the technicians and field personnel for use in their daily activities.

d) Case Studies

The Case Studies involve the activities of NRW management project in Meru Embu, and Narok WSP. The Case studies represent actual work done on a pilot scale by the WSPs working with the JICA Experts in developing and implementing NRW Plans. Using the water balance, site activities and review of practices, issues are identified and interventions categorised into technical, financial, social and institutional. These interventions were then prioritized and activity plans developed for immediate, midterm and long term implementation.

The case studies show that it is possible to identify a pilot area in which all or most of the interventions can be applied and impact monitored. The results of this particular area can then be scaled up to cover the whole operational areas of the water utility.

The philosophies, concepts, and recommendations contained in this standard reflect international best practice. It is recommended that all Water utilities in Kenya apply the approach in order to rapidly benefit from a greater understanding of their networks' performance, and knowledge of the tools available to identify and reduce their levels of NRW.

Abbreviations

BPT	Break Pressure Tank
CM	Commercial Manager
CRT	Cathode Ray Tube
DM	Direct Measurement
DMA	District Metered Area
EWASCO	Water and Sewerage Services Co. Ltd. (Embu WSP)
GI	Galvanized Iron Pipe
GIS	Geographic Information System
IWA	International Water Association
JICA	Japan International Cooperation Agency
KEWI	Kenya Water Institute
KNWSC	Kapsabet Nandi Water Sanitation Company (Kapsabet WSP)
Ksh	Kenyan Shilling
LMB	Leakage Monitoring Block
LVN WSB	Lake Victoria North Water Service Board
MD	Managing Director
MEWASS	Meru Water and Sewerage Services (Meru WSP)
MNF	Minimum Night Flow
MPa	Mega Pascal (1 Mpa≒102mAq) (mAq: waterhead pressure of one meter)
NARWASSCO	Narok Water and Sewerage Services Co. Ltd. (Narok WSP)
NRW	Non-Revenue Water
MWI	Ministry of Water and Irrigation
OJT	On-the-Job Training
O&M	Operation and Maintenance
PE	Polyethylene
PRV	Pressure Reducing Valves
PVC	Polyvinyl Chloride
PVC Pipe	Polyvinyl Chloride Pipe
Qcm	Quantity of Consumption
Qd	Quantity of Direct Measurement Flow
Qmn	Quantity of Minimum Night Flow
Qp	Quantity of Production
RV WSB	Rift Valley Water Service Board
SCADA	Supervisory Control and Data Acquisition
Tana WSB	Tana Water Service Board
TM	Technical Manager
WARIS	Water Regulation Information System
WASPA	Water Services Providers Association
WASREB	Water Services Regulatory Board
WSB	Water Service Board
WSP	Water Service Provider

Contents

Chapter 1
Basic Concept of NRW Management

1.1 Definition of Non-Revenue Water – NRW

NRW is defined as the amount of water which is not billed and does not earn revenue. This is the difference between the system input and billed authorized consumption in volume (m^3).

NRW = System Input Volume – Billed Authorized Consumption

Where;
System Input : The amount of water produced for distribution
Billed Authorized Consumption : The amount of water billed to consumers

NRW ratio is the percentage of the amount of water **not billed** against the total amount of water produced for distribution.

$$\text{NRW ratio (\%)} = \frac{\text{System Input Volume - Billed Authorized Consumption Volume}}{\text{System Input Volume}} \times 100$$

Note : the amount (in monetary term) that was billed but not collected should not be counted as NRW

1.2 Components of NRW

The volume of treated water that does not earn revenue is Non-Revenue Water. Components of NRW are described below:

- **Real Losses** : these are Physical Losses of water through leakages and bursts in distribution pipes and services pipes and overflow / leakages from water reservoirs;
- **Apparent Losses** : these are called "non-physical losses" or "Commercial Losses" of water due to illegal connections (or water theft), meter errors, meter reading inaccuracies and unmetered connections.

Unbilled authorized consumption: This is water taken by registered customers for public and institutional uses and is not billed for. This includes water for fire-fighting, backwash and public fountains.
Fig. 1.1 shows the component of NRW

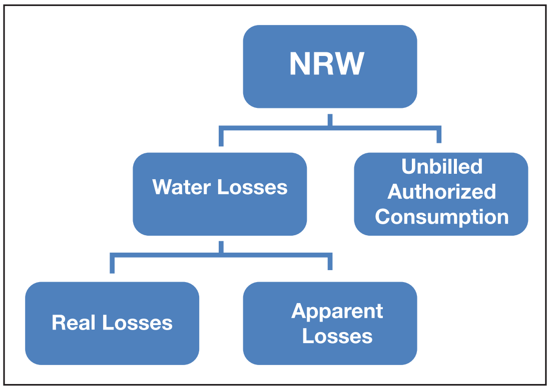


Figure 1.1 Components of NRW

1.3 NRW Reduction Measures and its Importance

Non-Revenue Water (NRW) Management consist of knowing what is happening to water supplied and taking corrective measures to reduce the loss of water or revenue.
NRW management offers the following benefits:

- Increased Revenue: By reducing causes of NRW such as water theft, meter inaccuracies and controlling leakages, water that was previously unbilled will be earning revenue.
- Sustains water supplies and increases the protection of potable water supply
- Reduces unauthorised usage.
- Reduces potential claim due to water damage
- Defers capital expenditure with respect to new water sources, treatment plans and distribution facilities.
- Reduces the cost of energy associated with water treatment, pumping, treatment and thus contribute to reducing global warming.
- By controlling NRW, precious water resources can be preserved.
- Improves public awareness of water value.

1.4 Characteristic of Water Supply systems in Kenya.

The characteristics of water supply system in Kenya differs depending on social, financial and geographical conditions, but the issues that are commonly seen are as follows;-

1. Dilapidated facilities
2. Weak materials such as asbestos cement pipes and cast iron pipes are still in use as distribution pipes in some water supply schemes.
3. Insufficient water distribution due to lack of water resources and/or insufficient water facilities.
4. In general, water pressure is low with the exception of WSPs located around the foot of Mt. Kenya. However, there are significant pressure variations depending on the service area of the WSPs.
5. Inadequate staff with capacity to implement NRW Management programs.
6. Lack of adequate equipment to address NRW issues.
7. Flow Meters have not been installed in appropriate locations.
8. Lack of uniform specific pipe standard to be used in the country.
9. Poor workmanship and construction methods.
10. Mapping of pipe network is inadequate and often outdated in most WSPs.

Customer meters are sometimes not read accurately. Illegal connections and failure to pay for water consumed are common.

1.5 NRW Reduction Measures

In developed countries, a large part of NRW is due to real losses (physical losses). However in developing countries including Kenya, high percentage of water is being lost through apparent losses (commercial losses) such as water theft, meter error, meter reading error and unbilled authorized consumption. Therefore NRW reduction measures in Kenya should take into consideration all these additional factors besides leakage.

Details of reduction measures are explained in Chapter 3: Reduction of Physical Losses and Chapter 4: Reduction of Commercial Losses.

1.6 Procedure for NRW Reduction

Procedures for NRW reduction will vary depending on the existing conditions of each WSP. NRW reduction measures that are implemented in developed countries are not recommended or suitable to the needs and requirements of WSPs in Kenya.

For any WSP to begin implementing NRW reduction measures, each WSP must first understand its existing position in regards to its NRW.

Table 1.1 shows the recommended NRW reduction measures by stages of NRW ratio. For each stage, the approximate NRW ratio is given with the prioritized NRW reduction measure required for that stage. This table will allow the WSP to check what stage it is at, as regards to the Table, and plan for the prioritized measure.

Table 1.1 Six Stages of NRW Control Measures

Stage	Approximate NRW Ratio	Recommended NRW Reduction Measure
1st	More than 35%	To address surface leakage and commercial losses
2nd	35% - 25%	To detect and decrease underground leakages
3rd	30% - 25% (Overlapping 2nd)	To stop recurrence of leakage and starting replacement of aged pipes
4th	25% - 15%	To carry out leakage control work. Acceleration of pipe replacement
5th	15% - 10%	To wrap up the proactive leakage control work. Completion of pipe replacement
6th	Less than 5%	To keep the minimum ratio

Reference: Mr. Shozo Yamazaki, Non-Revenue Water Management, 2011

NRW reduction measures should be implemented according to the existing current situation of each WSP. As it is difficult for any WSP to implement a comprehensive NRW reduction measure to all its supply area, it is recommended that each WSP conduct a Pilot Project first. In the Pilot Project, a Pilot Area should be selected and the most suitable and effective NRW reduction measure should be implemented. This tested prioritized measure should then be gradually applied to other areas within the supply area.

Figure 1.2 shows the flow chart for the procedures for NRW reduction.

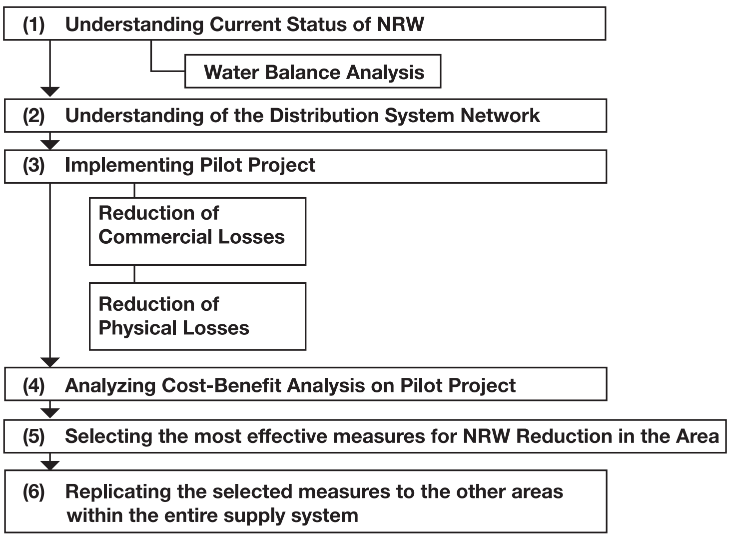


Figure 1.2 Procedure for NRW reduction

Details of the activities implemented in Pilot Area are explained in Chapter 5.

Chapter 2
Fundamental Measures in NRW Management

Fundamental Measures refers to the action that needs to be taken before starting implementation of NRW reduction programme. This Chapter outlines what the WSP are required to do before implementation of effective NRW reduction activities.

2.1 Understanding the Water Flow of the entire supply area

In order to understand the Water Flow, a Schematic Water Flow Chart showing the flow of water from the source works to the consumer must be prepared (Fig.2.1).

The ideal situation would be to have one distribution tank supplying water to one supply area. The distribution of water can be understood at a glance, if the flow of water can be indicated numerically onto the schematic water flow chart.

In reality, pipes are laid in a very haphazard manner in most WSP. Hence accurate volume of water distributed in the supply area cannot be obtained. In such a case, it is important to install Flow Meters at most suitable locations so that accurate volume of water distributed can be obtained. If Zoning of the supply area is to be considered in the future, it is important to install the Flow Meter in locations that will provide the volumes distributed for each zone.

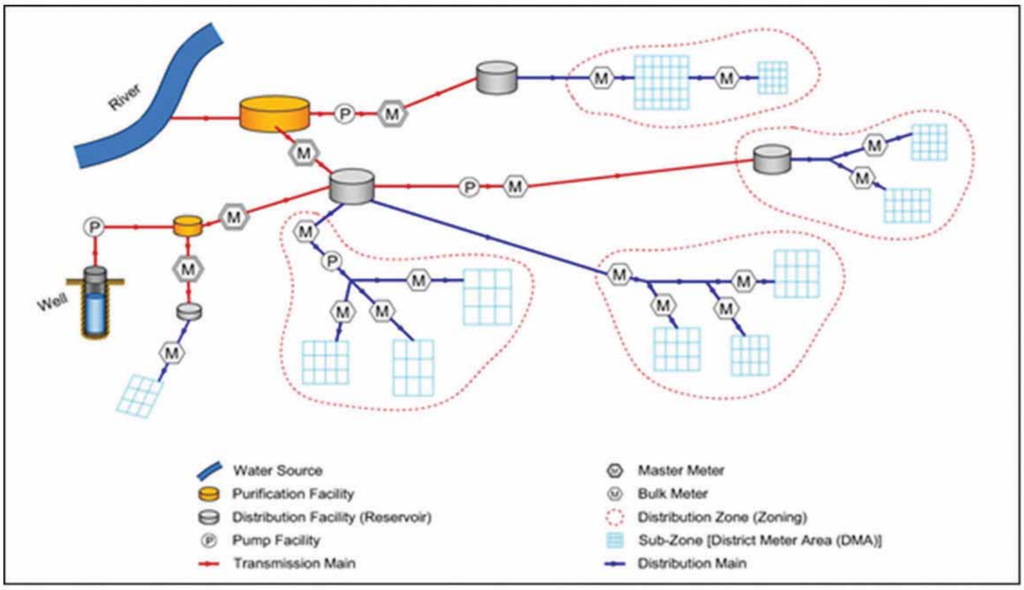


Figure 2.1: Schematic Water Flow Chart

A Flow Meter (or Master Meter) is mainly installed in the outlet of either the water treatment plant or the distribution reservoir while a Bulk Meter (or Trunk Meter) is installed at the inlet of a zoning area.

A bulk meter should be installed even if the zoning is not completed, so that the volume of water distributed in the area can be measured.

Distribution Reservoir | Flow Meter (Master Meter)

Flow Meter (Bulk Meter) Chamber | Flow Meter (Bulk Meter)

Photo 2.1: Location of Installation of Flow Meters

There are different types of flow meters, which can be used to measure the flow with the mechanical type of flow meter being the most commonly used in Kenya. Flow meters have different levels of accuracy as indicated in Table 2.1. The accuracy level of the flow meters must be put into consideration before installation any errors will have a great impact on the measurement of the total production volume.

Table 2.1: Indicative Example of Meter Accuracy

Equipment / Method	**Approximate Accuracy Range**
Electromagnetic Flow Meters	<0.15-0.5%
Ultrasonic Flow Meters	0.5-1%
Insertion Meters	<2%
Mechanical Meters	1.0-2%
Venturi Meter	0.5-3%
Meas Weirs in open channels	10-50%
Volume calculated with pump curves	10-50%

Source: World Bank Institute

2.2 Mapping

Pipeline network map is a fundamental requirement in NRW management. In Kenya, many WSPs do not have pipeline network map and where they exist, the maps have not been updated for many years. As the pipeline network map is considered to be a fundamental requirement in NRW management, it is advisable that WSPs begin with the preparation/updating of the pipeline network map.

The first step for the preparation /updating of the pipeline network map is to conduct a survey of the supply area on foot. The survey must confirm the location of pipes, types of pipes, pipe material, pipe diameter and length. If any of the information cannot be obtained by foot survey, missing information must be sought from technicians on site, residents and construction personnel who may have the information.

Photo. 2.2 Survey of the Supply Area on Foot

2.2.1. Steps in Preparation of Pipeline Network Map

a) A hand-drawn map must be sketched at the time of the foot survey.

Fig. 2.2.1 Handwritten map

b) All sketched maps must be organized to produce a sketch of the pipeline network of the supply area.

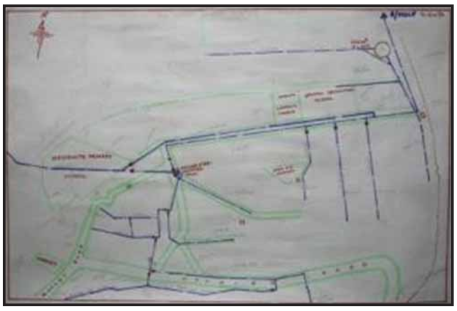


Fig. 2.2.2 Sketch of the pipeline

c) More information such as location of valves and information on water meters can be added onto this map. If the age of pipes can also be added, this will provide a more comprehensive map.

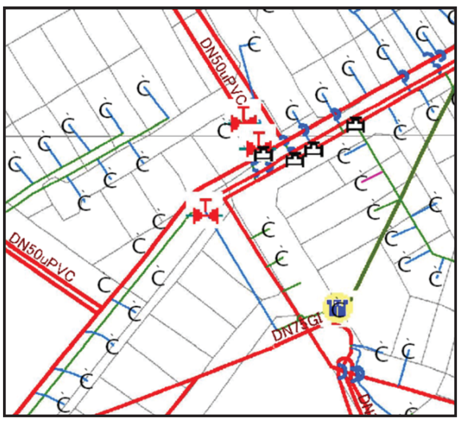


Fig. 2.2.3 Water Meter Information

d) The hand-drawn maps should eventually be converted to digital files using CAD and/or GIS.

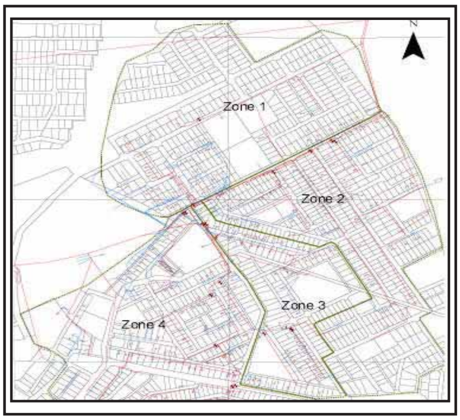


Fig. 2.2.4 Digital File Map

The locations where service water pipes take off from the distribution pipes are important locations for NRW reduction work and must be indicated on the drawings. Also the following information should be indicated in the pipe network drawing; type of pipe material, type of pipe, pipe diameter, pipe location, location of valves, Location of fire hydrants, etc.

2.3 Basic Information

It is necessary for each WSP to have data listed in Table 2.2 below. The items on this list provide the basis for WARIS Performance Indicators set by WASREB. The results are published in the IMPACT report prepared by WASREB.

For those WSPs that do not have any information/data at hand, some data can be calculated or deduced from maps, inspection of customer meters, and leakage records. For example, if there is no information on the population of served customers, this can be estimated from the number of connections in the area.

Table 2.2: Basic Information

No.	Item	Unit
1	Total population in service area	Number
2	Population served with water through unmetered connection	Number
3	Population served with water through metered connections	Number
4	Total number of water connections	Number
5	Total number of active water connections	Number
6	Total number of inactive water connections	Number
7	Total water produced per month and per year	m^3/month and year
8	Total billed volume per month and per year	m^3/month and year
9	Total length of distribution main	km
10	Number of leakage repaired per month, distribution main and service pipe	Number
11	Total number of staff	Number
12	Total Revenue collection from water and sewerage	Ksh/year
13	Total billing amount	Ksh/year
14	Total metered collections	Ksh/year
15	Total revenues	Ksh/year
16	Total operation and maintenance expenditures	Ksh/year
17	Total expenditures	Ksh/year
18	Total personnel expenditures	Ksh/year
19	Water production per day and month	m^3/day

20	Water production capacity per day, design capacity of the system	m^3/day
21	Average number of customers disconnected per month	Number
22	Total number of bills	Number
23	Number of meter readers	Number

2.4 Customer Metering

There are two systems for billing water used; the Flat rate system (unmetered) and the Charge system (Metered Volumetric Charge System). The Flat rate system is billed at a flat rate regardless of the volume of water used whereas the Charge System is billed according to the reading of volume used on the customer meter. Management of NRW aims to reduce water wastage, therefore, 100% water metering is always recommended. Even in areas where flat rates are being applied, these areas should have bulk water meters to measure the volume of water used in the area. Installing bulk water meters requires time and funds. It is not always easy for WSPs with financial difficulties to prioritize bulk meter installation. However in the long term, the effects of metering are more positive and therefore, it is important to plan for meter installation at the project formulation, planning and design stage.

Photo 2.3: Actual Installation of Customer Water Meter

The accuracy of customer water meters is equally important, and the major difference is that, there are many types of customer meters in operation and each measure a relatively smaller flow than production meters. The accuracy of customer meters depends on several factors such as meter type, brand, replacement policy and maintenance. In addition, water quality is not good in some regions in Kenya and hence, it is necessary to install a “strainer” to protect the moving parts of the meter from damage by debris as shown in Photo 2.3 & 2.4. Therefore, the WSP should install water meters appropriate to the quality of water it supplies.

Photo 2.4: Strainer (Installed at outlet of Water Treatment Plant) (Meru WSP)

Photo 2.5: Roots at Customer Meter (Embu WSP)

2.5 Water Balance Analysis

The entry point in Non Revenue Reduction measures is by first developing a global picture of how much and where water is being lost in the system. This process is called the water balance analysis or water audit.
Figure 2.3 shows a Water Balance Graph. The suitable method in Kenya is to calculate NRW ratio by using the system input volume (volume of distributed water) and the volume of water consumption.
Table 2.3 shows Water Balance Table as defined by the International Water Association (IWA). In reality, it is impossible to measure the volume of water described in each component and in most cases values (figures in percentage) are attributed according to experimental rules.

(1) Water Balance Graph

The NRW ratio is calculated based on data obtained on volume of distributed water and volume of water consumption. The calculated results are plotted on the graph where the volume of distributed water is indicated in blue and volume of water consumption is indicated in red.

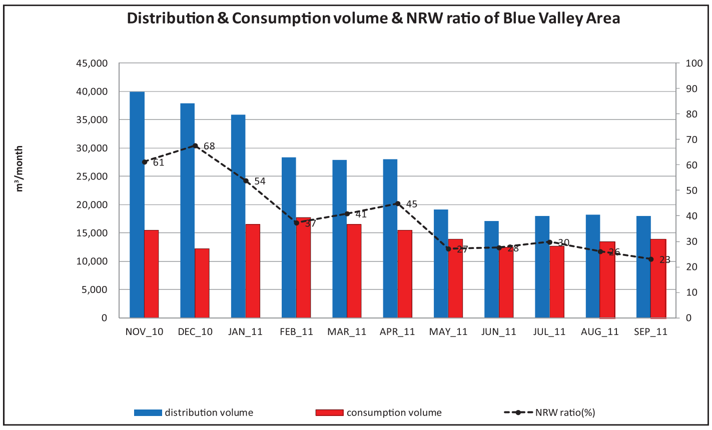


Figure 2.3 Graph of Water Balance – Blue Valley Area in Embu

(2) Water Balance Table

Table 2.3 shows the Water Balance Table prepared by the International Water Association (IWA).
The table shows the components of Non-Revenue Water

System Input	**Authorized Consumption**	Billed Authorized Consumption	Billed Metered Consumption	**Revenue Water**
			Billed Unmetered Consumption	
		Unbilled Authorized Consumption	Unbilled Metered Consumption	**Non-Revenue Water (NRW)**
			Unbilled Unmetered Consumption (eg. hydrant)	
	Water Losses	Commercial (Apparent) Losses	Unauthorized Consumption (eg. illegal connections)	
			Customer Metering Inaccuracies, Estimations and Data Handling Errors	
		Physical (Real) Losses	Leakage on Transmission and/or Distribution Pipes	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to point of Customer Use	

Source: IWA

Table 2.3: Water Balance Table

In Kenya, establishing all the components of the Water Balance Table with high accuracy is difficult. System Input Volume is obtained by measuring the volume of water distributed, and Billed Metered Consumption is obtained from customer water meters. Other components of the Water Balance Table are often not possible to measure therefore estimated figures obtained from experiences should be used.

(3) Definition of Water Balance Terminology

Table 2.4 explains the terminologies used in the Water Balance Table (Table 2.3). These are defined by IWA.

