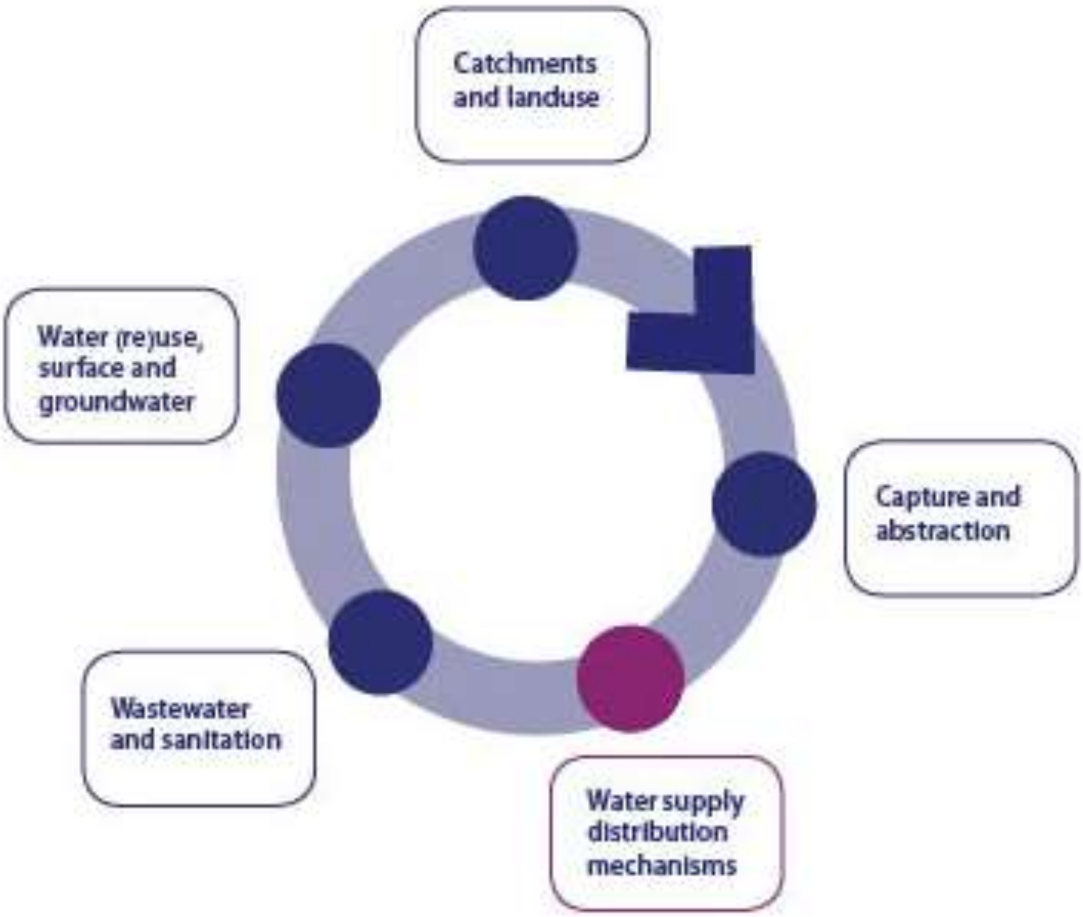
Guided learning to improve water and financial efficiency for water utilities in Ethiopia



Guided learning to improve water and financial efficiency for water utilities in Ethiopia

These Guided Learning modules have been developed to support the S2TAB project to reach out to water utilities in Ethiopia to benefit from the experience of the project partners. The concept of guided learning has been applied in different locations in Ethiopia.

The development of the modules has been a collaborative effort under guidance of Jan Teun Visscher with key inputs from Girma Senbeta and Simon Chevalking from MetaMeta. Implementation of the modules is being initiated in the first half of 2019 with water companies in Oromia with the first testing workshop in June.

May, 2019

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Preface

Significant progress has been made in the provision of safe water supply both in urban and rural areas in Ethiopia in the past 20 years. The comprehensive Water Sector Policy and the Water Sector Development Plans of the Government of Ethiopia have been very instrumental for making progress, but still very important challenges exist related to ensuring access to safe drinking water and the financial sustainability of water supply companies. The challenge is to provide higher levels of service at a fair price to a growing population in a sustainable manner.

The second Growth and Transformation Plan (GTP II) covering the period 2016 to 2020 stipulates increasing the safe water supply coverage, upgrading the service level, ensuring good governance in urban and rural water supply to enhance sustainability, effectiveness, efficiency, as well as including climate resilient WASH and emergencies and building the sub-sectors' overall capacity. GTP II includes the overall rural goal to raise water coverage to 85 per cent with a per capita water consumption rate of 25 l/c/d and within a one kilometre radius by 2020. The urban goal is raise coverage from the current 54.7 per cent to 75 per cent with per capita consumption of between 40 and 100 l/c/d, according to the set classification of towns. The plan also includes an ambitious goal of reducing Non-revenue water (NRW) to 20 per cent by 2020 in the water supply utilities of category 1 to 3 towns/cities. This goal is very ambitious and complex as a good overview of NRW in Ethiopian facilities is not available. A review of the one WASH program in 2018 indicates for example that the water utility in Gambela cannot be financially viable. The excessive NRW in the town is a huge drain on productivity and efficiency. Unmetered connections, defective water meters, leakages, fraudulent connections and inaccurate meter reading (due partly to the fact that the water meter readings are taken by the customer) are listed as causes for the high NRW. Reducing NRW will save considerable costs (One WASH National Programme - OWNP, 2018).

Although NRW, which according to OWNP (2018) may stand at an average of 40%, is a key issue in the lack of sustainability there are other issues as well. Utilities are not financially viable because water tariffs are not established based on a full cost recovery principle. Another challenge is matching supply with demand. When demand exceeds supply, intermittent and unreliable services result in inconvenience to users, reluctance to pay water bills, increased risk of compromised water safety, and reduced resilience to climate change. Other challenges include experienced staff shortage, inadequate maintenance and low financial capital to invest in upgrading technology and new infrastructure.

To be able to identify these problems and establish mitigation measures a detailed assessment of the system and its administrative organization is needed. Improvements may include technical measures to reduce technical water losses, but also improvements in administrative arrangements, and strengthening the relation with the users who can be of great support for example in the early detection of larger leakages, but in turn also can benefit from a closer relationship in obtaining information on efficient water use.

The review of the technical and financial performance of the water utility and water supply system can very well be carried out by a small team of staff from the technical and administrative sections preferably in combination with staff from other organizations and particularly the municipal administration. The Source to Tap and Back Program (S2TAB) has developed the training course presented in these modules to help staff from these organizations to actively pursue and prioritise problems and implement mitigation measures to reduce water loss and enhance financial performance.

Taking into account the limited impact of class room teaching as well as the relatively high turnover of staff an innovative approach to capacity building is chosen. In this approach, training activities are embedded in the daily routines of staff. Key to the approach is that participants in the course obtain a set of training modules as a document, complemented by the same course package and additional resource materials in electronic form. The self-learning modules comprise key information, specific field assignments with ‘learning-by-doing’ exercises and a question and answer section where participants can check their own progress. The training is arranged in short modules each of which addresses a main issue that needs to be understood by participants, some practical exercises that can be implemented at the place of work and questions to review the level of learning.

Together the modules build up towards making a plan to improve the efficiency of the water utility were participants are involved. The exercises are implemented by participants and shared with the course facilitators through internet, normal mail and/or face to face contact. Facilitators will come to the place of work of the small groups of trainees and will go with them into the field to jointly review the main field assignments. The main premises underlying the approach is that practical, problem-based learning can make a difference in the performance of staff and can support them to providing an improvement plan to their water utility that is revised by external advisors and can be directly implemented. The modules can also be used to support new staff joining the water utility and in that way help to reduce the negative impact of high turnover of staff.

I. General introduction to the course

Considerable efforts have been made in Ethiopia to improve water and sanitation coverage. As a result the number of improved water supply systems is growing but management and maintenance of these facilities is not well developed putting their sustained functioning at risk. A review of the service levels in 16 small and medium towns in four regions of Ethiopia showed for example that the number of people with access to improved water services is high, but only a small part of them (9%) has a service that meets the standards set in the Ethiopian government's Growth and Transformation Plan (GTPII) in terms of reliability, quality, quantity and travel and queuing time. The study stresses that these limitations in service delivery pose a huge challenge particularly for water supply delivery in small and medium towns, also taking into account their quickly growing population (Adank et al, 2017).