Table 2.4 Explanation of Terminology for Table 2.3

System Input	This is the Volume of treated water that is input into the supply system where water balance is to be calculated.
Authorized Consumption	This is the Volume of metered and/or unmetered water consumed by registered customers, water supplier and others who are authorized by the water supplier. This can be residential, commercial and industrial use. It also includes water exported across operational boundaries. Authorized consumption may include water for fire fighting and training, flushing pipes and sewers, street cleaning, watering municipal gardens, public fountains, frost protection and for building works etc. These may be billed or unbilled, metered or unmetered consumption.
Water Losses	This is the difference between System Input Volume and Authorized Consumption. Water losses consist of Physical (real) Losses and Commercial (apparent) Losses.
Billed Authorized Consumption	This is the part of Authorized Consumption that is billed and earns revenue (also known as Revenue Water). This is the sum of Billed Metered Consumption and Billed Unmetered Consumption.
Unbilled Authorized Consumption	This is the part of Authorized Consumption that is legitimate but not billed, therefore does not earn revenue. This is the sum of Unbilled Metered Consumption and Unbilled Unmetered Consumption.
Commercial (Apparent) Losses	This includes all types of inaccuracies associated with customer metering as well as data handling errors (meter reading, estimates on flat rates and billing), plus unauthorized consumption (theft or illegal use). Note: over-registration of volume of use by customer meters leads to under-estimation of Physical Losses. Under-estimation of volume of use leads to over-estimation of Physical Losses.
Physical (Real) Losses	This is water lost starting from the storage tank to the point of customer use. In metered systems, the point of customer use will be the customer water meter and in unmetered situations this will be the point of use (tap) within the property. The total annual volume of water lost through all types of leakages, breaks and overflows depends on the frequency, flow rate and average duration of individual leakages, breaks and overflows. Note: Although leakages occurring after the point of customer use (tap) are not included as Physical Losses, this does not mean that these leakages are insignificant or should be ignored.
Billed Metered Consumption	This is all metered water consumption that is billed. It includes all categories of customers such as domestic, commercial, industrial or institutional. It also includes water transferred across operational boundaries (water exported), which is metered and billed.
Billed Unmetered Consumption	This is all billed water consumption based on estimates or norms but is not metered. This may be a very small component in a fully metered system, but can be a key consumption component in systems without full meter coverage. This may also include water transferred across operational boundaries (water exported), which is unmetered but billed.
Unbilled Metered Consumption	This is metered water consumption, which is unbilled. This may include metered consumption by the utility itself or water provided to institutions free of charge and water transferred across operational boundaries (water exported) which is metered but unbilled.
Unbilled Unmetered Consumption	This is any kind of authorized consumption that is neither billed nor metered. This component typically includes water used for fire fighting, flushing of pipes and sewers, street cleaning, frost protection etc. In a well run utility, this component is small, but very often over-estimated. In rare cases, this component may also include water transferred across operational boundaries (water exported) which is unmetered an unbilled.
Unauthorized Consumption	This is any unauthorized use of water. This may include illegal water use from hydrants (for example, for construction purposes), illegal connections, bypassing meters or meter tampering.
Customer Metering Inaccuracies and Data Handling Errors	These are Commercial (Apparent) Losses caused by customer meter inaccuracies and data handling errors in meter reading and billing system.

Chapter 3
Reduction of Physical Losses

3.1 Components of Physical (Real) Losses

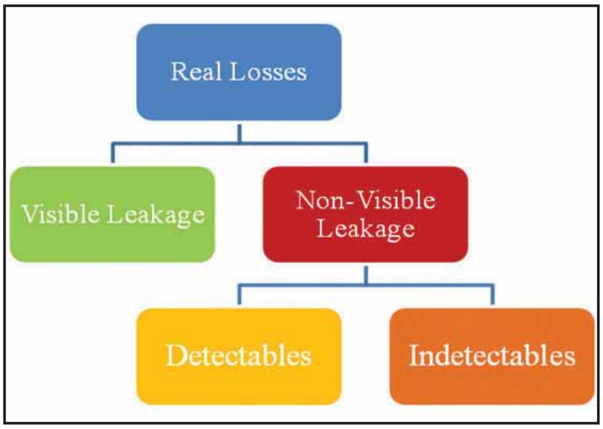


Figure 3.1 Component of Physical Losses

Physical Losses can be divided into visible leakage (surface leakage) and non-visible leakage (underground leakage). Surface leakages occur in areas with high water pressure, whereas underground leakages occur in areas with low water pressure and therefore difficult to detect. In general, there are more occurrences of leakages in service pipes compared to distribution pipes.

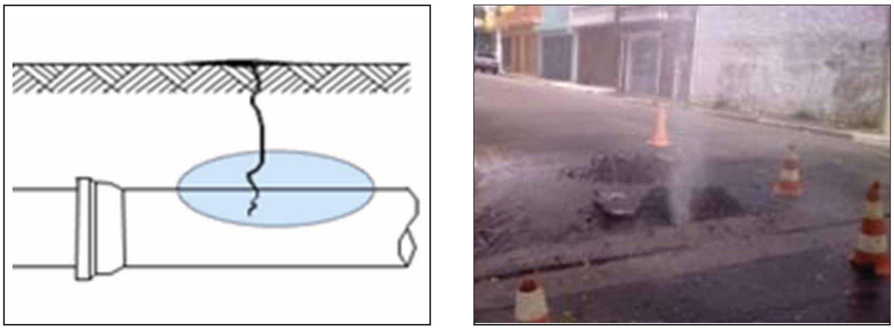


Photo 3.1: Visible leakage (Surface leakage)

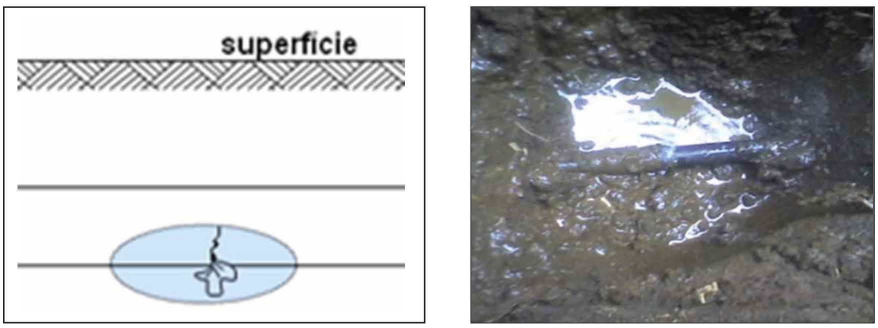


Photo 3.2: Non-visible leakage (Underground leakage)

Generally, leakages start off as a small leak that develops into a medium to a large sized leak as time passes. Small sized leaks may remain undetected underground for a long time. In cases of medium sized leaks, some may stay undetected but others will surface to the ground. Most large sized leaks will be detected on the ground surface within a few days of the leak up to several months. Some leaks may remain underground for years or forever. This all depends on the surrounding conditions of the laid pipes such as the condition or type of soil, presence of underground structures, and pipe material used.

Repairing surface leakages alone cannot decrease leakage ratio when the leakage ratio is less than 30%. In order to decrease this ratio, underground leakages must be detected and repaired. Underground leakages can go without repair since they are difficult to detect, and underground leakages often overwhelmingly exceed the number of surface leakages by more than ten times.

Thicker pavements on roads usually indicate a higher ground water level, which indicates lower water pressure in the buried pipes. Detection of underground leakages becomes more difficult as depth of buried pipes increases.

When leakages occur, extending the area of repair around the point of leakage will decrease recurring leakages around the same area. Planning for replacement of pipes must take into consideration the number of leakage repairs in the pipe and the age of pipes.

3.2 Main Causes of Physical Losses

Leaks can occur anywhere in the pipeline due to various factors such as age of pipes and traffic loads on the road. Table 3.1 shows the factors that can cause leakages (physical losses).

Table 3.1 Main Causes of Physical Losses

Causes of Physical Losses	
Factors	Causes
Poor Quality of pipe material	• Material and/or mechanical defects • Lack of corrosion resistance • Age and/or deterioration • Galvanic corrosion
Technicality in pipe laying or poor workmanship	• Design errors • Poor jointing of pipes • Inappropriate back filling • Contact with other structural objects • Defective corrosion protection methods
Poor Conditions	• Unsuitable water pressure (usually high pressure) • Water Hammer • Water quality (internal corrosion)
Environment of underground pipes	• Increase in traffic loads • Corrosive soils such as marine clay • Ground subsidence caused by excessive pumping etc. • Effects of other construction works

3.3 Reduction Measures for Physical Losses

Table 3.2 shows measures to reduce physical losses.

Measures		Activities
Pipe Work	Pipe Mapping	• Preparation of accurate pipeline drawing (Refer to Chapter 2)
	Zoning	• Determination of DMA or measurement blocks • Isolation of measurement blocks (Refer to Chapter 8)
	Taking Measurements	• Understanding leakage volume in measurement blocksby measuring MNF and implementing Step-Test (Refer to Chapter 3 Section 3.5)
	Leak Detection	• Detection of leakages by using leak detector (Refer to Chapter 3 Section 3.6)
	Leak Repair	• Adoption of optimum leakage repair method
Pipe Replacement	Planning	• Preparation of pipe replacement plan based on statistical analysis of the Pipeline network. • Determine correct pipe type and pipe diameter
	Implementation	• Implementation of pipe replacement
Water Pressure Control	Pressure equalization (Refer to Chapter 9)	• Zoning of distribution network • Installation of PRVs • Installation of Flow Meters and Pressure Meters
	Setting up Pressure Control facilities	• Construction of distribution reservoirs and / or pumping station
	Pressure Control at pumping station	• Pressure control by controlling pump flow and number of pump rotation

3.4 Recurrence of Leakage

Recurrence of leakages, refer to new leakages that occur near previously repaired leakages in the same pipe. When water distribution pipes are worn out, no matter how many leakages are repaired, there will be a great tendency for new leakages to occur. In order to further lower the leakage ratio, detection of leakages and repair work must outpace leakage occurrence. In cases where leakages still occur in the same pipe, or if the pipe is well over its life, the water pipe must be replaced with newer and stronger pipe.

Figure 3.2 shows the concept of recurrence of leakage

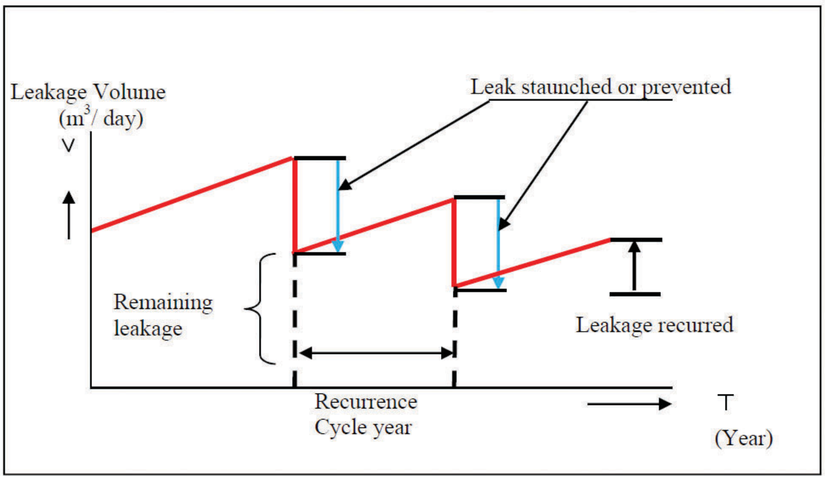


Figure 3.2: Concept of Leakage Recurrence

3.5 Quantifying Physical Losses

(Measuring Methods of Existing Leakage Volume)

In order to control leakages, it is a basic requirement for the WSP to know the existing leakage volume of the target leak survey area. Based on the existing leakage volume, most appropriate and effective pipeline maintenance work can be established. At the same time, leak survey blocks can be selected; best maintenance methods can be determined whether it be simply repairing of pipes or total replacement of pipes and overall improved effective control of leakages can be implemented.

Existing leakage volume can be measured by the following methods;-

(1) Estimation Method, by collecting leakage volume at the actual leakage point
(2) Estimation Method, by calculation using volume of distributed water and volume of water used
(3) Direct Measurement Method
(4) Minimum Night Flow (MNF) Measurement Method
(5) Step-Test Measurement
(6) Leak Survey Method for areas with low water pressure

(1) Estimation Method by collecting leakage volume at the actual leakage point

Leakage volume per minute can be established by measuring the actual leakage at the leakage point. By multiplying this value by the number of leakage points, the leakage volume of the target area can be estimated as follows:

Total annual volume of leakage from mains = Number of reported bursts x Average leak flow rate x Average leak duration

If no detailed data are available, utility managers can use approximate flow rates from the Table 3.3 below.

Table 3.3

Location of Burst	Flow rate for reported bursts (l/hr/m pressure)	Flow rate for unreported burst (l/hr/m pressure)
Mains	240	120
Service connection	32	32

Source: IWA Water loss task Force

Utility managers can then add estimates for background losses and excess losses (current undetected leaks). Background losses are individual events (i.e. small leaks and weeping joints) that flow at rates too low for detection by an active leak detection survey. They are finally detected either by chance or after they have worsened to the point that an active leak detection survey can discover them. Table 3.4 shows background losses from various components of the network with average infrastructure condition.

Table 3.4: Calculating Background losses.

Location of Bursts	Litres	Unit of measure
Mains	9.6	Litres per km of mains per day per metre of pressure
Service connection: mains to property boundary	0.6	Litres per service connection per day per metre of pressure
Service connection: property boundary to customer meter	16	Litres per km of service connection per day per metre of pressure

Source: IWA Water loss task Force

Photo 3.3: Measurement at Actual Leakage Point

(2) Estimation method by using volume of distributed water and volume of water used.

In certain areas, the existing leakage volume can be estimated by calculation.

Leakage = water distributed – water used (mainly billed water)

In the above calculation therefore, the difference obtained by deducting the volume of water used from the volume of water distributed is the volume of leakage.

In this method of calculation, the volume of leakage will include water losses due to water theft, unbilled water for public use, water for institutional use and water losses through metering error. This estimation method therefore gives only a rough idea of existing leakage volume.

(3) Direct Measurement (DM) Method

To measure leakage using the Direct Measurement Method, a measuring block consisting of approximately 3 to 5 kilometers of distribution pipe and/or 100 to 500 customer meters needs to be selected. All peripheral valves in the measuring block must all be closed and all customer valves must also be shut. The flow rate into the measuring block is then measured at one point. It is preferable to conduct this method after midnight to avoid inconveniencing customers.

This method is time consuming and requires manpower and due to these reasons, it has become unpopular.

Photo 3.4: Close all peripheral valves of the block and all the customer valves completely

Photo 3.5: Measure the flow volume into the block

(4) Minimum Night Flow (MNF) Measurement Method

Figure 3.3 shows a typical Water Demand Characteristic Curve. Water demand varies with respect to the time of day. Diurnal peaks typically occur in the morning and in the early evening, while lowest water usage occurs during night hours. By studying the Minimum Flow of this diagram, it is possible to estimate the volume of water leakage.

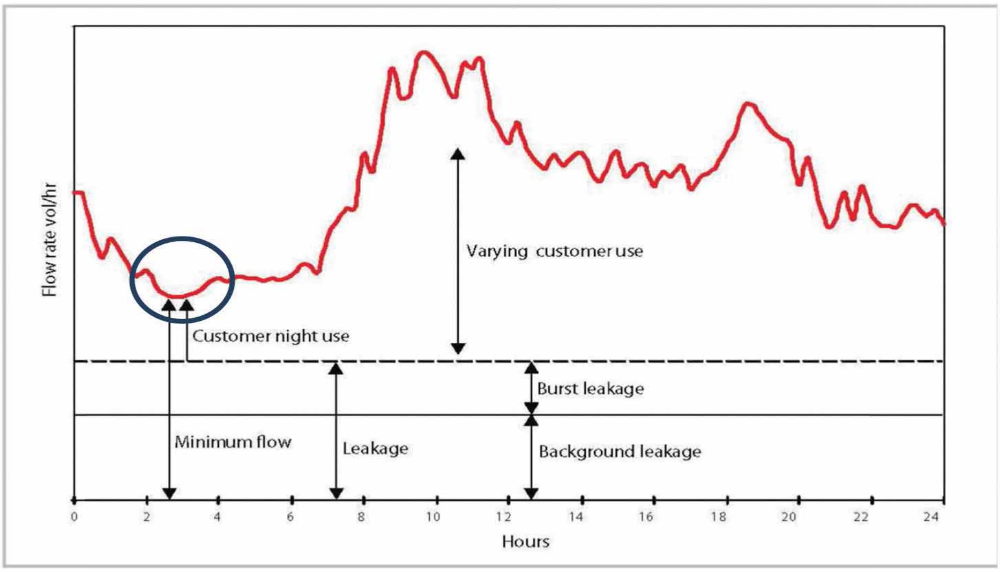


Fig. 3.3 Typical Water Demand Characteristic Curve

MNF measurement method in NRW Management refers to a method of estimating the volume of leakage within a target area or a Pilot Area by accurately measuring the Minimum Night Flow (MNF). In a Pilot Area, MNF normally occurs between 1:00 am to 4:00 am. It is only necessary to accurately measure the volume of water flow during this particular time period. When mechanical flow meters are used for measuring, it is better to have shorter reading periods, for example 10 minutes. The results of the reading should be put on a graph and the lowest point on the graph is the MNF. This method of measuring the volume of water flow does not require closing the customer meter valves. Therefore there is no interruption in water supply. Using electro-magnetic flow meter or ultrasonic flow meter can increase the accuracy of these readings. When implementing the MNF measurement, it is important to have the target area or the Pilot Area perfectly isolated from the adjoining areas. In general, the adequate size of a leak survey is considered to be 700 to 1,500 households, or 2,100 to 5,000 persons.

Based on the results obtained from the MNF Measurement, NRW Reduction measures should be implemented. Measurement "Before" and "After" the implementation of measures should be recorded to understand the effectiveness of the measures applied.

(5) Step Test Measurement

The Step Test allows detection of abnormal flow in an isolated distribution area. By measuring the MNF of a sub-block, and comparing the obtained readings to previous MNF records of same sub-blocks any abnormal flow and can be detected and can be appointer to possible leakage.

The procedure for Step-Test Measurement is as follows;-

The leak survey block should be completely isolated from adjoining blocks, and the survey block must be divided into sub-blocks using gate valves.
There should only be one flow meter for the leak survey block, and water should be allowed to flow into each sub-block, one by one, by utilizing gate valves.

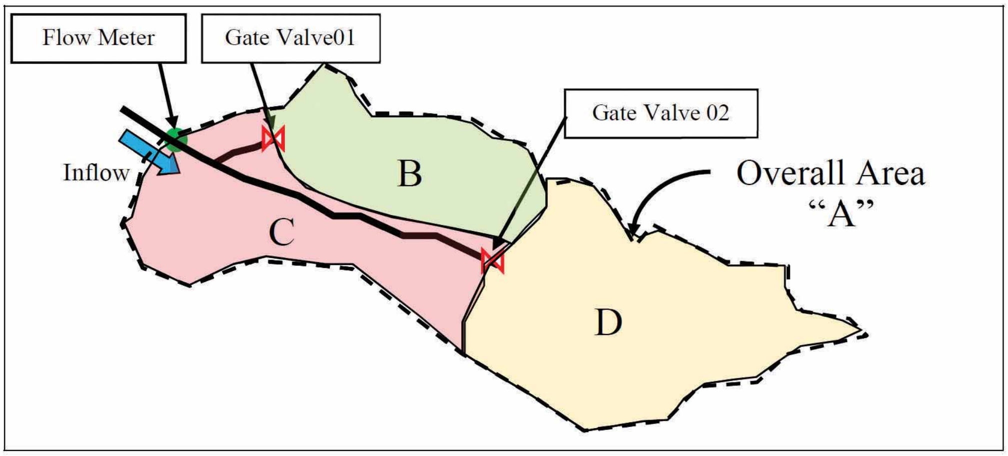


Figure 3.4: Schematic Diagram of Leakage Monitoring Block (Step Test)

The volume of water flow is measured by the flow meter as shown in Fig.3.4.

(a) Measure the volume of minimum flow for overall area "A".
(b) Close Gate Valve 02 and measure the volume of minimum flow for "B+C".
(c) The difference between volume of "A" and "B+C" is minimum flow volume of D, i.e. D = A - (B+C)
(d) Similarly, close valve 01 and measure the volume of minimum flow for "C".
(e) It can be determined that the difference "B+C" and "C" indicates the volume of minimum flow of "B", i.e. B = (B+C) - C.
(f) Then, volume of minimum flow for all could be determined.
(g) All measurements are recorded and compared to previous volume of minimum flow records. These comparisons can be found the abnormal flow and can be verify leakage occurrence.

Photo 3.6: Flow Meter Reading

Photo 3.7: Closing Gate Valve

Table 3.3 shows the result of step test in Meru WSP. In Meru WSP, Step Tests are implemented in 17 blocks.

Table 3.3: Results of Step Test (MEWASSs test case)

Result of Night Measurement Z-05 27-10-10

slno.	Pipeline No	pipeline route		Time to be measured		Meter Reading		Flow (3)	Flow (4)	Flow in Pipeline M^3/hr (5)	Priority
		From	To	Starting	Stopage	At starting time (1)	At stopage time (2)	(2)-(1) M^3/10min	(3)*6 M^3/hr		
1	Whole			23:56	0:06	2430506.00	2430512.30	6.30	37.80		
2	JW-01	DWO	End	0:10	0:20	2430514.00	2430518.01	4.01	24.06	13.74	measurement
3	Con 70 Police line	at the meter		0:22	0:32	2430518.90	2430522.31	3.41	20.46	3.60	status i.e burst
4	JW-05& DW-07	Sv @ BPT	End	0:34	0:44	2430522.95	2430526.45	3.50	21.00	-0.54	
5	JW-06 Lower & JW-05	@chamber	Sv @ BP	0:46	0:56	2430527.30	2430530.66	3.36	20.16	0.84	
6	DW-06E	Origin	End	1:04	1:14	2430533.30	2430536.30	3.00	18.00	2.16	5
7	JW-03 Lower	Backlays	End	1:16	1:26	2430536.80	2430539.51	2.71	16.26	1.74	6
8	JW-08	Origin	Sv Mid	1:28	1:38	2430540.00	2430542.52	2.52	15.12	1.14	
9	JW-06 Upper	Origin	@cham	1:40	1:50	2430542.90	2430544.82	1.92	11.52	3.60	1
10	DW-06D	Origin	End	1:52	2:02	2430545.25	2430546.94	1.69	10.14	1.38	7
11	DW-06B& DW-06C	Origin	End	2:04	2:14	2430547.25	2430548.71	1.46	8.76	1.38	7
12	DW-06A	Origin	End	2:16	2:26	2430548.95	2430550.29	1.34	8.04	0.72	
13	JW-03 Upper	Origin	Backlay	2:28	2:38	2430550.60	2430551.51	0.91	5.46	2.58	4
14	DW-05,	Origin	End	2:40	2:50	2430552.15	2430553.11	0.96	5.76	-0.30	
15	DW-04 & JW-02	SV @ DWO	End	2:53	3:03	2430553.30	2430553.82	0.52	3.12	2.64	3
16	JW-09	Origin	End	3:06	3:16	2430553.85	2430553.85	0.00	0.00	3.12	2
17	JW-02& JW-07	Origin	SV @ DWO							0.00	

Source: MEWASS

Abnormal flow cannot be determined solely by flow volume. It is important to understand and take into consideration seasonal movement of inhabitants, building developments, operation status of big consumers like hospitals and construction works, etc. Characteristics of the area as well as past experiences must also be considered. If an Abnormal Flow has been determined in a sub blocks, a leakage detection team must be dispatched the following day to determine the cause of abnormal flow. If the cause is leakage, repair works must be done immediately.

(6) Leakage Survey Method in Low Water Pressure

In some water supply systems, water supplied to the supply area has very low water pressure. In general, leakages occurring in water pressures of more than 0.1 Mpa can be detected easily by sounding method. Leakages occurring in water pressures under 0.05 Mpa are very difficult to detect.

Leakage detection and repairs in distribution pipes with water pressure of more than 0.1 MPA upstream but lower water pressure downstream should be conducted during the night when the volume of water consumption is low. For this exercise, the peripheral valves of service pipes located not too far from the distribution pipe must first be closed and this procedure must be taken throughout the distribution pipe until water pressure is restored.

3.6 Leak Detection

Non-visible Leakages (Underground Leakages) are often difficult to detect. In order to detect underground leakages, it is necessary to use leak detectors such as listening sticks and electronic leak detectors. Using leak detectors often require specific skill and experience, therefore training of staff is important.

3.6.1 Leak Detection Equipment

Underground leakages are usually detected by using a leak detector, which is placed on the ground surface or on the pipe wall, to detect leak noises. The sound and quality of leak noises vary depending on factors such as soil properties, pipe material, pipe diameter, depth of pipes underground, magnitude of leakage, water pressures and others. Detecting leak noises in clay soils or in pipes with large diameters is not easy, and requires experience.

The following are typical leak detection equipment;-

(1) Listening Stick

Listening Sticks have been used for many years to simply detect leaks and are the origin of the electronic leak detectors which are widely used at present. Its mechanism is very simple and consists of steel rod and a small circular vibration plate which is connected to the end of the bar at a right angle. It is a kind of stethoscope without an electronic amplifier.

Photo 3.8:
Listening Stick

Photo 3.9:
Leak detection using
Listening Stick

Photo 3.10:
Leak detection using
Listening Stick

The leak noises can be heard by putting the tip of the bar to a meter or a pipe fitting, followed by listening on the vibration plate set at the top of the bar. This method can only confirm the existence or non-existence of leakage near the listening stick but cannot locate the leak point. Listening Stick requires a lot of skill to distinguish the real leak noises from other similar noises. The equipment is still widely used.

(2) Electronic Leak Detector

An electronic leak detector consists for the main unit, a sensor (pick up), a headphone and a remote control unit. Leak noises are detected by placing the sensor on the ground surface. An amplifier is used to amplify the noise. The operator wears a headphone to listen to the amplified noise. The leak noise will become clearer and louder as the sensor nears the leak location. Using this device requires skill and experience.
As with the listening stick, this device is used mainly at night when there is less surrounding noise. Electronic Leak Detectors can greatly improve the efficiency of leak detection work.

Photo 3.11:
Electronic leak detector

Photo 3.12:
Leak detection using
electronic leak detector

Photo 3.13:
Leak detection using
electronic leak detector

(3) Digital Leak Noise Correlator

Leakages occurring in pressurized pipes will continuously generate random leak noises, which will travel in the pipe in both directions. The device transforms the noise that is detected into electrical signals which is displayed on the monitor of the correlator. This is not only to detect existence of leakages, but also the location by looking at the peaks of wave points.

Photo 3.14:
Digital leak noise detector

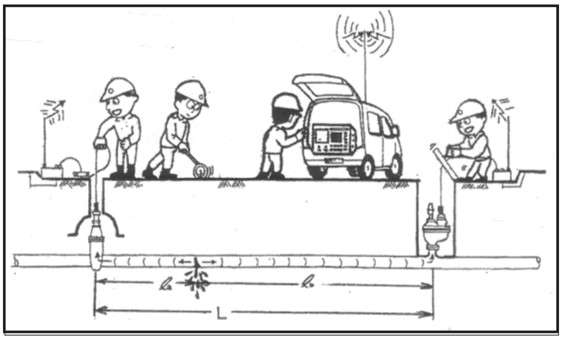


Figure 3.5: Conception diagram of cross-correlation type leak detector

(4) Time Integral Type Leak Detector

This detector is used to automatically determine existence of leaks in a specified area within a relatively short period of time.

The tip of the acceleration sensor is placed directly to the target customer meter or in case of pipes, to the nearest exposed service pipe.

Photo 3.15:
Time integral type leak detector

Photo 3.16:
Leak Detection using time integral type leak detector

Leakages in pressurized water pipes will generate a continuous noise from the leak point whereas noise from use of water taps or running vehicles will generate intermittent noises. This equipment uses this difference to determine presence of leakages.

The characteristics of this equipment are as follows.

- It is easy to handle and very effective in detecting leakages in service pipes. Leakages within 10 to 20 meters from a customer meter can be detected within seconds without any skill or experience.
- Using this equipment to screen areas suspected of leakages can greatly reduce labour costs. Meter readers can use this equipment during their reading rounds to screen areas of leakages.
- Isolation costs of LMB and labour cost implementing Step Tests can be reduced. Leakage areas can be determined by this equipment, therefore it will not be necessary to isolate new LMB and implement Step Tests.

(5) Other Leakage Detection Methods

1) Helium gas leak detector

When water with helium gas is injected into water pipes from a fire hydrant or taps, helium gas will flow out from leakage points in the pipe on to the ground surface. This is because helium gas molecules are very light and small, therefore are able to penetrate through the soil layer and the pavement. Helium gas emitted to the ground surface can be detected by a high performance helium gas detector.

2) Underground radar system

This system is able to determine the state of underground objects by radiating electromagnetic waves into the ground. The electromagnetic waves will bounce off any objects buried in the ground, which is captured on the ground surface to determine locations of buried objects.

3) Water quality examination method

Testing water quality at various points can determine whether there is contamination of water, therefore leakages. Generally, this test is conducted on water that flows through construction sites, basement of buildings or simply water flowing out onto the road. The quality of tested water must match that of tap water. The parameters to be examined are residual chlorine, PH, electric conductivity, water temperature, odor, etc. Additional test for trihalomethane may also be conducted.

4) Temperature difference method

Temperatures of ground water and water in pipes differ, especially during hot and cold seasons. A high performance infrared thermograph camera is used to measure the temperature of ground water. This method is applicable only for big leakages.

5) Differential pressure method

When water travels down a pipe, a head loss is created in the pipe. If there is a leakage in the pipe, the head loss recorded will be different from the theoretical head loss value. By using this theory, leakages, leakage volume and leakage location can be detected. This method is however difficult to apply since the head loss for small leakages will be minimal.

3.6.2 Buried Pipe Detection Technologies

In the absence of accurate drawings showing the exact location of buried pipes, it is important to be able to identify the exact location of distribution and service pipes to conduct leakage surveys. Some examples of methods of detecting buried pipes are outlined below;-

(1) Hammering Method

This method has been used for many years. A hammer is used in a uniform rhythm and strength on the road surface around the area where pipes are estimated to be buried. By using the listening stick or an electronic leak detector, the strength and changes of the sound is followed to identify the exact location of buried pipes.

(2) Metallic Pipe Locator

Metallic pipe locator is used to located metallic pipes. In this method, the pipe locator is placed on the ground above the buried pipes and a magnetic field is generated from a loop antenna with transmission coils. The magnetic current is conducted through the pipes and a secondary magnetic field is generated around the pipe, which can be detected by a separate antenna.

Photo 3.17: Metallic Pipe Locator

(3) Metal Locator

This locator is used to locate buried metal lids or other devices installed on pipes such as sluice valves, fire hydrant chests and customer meter boxes, etc. These may be buried due to pavements being constructed. The operation principle is the same as the Metallic Pipe Locator but the metal locator has a capacity to detect metal up to 50 cm in depth.

Photo 3.18: Metal Detector

(4) Sonic Type Non-Metallic Pipe Locator

A sonic pipe locator is used to detect non-metallic pipes, such as polyvinyl chloride, polyethylene and asbestos cement pipes.

Photo 3.19: Sonic Type Non-Metallic Pipe Locator

Chapter 4
Reduction of Commercial Losses

Reducing commercial losses is a key factor for NRW reduction in developing countries. NRW ratio can be reduced to as low as 30%, by only reducing commercial losses. In Kenya, challenges with respect to lack of integrity of utility staff have been identified as factors that significantly contribute to commercial losses.

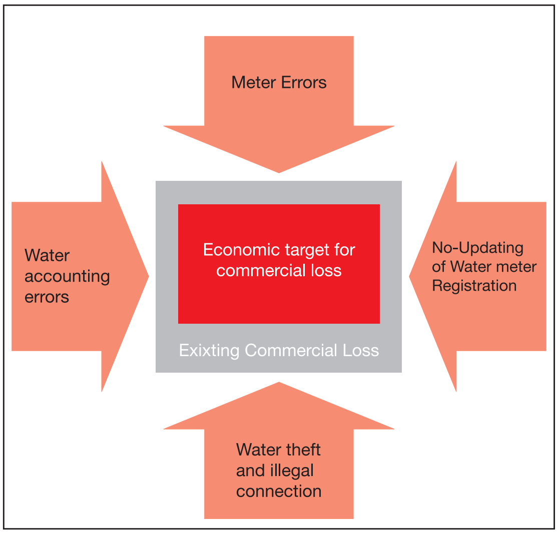


Figure 4.1: Four Pillars of Commercial Losses

4.1 General Condition of Commercial Losses

Water lost through Commercial Losses, also referred to as Apparent Losses is not a visible loss; therefore it is often overlooked by service providers who in most cases will focus on physical losses.

Commercial losses can amount to a higher volume of water than physical losses and often have a greater value, since reducing commercial losses increases revenue, whereas physical losses reduce production costs. For any commercially viable utility, the water tariff will be higher than the variable production cost. Therefore, even a small volume of commercial loss will have a large financial impact. An additional benefit in reducing commercial losses is that it can be accomplished quickly and effectively. This chapter reviews the four main elements of commercial losses and options to address them.

4.2 Commercial Losses Reduction Measures

Commercial Losses can be broken down into four fundamental components.

- Meter errors (customer meter inaccuracy)
- Under registration of connected meters
- Water theft and illegal connection
- Water accounting error

Measures to reduce commercial losses do not require high investment and results can be obtained relatively quickly. For these reasons, measures for reducing commercial losses should be focused at the beginning of the NRW reduction program. It however requires continuous commitment of the management, political will and community support.

4.2.1 Meter Errors

Inaccurate meters will have the tendency to under register water consumption and very seldom over register consumption. This means that inaccurate meters will contribute to reduced revenue.

When surveying for inaccurate meters, water meters of large volume consumers should be targeted first, as the revenue lost from large consumers will be big. Billing customers based on actual consumption is always preferable to flat rate billing. Common problems with customer meter inaccuracies and various solutions are described below.

1. Proper installation of water meters

Water meters should be installed according to the manufacturer's specifications to avoid unnecessary inaccuracies that may occur as a result of poor installation.

2. Water quality

Poor water quality due to inadequate treatment or dirt infiltration into pipes may cause sediments to settle in the water meters.

3. Intermittent water supply

Water meters in areas that receive intermittent water supply will begin to register volume of air. This normally happens when supply is resumed after a certain period of no supply. Sudden increase in water pressure can also damage the meter components. Intermittent water supply should be avoided as much as possible, as accuracy of water meter reading is greatly affected.

4. Meter Size

Customer meters are made to function within a defined flow range. Maximum and minimum flow volumes are normally defined by the manufacturer of meters, and in many cases, large meters will not register water flow when the flow volume is lower than the specified minimum flow volume. It is therefore important to conduct customer survey to understand the characteristics of each customer's water demand and their likely consumption, which will help to determine the correct size of meters required for each customer.

5. Class and Type of meter

Choosing the correct class and type of meter for each customer will ensure accuracy of customer consumption reading. More details on customer meters are explained in Chapter 6: Customer Meter.

6. Maintenance of meters

Water meters should be replaced systematically, beginning with the oldest meters and those that are in bad conditions. Poor maintenance of meters will result in meter inaccuracy and will also shorten the life span of water meters. A scheduled maintenance and replacement plan should be established to manage this problem.

4.2.2 Updating Water Meter Register

It is important to keep the water meter register constantly updated, as customer water consumption bills are based on information in the water meter register.

Updating of water meter register may range from a simple change of customer name or change from domestic user to a commercial use, to correcting information errors in the register.

In the Pilot Project, water meter register was updated at the time (Refer to Chapter 5: Activities in the Pilot Area).

There may be cases where information of new water meter connections is not transferred to the billing department. In such cases, customers are not billed and therefore there is loss in revenue. It is possible for trained and diligent meter readers to detect unregistered water meters during regular meter reading cycles, as unregistered meters will not appear on the meter reading book.

The best method for identifying billing system errors is by conducting a complete customer survey in the supply area. In this survey, each and every property, whether registered or not, should be visited to determine whether the connection is registered or not.

Customer survey should confirm the following information; name of customer, property address, type of meter and meter number, active or inactive meter, whether it is a high consumption meter, and year of installation.

Photo 4.1 Updating of Water Meter Register

4.2.3 Water theft and illegal connections

Illegal water connections, meter bypassing (water theft) and slum consumption are all part of unauthorized consumption. Some of the more common problems and possible solutions are described below.

(1) Detecting and Reducing Illegal Connections

An illegal connection involves establishing a physical connection to a water distribution pipe without the knowledge of the service provider. Meter readers should always be aware during their rounds and report any illegal connections immediately. Customers should also be made aware of the negative impacts of illegal connections and encouraged to report illegal connections when found. At the same time, strict regulations should be set in place to penalize illegal connections.

(2) Meter Bypassing

An additional pipe can be installed around the water meter, so that water bypasses the meter. In such a case, water bills are reduced, as true consumption volumes are not recorded. Often, the bypass pipe is buried underground and it is very difficult to detect it. Customer surveys and conducting leakage Step-Test can help in determining meter bypassing.

(3) Meter Tampering

This is another method used to record a lower water consumption volume than what is actually used. Meter functionality is tampered or disrupted by inserting pins or other small objects into the meters. Most reputable meter manufacturers now produce meters that are difficult to tamper with. Such meters are non-metallic with strong clear plastic windows and with casing that is difficult to penetrate.

(4) Influence of informal settlements on commercial losses

The influence that informal settlements may have on the natural and social environments cannot be ignored. Thus far, it seems that there is insufficient focus on water supply to the informal settlements. Although it is generally impossible to correctly determine the volume of water use in each household, it is important to at least know the amount of water that is being distributed to slum areas.

To determine the volume of water distributed in the slum area, the target slum area should first be isolated. The water entering into the target area should be taken at the few entry points created, as shown in Fig. 4.2. The entry points are indicated in this figure as red dots. Another method of determining the volume of distributed water is to use basic unit for consumed water volume per capita.

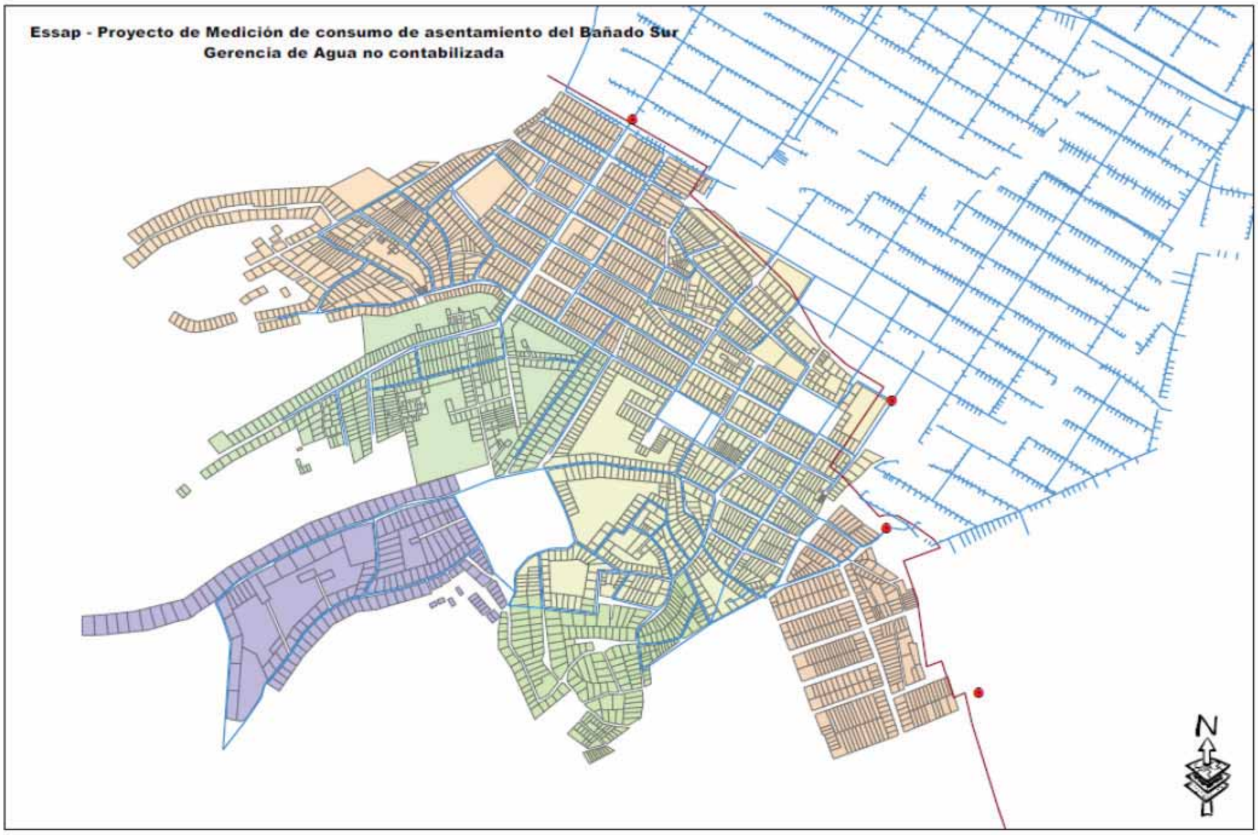


Fig. 4.2 Measurement of consumption volume in slum area

4.2.4 Water Accounting Errors

(1) Corrupt Meter Readers

Corrupt meter readers can have significant impact on a utility's monthly revenue. When the same meter reader is assigned to the same route for a long period of time, the meter reader may become very familiar with the customers in that route and may collude with customers to record a lower meter reading in exchange for monetary incentives. In order to reduce this risk, the meter routes of the meter readers need to be rotated on a regular basis.

(2) Meter Reading Errors

Meter reading errors may occur as a result of bad meter reading by incompetent or inexperienced meter readers, or simple errors while recording meter reading by placing decimal points in the wrong place. Errors can also occur as a result of dirty of faulty dials in the water meter.

Meter readers should immediately report any problems that they have observed and the maintenance team should take immediate action to remedy the problem. Meter readers' activities are in the frontline, liaising directly with customers therefore their activities have an immediate impact on the cash flow. Investments should be made in training and motivating meter readers to produce accurate and efficient work.

(3) Data Handling and Accounting Errors

Typically, the procedure for data handling and billing starts with the meter reader visiting each property / customer to read the customer water meter. The reading is then recorded by hand on a form and given to the billing department back at the office. The billing department then logs the reading into the billing system. The bill is then printed and mailed to the customer.

In this process, a variety of errors may occur at various stages of the process. Firstly, the meter reader may read incorrectly and / or record the reading incorrectly; secondly, the incorrect data may be logged into the billing system at the billing department; thirdly, the bill may be sent to the wrong address. One of the key factors in minimizing errors is to have a robust billing database and such a database should be the first investment for any WSP that is striving to improve its revenues.
Latest billing software has built-in analysis functions that can identify data irregularities, which could lead to potential identification of data handling errors. If financially viable, investment should be made to install electronic meter reading devices. These devices transfer all data to the billing department electronically therefore data handling errors will reduce drastically.

(4) Obstacles to Meter Reading

The meters are covered with mud, garbage or soaked in water, which frequently occur. Thus, the readers do not read the meters correctly. Installing the meters in accessible locations where the readers can easily read them.

Photo 4.2: Water Meter covered with Mud

4.2.5 Others

(1) Introduction GIS Database

GIS has been introduced as a platform for the management of water service system, especially for its characteristic capacity for comprehensive management of maps and databases. GIS is used in areas such as graphic management, customer registers, revenue collection, etc.

(2) Efficient Billing System

For efficiency and accuracy, a computerized billing system should be used.

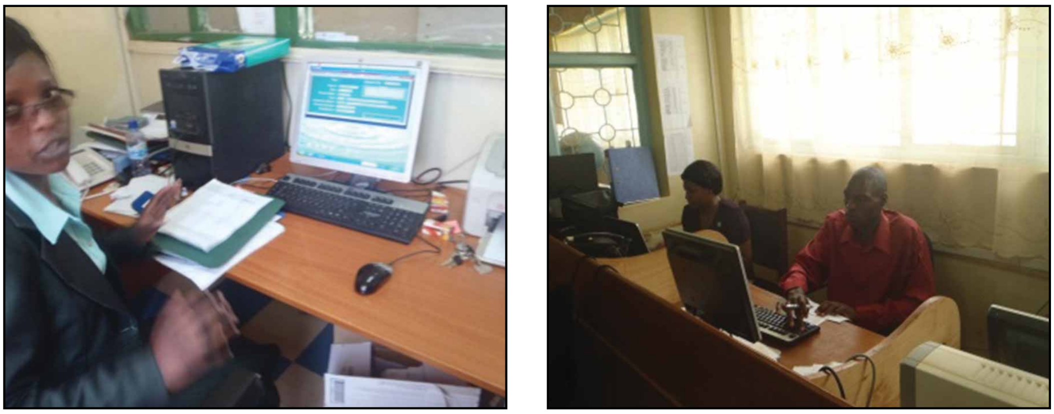


Photo 4.3: The Billing Unit for Narok & Embu respectively

(3) Customer Care System

To manage customer complaints, a customer care system should be established. This system should handle problems related to meter reading errors, lack of water supply, dirty water or insufficient water pressure and handled in a quick and efficient manner. Careful attention given to customers will increase customer trust, which can lead to better payment of bills and therefore stable revenue.

Photo 4.4: Customer Care System

Chapter 5
Activities in Pilot Area

This Manual strongly recommends that all WSPs implement a Pilot Project at the beginning of their NRW Reduction Procedure. A small section within the water supply area.

Figure 5.1 is a flowchart showing the Implementation Plan in a Pilot Area. Following are the main points of the Implementation Plan.

- Select a pilot area that consists of one district metered area (DMA), with several leakage monitoring blocks (LMB). Each block must be isolated from adjoining blocks by peripheral valves.
- Accurate pipe network map of the Pilot Area should be prepared
- Collect basic data necessary to prepare a plan of NRW reduction measures that are suitable to the area. At the same time, capacity building of staff should be implemented as part of OJT (on the job training)
- Integrated plan of NRW reduction measures should be prepared based on the data obtained Analysis of the data should determine the most cost effective and efficient measures to be implemented in the whole supply area, taking into consideration the financial availability of the WSP.