Lack of finance and high levels of water loss are among the key problems faced by many water supply systems. The Government of Ethiopia has indicated in their plans that particularly reduction of NRW is one of the strategies they pursue to improve upon the situation. Considerable effort however is needed to make these plans come through as the situation is quite complex with on the one hand users that expect low cost water supply and on the other companies with limited resources and a high turnover of staff. Other problems that water utility managers may face in different parts of the world include according to Drinan (2018) based on work of the Effective Utility Management Collaborative Effort (https://www.watereum.org/): rising costs and affordability problems, aging infrastructure, on-going and changing regulatory requirements, enhanced customers' expectations, and rapidly evolving technology.

In many municipalities in Ethiopia the situation is even more complex as the population has access to multiple water sources and their use may vary over the year depending on water availability. So during part of the year users may prefer these other water sources for which they may not have to pay, thus leaving the water utility with lower income during those periods.

Management and staff of water companies and municipalities are key actors to meet the challenge to provide efficient water supply as they are very well aware of the local situation and the performance of the water systems. The practical training course set out in this manual is meant to help these actors to cope with the development and implementation of a financial improvement plan for their water system. This 120 hour course is being implemented in a guided self-learning mode over a period of three months. It comprises the following course modules:

1. ***Introduction to technical and financial performance*** which helps participants to understand overall concepts and the steps involved including how to go about the presentation of essential data on the water supply system
2. ***Identification of non-revenue water and development of a water balance*** which includes learning about general problems related to technical and commercial water losses
3. ***Customer orientation*** which helps participants to obtain an overview of the situation and find improved approaches to dealing with customers
4. ***Practical improvement measures*** which includes identification, formulation and prioritization of measures based on priority problems
5. ***Towards implementation of a water and financial efficiency plan*** which includes completing the plan and a management and monitoring programme

At the end of the course participants will be able to: Indicate the main problems related to the financial and technical performance of the water supply system of their utility and to explain the improvement plan for the system.

II. How to go about the course

This training course has been established to help participants to acquaint themselves with technical and financial problems that may be present in their water supply system and to enable them to, jointly with other actors and users, find possibilities to improve upon the situation that can be embedded in a plan to enhance the financial efficiency among others by reducing NRW. At the end of the course they will have explored the water supply situation and will have developed a plan to enhance financial efficiency and particularly reduce NRW, whilst taking into account the overall context where people may not exclusively use the piped water supply but also may revert to other water sources.

The course follows an innovative approach of guided self-learning, where participants can access training modules, resource materials and resource persons, in different ways. The access may be through a paper based approach, electronic devises or the Internet. Participants will learn in their work environment and have face to face contact with fellow participants, course facilitators and resource persons. A proposed structure and possible timing of the course are shown in Table 1. Timing is based on an on average availability of one day per week. A shorter period can be used if participants have more time available per week or are already having considerable experience.

Table 1. Possible course structure and timing

Module	Activities	Timing of completion
Preparation	Formation of teams of trainees Agreement with water utility Development of a description of the water system by trainees	Prior to introductory workshop
Introductory workshop	Identification of trainer per team Establish contact arrangement with trainer Review Module 1 and key concepts of module 2	Start: two day meeting; (alternative is to visit trainees in their utility)
Module 1	Revisit module 1,and revise the information on the water supply system with the team and complete assignment	End of week 2
Module 2	Review module 2, meet with team, review the components of the water supply system and the water balance and submit assignment (as an alternative you can submit the assignment together with assignment in module 3	End of week 3
Module 3	Review module 3, meet with team, explore the customer situation and customer orientation; submit assignment, (together with assignment of module 2 if that was not yet discussed) and meet with facilitator	End of week 5
Module 4	Review module 4, meet with team, submit assignment	End of week 7
Module 5	Review module 5, complete assignments, complete the plan and the monitoring system; discuss with management and meet with facilitator	End of week 9
Final review	One day meeting to present and discuss results; alternative is to just discuss with the trainer in the office of the utility	Week 10
1. All assignments can be done in the water supply system of your utility, but some may require visiting the water intake and the distribution network.		

The course includes field assignments in which participants will work in small teams. Assignments in principal can be done in the area of their water supply system and may include interviewing for example water users, testing water meters, checking for leakages, and talking to staff involved in repairs.

Module 1 Technical and financial performance

This module provides an introduction to the technical and financial performance of urban water systems in Ethiopia. At the end of this module the participant will:

- *Be able to explain the objective and the steps involved in the assessment of the technical and financial performance of their water supply system*
- *Have improved the description of their water supply system with a view to the assessment of the technical and financial performance*

1.1 Introduction

Many water supply systems in Ethiopia face considerable problems in their financial performance. This may include a high level of non-revenue water due to technical but also administrative problems including problems with meter readings and users registration. Such problems may have a very negative impact on the financial performance of water supply systems and may strongly hamper their sustainability. It is therefore crucial for water supply companies to review their technical and financial performance and develop and implement improvement plans to ensure the health of the utility and its consumers. In fact this is an urgent need as according to a survey developed by Adank et al, (2017) showed in 16 small and medium towns in four regions of Ethiopia only 9% of the users received the service that meets the standards set in the Ethiopian government's Growth and Transformation Plan (GTPII) in terms of reliability, quality, quantity and travel and queuing time.

This problem is not only present in Ethiopia, but is occurring in a great many water utilities around. Despite many vary in their size, organisational culture and operating environments, the difficulties relating to management are often very similar. A vicious circle exist in many utilities in that their poor performance with sometimes more than half of their water being lost through physical and administrative losses creates a low level of service for which consumers are reluctant to pay a fair price. The consequences are that because of low revenues, operating costs are often not adequately covered which contributes to poor performance. This is aggravated by inadequate management practices as manifested by lack of clarity in organisational mandate and mission, inadequate management structures and systems for effective delegation, low human resources capacity and poor customer service.

Effective utility management can help utilities respond to both current and future challenges including enhancing the stewardship of their infrastructure, and improving performance in many critical areas to enhance the effectiveness of their own operations and meet customer needs (Fisher et al., 2006). This includes putting attention to systematic data collection to be able to monitor performance and take strategic decisions. Ideally a strategic planning process would be initiated which would include the steps indicated in Table 1. This process would start with a situation analysis including a comprehensive audit of the main functional areas of a water utility: Organizational Planning, Communication, Finance & Administration, Operations, and Technology.

Table 1 Strategic planning framework for water utilities

Step	**Main issue to explore**
Situational Analysis	Where has the utility come from and where is it now?
Objectives and Targets	Where does the utility wants to be?
Strategies and Concrete Actions	How might the utility get there?
Monitoring and Evaluation	How does it sustain success?
	(Mugabi et al. 2007)

The approach in this module is less comprehensive by focusing on just a part of the process relating to water loss and financial performance. But also in this case the steps indicated in Table 1 are useful. A detailed assessment of the system and its administrative organization will provide the basis to identify problems and establish mitigation measures. Improvements may include technical measures to reduce technical water losses, but also improvements in administrative arrangements and customer care to reduce economic losses. Strengthening the relation with customers is very important as they can be of great help for example in the early detection of larger leakages, but in turn they also can benefit from a closer relationship in obtaining information on efficient water use.

One special feature of the conditions in many small and medium towns in Ethiopia that should be kept in mind is that particularly in smaller communities people have access to multiple water sources. This may imply that the utility may be competing with other water sources including for example polluted rivers, rainwater fed ponds and shallow wells. Although some of these supplies may be unacceptable to outsiders, they may be well appreciated by local user. People create their own 'world view' and have their own perception of their situation which is shaped by history. This makes that the work of the water utility is not a straightforward engineering problem. In essence it is about people and much less about technology. Men, women and children may have different views about their water supply and its quality, and they, knowingly or unknowingly, interfere with their water supply systems.

In many places we see that people continue to use traditional water sources even after a piped supply is installed for example because they do not like the taste of piped water, they may have to walk further, wait longer or have to pay. This behaviour may be particularly happening in and after the rainy season when more water sources may be readily available. Hence the challenge of water providers is not only to provide safe drinking water in adequate quantities to consumers but also to do this in competition with other potential water sources.

The approach proposed in this module is that the technical and financial review will be carried out by a small team of staff from the utility preferably in combination with staff from other organizations and particularly the municipal administration. Such a small team would have the insight about the water utility but by adding staff from the municipality a strategic connection is being made with external interventions particularly related to road and housing construction that may have quite an effect on water systems. The overall aim of the approach is to help this team to actively identify and prioritise problems and propose mitigation measures that can be quickly implemented to reduce water loss and enhance financial performance. This approach needs to take into account that a water supply system is not static. It changes over time because the community may grow, the system gets older and may deteriorate, users may adopt new habits which may affect their water consumption. The dynamics of a water supply system need to be recognized and taken into account to ensure long term sustainability of the system. Reducing water loss and enhancing water use efficiency is a great way to contribute to sustainability and to provide better water services to more people with the available sources. Hence it may reduce the need of the water utility to look for other water sources to provide water to a growing population.