Each activity is explained in further detail in the next section

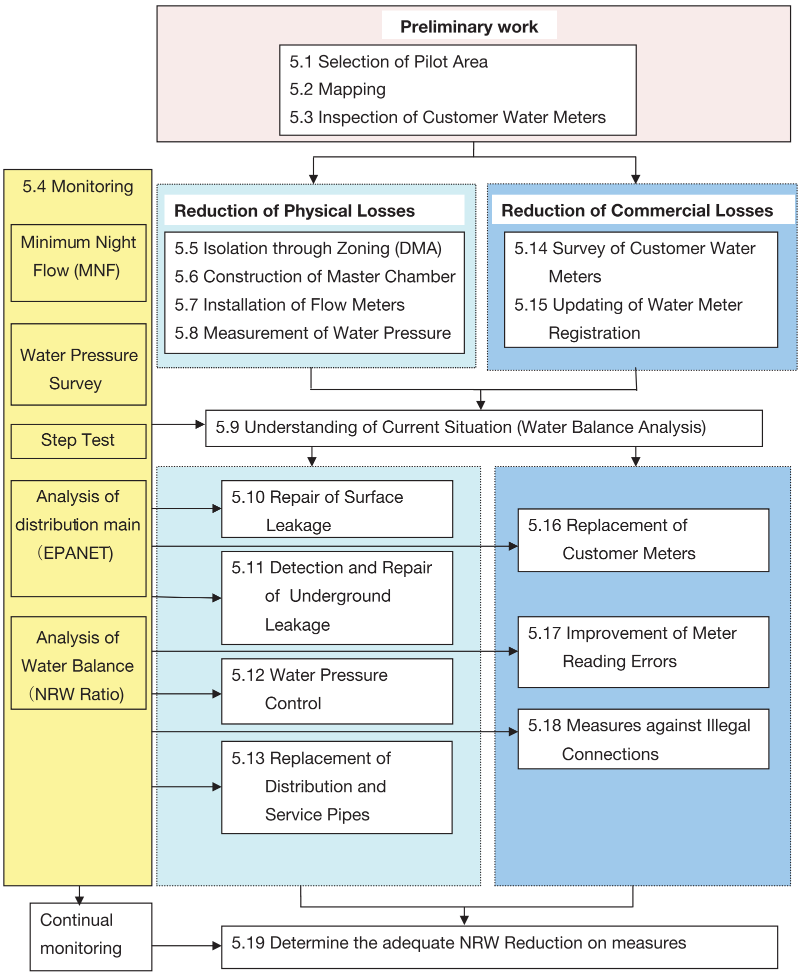


Figure. 5.1: Flowchart showing Implementation Plan of Pilot Project

5.1 Selection of Pilot Area

The following must be taken into consideration when selection the Pilot Area.

- The selected area must be isolated from neighbouring areas
- Volume of water supplied to the selected area must be measurable
- Volume of water used in the selected area must be measurable
- Population and number of pipes running in the selected area must be reasonable. A good guideline would be an area with a population of around 5000 people, total length of distribution pipe of approximately 8 km, and water connections of about 1,500.

In Embu, Blue Valley area was selected as the Pilot Area. The criteria for its selection were, firstly Blue Valley has approximately 1500 water connections. Secondly Blue Valley can be isolated from neighboring areas, and thirdly Blue Valley has one point of water supply entry into the area. The Pilot Area was divided into three (3) sub-blocks and this sub-division was relatively easy as there were no complicated pipe layout.

In Narok, Majengo area was selected as the Pilot Area. Majengo has a population of around 19,000. It has two points of water supply entry and there are relatively few water pipes connecting Majengo to neighboring areas. However, due to the complicated pipe layout and no pipeline network map, it was difficult to divide Majengo into sub-blocks. Three (3) sub-blocks were eventually created by installing twenty-two (22) gate valves. However, a population of 19,000 proved to be too large.

Details of the Pilot Projects are given in Part II of this Manual.

Photo 5.1: Embu Pilot Area

Photo 5.2 Narok Pilot Area

5.2 Mapping

Accurate pipeline maps should be prepared.

Fig. 5.2 shows the distribution pipeline network and water meter mapping in pilot area of Embu WSP.

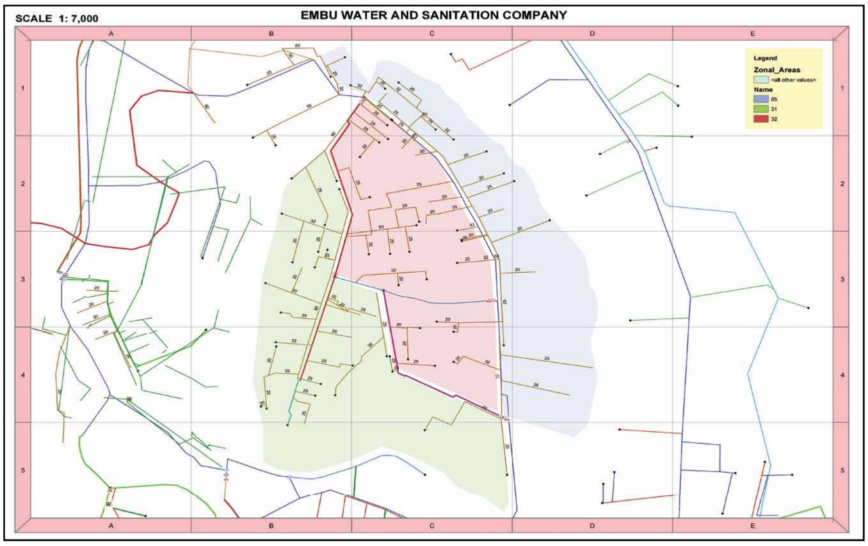


Figure 5.2: EMBU Pilot Project Blue Valley Area Water Pipe Network Map

In Majengo, the Pilot Area in Narok, there was neither pipeline network map nor water meter register. In order to create the pipeline network map, ground surveys were conducted, and then pipeline map was drawn by hand. As a result, a digital pipeline network map with information on location of water meters was prepared, as shown in Figure 5.3.

Figure 5.3: NAROK Pilot Project Majengo Area Water Pipe Network Map

5.3 Inspection of Customer Water Meters

All customer meters in the Pilot Area should be inspected as part of preliminary work. Location, its operation and registration information for each meter should be confirmed.

Photo 5.3: Customer Water Meters in Pilot Area

5.4 Monitoring (Installation of Data Transferring System)

In Embu Pilot Project, a data transferring system was installed at the entry point of the Pilot Area. The transferring system is composed of a Data Logger, which stores data of the flow meter, and a GSM telephone line that transmits data as SMS to the office. The data logger runs on solar energy.

Photo 5.4: Installation of digital flow meter and data logger for monitoring

5.5 Isolation through Zoning (DMA)

In the Pilot Project, it is imperative to have the Pilot Area that is totally isolated from adjacent zones. It must also be possible to close off water flow temporarily into the Pilot Area using gate valves.

Photo 5.5: Isolation through Block (DMA)

5.6 Construction of Master Meter Chamber

A master water meter chamber is constructed to install flow meters that measure water flow into the Pilot Area. An electromagnetic flow meter is usually installed in the chamber and when constructing the chamber enough space must be considered to conduct measuring activities in the chamber.

Photo 5.6: Construction of Master Meter Chamber

5.7 Installation of Flow Meters

In order to undertake MNF measurements in the Pilot Area, it is necessary to install a flow meter such as Electro Magnetic Flow Meter or Ultra Sonic Flow Meter, which has a very high accuracy.

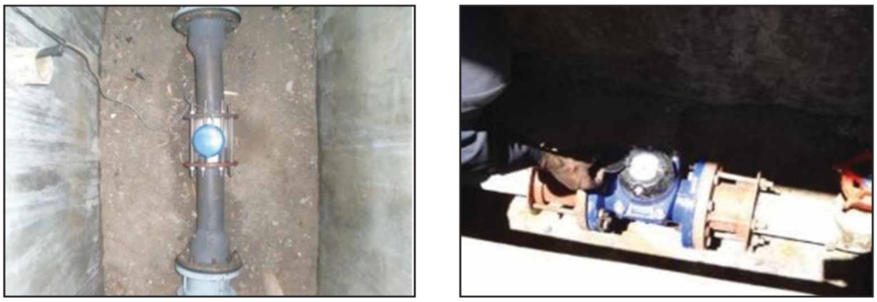


Photo 5.7: Installation of Master Meter and Valves

5.8 Measurement of Water Pressure

Water pressure in the Pilot Area is measured using a pressure gauge. Based on the results, a plan is prepared for the installation of pressure reducing valves.

Photo 5.8: Pressure gauge
for water taps

Photo 5.9: Measurement of Water Pressure (Embu WSP)

5.9 Understanding of Current Situation (Water Balance Analysis)

To understand the actual situation of the Pilot Area, firstly the total volume of water distributed must be established through data obtained from the Master Meter that is installed at the point of water entry. Secondly, the volume of water used must also be determined through data obtained from customer water meters. In cases where there are customers with flat rate consumption, the billed water volume should be used to estimate the consumption.

With the above data, the ratio of NRW of the Pilot Area can be calculated.
In the Pilot Project, it is important to compare the NRW ratio of the Pilot Area before and after the implementation of the NRW reduction activities to understand the effectiveness of the NRW reduction activities.

5.10 Repair of Surface Leakage

Surface leakages can be detected by line patrolling or by reports from residents. Detected leakages must be repaired immediately.

Photo 5.10: Repair of Surface Leakage

5.11 Detection and Repair of Underground Leakage

Underground leakages can be detected by using leak detection equipment such a Listening Stick or Electronic Leak Detector. Underground leakages that are detected must be repaired immediately.

In cases where distribution pipes must be replaced, it is advisable to replace service pipes at the same time. Water Pressure Test must always be conducted to service pipes that are replaced, to ensure proper installation of pipes (Refer to Chapter 7: Construction Method)


Photo 5.11: Detection of Underground Leakage



Photo 5.12: Repair of Underground Leakage and Water Pressure Test

5.12 Water Pressure Control

Controlling water pressure is one of the effective methods of reducing NRW. In high altitude areas, difference in elevation affects water pressure. This difference can generally be adjusted by installing Pressure Reducing Valves. Details on water pressure control are described in Chapter 9: Water Pressure Management.



Photo 5.13: Installation of Pressure Reducing Valve

5.13 Replacement of Distribution and Service Pipes

Care must be taken in the quality of construction when replacing pipes. Despite the old pipes being replaced by new ones, if the construction quality is poor, this will only lead to additional leakages.
(Refer to Chapter 7: Construction Work). It is necessary to conduct OJT on the quality of construction and construction supervision during the Pilot Project.

Photo 5.14: Replacement of Distribution Pipes

Photo 5.15: Replacement of Service Pipes

5.14 Survey of Customer Meters

All customer water meters within the Pilot Area must be inspected.
The following data and information must be collected at the time of meter inspection.

- Type and material of meter
- Manufacturer of meter
- Location of water meter
- Customer registration details
- Connection status (active or inactive)
- Year of meter installation (if possible)

It is important to conduct this survey as existing data may not match the survey data, which was the case for Embu WSP.

Photo 5.16: Survey of Customer Meters

5.15 Updating of Water Meter Register

In the Pilot Projects, updating of water meter registration was done at the same time the survey of customer meters was conducted.

5.16 Replacement of Customer Meters

Based on the information obtained from (5.14) Survey of Customer Meters and (5.15) Updating of Water Meter Registration, those customer meters requiring replacing should all be replaced during the Pilot Project. In addition, all illegal connections and direct connections should all be either disconnected or new meters installed. The accuracy of determining the volume of water used should improve by implementing these measures.

Photo 5.17: Replacement of Customer Meters

5.17 Improvement of Meter Reading Errors

Errors in meter readings are usually human errors. It is therefore necessary to train meter readers during the Pilot Project.

Photo 5.18: Meter Reading

5.18 Measures against Illegal Connections

It is necessary to take firm action against illegal connections. As soon as an illegal connection is detected, it must be disconnected immediately. It is equally important to restore the water supply once the connection is legalized. Where high volume of water has been used illegally for activities such as irrigation, this connection should never be reconnected and action should be taken in accordance with the law in force.

5.19 Determine the adequate NRW Reduction measures

There are various NRW reduction measures that can be implemented. To understand the effectiveness and see the results of these measures, it is important to implement the measures one by one. The effectiveness of each measure can be determined by conducting MNF measurements after implementation of the each activity.

Chapter 6
Customer Meter

Customer water meters provide important basic data. For example, it provides basic data necessary for computation of water rates and data necessary to calculate NRW ratio. It is therefore of utmost importance to connect customer meters to each and every household.

6.1 Selection of Customer Meters

In selecting customer meters, it is important to select the type of meter that is most suitable for the consumption trend of each customer. Considerations to the maximum monthly consumption and maximum flow rate are important to select a meter that will assure steady performance for a long period of time.

Criteria for Selection of Water Meter

1) Meters can be selected based on the design of the water supply system. Maximum consumption flow rate must be taken into consideration to select the most suitable meters.
2) Meters can be selected based on survey data. Typical patterns of consumption per hour must be summarized and the monthly maximum and minimum consumption must be determined.
3) Meters can be selected by quality of meter material. Selection of meters should not only depend on price, but more importantly on the quality of water meter material.

		
Impeller type	Rotary type	
Metallic Water Meter		Plastic Water Meter

Photo 6.1: Various types of customer meters

Photo 6.1 shows the various types of customer meters. Metallic water meters are better in terms of accuracy and durability, but they are more expensive and they also have a high risk of being stolen. On the other hand, plastic water meters are cheap and have a low risk of being stolen, but it is relatively less durable.

CHOICE OF WATER METER

- ✓ ***Class B-Where water quality is low as sediments will not affect meter.***
- ✓ ***Class D-Where water quality is good - have specs for a minimum flow rate***
- ✓ ***Class C- compromise- can measure low flows better than B and less expensive than D.***

USING THE RIGHT WATER METER

- ✓ ***Positive displacement meters (15mm-20mm) commonly used in domestic and small commercial installation.***
- ✓ ***Single jet and multi jet meters Connection size - 20mm to 50mm.***
- ✓ ***Electromagnetic meters- connection size 100mm and above.***

6.2 Installation of Customer Meters

Factors to take into consideration when installing customer meters are the reliability of meter performance, ease of reading and ease of replacing and maintenance.

Photo 6.2: Installation of Customer Meters

(1) Location for Installation of water meters

The following factors should be considered when selecting a site for installation of meters.

i. Meters should be located at points where meter reading, inspection, and maintenance can be easily be performed.
ii. Sites selected should be in dry areas away from waste water.
iii. Meters should be installed in locations away from contaminated air or exhaust air.
iv. Meters should not be easily exposed to vandalism or accidents.
v. Meters should be located in areas free from water logging and flooding.
vi. Meters should not be installed in areas with excessively high temperatures
vii. Meters should not be installed in locations where water pressure fluctuates excessively
viii. Meters should be located in areas where they are not subjected to shocks or vibrations.

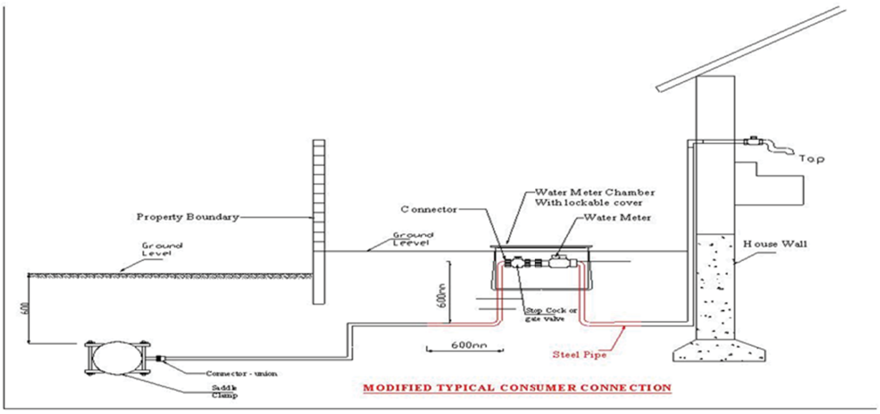


Figure 6.1 Typical Customer Meter Locations in Kenya

There are many cases in Kenya where meter readers cannot read customer meters as they are buried underground. This can also be a cause of errors in meter reading. It is recommended to install water meters above the ground in order to facilitate meter reading. In Kenya, water meter installed above ground are more susceptible to theft. In such cases plastic water meters are recommended.

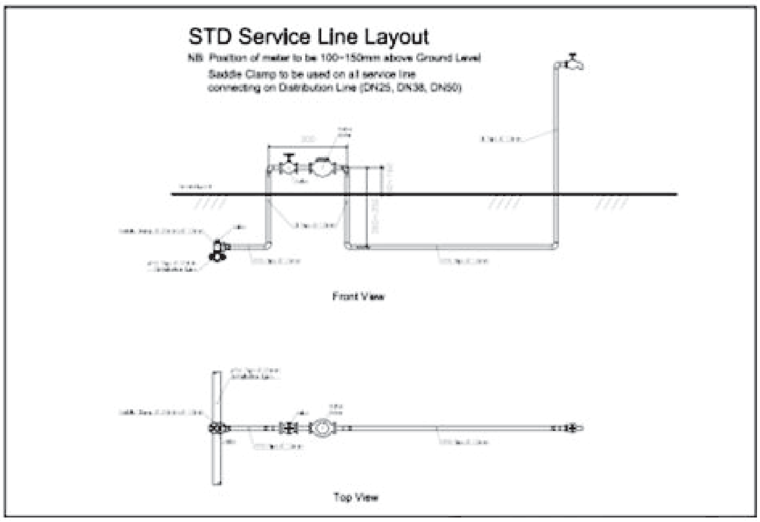


Figure 6.2 Installation methods to expose customer water meter

(2) Precautions for Installation

Poor installation can impact negatively on the performance of meters. Following precautions should be taken at the time of meter installation to minimize sub standard performance of meters.

i. Clean the interior of pipes thoroughly so that they are free of any debris, sand and foreign matters. Recording errors will develop if the strainer of a single-casing meter is clogged. Meters can be easily damaged by presence of foreign matter.
ii. Install meters horizontally at the designated location, with the arrow on the lower case facing towards the direction of the flow of water. When meters are not installed horizontally, meter sensitivity and durability can be highly compromised.
iii. Meters should be installed with sufficient pipe length on both sides of the meter. Insufficient length or bent pipes will affect the accuracy of meters and it may also strain meters. In cases where the length of pipes are too long, it will be necessary to make sure the meters structurally well supported for stability.
iv. Use gaskets that properly match the diameter of meters. Instrumental errors may occur when gaskets are projecting inwards.
v. For Wotlmann horizontal type, Venturi-tube bypass type and turbine driven meters, a straight tube should be installed on the upstream of the meter. The straight tube should be at least five times larger than the meter diameter and at least three times larger than the meter diameter on the downstream.
vi. Upon completion of installation, care should be taken to open the stop valve slowly when admitting water for the first time, in order to prevent water hammering.

6.3 Maintenance

Maintenance of water meters involves making sure that meters maintain accuracy and being prepared to replace meters at all times.

(1) Maintenance for Accuracy

In order to maintain meter accuracy, the following must be done

i. Analyze actual consumption based on data obtained from meter readers on a monthly basis
ii. Conduct surveys to keep track of actual consumption flow rate
iii. Replace meters based on planned replacement schedule

(2) Management of Meter Installation

Meter installation should be managed by the following.

i. Ensure that meter boxes are not buried in sand or mud
ii. Ensure that meters are installed horizontally
iii. Check that there are no leakages around meters
iv. Check that quality certification is properly affixed on the meter

6.4 Specified Qualification Test (Meter Test)

(1) Program of tests applicable to all water meters

All meters should undergo the following program of tests. Meters that pass this program should be considered safe to use.

"Error of Indication" listed in 2) below should be used to determine meter accuracy. Although this is a program, each individual test must be thoroughly understood independently. Error of Indication test will be revisited with Meter Accuracy Test.

Test Programme	
1	Static pressure
2	Error of indication
3	Water temperature
4	Water pressure
5	Flow reversal
6	Pressure loss
7	Discontinuous flow durability
8	Continuous flow durability

1) Static Pressure Test:

Maximum permissible pressure is desirable to be 1.0 Mpa and it must be verified that there are no leakages.

2) Error of Indication Test:

To test the relative error, it is a fundamental requirement to maintain pressure at a constant. The tolerable range of pressure oscillation depends on the test method, but it should be maintained in the range of ±2.5%~±5.0%. To test the relative error in specific meter, test of intrinsic errors is conducted with 7 points of flows and the measurement is conducted twice.

3) Water Temperature Test:

Under standard conditions, the standard temperature is 20 degrees C, and the test is conducted under 30 degrees C.

4) Water Pressure Test:

Minimum permissible pressure must be 0.03 Mpa and the maximum permissible pressure must not fall under 1.0 Mpa.

5) Flow Reversal Test:

The tolerance for this test is the same as the tolerance for normal flow.

6) Pressure Loss Test:

Pressure loss within flow range from Qmin to Qn should not exceed 0.063 Mpa.

7) Discontinuous Flow Durability Test:

The number of interruptions created in 100,000 with 15 seconds intervals

8) Continuous Flow Durability Test:

There may be variances in duration of durability test depending on the volume of maximum flow; however the standard for 15 mm diameter meter is 100 hours.

(2) Meter Accuracy Test

i) Relative error

Relative error occurs when volume of water measured by meters compared with the real volume of water shows excess or less volume. As the ISO standard, the relative error could be represented in percentage calculated as follows:

$$\text{Relative error } E\,(\%) = \frac{I - Q}{Q} \times 100$$

Where:
I: Indicated volume
Q: Real volume

ii) Sensible water curve and relative error

Where

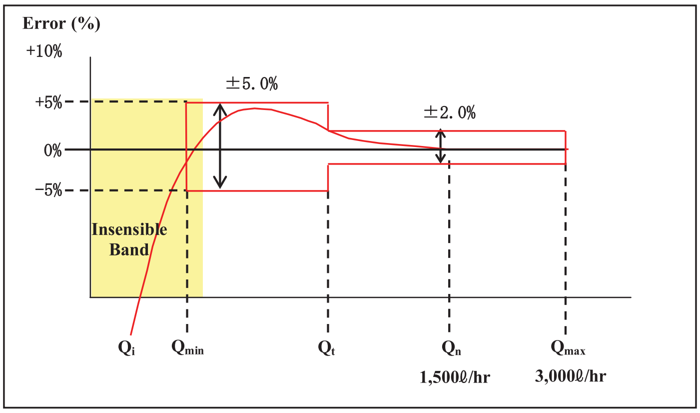


Figure 6.3: Curve of Relative Error in Class C

Qi : Initial Sensible Minimum Flow (8-10l/hour)
Qmin : Minimum flow
Qt : Transitional flow
Qn : Normal/ Permanent flow
Qmax : Maximum /Overload flow

Table 6.1 shows standard of customer meter class A, B, C and D

Table 6.1 ISO Standard of customer water meter Unit: liter/hour

	CLASS A	CLASS B	CLASS C	CLASS D
Qmin (Minimum flow)	60	30	15	11.25
Qt (Transitional flow)	150	120	22.5	17.5
Qn (Normal/permanent flow)	1,500	1,500	1,500	1,500
Qmax (Maximum/overload flow)	3,000	3,000	3,000	3,000

Photo 6.3: Water Meter Test Bench

Before conducting a meter test, it is important to understand class specifications of each meter. For Class A to D meters, the Qn (Normal / Permanent Flow) has been set to 1,500 liters / hour; therefore there is no variance in volume between the meter classes. It can be seen from Table 6.1 that decrease in volume of water increases meter class performance (A<B<C<D).

Approximately 10% of all water meters in the target area should be randomly selected for meter testing. Selected water meters should be categorized by “Count Flow” (number of times it has be counted in the past) and also by Class.

Meters in Qmin~Qtf range must operate within 5% of specified tolerance. Meters in Qt~Qn~Qmax range must operate within 5% of specified tolerance. The acceptable tolerance range for users should be up to double the specified tolerance.

6.5 Expired Water Meters

Expiry date of water meters is established in accordance with the Weights and Measures Law. In general, water meters will expire after eight (8) years from the date of installation subject to the meter having passed the qualification test before installation.

6.6 Replacement of Defective Meters

In developed countries, customer meters are required by law to be replaced periodically. For example in Japan customer meters must be replaced with new meters every **eight (8) years** whether the meter is malfunctioning or not.

Replacements of meters are not regulated by law in developing countries. Furthermore, inferior quality meters, cheap new meters and even used meters are being sold in the market. Cases of recycled meters being installed as replacements are not uncommon.

Customer meters are the most important element for any utility; therefore it is important to install customer meters that will give high performance and a long life. Using cheap and inferior new meter may seem economical; however in the long run it will prove to be costly as it will not last long and accuracy is compromised.

Before replacement of defective meters, a “Notification for Replacement of Expired Water Meter”, and “Schedule for Replacement of Expired Water Meters” must be issued to the client whose meter is due for replacement. The schedule for meter replacements must be prepared by the relevant department in the utility and the meter replacements must be conducted in accordance with this schedule.

Photo 6.4: Classification of Expired Water Meters

6.7 Measures against Meter Theft

In developing countries, in order to avoid theft of meters and meter boxes made out of metal, meters are secured in concrete chambers with heavy concrete lids, which are hard to open. This causes difficulties for meter readers and for conducting leakage control work.

It is recommended that metal meters and metal boxes be replaced with plastic meters and boxes. Plastic meter boxes may be inferior to metal boxes in terms of robustness, but quality of plastic has recently improved and therefore can be used sufficiently.

Chapter 7
Leakage Prevention in Construction Work

- Leakages still occur even when distribution and service pipes are all replaced, where excavation, plumbing works and construction workmanship are poor.
- The Importance of a Site Manager and his supervisory role in construction work is often ignored and this can lead to sub-standard piping work.
- Leakages often occur at pipe joints, especially on service pipes, and many pipe breakage incidences occur due to shallow pipe depth.
- Leakages will also occur immediately the pipes are replaced, if the construction work is poor. This is ineffective use of resources.

This Chapter focuses on construction management and methods of pipe connection, particularly for sub-mains and PVC and HDP pipes.

7.1 Standardization of Pipe and Joint Materials

The most important requirement in Kenya is to adopt usage of standards of materials and construction methods on a consistent basis. Fire coupling and plastic paper bends can be seen often in pipe connection in Kenya. This is not only due to poor construction quality, but also due to lack of pipe standards at the manufacturing level.

Kenya uses both inches and meters, and in addition the ISO standards are also being used. This results in variations in pipe thickness and internal diameter therefore needing adjustments at site. Also, the couplings that come from the manufactures are not uniform.

Regardless of the construction quality, the problem of water tightness could still exist. “Pipe Material Standards” should be established by WASREB and it is important to target improvements in quality of pipe material.

Photo 7.1: Fire Coupling
(used for pipe connections in Kenya)

Photo 7.2: Plastic Paper Bend
(used for pipe connections in Kenya)


Photo 7.4: Socket of pipe connection


Photo 7.5: Connecting pipes (Meru WSP)

7.2 Inspection of Piping Work

Leakages will continue to occur if the quality of construction is poor. Construction management is vital to ensure good quality construction that prevent occurrence of many leakages. In cases where construction work is done in-house, the utility must ensure that the construction team is well trained in terms of quality. In cases where the construction work needs to be outsourced, the water utility must supervise the construction work for quality assurance.

Following are some important quality standards.

(1) Piping

- Pipe depth is more than the standard requirement (0.3m)
- Piping at site should match with the applicable design
- There should be no cross connection
- Are necessary pipe protections installed? The method of pipe protection must be confirmed
- Are pipes appropriately jointed?
- Pipes should not be directly connected to the pumps as this affects the water pressure in distribution pipe
- Pipes must satisfy the material and structure standards of installation

(2) Equipment

- The equipment should satisfy the material and structural standards of installation
- Equipment etc. must be appropriately jointed
- Cover boxes should satisfy the material and structural standards of installation

(3) Water pressure

- There should be no leakage from joints, or any other defects should be seen at the standardized pressure test

(4) Water meter surrounding

- Water meter should be appropriately installed and there should be no obstruction for reading and replacement of meters
- Base plate and sand stopper should be appropriately installed
- Appropriate preparation for meter installation like spacer should be taken

(5) Others

- Confirm whether installation is good or not
- In case of direct connection of service system)
- Air Valve (suction/blow type) is appropriately installed
- Always confirm that valves of decompression type are appropriately installed

7.3 Example of Inspection of Construction Work

The following are some of key elements in inspecting the Piping Work.

(1) Backfilling
(2) Connections (joints)
(3) Water Pressure Test
(4) Record keeping with photographs (evidence)

Using the case for Japan, the key elements of Inspection work are explained in this section. This shows as an example, the extent or "level" of inspection work done in Japan, and it is not intended to impose this level in Kenya.

7.3.1 Backfilling

The following should be confirmed.

- Pipe depth is more than 0.3m
- Good quality sand is be used
- Compaction is done in accordance to the standards of construction work

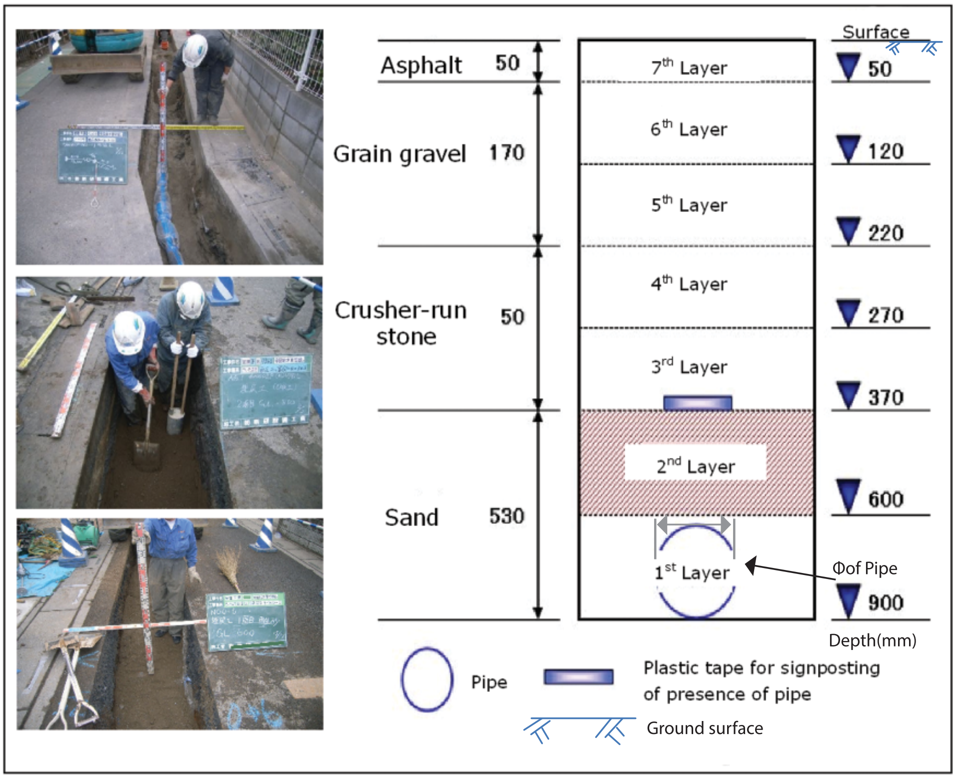


Figure 7.1 Backfilling work of pipe (Japanese Case)

7.3.2 Connections (Joints)

Sufficient length of pipe jointing is necessary.

Photo 7.6 Connection work of Pipe (Japanese Case)

7.3.3 Water Pressure Test

Water Pressure Test must always be conducted after construction work, to confirm that leakages are not occurring.

When conducting the Water Pressure Test, water pressure in the pipe must be increased to up to 0.75 MPa (approximately 75 meters)

Photo 7.7 Water Pressure Test

7.3.4 Record keeping with photograph

Photographs should always be taken at leakage repair site and replacement of service pipes and distribution pipes. Record must be immediately mapped and reflected in the water ledger.

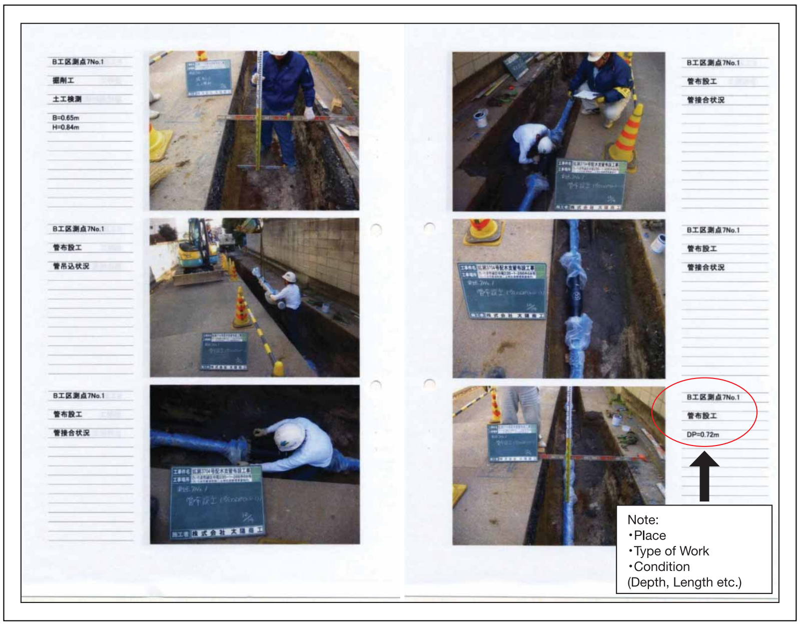


Figure 7.2 Example of Ledger after Construction Work (Japanese Case)

7.4 Example of Pipe Jointing

Pipe jointing work is very important in leakage prevention. Those who supervise pipe work installation should not depend on the skills and experience of the workers but should themselves have adequate knowledge, experience and understanding of the principle of various types of joints.

Below is an example of Pipe Jointing standards in Nagoya Waterworks Bureau in Japan. It is advisable to set up standards of pipe jointing that is most suitable to Kenya.

7.4.1 Connecting PVC Pipes

Polyvinyl chloride pipes can either be connected by bonding, welding, or using a rubber ring or special joint. The Taper Socket (TS) bonding method is generally used for this purpose.

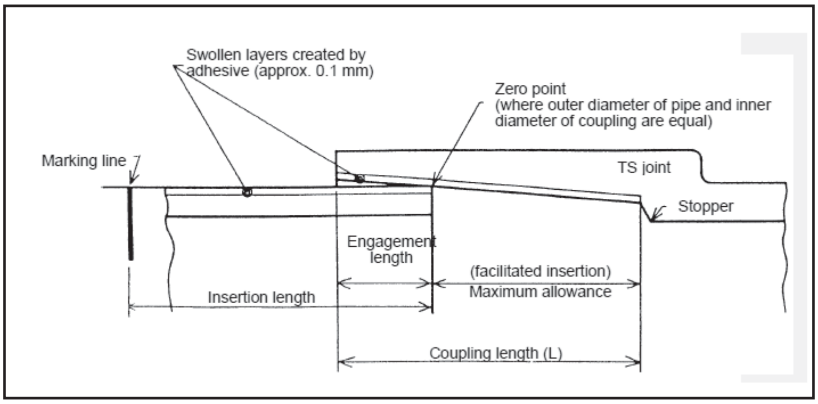


Fig 7.3: Detail of PVC joint

1) Principle of Taper Socket (TS) bonding method

This method uses a joint with a tapered end and utilizes the swelling and elasticity of polyvinyl chloride when combined with an adhesive.

i. As adhesive is applied to the pipe and joint, a swelling of approximately 0.1 mm thick is produced on the surfaces as shown in figure below, this facilitates insertion of the pipe. After the pipe is inserted to the point of stopper, the swollen layers bond to join the surfaces together. The counter force from expanded socket also has the effect for tight joint.

ii. Before applying adhesive, following procedure is necessary:
Measure the coupling length
Temporarily and lightly insert the pipe into the socket and check to ensure the engagement length is 1/3 - 2/3 of coupling length.

iii. Quick drying adhesive should be used as a rule. The pipe should be inserted as soon as the adhesive is applied, especially under a hot sun in the summer where adhesive is likely to dry very quickly.

iv. It is wrong to assume that when too much adhesive is applied then the better the bonding. When too much adhesive is applied, the vapor weakens the pipe and also the adhesive disturbs the water meter and causes the water to have bad odour.

v. To obtain strong adhesion, the surfaces to be joined should be clean and dry. Oil sticking to the surfaces will decrease the adhesive strength as the adhesive reject the oil and does not expand. The adhesive also rejects water, dust and other particles.

vi. In order to confirm that the pipe is inserted to stopper, marking length of the insertion (= coupling length (L)) before inserting is indispensable.

vii. After inserting, it is necessary to hold the pipe and socket for specified period because the counter force of expanded socket will push out the pipe from the socket.

2) Procedure of PVC pipe connection

i. Cut PVC pipes so that the end is straight.
ii. Deburr the cut section by lightly chamfering.
iii. Clean the joint end and outer surface of the pipe spigot. Oil and water should be cleaned off completely.
iv. Measure the joint coupling length (L) and draw a marking line of the joint coupling's length away from the pipe end.

Table 7.1: Standard TS joint coupling length (13-40 mm dia) Unit: mm

Diameter	13	16	20	25	30	40
Joint coupling length	26	30	35	40	44	55

For joints with a diameter between of 50 mm and 150 mm, a marking line should be drawn at a point the zero point distance plus the adhesion length specified in Table below away from the pipe end. The zero point should be determined with the pipe lightly inserted in the joint as it depends on the dimensional tolerances of the outer diameter of the pipe and inner diameter of the joint coupling.

Table 7.2: Adhesion allowances Unit: mm

Diameter	50	75	100	150
Adhesion allowances	20	25	30	45

i. When pipes are connected at a right angle using a joint such as an elbow or bending coupling for a tap, indicate joining marks on the pipes and joint.
ii. Apply PVC adhesive over the inner surface of the joint and the outer surface of the pipe spigot. The adhesive layer must be thin and uniform.
iii. Do not apply PVC adhesive beyond the marking line on the pipe.
iv. If too much adhesive is applied, it may enter the pipe and disturb the water meter, causing abnormal smell and taste.
v. Rapidly insert the pipes straight into the joint. Hold them for a time not shorter than that shown below.

Table 7.3: Standard holding time for TS joints

Diameter (mm)	50 or less	75 or more
Standard holding time	30 sec or more	60 sec or more

vi. If you release pipe and socket before the specified holding time has elapsed, the pipe may fall out of the joint.
vii. Check and ensure that the pipe is inserted to the marking line.
viii. In case of improper insertion, do not repeat the above steps using the same pipe surfaces. Cut off the pipe by the length of the spigot where adhesive has been applied and replace the joint with a new one.
ix. Adhesive forced out should be wiped off immediately.
x. Spigots of manufactured joints do not need to be chamfered.

3) Precautions for prevention of leakage

i. PVC pipes are susceptible to heat. Their structural strength decreases with a rise in temperature. They are softened around 180°C.
ii. PVC pipes are susceptible to cold weather. In cold area, they are easily broken by an external impact. They become brittle at -18°C.
iii. PVC pipes expand much with heat. They expand and contract more with temperature changes than steel pipes.
iv. PVC pipes are susceptible to solvents, especially antiseptics (creosote oil) and acetone. They are also affected by pipe adhesive.
v. PVC pipes are not suitable for use in temperatures exceeding 50°C or low temperatures. A straight PVC pipeline exposed to extreme temperatures should be supported with expansion joints at intervals of 30 to 40 meters.
vi. PVC pipes should be protected from direct sunlight. Do not stack them to a height over one meter. Do not throw them, especially in cold weather.

7.4.2 Connecting Polyethylene (PE) Pipes

Polyethylene pipes can be connected using the following joints.

- Fused sleeve joints (see JIS* K 6763 "Polyethylene water pipes")

Cold joints	Tight joints (see JWWA* B 116 "Metal joints for polyethylene water pipes")
	Quick-connection joints (The Poly Fitter has been adopted by Nagoya city.)

The polyethylene pipe joint adopted by Nagoya city in Japan is described below.
JIS = Japan Industrial Standard
JWWA = Japan Water Works Association

1) Connecting polyethylene pipes with quick-connection joints

Connection procedure:

i. Before connecting pipes, check O ring and wedge ring are installed correctly without damage and twisting.

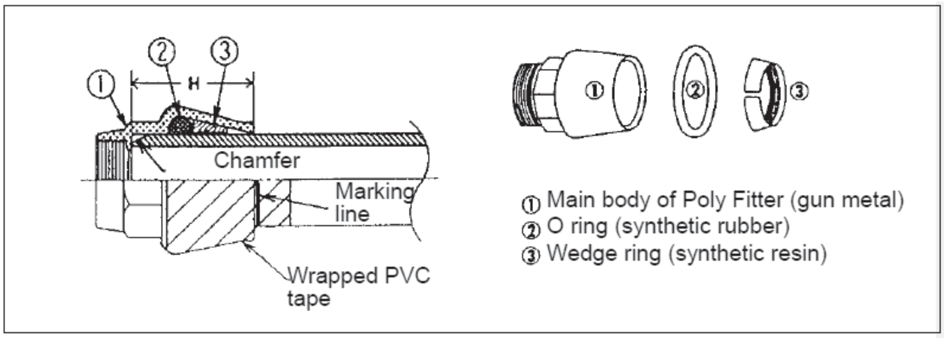


Figure 7.4: Quick-connection joint

ii. Taper the pipe end, as directed down, to 3/4 of the pipe wall thickness. Remove cutting chips. As any remaining cutting chips may disturb the water meter.

iii. Draw a marking line on the pipe to indicate the coupling length (H). This is used to check that the pipe is fully inserted.

Table 7.4: Insertion length Unit: mm

Diameter	13	20	25	40	50
H	42	52	63	91	103

iv. If the pipe has to be removed from the joint because of improper insertion, cut off the pipe by the length of the spigot and replace the O ring and wedge ring with new ones.

v. When the coupling is disassembled for reuse, replace the O ring and wedge ring with new ones.

vi. After the pipe is connected, wrap the Poly Fitter with vinyl tape over more than two thirds of its surface to prevent the intrusion of sands and other foreign matter through a gap in the joint end.

vii. When the pipe is to be bent, the bending radius should be more than 20 times the outer diameter of the pipe.

Diameter	Bending radius (R cm)
13	43 or more
20	54 or more
25	68 or more
40	96 or more

Table 7.5: Bending radius

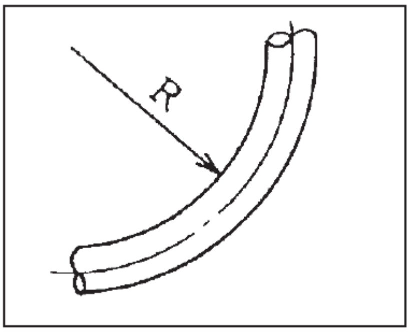


Figure 7.5: Bending radius

2) Disassembling procedure:

i. Fully insert the pipe into the main body of socket to create a clearance between the main body and the wedge ring.

ii. Fully insert two dismantles (A) facing each other between the pipe and the wedge ring. Remove the pipe while firmly holding the main body.

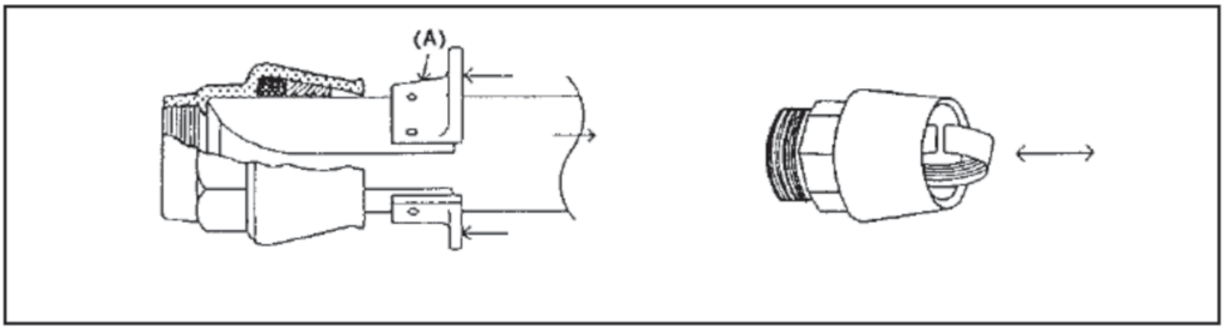


Figure 7.6: Disassembling of quick-connection joint

3) Categorization of quick-connection joints

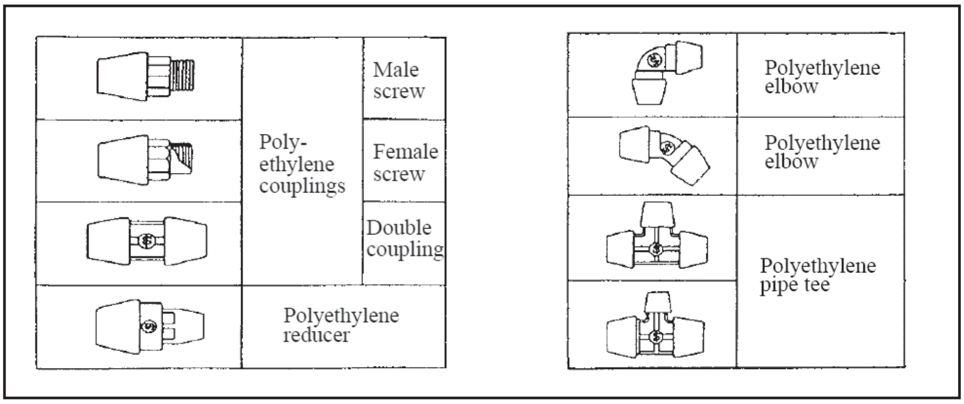


Figure 7.7: Quick-connection joints

4) Precautions for prevention of leakage

i) PE pipes have a lower tensile strength. Their strength is only about one fifth of that of PVC pipes. As they have soft surfaces, they tend to be easily damaged externally.

ii) They are combustible. Their strength decreases as the temperature rises. They soften around 90°C.

iii) They are susceptible to organic solvents and gasolines.

iv) White ones quickly age if exposed to direct sunlight for an extended period.

v) Depending on the water quality, black colored PE pipes react with chlorine to generate air bubbles. Very thin layers may peel off the inner surface after an extended period.

vi) It is preferable to store them indoors. When they are stored outdoors, they should be protected from direct sunlight and well ventilated. They should be stacked on a flat floor to a height not exceeding 1.5 meter regardless of whether they are in coils or not.

vii) Joints should be stored as packaged in an indoor location where they are not exposed to sunlight.