"Reducing water loss is one of the best ways to make your water source last longer whilst providing a good service to your customers"

In the next section we will discuss the issue of providing a good overview of your system and the way it performs.

1.2 Description of the water supply system

Making a good description of the water supply system provides the basis for the identification of problems and limitations in relation to technical and financial performance. In most cases part of this information may be readily available either in available data bases or in writing or in the heads of people working with the utility, but additional data may need to be obtained. As a start it is necessary to provide an overview of the main characteristics of the water supply system and its users (see Table 1.1).

Table 1.1. Basic information about the water supply system

Name	
Location	
Type of water source(s)	
Population	
Water supply coverage	
Number of boreholes Number of water intakes*	
Design capacity l/s	
Age (average and range)	
Average water production (m^3/day)	
Per capita consumption (l/c/d)	
Type of water treatment	
Transmission lines (pumping mains) (km)	
Distribution system (km)	
Water storage tank(s) average (+range) m^3	
Number of water pumps	
Length of distribution system (km)	
Number of house connections	
Part of house connections with meters (%)	
Number of standpoints	
Operating hours / day	
Main Power source	
No. pumps (average age + range)	
No of bulk water meters	
Non-revenue water (NRW)	
Number of pipe bursts (No/km/year)	
Cost of Water Production (Birr/m^3)	
Average tariff (in to supply) (Birr/m^3 sold)	
* Chose the option that relates to the system; if you have both ground water and surface water than you need to indicate both	

The next step comprises of the preparation of a flow diagram that shows all the major elements of the water supply system (Figure 1). The objective of the description is to have a clear understanding of the main components of the water supply, i.e., how the water supply system is designed and functioning from catchment to point of use. The description includes the catchment area, type of the source (s), intake, treatment plant, reservoirs, distribution system with primary, secondary and tertiary pipe networks, pump stations, valve boxes, bulk water meters, public stand posts and/or household connections. Information may be readily available in the office but it will be necessary to validate the information in the field and visually inspect the main features of the system and assess their condition. This inspection can be done in the next step of the process which comprises identification of possible leakages.

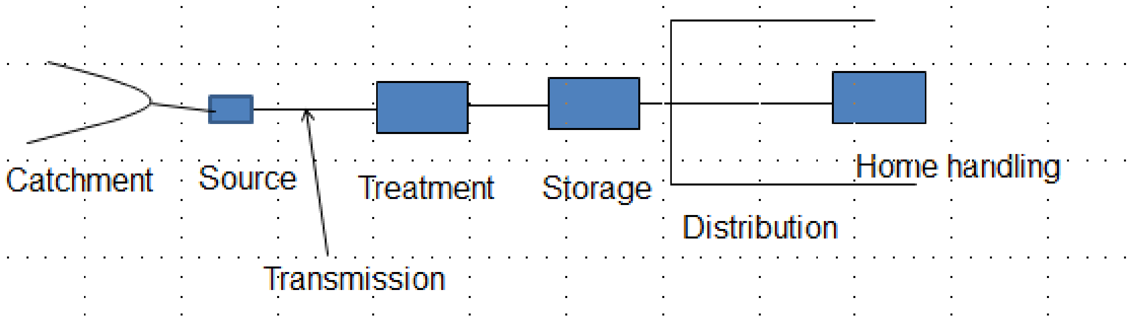

Figure 1.1. Profile of the water supply system

1.2.1 The water catchment

Understanding the water catchment in relation to the water source is particularly relevant in relation with the water availability or water concession of the water utility, and which part of the available surface or ground water is used. The risk to be assessed is whether the volume of water that is abstracted is close to or even over possible limits, as that would make water saving even more important. In the case of ground water sources it is important to know whether the water table is falling as this might affect water availability and pumping cost.

1.2.2 Water source and water intake

The system may draw water from a single or multiple sources which may include: surface water (river, lake), ground water (deep borehole, a spring), and rainwater. So it is important to describe the water source and the pumps (or gravity system) that is used. For surface water sources the description should include, the water intake structure(s) including possible pumping system(s) and for groundwater the description should include the characteristics of the well(s) (including location, depth, water level) and the pumping systems.

1.2.3 Transmission main

In many systems a transmission main takes the water from the water intake or the borehole to the water treatment plant or to a storage tank. Details of the transmission main to be presented include: the length, diameter, type of material, age, and whether it is buried or above ground.

1.2.4 Treatment system

The description of the system should include the type of treatment process(es), the lay-out and dimensions of the system, the flow rates, main operating devices, the age, consumption of chemicals and data about system performance. It needs to be kept in mind that the main interest in this case is possible water loss which may be the result of leakages but also inefficient backwashing of rapid filters.

1.2.5 Storage reservoir(s)

Usually the water is stored after treatment in a water storage tank which may be a ground tank or an elevated tank. The description should include the location, the volume, dimensions, materials, and age of the tank and the resident time of the water. The latter is particularly important if chlorine is dosed at the tank entrance. The description should also include the water main that transports the water from the treatment plant to the storage reservoir. If available do include information in water being lost from the tank through leaks.

1.2.5 Distribution systems

The drawing of the distribution system needs to include the primary, secondary and tertiary pipe networks, pump stations, valve boxes, bulk water meters, public stand posts and/or household connections. It is highly relevant to add if available information on water pressure. These data can be included in summarized form with possible details presented separately (in electronic form).

1.4.6 Household water storage

It is also important to briefly describe whether water is stored at home indicating the types of containers that are being used and to provide an indication of the percentage of households that have such devices.

1.4.7 Alternative water sources

The last point to include in the description concerns alternative water sources the population may be using (during part of the year). This point is often overlooked, but may be critically important. Such sources may include ponds, open wells, springs, rivers and rainwater, which should briefly described including location, availability throughout the year, users and the way they are using the water. This type of ‘competition’ for your utility may imply that during part of the year you will be able to sell less water. Hence you need to get insight in the water culture of your consumers, the way in which people deal with water and the water sources and systems they use as just providing a safe piped water supply is usually not sufficient to ensure that people turn to this system and use it exclusively.

1.3 Description of financial situation

The financial situation of a water company includes different cycles:

- ***The operating cycle*** which includes the cost to obtain the raw water, electricity, chemicals for water treatment, cost of water distribution, delivery and invoicing (Figure 1.2). These costs include payments of salaries and all the inputs required to operate the systems.

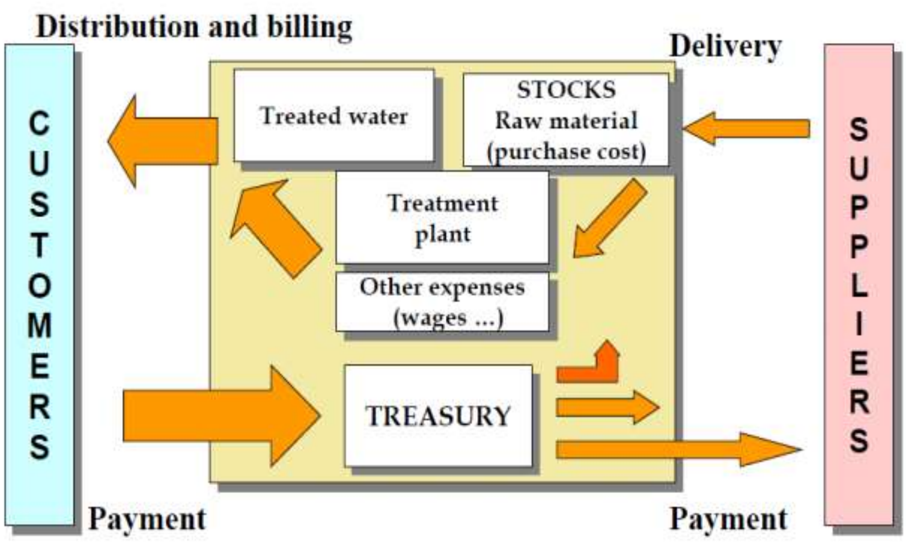

Figure 1.2 The operating cycle of a water company (CEFEB in Fritsch, 2016)

- The investment cycle dealing with the finance that is put into the water system and its rate of return. In many water systems in Ethiopia the investment cycle is dominated by the public sector and is not really taking into account in the real value of water security to wider economic development. With economic growth this however may change and more emphasis may be put on recovering the full cost of water supply including investment and replacement cost.

In this section we will not go into much depth about these issues, but just will provide the information that will allow the team to give an overview of the financial situation of the water utility. This implies developing a breakdown of the main cost elements that are in place, possible subsidies that are being provided and the revenues that are being obtained.