7.4.3 Connecting Pipes of Different Types

1) Steel pipe and PVC pipe

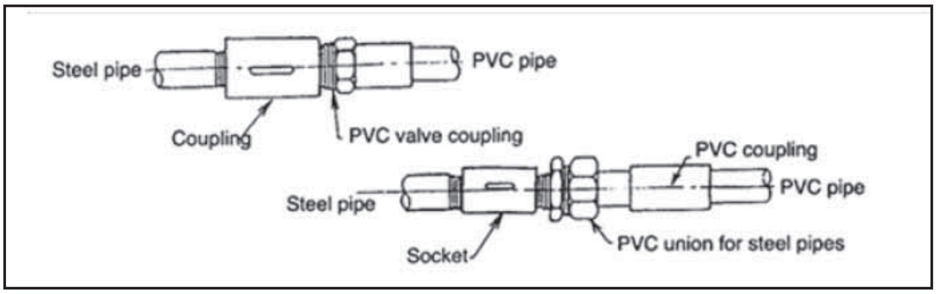


Figure 7.8: Connection between Steel pipe and PVC pipe

2) Steel pipe and Polyethylene pipe

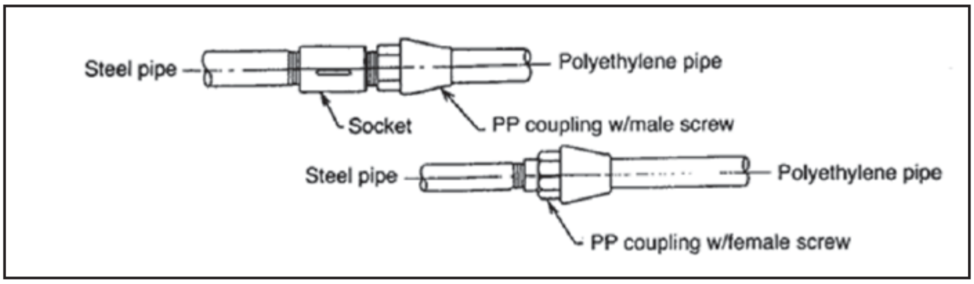


Figure 7.9: Connection between Steel pipe and Polyethylene pipe

3) PVC pipe and Polyethylene pipe

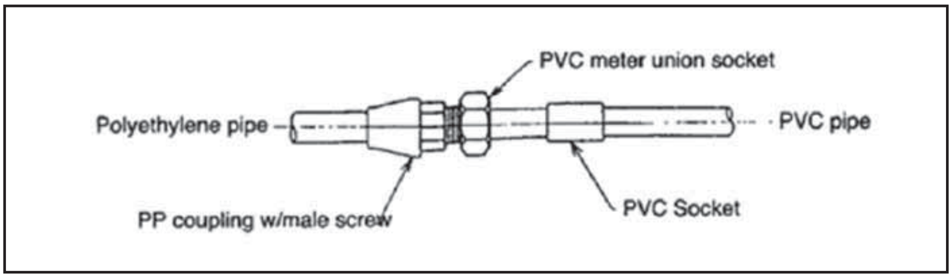


Figure 7.10: Connection between PVC pipe and Polyethylene pipe

4) PVC lining lead pipe and PVC pipe

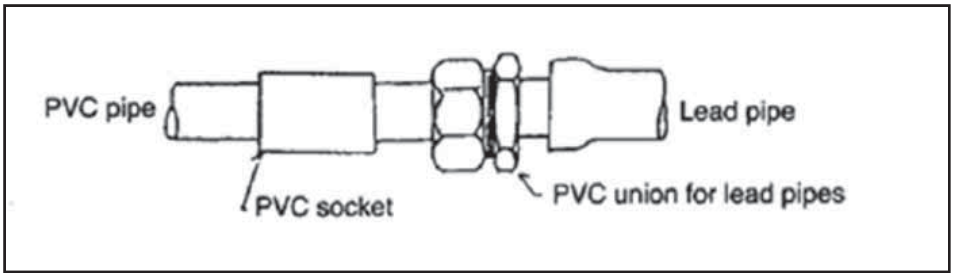


Figure 7.11: Connection between PVC lining lead pipe and PVC pipe

7.5 Examples of Tapping under Pressure

Below is an example of tapping under Pressure standards in Nagoya Waterworks Bureau in Japan.

(1) Significance of Tapping under Pressure

Branching under pressure is the work that branches distribution pipes and service lines without stopping water supply in existing pipes, which has the advantages as stated below:

1) Reduction of NRW volume

If pipes are cut and branched by suspending water supply, water remained in the pipe will be wasted, and a lot of water will be wasted during washing of pipes after completion of the work. This kind of water is NRW since it does not earn revenue to the WSPs. Branching under pressure can eliminate NRW due to such construction work.

2) Avoidance of the interruption of the water supply

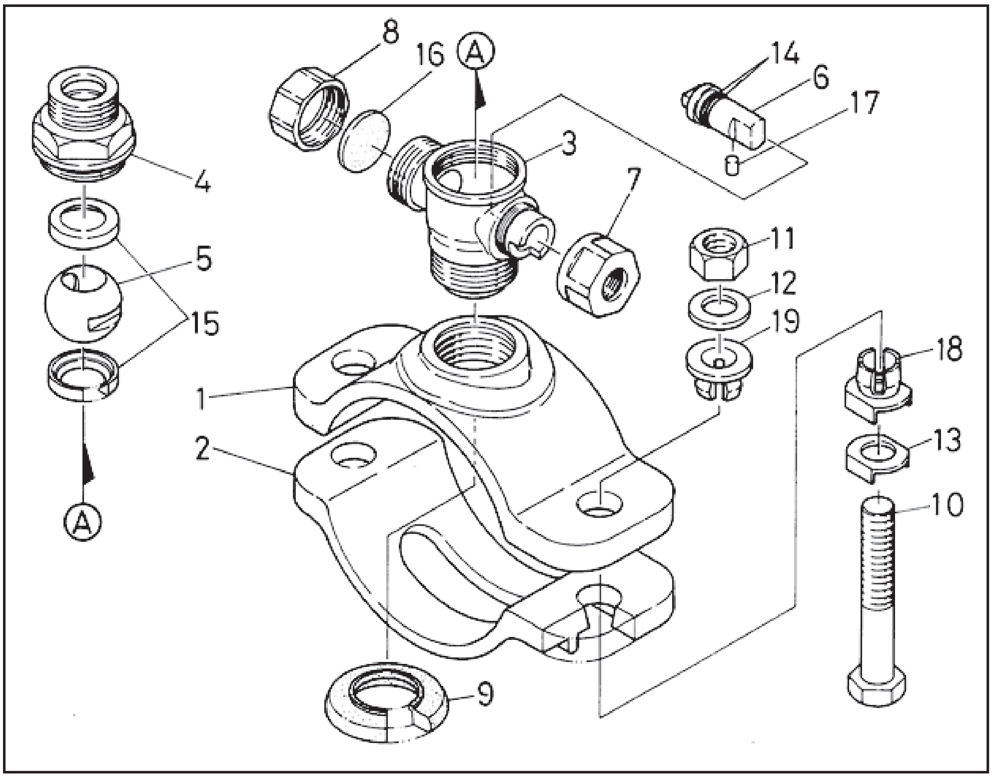
The water supply services are important to the daily life's of the consumers. Prior arrangement must therefore be made to inform the consumers about any intended interruption of the supply and alternative source provided to them for use during the interruption period.

Otherwise there would be a lot of complaints on the sudden suspension of the water supply.

By adopting a method to branch pipes under pressure, time required for negotiation for water supply suspension can be minimized, and resentments due to water supply suspension can be avoided.

(2) Saddle Ferrule (Saddle Ferrule for Polyethylene Pipe (φ40×φ20))

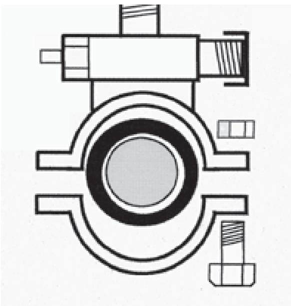
1) Structure and part names



No.	Part name	Material	Qty	No.	Part name	Material	Qty
1	Saddle	FCD45	1	12	Washer	SUS304	2
2	Band	FCD45	1	13	Stop washer	SUS304	2
3	Body	BC6	1	14	O-ring	NBR	2
4	Ball retainer	BC6	1	15	Ball seat	Teflon	2
5	Ball valve body	BC6C	1	16	Cap packing	NBR	1
6	Spindle	BC6C	1	17	Stop pin	SUS304	1
7	Protective nut	BC6	1	18	Insulator A	Polycarbonate	2
8	Cap	BC6	1	19	Insulator B	Polycarbonate	2
9	Saddle packing	NBR	1	20	Core	C1220T	1
10	Bolt	SUS304	2	21	Anti-corrosion film	Polyethylene	1
11	Nut	SUS304	2				

Figure 7.12: Structure and part names of Saddle Ferrule

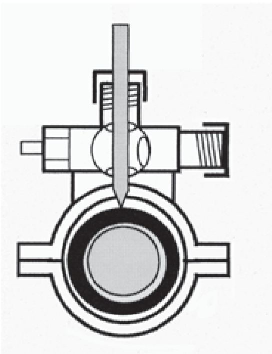
2) Branching procedures

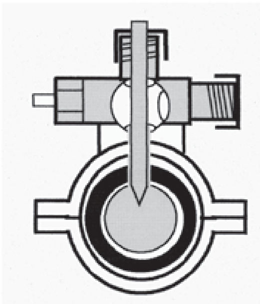


i Pipe and saddle ferrule should be cleaned and installed it with bolts and nuts to an extent that the polyethylene pipe slightly flexes.

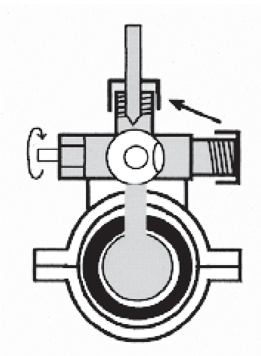
ii Attach a cap to a service pipe take-out port on the side so that water does not come out from it when a hole is bored.

iii Looking into the port from above, confirm that the ball valve is open and the hole can be bored. If the hole is bored with the ball valve closed, the ball valve body will be damaged.



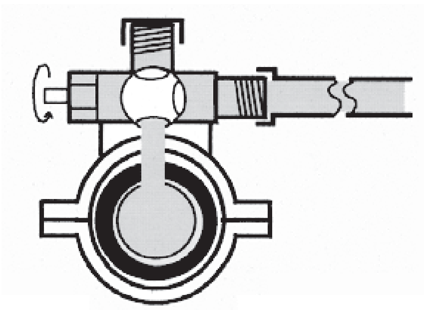


iv Set a boring machine to the port at the top, and bore a hole. Be careful not to bore the opposite pipe surface.



v After the hole is bored, lift the drill to the top, and turn the ball valve 90^{o} to stop water.

vi Remove the boring machine. Remove the cap attached to the screw on the side, and set it to the port at the top.



vii After jointing to the service connection which is already connected to taps or a stop valve, open the ball valve to supply water.

Figure 7.13: Branching procedures
Source: JICA NRW Training Text (made by NAGOYA Waterworks Bureau)

7.6 Updating of Mapping

When repair work is conducted, the results must be recorded and reflected into the updating of the map. It is important to record the type, diameter, location of pipes, valves, etc. on site by hand sketching and bring the records to the office and update of the maps. This can lead to improvement in the accuracy of mapping.

Fig. 7.14 shows an example of Update Sheet.

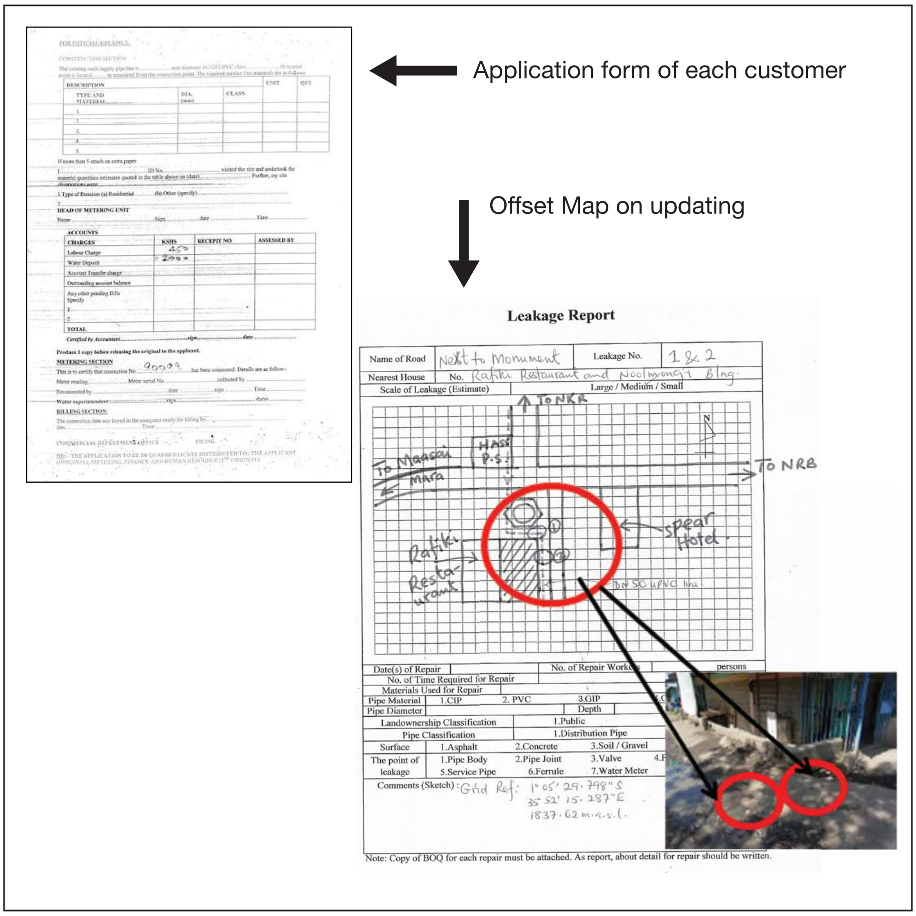


Fig. 7.14 Update sheet of service pipe replacement

Chapter 8
Concept of Zoning

Zoning is dividing a water network in smaller components for the purpose of monitoring water flows, leakages and water pressure. Such components are usually referred to as District Metered Area (DMA). The DMA meters are sometimes linked to a central control station via telemetry so that flow data is continuously recorded. Leakage monitoring requires the installation of flow meters at strategic points throughout the distribution system. Each meter records the flow into a zone which has a defined and permanent boundary. Zones may follow either administrative or hydraulic boundaries.

Administrative boundary zoning:
This zoning approach may be convenient for general administration of Municipality but may be inconvenient for water distribution and pressure controls.

Hydraulic boundary zoning:
This zoning approach may not be convenient for general administration of water service provider but is very convenient for water distribution and pressure controls.
Zoning for the purpose of implementing water works will follow Hydraulic boundaries.

8.1 Design of DMA

This involves dividing the distribution network into a number of zones or DMA, each with a defined and permanent boundary, so that the flow of water into each district can be regularly monitored.

Ideally, one distribution zone should consist of one DMA. Each DMA should be isolated from adjoining zones or DMA by gate valves. A Flow Meter should be installed at the inlet of the DMA. In some cases the flow meter installation will incorporate a Pressure Reducing Valve.

Figure 8.1 and 8.2 shows optimum water supply system of DMA for NRW Management.

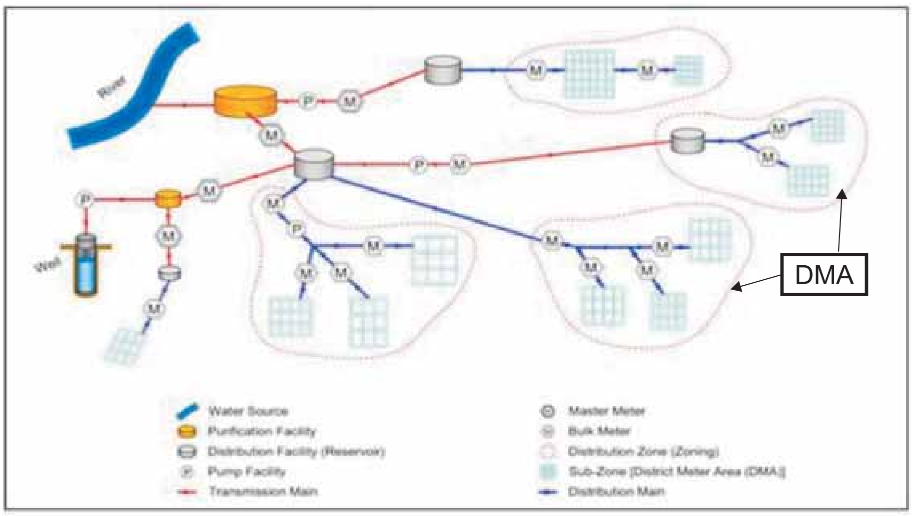


Figure 8.1: Concept of Zoning with DMA

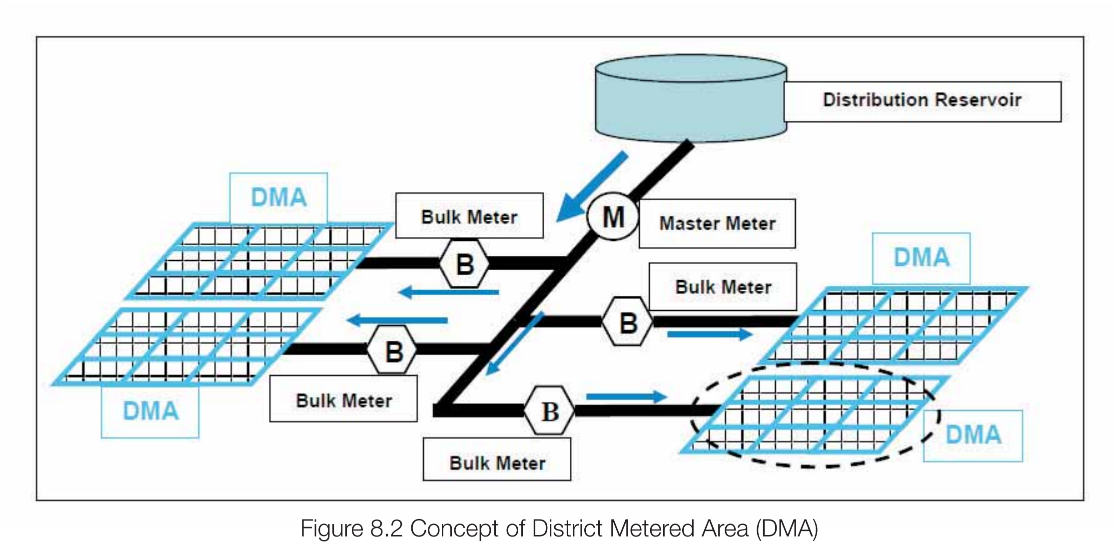


Figure 8.2 Concept of District Metered Area (DMA)

8.2 Advantage of Zoning

Advantages of zoning are as follows.

8.2.1 NRW Management

Flow volume and the volume of water consumed can be determined, therefore facilitating NRW management.

For NRW Management, the distribution area should be divided into DMA. There will be better control of the flow volume when the DMA is divided into smaller areas. With zoning, MNF of each DMA can be regularly monitored for bursts and leakages.

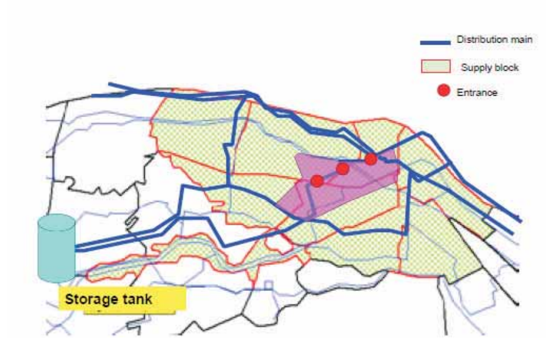


Figure 8.3 Dividing distributions into DMA

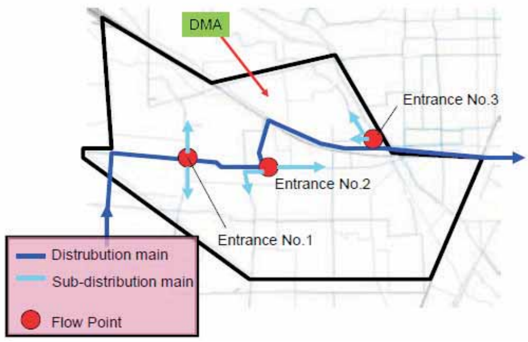


Figure 8.4 DMA in sub-blocks

Although establishing DMA has its merits, it can be a costly exercise, and installation of flow meters in each DMA may not be realistic. Another method of NRW management is the measurement of MNF by creating a DMA that can be temporarily isolated by use of valves and electromagnetic flow meters.

8.2.2 Facilitating measures against leakage occurrences

In case of leakage occurrences such as bursting of pipes, zoning allows repair work to be conducted with minimal risk. In such cases, valves can be used to minimize water stoppage by keeping water interruptions to a restricted area.

Zoning can facilitate in identifying incidences within a network. By installing flow meters and pressure gauges it is possible to identify whether leakage incidences have occurred within the network. Repairs can be conducted with minimal disruption of water supply to customers, as areas can be isolated with valves.

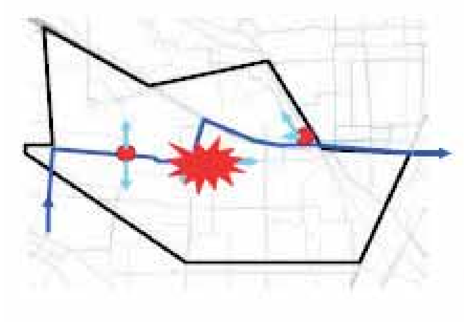


Figure 8.5 Areas can be isolated in case of leakage incidences by using valves

Accidental Simulation (Flow Direction)

Figure 8.6 The flow in distribution pipes can be changed to assure undisrupted supply of water

8.2.3 Pressure Management

Where there is a big water pressure difference within one geographical area, it is possible to avoid excessive pressure build up through zoning or by installation of pressure reduction valves.

Leakages and bursts are often related to pressure. Excessive pressure is a major source of leakages and bursts. Managing pressure in low-pressure systems is also beneficial. Reducing pressure has direct impact and immediate results on existing leaks.

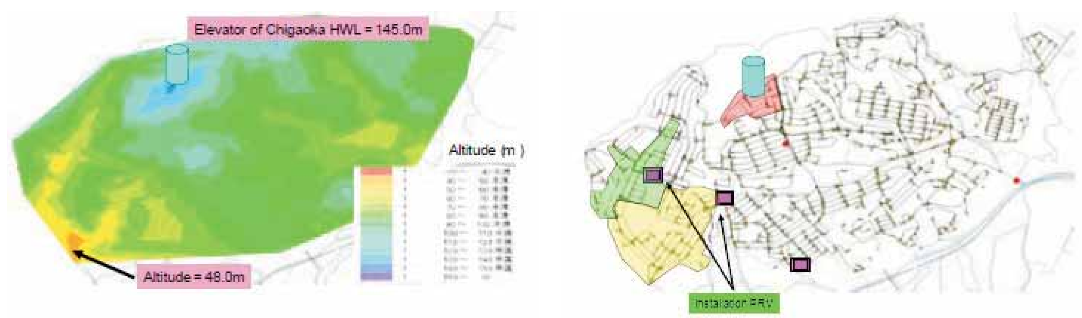


Figure 8.7: Control of Pressure in Block

8.3 Planning and Implementation of DMA

(1) Criteria of Planning

- Wherever possible, there should be only one point of entrance.
- Size should be between 500 and 3,000 pipes
- The total length of distribution network should be approximately 25 km of pipes
- Topographical variations should also be considered (minimize variation)

(2) Isolation of DMA

- DMA should be isolated by using Gate Valves
- Pipe connections with adjacent DMA should be minimized by relaying pipes

(3) Installation of Equipment

- To measure flow ratio and pressure at the entrance and average pressure
- Remote measuring of flow rate at the entrance in detail
- Utilizing data with graphs (sequence of MNF and moderation of daily leakage)
- Analysing data to establish Water Balance

8.4 Monitoring of NRW

Once the DMA has been established, it will become an operational tool for monitoring and managing physical and commercial losses.

(1) Calculation of NRW of a DMA

NRW in a DMA is calculated as follows.

NRW of DMA = Total inflow into DMA – Total DMA Consumption

Flow meters must be installed at all points of water entry into a DMA. The total volume of water entering into the DMA can easily be calculated by measuring the volume of inflow at all entry points.

Total DMA consumption will depend on customer meter coverage. If all customers in the DMA are metered, therefore 100% customer meter coverage, then the Total DMA Consumption can be calculated by simply adding meter measurements.

If 100% customer meter coverage has not been achieved in the DMA, then the Total DMA Consumption can be estimated by using per capita consumption. Before conducting this exercise, a survey of all properties in the DMA should be conducted. Initially this survey may be limited to obtaining information on the number of properties in the DMA and estimating the number of occupants in each property. To obtain a more accurate estimate, surveyors will interview all households to determine the exact number of occupants living in each property.

(2) DMA Management Method Approach

When a DMA is first established, NRW ratio, MNF and commercial loss calculations must be conducted and the main areas of concern must be identified. If the DMA has high leakages or high commercial losses, NRW reduction measures should be implemented as a matter of priority.

Keeping a permanent leakage detection team in a DMA is neither efficient nor possible for most water utilities. Instead, a monitoring team that would intervene at appropriate times should be established. A limit or a level of NRW ratio should be established for intervention. Once this limit/level is reached, the monitoring team should be dispatched to detect and solve the problem.

Generally NRW ratio can be normalized within two to four weeks. Monitoring should continue after repairs until the intervention limit is reached again. Repetition of this cycle will develop into the optimal management cycle of the DMA.

Time taken for NRW ratio to normalize after repairs should always be recorded. If the time taken to reach intervention limit decreases, this would signal that more leakages are occurring in the DMA, which would mean that the facilities are also deteriorating. In such cases, plans for pipe replacements should be considered rather than conducting continuous leakage detection and repair.

Chapter 9
Water Pressure Management

Managing water pressure is one of the fundamental components of leakage management strategy. Water pressure in pipes has a direct impact on the rate of leakages in the water distribution network, and the high pressure may occur as a result of gravity or through pump pressure. Water pressure also affects the frequency of new bursts. In general,

- The Higher the pressure, the higher the leakage
- The Lower the pressure, the lower the leakage

Although this relationship is complex, utilities should initially consider a more or less linear relationship, 10% less pressure = 10% less leakage.

9.1 Measuring Water Pressure in Distribution System

Controlling water pressure in a distribution system that depends on gravity flow is relatively more complicated compared to controlling water pressure in a pump pressurized distribution system. The advantage of gravity flow system is that water distribution is secure even during power failures. It is necessary to carefully consider water pressure when installing a distribution tank in the distribution area.

Topography will be an important factor in a distribution system that uses a combination of both gravity and pump systems. Pump pressurization will be used in areas where gravity flow is insufficient to distribute water and also to pump water into main storage facilities for distribution by gravity flow.

Management of water pressure in a distribution area is vital. In large distribution areas that have complicated topography, the distribution area should be divided into sub-zones with high pressure and sub-zones with low pressure (or high, medium and low pressures). The separation of pressure zones should be approximately 30 meters altitude brackets. It is necessary to study each sub-zone and adopt the most suitable system for each zone.

Volume of water distributed within a distribution area will depend on “time”; either day or night, any given week, month or time of year. Water pressure will also vary in relation to these factors. Low water pressure in the distribution system will interfere with adequate water supply and it can also prevent ground leakages from being detected on the surface.

Leakages in pipes with high water pressure will be easier to detect on the surface, but the frequencies of leakages in distribution pipes and / or distribution devices can increase. Suitable water pressure range is 0.15 Mpa to 0.4 Mpa. Based on this range, improvements to the distribution system should be made.

9.2 Measures to Water Pressure Management

Water pressure can be measured daily, periodically or at random.

Daily measurement should be at the focal points of the distribution system, in the distribution pipe, at the storage tank and at the pumping station. This is to ensure that water pressure is being maintained at the correct pressure in the entire distribution area.

As water pressure varies with water demand, periodic measurement should be taken at pipe branching locations to survey variations in water pressure. It is important to understand the relationship between water demand and water pressure.

Random measurements are taken to measure localized water pressure or as a supplement to the daily or periodic measurements.

9.3 Water Pressure Mapping

As shown in Figure 9.1 and 9.2, the measured water pressure is indicated by area onto the map. This allows easy and quick understanding of the status of water pressure.

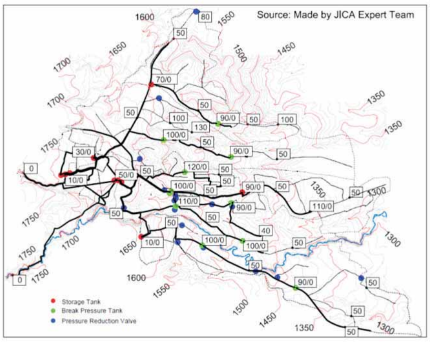


Figure 9.1: Distribution Map of Water Pressure

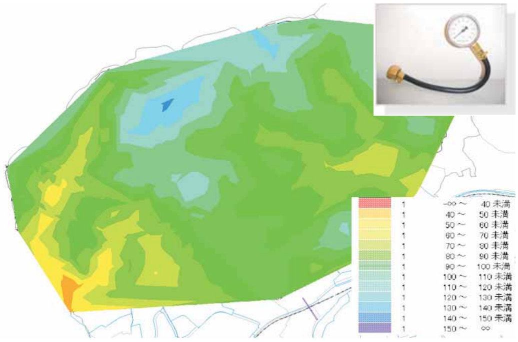


Figure 9.2: Distribution Map of Water Pressure

9.4 Water Pressure Management

Leakages and bursts are directly related to water pressure. Lowering high water pressure will lower incidences of leakages.

It is thought that there are many small underground leakages that go undetected and by lowering water pressure, the number of undetectable leakages will also decrease. Managing water pressure in water systems with very low pressure is important.
In high pressure systems, lowering pressure is vital, but without compromising water flow to customers.

Photo 9.1: Break Pressure Tank (BPT)

Photo 9.2: Pressure Reducing Valve

Photo 9.3: Pressure Reducing Valve

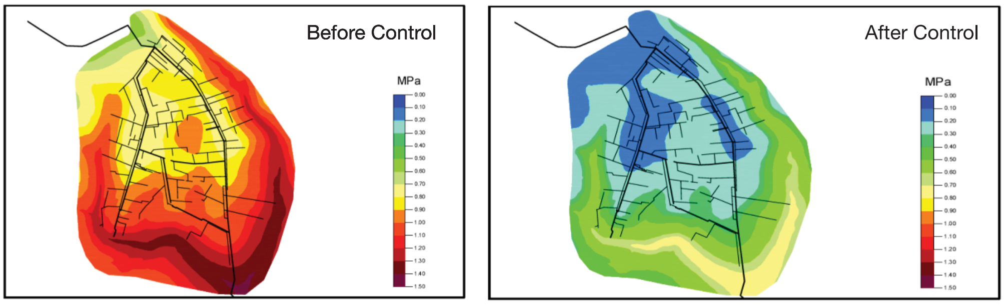


Figure 9.3: Distribution map of water pressure (Pilot Area: EWASCO)

(1) Pressure Control for Gravity Flow System

With Gravity Flow System, it is difficult to control water pressure during the night when water demand is low. When planning for a Gravity Flow distribution system, it is necessary to consider the topography of the distribution area. Surveys must be conducted to select areas carefully and pipe materials selected must be designed to withstand the pressures.

In areas where water pressure exceeds acceptable pressure levels and / or in areas where there is much variance in water pressure, pressure regulating chamber and pressure reduction valves must be installed to adjust water pressure.

Pressure control water tank is a simple structure with relatively low breakdowns. However, since the site for its construction requires to be secured and the construction is costly, then the use of pressure reducing valves is more common.

Pressure reducing valves should be installed at locations of pipe branching rather than in distribution pipes. It is advisable to install the valves at the side of the roads in public locations, rather than under the road in a town area.

Pressure reduction valves will stabilize water pressure downstream. This is the water pressure created after the pressure reduction valve, and the water pressure at this location is irrespective of water volume and upstream water pressure. It is always possible to attach secondary devices to alter downstream water pressure during the day and night, or to have valves open during the day and adjust during the night only.

Necessary considerations for installing pressure reduction valves are explained below.

i. It is not absolutely necessary that the diameter of the pressure reducing valve and diameter of the pipe match. Valve diameter that is 1 or 2 classes lower than the pipe diameter is commonly found in the WSPs networks. Care must be taken with smaller valve diameters as turbulence can be created in the flow. In a flow speed of 0.1 – 0.2 m/s, the range of pressure should be maximum 0.7 MPa and the optimum is between 0.1 – 0.15 MPa. When the range increases, there will be increased noise, vibrations, wear and tear of the valve sheet and cavitations.

ii. When several pressure reduction valves are installed on one pipeline, “hunching” may occur. It is necessary to install safety valves and pressure regulating chamber between the two pressure reduction valves. However, if there are branching pipes between two pressure reduction pipes and the volume of water flowing is relatively large, this problem will not arise.

iii. In cases where several pressure reduction valves are installed in one area, regulating downstream pressure at each valve is important. When the demand volume is low, (at midnight for example) obstacles such as valves closing or vibrations could arise from presence of interference upstream and downstream and cause leakage. Therefore in cases where several valves are installed, it is necessary to have identical downstream static water pressures. As much as possible, it is better to have one pressure reduction valve within one zone.

iv. Care must be taken that there is no negative pressure created with the installation of pressure reduction valve. Care must also be taken to install pressure reduction valves in locations where pipe bursts would not occur even if temporary pressure is exerted directly.

v. It is important to install sluice valves before and after the pressure reduction valves, which will completely stop flow of water. There are cases where strainers are also used together. In order to avoid suspension of water supply during inspection or repair, a bypass pipe should be installed. Pressure reduction valves can be installed in both large and small zones, and if necessary secondary pressure settings are possible. Pressure reduction valves are therefore a useful management equipment. The weak points of pressure reduction valves are that suspension of flow can result from breakdown of the valves and there is no convenient feature, as seen with pressure equalization chamber, of fixed time distribution. In order to detect breakdowns in pressure reduction valves, it is necessary to monitor secondary pressure at least once a year.

(2) Pressure Adjustment by Pump Boosting Method

Volume of distributed water varies greatly with time, maximum hourly volume distributed is usually approximately ten times the minimum hourly volume distributed. This also means that there is great variance in water pressure. In order to prevent excessive pressure build up, it is necessary to carefully adjust the pump pressure.

One method of controlling pump pressure is to adjust the number of large/small capacity pumps that are operational.

Chapter 10
Information Management System: GIS

In order to reduce NRW, it is required to effectively utilize the data relating to the items described below.

- Mapping system
- Customer information system
- Water supply operation system
- Remote meter reading system
- Statistical processing system relating to NRW management

Ideally, all these systems should be combined into one system. However, the tendency has been to have each system independently built-up. Currently, the GIS has been introduced as a platform for the management of water service system.

10.1 Summary

In the process of comprehensive management of methods for NRW reduction, it is necessary to rationalize the information and users in the administration of water service facilities, and promote the development of information to assist in standardized management in the following manner:

Recently, the GIS have been introduced as a platform for the management of water service systems and facilities in water-related organizations, especially for its characteristic capacity of comprehensive management of maps and databases. The operation is being used in areas such as graphic management, users' registers, revenue collection and marketing.

In the initial phase of adoption of GIS system, the following activities are carried out:

1) Mapping of water service facilities
2) Updating register of installed facilities, service pipe networks and users list
3) Development of mapping information and database

This system can improve information and utility management, making some components with which other systems develop, such as maintenance of facilities and users management for revenue collection.

To promote the information handling, the inventory of registry arrangement for installation of service pipes network and user management and mapping of water service installation at the initial phase of development are carried out. Also, the development of mapping information and database is introduced. This component extends in the information of the systematized direction management like other components of development, including maintenance and administration of facilities, user management for revenue collection.

The form and the type of GIS system introduced differs depending on the prevailing situation of the organization and structure for its administration, operation and information flow arrangement to other counterpart organizations or within the organization itself. In addition, the efficiency of the system depends on the organizational internal factors like administration structure, operation of the resources such as the graphics, registries and data management. Therefore, it is not practical to establish the system at the same time. Thus, it should only be established from a possible point. With the structural reinforcement of the organization, the management system of the information should be enforced gradually.

Figure 10.1: Example of map of existent service pipe works

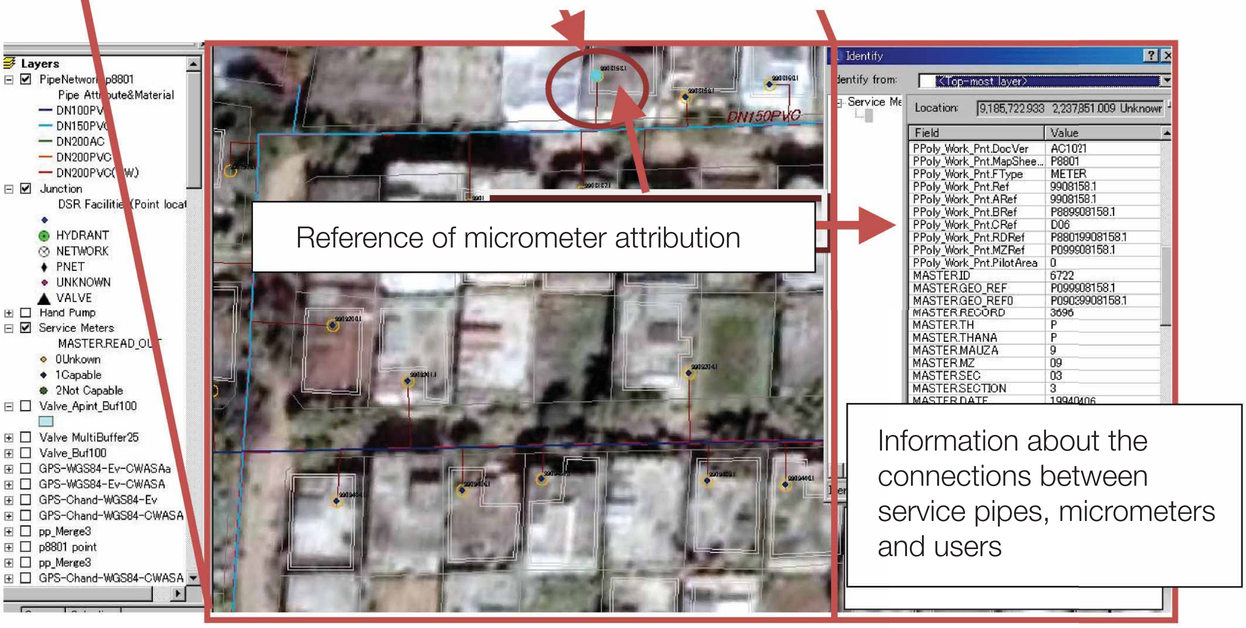


Figure 10.2: Example of information reference about mapping of pipe network and service pipe connection by GIS system

Figure 10.1 shows the original existing figure. Figure 10.2 shows the situation where the last image of satellite combines with the map of service pipe network incorporated in the GIS system after the digitalization of Figure 10.1. From the points of micrometers in this screen, we can see the service pipes, micrometers, user registry, etc. in the system.

10.2 Information System in GIS Database

Typical information that should be incorporated in the GIS database for management of NRW is shown in table 10.1: below.

Items of database	Contents of database (Proposal)
1. Basic Map	Topography, thematic map made for high resolution images of satellite
	Route map, administration map (city, county, sub-county, parish), construction map, mapping note, curve level, elevation point, grid elevation data, cadastral map (land property)
2. Installation of transmission and distribution network	Thematic map show the installation of transmission and distribution network
	Water service district map, water service block map, map of transmission and distribution installation (distribution pipes of transmission and distribution and related installations: pump, valve, hydrant, etc.)
	Registry for installation of transmission and distribution, registry for the maintenance and installation management: records of leaks, maintenance, methods, etc.
3. Installation of service pipes	Thematic map shows connections of service pipes
	Service pipe map, customer meter map
	Registry for service pipe connections: Information of customers: account number, applicants' name and address, address of installation site, user, administration code, cadastral map number, building number User type (public or private) Connection type (domestic or commercial) Water service use (home, industry, office, entertainment, religion, business, public facilities) Customer meter number Situation of micrometer operation (flat rate system or measured rate system, disconnected connection) Unit of measured water volume (gallon, m3), diameter of service pipes, date of installation of water service connection)
	Elements of service pipes: piping type (diameter, material) Length of service pipes Pipe condition (worn out, curved, rusty, etc.) Map showing location of installations (map of ending of the work, offset map) Photos
	Elements of service meters: meter number, trade name, country of origin, calibration unit (G/m^3), installation date, starting date of operation, existence of flow meter, situation of meter operation, possibility of visible meter, map of installation position (map of ending of the work, offset map), photo Existence of meter box Reading capacity Existence of meter stamp Condition of water service connection (connection, disconnection) Existence of illegal connection Existence of leak Possibility of opening or closing of valves
	Information of revenue collection: users' account number, name and address, address of installation site (administration code, cadastral map number, building number), meter number, revenue collection method (measured rate or flat rate system, disconnection) Price per water unit Unit of measured water volume(gallon,m3) Diameter of service pipes Volume of used water per month (volume and measuring date of last month / this month) Due date Number of reader and the person in charge of data entry
	Condition of water use: Number of home and family per connection, existence of bathrooms, sanitation and others
4. Other information about image	Figure of current use of land, figure of planned use of land, house map, figure of natural disaster record, etc.

10.3 Procedure for Establishing GIS Database

(1) Establishing of GIS Database for NRW Management

Figure 10.2 shows the work flow for establishing a series of GIS data. The established activities includes the following issues:

1) Collection of data such as graphics, meters, user information, maintenance and management.

2) Computerization of data, if the graphics and information are only available as printed documents.

3) Codification of data; definition and nomination and rearrangement.

4) Correlation and reconfirmation of information; confirm the existence of unknown points and duplication.

5) Check service pipes and meters in the field; confirm unknown points in 4.

6) Updating work of existing data with the information of users, maintenance and management.

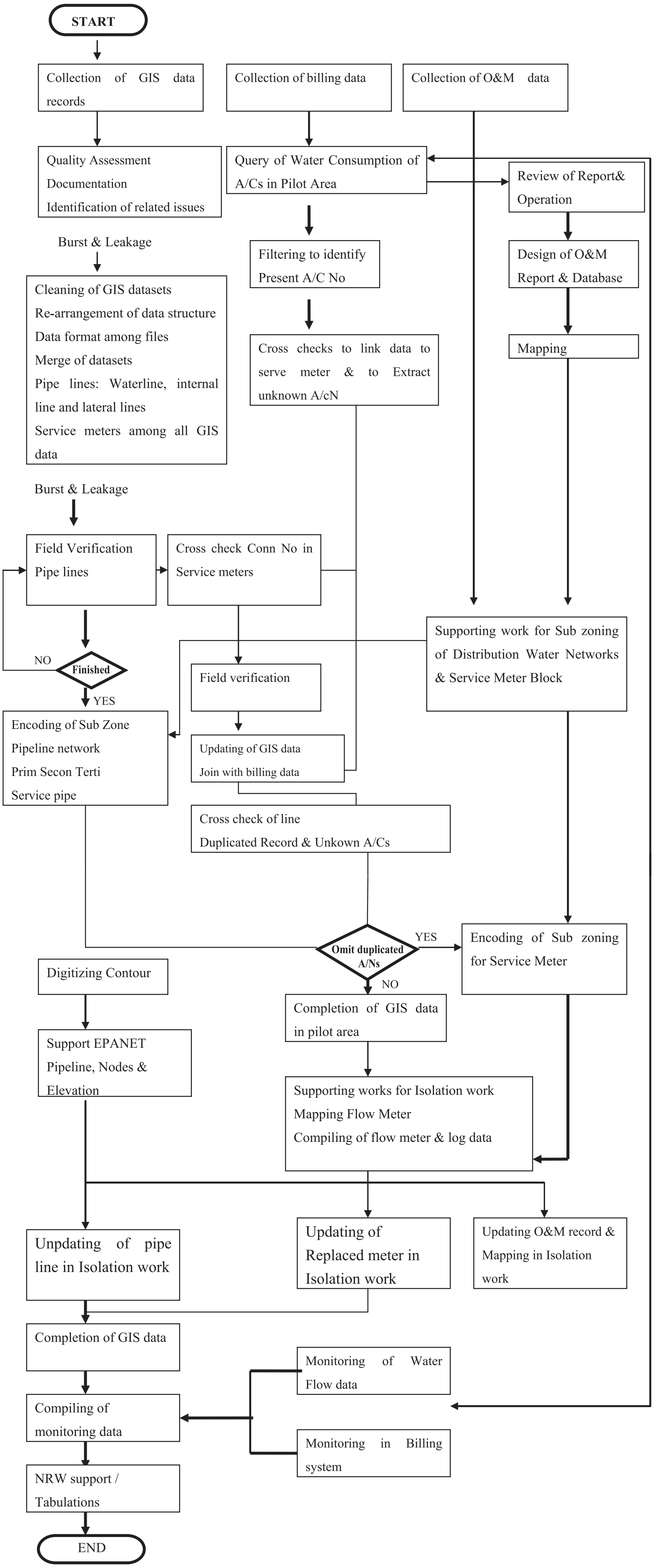
7) Codification if the sub-zone or pilot area is established.

8) Reflection and renovation work of the results of monitoring in sub-zone or pilot area.