Existing Water Revenues
The water utility derives revenue from a variety of sources (Table 1.4). At this stage the idea is to obtain an overall view of the situation without too much detail.

Table 1.2. Main sources of income of the water utility

Source of income	**Income per year in Birr**
Rate revenues(metered)	
Income from flat rates (not metered)	
Income from public taps	
Subsidy (government, municipality)	
Other income	
Total annual income	

Existing cost
The water utility has a range of cost to cover during the year (Table 1.5). Also in this case the idea is to present the overall picture without too much of detail. In a number of cases it may well be that cost are not fully known as for example cost of larger repairs may be covered by regional water bureaus. Still it is important to indicate these cost elements even just as an in-kind contribution to get the full picture.

Table 1.5. Main cost items for the water utility

Cost elements	**Cost per year in Birr**
Staff cost	
Transport cost	
Energy cost	
Chemicals	
Materials	
Contracts for larger repairs	
Other	
Total annual cost	
Indicate possible in-kind contributions that are not charged to the utility	

1.4 Self Evaluation

This is an individual evaluation of your understanding of the information presented in this module. Answer the (multiple choice) evaluation questions and check your own answers (section 1.9) and review the module again if you had many mistakes.

Q1. Why is a strategic plan needed for your water system?
A: To increase the efficiency of your water supply system
B: To understand the main problems and be able to identify the main mitigation measures to keep the system functioning properly

C: To understand what is needed to ensure long term sustainability of the water supply

Q2. People with access to a piped water supply system will use this exclusively?
A: Yes
B: No
C: May not be the case

Q3. Making and implementing a detailed plan to reduce water loss and enhance financial sustainability just needs to be done once say every five years.
A: Correct: Such plan looks at all the short and long term problems related to water loss and financial sustainability, so it covers the problems and planned interventions for a period of several years
B: Not correct: We need to review the plan every year
C: Not correct: We need to review the plan at least every year and need to monitor performance more frequently

Q4. Which of the following answers related to the team that will make the plan is correct? (Multiple answers possible)
A: The team needs to include operational staff from the utility
B: The team needs to include staff from the municipality
C: In most cases the team needs to consult with different experts
D: The team needs to include water users

1.5 Assignment

In this section you will find the assignments related to this module. Preferably you do this assignment with your training group by dividing the tasks and make one collective answer.

1. Make a description of the main components of your water supply system including a flow diagram.

2. Make a brief report on the financial situation of your water utility

3. List the main problems involved in your water utility

Action: *Copy the collective answers of your group to assignments 1, 2 and 3 and submit this or show this to your trainer through the means of communication you have agreed upon.*

1.6 References and further reading

This section includes the references for the section as well as some publications that may be interesting to gain more insight in the issues that are being discussed

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- Drinan (2018). Asset Management Leads to Effective Utility Management
- Fisher, J., Kayaga, S. and Mugabi, J., (2006). Improving water utility management and performance in developing countries. Water Utility Management International, 1 (4), pp. 6-8.
- Fritsch, R (2016). Comparative Financial Analysis of Water Utilities in West Africa. Journal of Management and Sustainability; Vol. 6, No. 4; 2016

- Mugabi, J., Kayaga, S. and Njiru, C., (2007). Strategic planning for water utilities in developing countries. Utilities Policy, 15 (1), pp.1-8.
- OWNP, (2018). One WASH National Program; a multi-sectoral SWAP, review of phase i

1.7 Answers to self-evaluation questions

Q1. All answers are correct; a strategic plan will help you to systematically look at all your problems and establish mitigation measures. It will also allow you to establish a good but simple monitoring system that will help you to prevent problems or at least detect them quickly. Making the plan will also force you to think about the future and the longer term sustainability of your water supply and water utility. Having the plan will make it easier to orient staff and customers as it is clear where you want to go.

Q2. Answer C is correct as a having a piped supply does not imply that people use it exclusively. People may use alternative water sources (for example because of cost involved) instead of the piped supply.

Q3. Answers C is correct as the plan needs to be updated and this can be done on an annual bases, but that may not be sufficient. Yet unforeseen changes or disaster situations may make it necessary to review the plan even earlier. What is even more crucial is to have a good monitoring system in place to ensure that your performance is in line with your plan.

Q4. Answer C is correct, but the other answers are possibilities that are worthwhile to reflect upon. In many cases it will not be feasible to have specialist expertise on the core team, but this can be overcome by consultation at strategic moments. With respect to answer A, operational staff can be included in the team but at least need to be consulted as they often know a lot about system performance. Having them on the team may facilitate the consultation process as well as the implementation of the plan. With respect to answer B, staff of the municipality can be included in the team but at least need to be consulted as they are knowledgeable of possible risks related for example to road construction. Having them on the team may facilitate the consultation process as well as for example the implementation of standard operating procedures related to road construction and repairs. With respect to answer D, users need to be consulted but usually are not formally included in the team, although it may be worthwhile to consider having a user representative on the team.

If you failed to provide several of the correct answers, then review this module again.

Module 2 Non-revenue water and water balance

This module provides an introduction to analysing the non-revenue water situation in the different components of a water supply system and to making a water balance. At the end of this module participant will:

- *Be able to explain the concepts of technical and economical water loss*
- *Have identified main water loss problems in their water supply system*
- *Have prepared a diagram of their distribution system*

2.1 Introduction

Non-revenue water is an important topic for drinking water companies, as it influences the financial sustainability, serviceability and the management of precious water resources to a large extend. According to the World Bank[1], in developing countries, roughly 45 million cubic meters of water are lost daily with an economic value of over US$3 billion per year.

According to the Kingdom et al., (2006) a number of complex reasons exist why utilities struggle to control NRW. These include:

- Failure to understand the problem (magnitude, sources, costs)
- Lack of capacity (insufficient trained staff)
- Inadequate funding to replace infrastructure (e.g. pipes, meters)
- Lack of management commitment
- Weak enabling environment and performance incentives

It is particularly important to understand that NRW is not about solving a technical problem. The essence is to recognise that it is a complex issue that relates to all aspects of the company including overall management, asset management, financial management, information management, and customer's relations. It requires long-term commitment of all sections in the utility in the understanding that it is the responsibility of everyone in the utility.

Non-Revenue Water (NRW) is defined by the International Water Association's (IWA) as the difference between the cubic meters of water that are distributed into the water distribution network and the cubic meters that are invoiced to the customer. It is the water that has been produced and is "lost" before it reaches the customer.

NRW = System Input Volume - Billed Authorised Consumption
Where: ***System Input Volume*** = the total volume put into the distribution system
Billed authorised Consumption = the total volume of water that is actually paid for

NRW includes real losses (physical losses, such as leakages, flushing of network), apparent losses (commercial losses, such as illegal water connections) and unbilled authorized consumption (such as water used by fire fighters, or for flushing pipes). NRW also contains the billed water that is not paid which may be an important portion of the revenue water if the administration is not well organized (Table 2.1).

[1] World Bank (2016); http://www.worldbank.org/en/news/press-release/2016/09/01/the-world-bank-and-the-international-water-association-to-establish-a-partnership-to-reduce-water-losses

It is important to realize that water loss at the water intake, during transport to the treatment plant and in the treatment plant itself are not included in the definition and calculation of NRW. These losses however should also be analysed as they involve cost and may put unnecessary stress on the water resources that can be reduced by proper interventions.

A point of attention is the assessment of the volume of water that is provided to consumers. Utilities may charge a minimum volume of water whether this is actually used or not (or may not even be provided) and in addition charge the extra volume of water that is registered. This approach may generate income from water that is not actually delivered, so in that case you cannot just calculate the delivered volume from the income, but need to make an adjustment for the volume that is charged but not consumed.

Table 2.1 Revenue and non-revenue portion of water distributed to consumers

<table>
<tr><td rowspan="6">Authorized consumption</td><td rowspan="4">Billed</td><td>Metered</td><td rowspan="2">Revenue water</td></tr>
<tr><td>Unmetered</td></tr>
<tr><td>Unpaid metered</td><td rowspan="8">Non-Revenue water</td></tr>
<tr><td>Unpaid unmetered</td></tr>
<tr><td rowspan="2">Unbilled</td><td>Metered</td></tr>
<tr><td>Unmetered</td></tr>
<tr><td rowspan="4">Water losses</td><td rowspan="2">Apparent losses (commercial losses)</td><td>Metering inaccuracies</td></tr>
<tr><td>Unauthorized consumption (illegal connections)</td></tr>
<tr><td rowspan="2">Real losses</td><td>Leakages in storage reservoirs, distribution mains and service lines</td></tr>
<tr><td>Overflow of water tanks, flushing of pipes</td></tr>
<tr><td colspan="4">This overview only concerns the water loss as defined by IWA which is about the water that is produced and put into supply. In addition however water may be ‘lost’ in the intake structure and in the transmission main to the water treatment plant, (or water tank with disinfection as is common in Ethiopia), the treatment process (back wash) and the transmission to water storage tanks.</td></tr>
</table>

A special feature that needs to be taken into account is that a considerable number of water supply systems in Ethiopia are operated intermittently and may not be metered (or meters may not be accurate). As a result consumers may get their own storage tanks. Under low pressure conditions however the water flow to these tanks may be very small and may not be detected by the meter and therefore will not be charged. This may also imply that water lost within the private property (overflows of private tanks, dripping taps etc.) goes unnoticed to the water utility. Hence it is important to also have a look at the situation at the household level particularly exploring the difference between actual consumption and wastage. This is important as it will help to design water loss reduction measures.