(2) Flowchart of Working Procedure

Figure 10.3 shows the flowchart of working procedure to establish the database of GIS focused on NRW management.

Figure 10.3: Flowchart of Working Procedure



Chapter 11
Cost-Benefit Analysis

11.1 Outline

It is most probably fair to say that most utilities would benefit from a NRW management programme. However the big question is usually the extent of the potential benefits. Therefore it is important for water utilities to consider conducting Cost-Benefit Analysis when they are trying to determine the scope of the NRW reduction measures that should be implemented. Cost-Benefit Analysis will show the effects of the invested cost by comparing the benefit obtained with the cost invested.

Normally cost and benefit are correlative therefore, when more cost is invested, more benefit can be expected. In the application of NRW reduction measures however, when a certain level of low NRW ratio is achieved, the correlative benefit cannot be expected, no matter how much more cost is invested. This occurrence is usually observed around the NRW ratio of 15% although it depends on the conditions of the relevant water utility.

In Kenya where the average NRW ratio is at 45% or above, the priority should be placed on bringing down the NRW ratio to around 15% at any cost. Once a low NRW ratio of around 15% is achieved, then a detailed Cost-Benefit Analysis can be performed to assess whether injecting cost to NRW reduction measures is advantageous or not.

11.2 How is a Cost-Benefit Analysis conducted?

When estimating the economic value or cost/benefit of NRW projects, consider the following:

i. The additional revenue that will be generated owing to higher volume of water
ii. The reduction in operating costs that may occur
iii. Improvement in service delivery
iv. The cost of implementing the projects

It is strongly recommended that the cost-benefit analysis should be conducted based on the results obtained from a Pilot Project. The results should then be spread to other adjacent areas. The purpose for conducting a cost-benefit analysis is to obtain maximum effects and benefits. Through the cost-benefit analysis the profit-loss break-even point is determined (Fig 11.1).

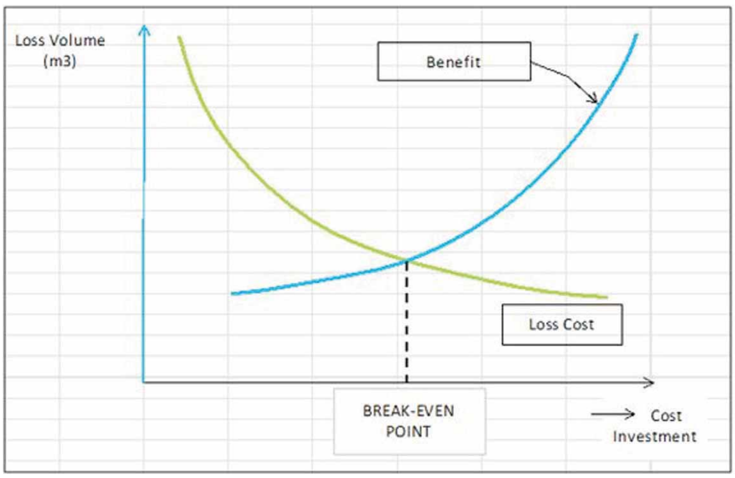


Figure 11.1: Graph for Cost-Benefit Analysis

The Graph depicts the cost-benefit analysis with the assumption that the funds that are invested into implementing NRW reduction measures are most effectively used when the funds are injected at profit-loss break-even point.

In regards to the cost-benefit calculation, the figures may greatly change depending on the level of consideration that is placed on the cost and the benefit.

The most difficult point in regards to the calculation of cost-benefit is to determine the extent to which costs for leakage repairs and replacement of pipes could be considered as NRW reduction costs. Decisions of this nature may depend highly on policy and/or strategy of the relevant water utility in place, because leakage repairs and replacement of pipes areconsidered as part of fundamental and mandatory operations for water utilities. For this reason therefore, it is deemed normal that only the costs associated with the replacement of pipes that have numerous leakage occurrences are considered as part of the NRW reduction costs but costs associated with planned pipe replacement should not be considered as part of NRW reduction costs.

“Cost” for the cost-benefit analysis for the Pilot Project should reflect the amount of funds spent. In regards to the “benefit”, the amount of benefit that was achieved by the implementation of NRW reduction measures must be calculated. Cost must then be compared against the benefit and the disparity must be checked. In most cases, the final decision on what NRW reduction measures to be implemented will be conducted based on the results obtained by cost-benefit analysis. In addition to the results obtained, there will be policy and/or strategy including political factors to be considered.

Such considerations are necessary because to implement the ideal NRW reduction measures requires tremendous amount of funds and labor. It will be difficult for the majority of the water utilities in the developing countries to implement the full-scale activities. Often, items such as full-scale construction of DMAs are omitted from activities to be implemented.

11.3 Calculation of Cost for NRW Measures

For this purpose, the actual cost spent for the implementation of Pilot Project NRW reduction measures should be used. The following items and the costs associated with the items should be used as reference when spreading the NRW activities to adjacent areas.

- Organization Maintenance Cost : personnel cost, office maintenance cost
- Purchase of equipment and material and maintenance cost for equipment.
- Costs of establishing District Metered Areas (DMAs)/ leakage Monitoring Blocks (LMB)
- Cost for installation of measuring devices
- Cost for replacing all customer meters
- Cost for leakage / water theft control
- Cost for pipe replacement

Attention must be paid to the extent to which costs for renewal of facilities such as pipes and / or water meters are included, especially if regular or periodic facility replacement plan is not in place.

It is absolutely imperative to have a proper sustainable O&M guideline for any water utility to function well. Sustainable O&M measures should be included in the ordinary facility replacement plans.

Planning for facility replacement according to the ages of the facilities is the more suitable planning method, rather than including it as part of NRW reduction measures.

Facility replacement should therefore be considered as duty of water utilities, and not be included as part of NRW reduction activity. Cost-benefit analysis for NRW reduction measures should only include costs for those pipes requiring urgent replacement as a result of frequent numerous leaks.

Existence of pipes with numerous leaks may be a reflection of the status of the utility, however for the purpose of establishing NRW reduction plan, the following guideline should be considered:

- Distribution Pipes : 5% to 10% of the pipe network's pipe length need replacement (with the assumption that these pipes are either aged and /or have advanced corrosion)
- Service Pipes : 10% to 30% of service connection can be replaced
- Water meters : 10% to 30% of total number of connections shall be replaced: (in cases where there is no periodic replacement plan)

11.4 Calculation of Benefit for NRW Reduction Measures

The calculation of "benefit" for NRW reduction measures takes into consideration the volume of NRW reduction before and after the implementation of the reduction measures. Once the figures are obtained, the benefits are quantifies as either

a) Profit from increase in volume of revenue water: in utilities where water demand is much higher than water distributed, the volume of water reduced as a result of the implementation of NRW reduction measures can be considered as increase in volume of revenue water. In other words, the water that has been "saved" as a result of NRW reduction measures can now be tariffed water and considered to be "benefit".

b) Raw water/treated water/profit from reduced cost of water distributed: in utilities where volume of water distributed meets the water demand, the cost of producing the volume of water "saved" can be considered to be profit. Reduction in operational cost such as chemical cost and/or electricity costs associated with reduced production of water can be considered to be "profit".

11.5 Example of Cost-Benefit Analysis

Following is an example showing the cost-benefit calculation for Embu WSP from the result of implementation of pilot project.

Real costs to implement the Embu Pilot Project and real results (benefit) achieved will be used in the example. The results should be used as a basis to prepare NRW Reduction Plan for adjacent areas within the supply area.

The performance data for the Embu WSP Pilot Project was:

- NRW ratio: 48%
- Total length of distribution pipe: Approximately 700 km to 1000 km
- Total number of connections: 5000 to 6000 connections
- Population served:15,000 to 20,000 people

The structure of Embu WSP NRW Reduction Measures Team was composed of:

- Supervising Engineer: 1 person
- Technicians: 4 people
- Skilled staff: 10 people
- Administration staff: 2 people

Table 11.1 shows the example of Cost-Benefit Analysis and example analysis based on the result of Embu Pilot Project.

Table 11.1 Loss and Benefit Items for Cost- Benefit Analysis

Loss Items (Costs for NRW Reduction Measures)

1	Labor Cost	Average Salary x Number of Persons
2	Purchasing Cost of Materials & Equipment	Unit Price of Leak Detector, MNF Measuring Car, etc. x Necessary Quantity
3	Construction Cost of DMAs & LMBs	Purchasing Expenses of Flow & Pressure Meters and Valves + Construction Expenses
4	Installation Cost of Trunk Measuring Equipment	Purchasing Expenses of Flow & Pressure Meters
5	Replacement Cost of Malfunctioning Customer Meters	Purchasing Expenses of Customer Meters
6	Office Maintenance Cost	Annual Office Maintenance Expenses
7	Repair Cost of Leaks & Illegal Connections	Unit Repair Expenses of Leaks & Illegal Connections x Necessary Quantity
8	Pipe Replacement Cost	Unit Replacement Expenses of Mains & Service Pipes x Necessary Quantity

Note: Usually most costs of No. 3, 4, 5, 7 and 8 are considered to be mandatory costs for the relevant water utility.

Benefit Items (Profits by NRW Reduction Effects)

1	Profit by Increase in Revenue Water	Unit Sales Cost x Annual Revenue Water Increasing Volume x Effective Term
2	Profit by Reducing Operating Cost	Unit Production Cost x Annual Leakage Reducing Volume x Effective Term
3	Profit by Suppression of Development Cost for New Water Resources	Unit Water Resources Development Cost x Annual Leakage Reducing Volume
4	Profit by Suppression of Construction Cost for New Waterworks Facilities	Unit Facility Construction Cost x Annual Leakage Reducing Volume

Cost (for (3) three years)
- Cost for Staff relate with NRW Reduction: 14,490,000 Ksh
- Cost for Pipe Replacement (including construction fee): 1,750,000 Ksh
- Cost for Meter Replacement: 949,000 Ksh

Sub Total of Cost: **17,189,000** Ksh

Benefit
- Reduced Volume: 434,472m^3
- Unit Price of water tariff: 65 Ksh/m^3

Sub Total of Benefit: 434,472×65 = **28,240,680** Ksh

Profit: **28,240,680–17,189,000** = **1,105,680** Ksh (for (3) three years)

Chapter 12
NRW Reduction Plan

12.1 Developing and Implementing a NRW Reduction Plan

Water is a fundamental resource for human and economic development. Many water Utilities in Kenya, are not able to account for large portions of water they deliver. In some cases the NRW is above 50%. This is a major cause of concern in terms of inefficient use of the scarce water resources. It also affects a Utility ability to earn revenue to support its financial sustainability and thereby offer efficient services. A utility which has a high NRW means it has lower revenue which implies it does not have funding to fix the problem that causes NRW and NRW increases.

In order to address the situation of high NRW and achieve the required efficiency, a water utility need to operate in an environment in which NRW declines, revenues increase, the utility has funding to invest in system improvement and net work expansion resulting to further decline in NRW.

Developing and implementing a successful NRW reduction plan entail the following steps.

Step 1: Gain support for a Non Revenue Water Reduction Project.

NRW programmes require resources and time which are scarce. Therefore the first step should be to outline an NRW programme. The programme should show the anticipated benefits in order to gain support of utility leadership and customers.

Step 2: Establish an NRW management team.

The team performs the analysis and develops a strategy, recommends intervention and oversees implementation. The team must include members from all the utility departments, that is Administration, Technical (production, distribution) and incorporate (customer service, communication etc). This is crucial in order to promote ownership and build consensus by the utility senior management.

Step 3: Calculate the water balance.

The water balance will show the magnitude of the losses and the areas where NRW is present. This will enable making decisions in the use of the limited utility resources in areas of high return in revenue and cost cutting.

Step 4: Set NRW reduction targets.

The utility should set realistic targets for NRW reduction taking into consideration the utility’s goals, policies and resources and any targets established by the National water policy and the regulator. The National Water Services Strategy (NWSS-2007-2015) for NRW is 30% by 2015 while the benchmark by Wasreb is 20%.

Step 5: Identify NRW reduction projects.

Undertaking Pilot Project to demonstrate the effectiveness of NRW reduction is a useful way to start because it will generate lessons and it will show the value of NRW reduction strategy. Pilot Project cover small areas that are still large enough to test the NRW reduction strategy.

The type of pilot projects can vary from improved metering to better customer accounting to full-scale repair and rehabilitation of the network and customer service connections

Step 6: Prioritize NRW projects.

Most utilities face scarce resources in staffing, equipment or funding. The potential projects will have different levels of payback, impacts on service, timing etc. Prioritizing is the way to select the projects that will have the greatest overall benefit and to decide on the timing of when projects are accomplished.

Some projects may reduce NRW significantly but will have a high cost. Others may have a lower cost and lower reduction but can be accomplished more readily because resources are available. Gains from doing these projects may generate additional revenues, which can then be used to accomplish the more expensive projects.

Step 7: Planning and Approvals

In order to gain resources, the NRW team will need a budget that is approved by the utility leadership. Therefore when developing a NRW plan, remember that reducing NRW is not a short- term process. Some activities may span years rather than months. A time frame between four and seven years is reasonable. Anything less is ambitious and any more will not be as cost effective.

In preparing the budget, the team must identify costs that may include:

i. Staffing for both direct NRW Works (e.g. Leakage technicians) and indirect support (e.g. Procurement staff)

ii. Equipment installed permanently (e.g. DMA meters) and those used on a day to day basis (e.g. Leakage detection equipment)

iii. Vehicle and equipment to maximize the productivity of staff

Step 8: Implementation and Monitoring.

As the Project takes place, it is a good idea to monitor both the costs and benefits and compare them to budgets and NRW targets. This will demonstrate the benefits of NRW reduction and build support for the strategy. It will also allow the team to take action to improve performance as needed.

Step 9: Sustain the gains of an NRW reduction projects.

NRW management is a continuous process. Even after the initial gains are made, NRW must continue to be managed. This requires vigilance and attention to make sure that leaks are eliminated when they occur, that all customers are legally connected and billed and all water uses are tracked.

12.2 Contents and Layout of NRW Reduction Plan

There are many activities that constitute NRW reduction measures. The purpose of a NRW Reduction Plan is to determine the most suitable measures for adoption and use the available budget effectively.

A NRW Reduction Plan must include the following components.

a. Introduction

This covers the WSP's background; rationale for the Reduction Plan, assumption in developing the plan, methodology of developing the plan, and organization of the plan.

As geographical and social conditions are unique to each WSP,anyexisting problems related to these conditions must be identified. Hence the overall management, financial status and funds availability are all important factors in the planning for NRW reduction.

b. Analysis of the current status

It is important to first understand the current situation that is causing high NRW in the WSPs. Therefore the analysis of the current status should be based on a self-assessment carried out by the WSPs using the SELF ASSESSMENT MATRIX.

As a first step it is important to understand to what happens to water when it enters the net work. Therefore NRW ratio must be calculated by using volume of distributed water (system input volume) and billed authorized consumption volume.

In cases where the volume of distributed water and/or volume of consumption cannot be correctly established, then the priority should be placed on the installation of flow meters and/or water meters.

c. Objective (target NRW ratio and target area)

A company wide target for NRW reduction, taking into account the utility's other goals or policies that will either complement or conflict with NRW reduction should first be established. This target should be guided by the National water services strategy and the sector benchmark as issued by the Regulator. Often, many utilities chose the NRW target arbitrarily, without any real consideration of cost implications or whether it is achievable.

Identifying the economic level of NRW is essential to setting the initial NRW target, and it requires a comparison of the cost of water being lost versus the cost of undertaking NRW reduction activities.

For utilities with more than 35 % NRW ratio, commercial loss reduction and visible leakage reduction measures must be given priority. For those utilities with NRW ratio of between 35% and 25%, invisible leak detection and repair are necessary. At 25% to 15%, it is necessary to replace aging pipes. Significant amount of funds will be required to replace all aging pipes and therefore, it is necessary to prioritize areas and also activities.

Generally, leakage occurrence record must be plotted onto a map, which will show areas with high occurrences of leakages. Areas with high water pressures and also large pressure variations should be given priority. Further if there are any asbestos cement pipes, replacement of those must be prioritized.

d. Implementation plan of NRW reduction

It presents the implementation matrix, which covers for each of the strategies, proposed actions, Bill of Quantities and Cost Estimates, Implementation Schedule, expected outputs and output indicators.

e. Monitoring and Evaluation

This is essential for the success of the NRW management programme. It allows managers to track progress against plans, budgets and expected results in the form of performance indicators. It also allows managers to take action when performance is lagging behind expectations or exceeding budgets. To achieve the desired results from this plan, Monitoring through regular observation and recording of activities taking place is important.

12.3 Prioritizing Implementation plan of NRW Reduction

Once the utility-wide NRW target is set, utility managers should calculate the proposed volume of water saved by comparing the NRW baseline with the target level. The various components, as detailed in the implementation plan for NRW reduction Table 12.1 are then prioritized according to how the required total reduction can be most cost-effectively achieved. That is, some components may comprise a significant volume, but would not be targeted because of the high cost to achieve reductions in that component. On the other hand, focusing on another component may cost less while reducing the same volume. Therefore the scope of implementation will depend on the financial capability of each and be guided by the action plan in Table 12.2.

In general, if a physical loss is detected and repaired thenthe savings will be in terms of a reduction in variable operational costs. When a commercial loss is detected and resolved, then the saving will be an immediate revenue increase and this is based on the water sales tariff.

The water sales tariffis higher than the variable production cost for all profitable water utilities. Therefore a smaller volume of commercial loss may have a higher financial value, so if increasing financial resources is the objective, then commercial losses should be prioritized.

Similarly, where a water utility has a shortage of treated water, and some customers receive less than a 24-hour supply or the supply coverage is less than 100%, then reduction in physical losses would effectively create additional water supply. Hence if increasing water supply is the objective, then prioritizing physical losses could enable customers to receive water 24 hours a day, or new customers to be connected to the supply system.

Table 12.1 Implementation Plan of NRW Reduction

Issues	Activities	Description of Activities	Concept & Quantified Aim
Fundamental Measures; Water Balance/ Flow/ Pressure Monitoring/ Mapping	Water Balance	Establishment of the water balance	This should be the first step in NRW reduction plan in order to establish all the necessary components.
	System Input Metering	Master and Bulk Meter Installation	To determine actual levels of authorized consumption and water losses in a water supply scheme, it is imperative that master meters are installed at the exit of water treatment works and bulk meters at the entrance of each zone.
	Consumption Metering	Customer Meters Installation	Installation of customer meters at every household to aid in the determination of consumption and billing process and also to assist in the establishment of NRW volume in the system is therefore paramount.
	Pressure Monitoring	Pressure Gauge Installation	Determine current water pressure.
		Water Pressure Map	Water Pressure Map must be prepared by result of water pressure gauge.
	Maps/GIS	Pipeline map	Pipe network maps and drawings are absolutely necessary for WSPs to implement efficient and effective NRW reduction measures. In the absence of drawings, the WSP should start to build up the drawings of distribution mains and major distribution facilities. Coming up with pipeline map which contains types of pipe, age, length. Valve. Size information
		Digitize the mapping data	Comprehensive map of the pipeline by computer aided design.
	Leak Repair Records	Check for any leakage. Reporting the leakage promptly. Checking & reporting meter tempering.	It is necessary toprovideRepair records, such as pipe diameter, material, location, etc.
	Provision of necessary basic equipment		Procurement of equipment related to NRW reduction. To carry out the leakage control work at least the following equipment are necessary; Hearing bar, Electronic leak detector, Pipe locator (for metallic and non-metallic pipes). Necessary number of basic equipment depends on the size of the WSP.
	DMA		Establishment of DMAs requires a lot of resources. It is therefore recommended to begin by establishing pilot DMAs to conduct training of NRW reduction measures for relevant WSP's staff.

Reduce Commercial Losses	Customer Metering	Inspection of all customer meters	- Inspection of stuck meter, non-active and/or aged customer meter
		Ensure 100% meter connection	- Improving the customer meter ratio.
	Customer Meter Replacement and Age	Replacement of non-active and/or aged customer meter	- Investing all customer meter tempering suspect - Repairing and/or replacement of customer meters
	Customer Meter Class	Ensuring the purchase of meters that meets the required standards	- Replacement of existing meters not meeting the required specifications
	Customer Data Base	Customer Data Base & Billing	- Update and maintain the data base with specific times of update - Purchase of software to make work easier to manage database
	Customer Meter Reading	Reading all Meter monthly	- Develop a schedule on the meter readers rotation
		Billing all customer on monthly basis	- Printing & preparation of meter reading books - Capturing of all the meter reading - Bill adjustment - Processing the bills
		Less errors in meter reading. Loss corruption cases	- Correct reading of meter - Rotating meter readers in the company - Sub contract meter reading - Ensuring proper routing
	Illegal Connection, Meter tampering, bypasses	Illegal & Dormant connection Inspection	- Identifying illegal account - Disconnecting/legalizing the account - Management to take stern, stiff and legal action on corrupt staff manipulating meter reading, meters, etc.
		Forming inspection team taking legal actions on the illegal cases random monthly inspection by top management	Management to be swift steady fearless & persistent in dealing with corruption cases like meter interference, illegal connections
Reduce Physical Losses	Active leakage control	Leakage Detection	Conduct continues non-visivel leakage detection activity
		Leakage Repair works	In principle, detected leakages must be repaired immediately.
		Replacement of service pipes	When leakage occurs in the service pipes, the fundamentals are to replace rather than to repair.
		Replacement of Distribution pipes	Plans for distribution pipe replacement are affected by the availability of financial resources. However, replacement is preferred option.
	Reduce repair time in Distribution Pipes	Record time taken to repair leakages. Analysis the data to determine average time taken	Reduced reaction time of pipe repair to 6 hrs irrespective of size
	Water Pressure Management	The most common and cost effective is the use of Pressure Reducing Valve - PRV	Water pressure of around 1 MPs must be maintained as much as possible throughout the distribution system.
Capacity Building	Training on NRW management	Taking the relevant staff for training on NRW management Field visitation OJT	To improve technical skills and capacity.
Public Awareness	Awareness of stakeholder on NRW management	NRW public campaign	Create stakeholder awareness for proper water use and disseminate benefit of NRW management.

Action plan would be summarized the Implementation Plan as shown in the Table 12.2

Table 12.2

	Issues / questions	**Desired Status / Target**	**Short Term Measure**	**Resources Required**	**By Whom**	**By When**
1	**Water Balance, Flow and Pressure Monitoring, Mapping**					
1.1	**Water Balance**					
1.2	**System Input Metering**					
1.3	**Pressure Monitoring**					
1.4	**Maps/GIS**					
2	**Leak Repair Records**					
2.1	**Leak Repair Records**					
3	**Performance Indicators**					
3.1	**Performance Indicators**					
4	**Active leakage control**					
4.1	**Active leakage control**					
4.2	**District Meter Areas (DMAs)**					
4.3	**Leak Repair - Distribution Pipes (Repair Time)**					
4.4	**Leak Repair - House Connections**					
5	**Customer Metering**					
5.1	**Customer Metering**					
5.2	**Customer Meter Replacement and Age**					
5.3	**Customer Meter Class**					
5.4	**Customer Database**					
5.5	**Customer Meter Reading**					
5.6	**Illegal Connections, meter tampering, bypasses**					
6	**Other Interventions**					
6.1	**Capacity building on NRW Management**					
6.2	**Stakeholders awareness on NRW Management**					

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