To develop a good water loss reduction strategy all potential water loss needs to be explored that may affect the water utility. This implies that a systematic assessment of the total water chain from catchment to consumer is needed. An important tool for this assessment is the physical inspection and documentation of the water system. This will help to get the overview that is needed to subsequently take measures to reduce water loss which may include the divide the system in different district metering areas (DMA). A DMA is an area of the piped network that is hydraulically isolated which allows the measurement of water inflows and outflows to enable the estimation of water loss within the DMA.

2.2 Exploring physical water loss

Physical water loss is the water that is lost along the water chain. In the water balance indicated in the previous section this concerns water loss on transmission and distribution mains; leakage and overflows from storage tanks; and leakage on service connections up to the customer meter. Nevertheless water loss may also occur in the water intake, transmission to the treatment plant and in the treatment process. These losses may make that more water needs to be abstracted from the water source leaving less for other water users. It may also imply cost for the utility when for example treated water is used for an inefficient backwashing process or water that has been pumped leaks from cracks in the treatment plant.

Different computer programmes exist to calculate water loss such as AQUALITE, WB-EasyCalc, and Sigma Lite 2.0. In this document we will not enter into the presentation of this type of software. The approach is kept simple in that possible water loss in different parts of the system are discussed and assessed. Thereafter the total overview can be provided in an excel sheet to be able to easily visualize the overall situation. This insight will be sufficient to take priority action. When the team advances in time a next step may be to use one of the computer programmes for more detailed calculations.

2.2.1 Water intake and transmission to treatment or storage

Water loss from the water intake and the transmission main can be explored by a physical inspection and if feasible flow and pressure measurement. An important issue to take into account is whether the water is pumped from the source, in which case subsequent water loss represents a cost to the utility. Furthermore it needs to be explored whether water that leaks from the structure flows back to the water source. If water that is lost is not pumped, flows back to the source, is not needed for the water supply, and is not posing a risk to the infrastructure than repairing this leakage is not a priority.

2.2.2 Water treatment units

This section relates to those systems that have a water treatment plant such as a rapid filtration unit. It does not relate to the chlorination unit as this is usually connected to the water storage reservoir to ensure sufficient contact time with the chlorine. So that part is dealt with under water storage.

In water treatment part of the produced water may be used to backwash the filter units. The problem is that this process may be quite inefficient so a lot of water may be used. Revising and possibly optimizing this process is an issue that merits exploration. Also it is important to ensure that the filter units and other parts of the treatment unit are no leaking. A simple method for the latter is to fill the units with water with the outlet closed and to review whether the water level in the unit is falling.

2.2.3 Water storage

Water loss from the water storage tank(s) can be explored by a physical inspection and a test to explore the water tightness. The latter basically implies filling the tank(s) with water with the outlet valve closed and to review whether the water level in the unit is falling. By measuring the fall of the water level you can calculate the volume of water that is being lost. In this test it is important that you check whether the outlet valve indeed is closed and does not let water flow into the network. Here the system may include a tap close to the valve that may be used for this or you may need to listen yourself by putting a 'listening' stick to the valve. If the outlet valve cannot be closed then you can consider putting a temporary plug in the outlet on the inside of the tank.

By adding a cable to this plug you can remove it easily without the need to get into the tank again when you complete the test. In case of an overhead tank the physical inspection is likely to be sufficient as physical leakages should be visible in those structures, whereas in ground tanks water may seep directly into the ground and so water loss may go unnoticed.

One point to take into account is the possibility that the tank(s) include a water overflow which may spill water for example during the night. Hence you need to check this carefully.

2.2.4 Water distribution

Water losses occur in all distribution networks, even new ones. The losses may stem from water mains, services pipes, booster stations, service tanks, pipes, air valves, washout valves and hydrants. The real losses or leakage in the distribution system according to IWA (2007) are made up of three components:

- **Reported leaks and breaks**, which are typically leaks with a high flow rate that are easily visible and are reported to the water utility by customers and therewith can be repaired fairly quickly (on an emergency basis) thus being of short duration. This type of leakages is usually more frequent on water mains.

- **Unreported leaks and breaks**, which are typically leaks with a moderate flow rate that are not very visible and therefore may go unnoticed for a long time unless active leakage control is in place. The long duration may imply that water loss is considerable.

- **Background leakage**, which mostly occurs at joints and fittings. This concerns generally leakages with flow rates (< 250 litres/hour) that are too small to be detected, by traditional acoustic leak detection techniques if occurring in buried pipes. The leakage per hour may be relatively small but the flow is continuously and so the total water loss may be considerable. They will continue to flow until detected by chance or when they gradually worsen to a point where they can be detected.

In general the volume of water lost by bursts of mains and of service lines is considerably smaller than water loss related to the other two components and may account for less than 10% of the annual real losses volume. The largest real losses occur from background and long-running unreported leakages as well as from reported leakages the water utility does not bother to repair. Time is important as the longer a leak runs the greater volume of water that is lost. In case of leakages three time factors can be distinguished: the awareness time (A), location time (L) and repair time (R).

Detecting leakages in distribution systems is not easy except for pipe bursts that are visual and reported. The approach that has been traditionally used is to visually inspect the lines to look for leakages and to use wooden listening sticks or stethoscopes. According to Mandli (2017) an experienced person can identify water leaks where the pressure inside and outside the pipe is large enough to generate water turbulence in the water leak. This provides a sound that can be identified by putting a listening stick or another listening device to the pipe and in that way leaks can be detected. Usually the noise is strongest at the location of the leak.

Today many electronic acoustic listening devices exist that can be used to find water leaks that produce sounds that can be detected by the human ear. Different factors will affect the amount of turbulence emitted from a leak, including the size and the shape of the leak, the pressure behind it, and even the type of soil surrounding it. An important problem for this type of leak detection is background noise. This includes wind, road traffic, noise created by neighbouring businesses and residences, and the hum of electric transformers. This type of noise should as much as possible be avoided.

Detectors available in this moment range from simple devices that are economic and primarily meant to be used for occasional testing to advanced wireless devices that can be used permanently installing units at different strategic points in the distribution network.

Water pressure is a very important factor in relation to physical water leakage. The higher the pressure the more water will be lost from existing leaks, but a high pressure also puts more stress on pipes and joints and therewith may cause new leakages because of the development of cracks in pipes and leaks in fittings. It is important to realize that water pressure will depend on the flow conditions in the network. Leakage is proportional to the pressure in the system. When consumption is high, the flow in the pipes will be high and as a consequence frictional head loss will be high which makes that the pressure is lower. When consumption is low (during the night), flow velocities and frictional head loss will be low so the pressure will be high and as a result more water will be lost at that time.

2.2.5 Water loss at the consumers end

In Ethiopia consumers may have metered connections to their homes, unmetered connections, shared connections or obtain their water from public taps against payment. Water may be ‘lost’ here as well. This includes losses from reading errors, slow running meters, tampering with meters, broken meters, no meters, and illegal connections. One problem with water meters is that they may not be able to detect very low water flows for example from dripping taps or leaking pipes. A special point in many systems in Ethiopia is that water is also lost because of water spillage at public taps.

2.2.6 Leakage monitoring

To increase the efficiency of leak detection and control utilities introduced the concept of leakage monitoring which basically consist of the installation of flow meters at strategic points throughout a distribution system that often record both flow and pressure. The aim is to divide de system in different sectors or districts, termed District Meter Area (DMA) where both the inflow and outflow are registered. This division allows monitoring the water supply pattern and particularly facilitates obtaining a more accurate picture of the minimum night flow (MNF), the flow at the time that water consumption is lowest. Regular or continuous monitoring of the MNF in each DMA facilitates the identification and location of non-visible bursts and leaks more efficiently.

2.3 Commercial water loss

Commercial water loss (sometimes referred to as: ‘apparent loss‘), is an important problem for water utilities. Even a small volume of commercial loss will have a large financial impact as in general water tariffs are considerably higher than the production cost. Commercial water loss consists of:

- ***Meter inaccuracies***, which imply that water has passed through the meter but is not recorded accurately. This primarily concerns meter under registration which increases with age. A study by Crimini et al (2009) looking at meters between less than 5 years to 40 years old shows errors between 0,8 to 83% with the higher errors relating to older meters and for smaller flows. This is a point to take into account in meter management and in systems with intermittent water supply where users have storage tanks. If these tanks fill up gradually at low flow conditions under registration may be serious and may be reaching even up to an additional 40%. On the other hand it is important to also mention that meters may be moved by air in intermittent systems which may result in over registration.

- ***Water accounting errors*** which are the result of inaccuracies in the method of data handling and billing. The typical process is that the meter reader who visits the customers to read the meter, records these data in a meter reading book and passes these on to the billing department where the data are typed into the billing system. This process may include different possibility for errors including writing down incorrect data (accidentally or on purpose in case of corruption), transferring incorrect data into the billing system and sending the bill to the wrong address.
- ***Unauthorised consumption,*** water theft through illegal water connections. These connections may be of good quality as they may have even been made by staff from the water company, but also may be of poor quality adding to water loss and problems in water distribution
- ***Unpaid water bills*** which are bills that have been submitted but that are not paid. This may include even large government consumers but also a range of other customers as well as bills that are 'misplaced'.

Water meter inaccuracies are considered to be the most significant commercial water losses and hardest to quantify. Water meter errors are larger in networks with intermittent water supply or low water pressures, where users install private storage tanks to cope with the situation.

Illegal connections may be another problem which is not so easily solved. One option is to adopt a technical approach of identifying illegal connections as part of identifying water leakages. The problem is that if you ask users to close taps the illegal connections may do the same so they may not appear in this type of surveys. The alternative option is to adopt a social strategy where consumers are informed about the effect of illegal connections which in fact makes the water more expensive for the other consumers. In combination with sharing this information with consumers a grace period can be given to those people that legalize their connection, which in fact may be of good quality as it is not uncommon that staff from the utility is involved in making such connections. This approach can be further fine-tuned by comparing the existing meter registration in the company with the existing households.

Reducing commercial loss can be the start of a turn-around strategy. If you use the additional income to repair leakages you will be able to improve your service level and increase appreciation of customers who in turn may be willing to pay a bit more for this improved service, thus the utility can generate more income for repairs and improvements.

2.4 Estimating physical water loss

The physical water loss can be estimated as the difference between the total annual volume of water that is put into supply and the sum of the volume of water that is billed and the volume of authorized unbilled water.

A practical approach is to take the following steps:

1. Estimate the water input over a longer period of time, looking at all water that is put into supply as well as water that is exported in bulk to other users.

2. Calculate billed metered water consumption from different consumer categories (domestic users, industry, commercial) from the customer data base. Possibly combine with a user's survey to analyse different categories of use with low, medium and high consumption to understand consumption patterns and check meter readings. It is important to ensure that the period used to calculate the volume of billed water coincides with the period that the water was produced
3. Estimate billed non-metered water consumption which may require some fieldwork to measure water consumption by for example metering a small area of unmetered consumption as measuring on an individual basis may make people 'temporarily' changing consumption.
4. Calculate authorized unbilled metered water consumption
5. Estimate unmetered authorized unbilled water consumption (pipe flushing, firefighting)

In this calculation the essence is to look at actual water volumes over the same period. In some cases, for example, water utilities charge a fixed rate for the first say 20 m^3 irrespective whether this is actually consumed and charges for the additional consumption on the basis of the metered consumption. Here it is essential to explore the real volume of water that is delivered as several consumers may use less than the 20 m^3 for which they pay. So you would be making a mistake by obtaining the volume that is supplied, by taking the total revenue of consumers and divide this by the water price. You really need to estimate the water volume that is delivered from the meter readings to obtain the real level of water loss.

Calculating the water loss in this way implies that you include the leakages from the system as well as water theft and water not being billed because of meter inaccuracies. The approach outlined here leads to a rough estimate of the situation and allows for some ideas where to start improving. A more detailed approach is to introduce the concept of district metering areas as outlined in the next sections

2.5 District metering areas

A structured approach to better come to grips with water loss is the division of the water supply system in DMAs. A DMA as indicated earlier is an area of the piped network that is hydraulically isolated which allows the measurement of water inflows and outflows to enable the estimation of water loss within the DMA (Pilcher et all, 2007). The area should not be too small or too big and may comprise say between 500 and 3000 connections (BEWOP, undated). A main aim is to arrange the situation in such a way that with a minimum number of meters, the night flows in each DMA can be regularly or continuously monitored. This regular monitoring will allow earlier detecting non-visible bursts and leaks and locating them more efficiently.

Dividing the network into smaller, more manageable DMAs enables more effective management of the system in terms of NRW and pressure control and facilitates better understanding of the network, and allows to more easily analysing pressure and flows in problem areas. Night flow data from DMAs provides the information that enables the prioritization of leak detection and location.

The Minimum Night Flow (MNF) is the lowest net flow into the DMA over a 24-hour period. The reason why it is indicated as MNF is that at night most consumers are inactive and therefore consumption is minimal whereas leakages will be maximum as the water pressure is higher during the night when less water is abstracted from the system. This MNF needs to be measured from the meter(s) that control the DMA. It is important to realize that the MNF calculated in this way includes a proportion which is called the legitimate night flow (LNF), i.e. the water some customers in the night for toilet flushing, filling storage tanks, etc. The other (and larger) part concerns the water that is lost through leakages and illegal connections. A point to take into account is that intermittent water supply may complicate things. This usually implies that during part of the night no water is being delivered. In that case it may not be easy to establish the MNF because consumers may leave their taps open to collect water when it comes in the morning.

An approach with active participation of consumers may in fact be more precise and practical. If users can be convinced to close their main water valve (before the water meter) when the system is tested for leakages and prior to that moment store some water for their needs (in the night), then the situation is more clear as the (night) flow in that case only relates to the water that is lost in the DMA.

Often it is possible to come up with different designs of a series of DMAs in the same network as the criteria are fairly broad. The preliminary design must be tested either in the field or using a network model before putting it into practice. According to Farley et al. (2008 p 56) "the criteria that are often used for a preliminary DMA design include:

- .Size of DMA (e.g. number of connections—generally between 1,000 and 2,500)
- Number of valves that must be closed to isolate the DMA
- Number of flow meters to measure inflows and outflows (the fewer meters required, the lower the establishment costs)
- Ground-level variations and thus pressures within the DMA (the flatter the area the more stable the pressures and the easier to establish pressure controls)
- Easily visible topographic features that can serve as boundaries for the DMA, such as rivers, drainage channels, railroads, highways, etc."

The isolation of a DMA, may include closing valves to isolate a certain area and install flow meters. The water utility therefore has to ensure that possible changes in the system's pressures and flow resulting from this process do not compromise the water supply to all customers. Testing the DMA design(s) can be done by using a calibrated hydraulic network computer model of the supply system, which has the advantage that simulation will enable analyses of system pressures and flows without affecting supply to customers. If such model does not yet exist for the water supply system it is better to start by establishing DMAs in network areas that can be easily isolated, i.e. areas with a separate supply zones, as developing the computer model will take time.

Water loss should be recorded in the DMA and leaks identified and repaired. This can be done by a step test in which sections are closed off and water flow and pressure are measured. The reduction in flow is the part of the water that was consumed in the section that is closed. In this way sections with larger leakages can be identified. Subsequently these sections can be tested with sounding devices to spot and repair leaks. Once the initial repairs are being done recording in the DMAs should continue and the usual situation will be that water loss will gradually increase again. For each DMA the maximum level of increase needs to be set and when this level is reached the step test procedure and the sounding should be repeated.

2.6 Self evaluation

This is an individual evaluation of your understanding of the information presented in this module. Answer the (multiple choice) evaluation questions and check your own answers (see section 2.9). In case your answers had many mistakes it is suggested that you review the module again before doing the assignment.

Q1. Is non-revenue water the same as physical water loss?
A: Yes
B: No
C: May be the case

Q2. Indicate which of the following statement is correct. (Several may be correct)
A: Non-revenue water includes water loss during transport to the treatment plant
B: The presence of private water tanks at household level increases commercial water loss
C: Intermittent water supply increases water losses in the water supply system
D: Large reported pipe burst generate more water loss than smaller undetected leaks

Q3. Commercial water loss
A: Consists of water loss from meter inaccuracies, water accounting errors, unauthorized consumption and unpaid water bills
B: To an important extent is due to meter inaccuracies
C: Includes illegal water connections that should be disconnected

Q4. Indicate which of the following statement is correct. (Several statements may be correct)
A: A DMA is a District Monitoring Area
B: A DMA allows the identification of changes in the night flow more accurately than in a large system which is not separated in different DMAs
C: A DMA is a pilot area to reduce non-revenue water
D: Consumers participation may be required to estimate the MNF in a DMA

2.7 Assignment

In this section you will find the assignments related to this module. Preferably you first do this assignment for yourself and then you discuss with your training group and make one collective answer.

1. Complement the description of the main technical components of your water supply system from module 1. Including a diagram of the distribution system that indicates the position of bulk water meters and main valves.

2. Provide a brief description how water loss is taken into account in your water system

3. Make an estimate of the non-revenue water of your water supply system.

4. Conduct a review of the main components of the water supply system to look for possible leakage (this assignment can be distributed among team members who perhaps can work in pairs whilst possibly involving external advisors for example in the review of the catchment area)

Action: *Provide results of the assignments to your trainer.*

2.8 References and further reading

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Mandli, C. (2017). Cut Through the Noise of Acoustic Leak Detection.

2.9 Answers to self-evaluation questions

Q1. Answer B. The two are not the same. Non-revenue water is the part of the volume of water that is put into supply that is lost through physical losses and through commercial losses.

Q2. Answers B is the only correct answer, as the flow to these tanks may be low and this may not or not fully be detected by the water meter**.** Answer A is not correct as the definition of non-revenue water relates to the water that is put into the distribution network. Answer C is wrong as during the time (several hours) that the system is not working water does not leak out of the system. Answer D is wrong as large reported pipe burst do lose a lot of water but are usually quickly repaired. Smaller undetected leaks may leak for month or years and so over this period of time loose more water.

Q3. Answer A and B are correct. Commercial water loss includes meter inaccuracies, water accounting errors, unauthorized consumption and unpaid water bills with meter inaccuracies often being the largest loss. Answer C is partly correct as commercial water loss includes water lost through illegal connections but if of good quality these connections should not be closed but legalized and if the quality is not good it should be explored whether they can be improved and legalised as in this way they will generate income for the utility

Q4. Answers B and D are correct. A DMA allows a more precise indication of changes in the night flow as it allows measuring the inflow and outflow of the isolated area of the DMA. Consumer's participation indeed may be required to estimate the MNF in a DMA particularly if the water supply is intermittent. In that case the best approach is to ask people to close their water intake at the entrance to their house. Answer A is not correct as a DMA is a District Meter Area. Answer C is not correct because a DMA is a segment of the water system where you can measure the inflow and outflow. The approach is to divide the system in several DSA and in that context the first one can be used as a pilot to learn to apply the concept.

If you failed to provide several of the correct answers, then review this module again.

Module 3 Financial aspects and customer orientation

This module introduces financial aspects and discusses customer orientation in support of sound management. *At the end of this module the participant:*

- *Will be able to explain why it is important to connect to the customers and be responsive to their needs*
- *Can explain why improved billing may have a larger impact than reducing water loss*
- *Will be able to provide information on the customers and their water habits*

3.1 Introduction

NRW is not just about solving a technical problem but is a complex issue that relates to all aspects of the company including overall management, asset management, financial management, information management, and customer's relations. It requires long-term commitment of all sections in the utility in the understanding that it is the responsibility of everyone in the utility. A good NRW plan is imperative for breaking through the spiral of performance decline (Figure 3.1). Improving efficiency allows utilities to deliver better services more cheaply. Increase in efficiency can free-up resources to invest in improving or extending services. It can also help justify increased tariffs as customers are likely to be more willing to pay when they get a better service.

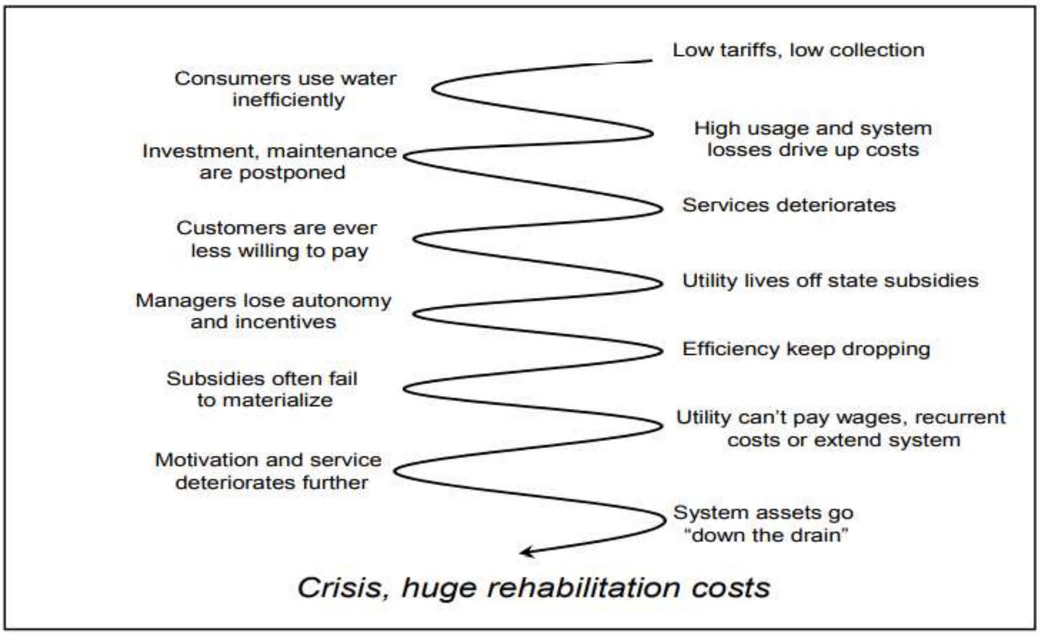

Figure 3.1 The Vicious Spiral of Performance Decline of Utilities (WSP/PPIAF, 2002. New Designs for Water and Sanitation Transactions: Making Private Sector Participation Work for the Poor)

Improvements in administrative arrangements and customer care are mentioned in module 1 as an important approach to reduce water and economic losses. Such improvements are crucial for the sustainability of the water supply system. It is worth noting that improvements in revenue collection and reduction of illegal connections in fact are even more interesting than reducing water loss. The water tariff usually includes different component such as: operational cost, staff cost, maintenance cost, and cost of infrastructure. Tariff setting entails both defining how much should be recovered via tariffs (setting the tariff level) and defining how revenues should be recovered from different customer classes via tariff structures. The tariff is often considerably higher than the production cost and as a result improved water billing generates more income per m^3 than reducing water loss which relates to the production cost per m^3. Improved billing includes a careful check of your data base but you also need to look into facilitating payment of the bill and possibly practical arrangements for people to pay possible depth or to legalize illegal connections that are of good quality.

Strengthening the relation with customers is very important as you need to understand they can be of great help for example in the early detection of larger leakages, but in turn they also can benefit from a closer relationship in obtaining information on efficient water use. Yet improving customer relations may not be that straightforward as utilities may be struggling to meet even the more basic needs of customers or worse in case of growing populations and aging water systems.

To be able to provide better and more efficient services, the customers must understand the real situation, the problems of the utility, how they can help and how this may improve their water service. They can play a key role in reporting burst pipes, faulty valves, leaks, or other problems that the limited utility crews may not detect. Water loss from a leak is a function from awareness (A) of the company about the leak, location (L) for example on a high pressure water main or at the end of a low pressure distribution line, and repair time (R). Early warning about leakages may lead to quicker repairs, thus reducing water loss. Customers can also help to reduce illegal connections if they understand that these in fact are stealing water from other customers as tariffs need to be sufficient to cope with water theft.

3.2 Customer data base

Effective billing and revenue collection is essential for the financial health of a utility. One key ingredient is the customer data base which needs to be up to date. In many utilities it will be necessary to review and update this data base to ensure that it comprises all users. This requires a number of steps including:

- Checking if all customers are represented in the database and their information (such as name, address, phone number, email, number of users, and meter brand, type, size, material, date installed, serial number, GPS coordinates) is correct
- Finding out customers that are not registered in the database
- Cleaning up double or 'ghost' entries in the database
- Double checking dormant and disconnected connections
- Finding out customers that do not receive invoices
- Cleaning up

To be able to do this it may be required to undertake a house-to-house survey of all customers and compare the field data thus collected with the database. This may be a challenging task that will be easier if DMAs have been established as in that case the cleaning up can be done one DMA at the time. The survey can also serve to check user satisfaction and to identify potential problems for example with water meters (leakage, non-functioning, tampered, by-passed). Once you have a better data base you can start to use the data base in combination with the consumption levels that are registered for each customer and you can start to triangulate data. You would expect for example that larger families have a larger consumption. In those cases where the data base does not confirm this it will be useful to check as in that case the water meter may have problems. For small families you would expect a smaller consumption. When the data show that this is not the case you may want to visit and check as in that case the consumer may have a lot of internal leakage and may be very grateful if that is detected.

Updating the customer database and following up on unregistered or unbilled customers can generate an important increase in revenues for the utility. It is also important to consider as shown by Lates et al, (2017) to put the data base into a GIS system that includes both information on real estate cadaster and water supply networks including information such as pipe diameters, hydrants, valves, and bulk water meters. This will be very helpful as it allows you to visualize the problems that are occurring.

You can also combine this for example with taking aerial photographs or using google maps to see where new houses have been built and compare this information with the customer data base. It will be necessary to be very clear on what data you want to include in such system as entering data is time consuming and may be costly. So be sure that you include in the data base and in GIS what you really need in terms of information and not information that is nice to have.

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3.3 Reducing NRW and water use everyone's responsibility

It is essential to help customers to increase their awareness of NRW and how reducing water losses results in improved water supply and quality. It is equally important that customers understand that water saving is crucial to help others to get their share. Customers can be very helpful in early warning about pipe bursts and other leakages and may even give a hand in identifying illegal connections. They can also help to make water available for other customers by adopting water use efficiency.

To be able to orient your customers you have to know them and understand what is important to them. A good approach is to do a survey with questionnaires and also some interviews. The first step is to list the type of customers you have and give an indication of their number (see Table 3.1) and make a list of issues you need to know about them. This list you can then turn into a questionnaire which may include some inspection points as well such as state and type of water meter.

Part of the information such as number of users may already exist in the data base and this may help you to set up a small pilot test where only a small number of customers are visited, but making a selection that looks at for example large, medium and small families, or if that information does not exist large, medium and small consumers.

Table 3.1 Overview of customers

Type of customer	Number	Annual Volume of water m^3
Domestic user		
Industrial user		
Commercial user		
Public Taps		

NRW is also a responsibility of all staff involved in the water utility. Setting up a dedicated ‗NRW team', may not generate the desired outcome as other staff in the utility may leave NRW management to this team and forget about their own responsibility. Hence an NRW reduction strategy should encompass the consumers as well as all staff with each department's responsibilities outlined in detail.

3.4 Reporting and complaint service

It is necessary to be able to contact the utility easily in order to facilitate that the public reports visible leaks, pipe bursts or other concerns quickly. This is also important to be able to receive complaints from the consumers. Several options may be available to receive complaints which may include receiving complaint forms in different locations, registering calls, but also other options may be available including internet based reporting. Information or complaints received from customers need to be passed on as soon as possible to the relevant operational units so action can be taken quickly.

It is important to realize that the information thus received is very relevant for the management of the utility.

A more structured approach is to establish a customer survey that can serve different purposes at the time. It is needed to establish or verify the data of the consumers and the distribution network, but by adding some questions on users satisfaction it also becomes a self-evaluation tool for the organization that enables to identify the key drivers that enhance its customers satisfaction. Table 3.2 provides an example of a users' survey that collects information on users' satisfaction, but also on important NRW issues.

Table 3.2 Possible questions in an NRW user's survey

#	Requested data or question	Answer
1	House address + GPS location	
2	Name on water contract (water bill)	
3	Contract number	
4	Water meter number and type	
5	Water meter age	
6	Diameter connecting pipe to network	
7	Meter reading[1]	
8	Do you check the meter reading	
9	Number of people using the water	
10	Do you experience low water pressure	
11	Do you have a storage tank connected to network (what is volume in m^3)	
12	Hours of water service per day	
13	Days without water supply per week	
14	How satisfied are you	Very satisfied Satisfied Not satisfied,
15	Have you filed a complaint	
16	If so did you get an answer	
17	How do you pay your bill	
18	What can be improved	
19	Do you know of people selling water from their house	
20	Are you aware of any illegal connection	
	1. An option is to re-read the meter after a few weeks, to get a check on consumption	

3.5 Awareness raising

Awareness programmes should be organised with a variety of stakeholders from the public, including politicians, community leaders, and household and industrial consumers. Programmes generally focus on basic NRW concepts and how reducing NRW helps ensure that communities receive better water supply and services. It can be contemplated to include in the awareness raising approach the issue of NRW, the need for fair water tariffs and how the public can help to reduce NRW, as well as the concept of efficient water use. The latter may seem strange as a lower water consumption of individual users may reduce income. However this may be compensated by reducing meter inaccuracies, which otherwise would imply an increase in cost for the consumer unless he or she safes water. Furthermore a considerable number of water system have problems in providing sufficient water to meet the needs of all consumers, so if some consumer safe water others may get the additional water they need.

3.6 Self evaluation

This is an individual evaluation of your understanding of the information presented in this module. Answer the (multiple choice) evaluation questions and check your own answers. In case your answers had many mistakes it is suggested that you review the module again before doing the assignment.

Q1. Controlling commercial water loss has a higher impact per m^3 than reducing physical water loss

A. Yes
B. No
C. Perhaps

Q2. Indicate which of the following statement is correct. (Several statements may be correct)

A. Reducing NRW is basically a technical issue which you can manage without customer involvement.
B. The customer data base is the backbone of any strategy to reduce NRW
C. Updating the customer data base does require very little resources and is a quick process
D. Registering complaints in a data base is useful

Q3. Raising awareness about NRW is particularly important for the customers

A. This statement is correct
B. This statement is not correct

3.7 Assignment

1. Develop an overview of the type of customers of your water supply
2. Develop a survey form and implement a small pilot survey
3. Process the survey results into a small report
4. Review the interest in reducing non-revenue water among staff and management

3.8 References and further reading

- Kefyalew, L. (2018) Urban water supply system performance assessment; the case of Alem Gena town.
- Lates, I., Luca, M., Chirica, S., and Iurist, N. (2017) The use of the GIS model on the implementation of urban cadastre; PESD, VOL. 11, no. 2, 2017. De Gruyter online publishing

3.9 Answers to self-evaluation questions

1: **Answers A is correct**. The tariff is often considerably higher than the production cost as it includes cost for staff, equipment, housing etc. As a result improved water billing generates more income per m^3 than reducing water loss which relates only to the production cost per m^3. It can be argued that answer C may have some validity in case the water tariff is lower than the production cost which may be the case in highly subsidized systems. This however is an exception and therefor answer A is more appropriate.

2**: Answers B and D are correct**. Answer A is wrong as reducing NRW is a complex strategy that needs close interaction with users. Answer B is correct because an up to date customer data base is essential to improve the efficiency of the utility. Answer C is not correct because updating the data base may be quite time consuming as in many systems important problems exist with the data. It may require a house to house survey to verify the information. Subsequent updates will be less time consuming. Answer D is correct provided the data base is being used as a management tool. Complaints can provide rich information on system performance and recurring problems.

3: **Answer B is correct**. Raising awareness about NRW is not just for customers. It needs a utility wide approach where all staff as well as the customers understand the concept and promote measures that can reduce NRW.

If you failed to provide one of the correct answers, then review this module again.

Module 4 *Practical improvement measures*

This module introduces technical improvement options to overcome some of the risks that may have been identified.

At the end of this module the participant will:

- *Be able to present some options to reduce NRW which may include working closely with water users*
- *Have identified possible remedial actions in their water supply system including issues where they may need to seek expert advice*
- Can give an example of an Standard Operating Procedure (SOP) that can have impact on reducing NRW

4.1 Introduction

Many water supply systems in Ethiopia have limitations in the way they are being operated and maintained, and staff may have limited skills and resources to overcome problems that are occurring. In theory they may have support from external bodies (usually an arm of local or national Government or an NGO) to provide support for problems beyond their capacity but in practice this may be limited or may not be timely and effective. The challenge is to work to overcome these limitations as much as possible and to introduce NRW interventions that can be mastered by available staff. This will require however a strong support of management to ensure that interventions can be made and will be effective.

Reducing NRW is a complex process that requires different types of interventions. In the next section we will explore options to reduce commercial water loss which will help to increase the income of the utility and in section 4.3 we will look at successful leakage management options, which will reduce production cost and implies that more water can be made available to sell to (new) customers.

4.2 Interventions to reduce commercial water loss

Reducing commercial water losses may include three main issues: introducing strategic metering, improving the billing system and reducing illegal connections

4.2.1 Strategic water metering

Implementing a strategic water metering practice, both for bulk water meters and house hold water meters, is necessary. Many meters may show a considerable lower consumption than actually is the case and this implies a loss of income to the company. Under-registration may be considerably higher in older water meters. So the company needs a policy in relation to checking and if needed replacing water meters. Under-registration is also affected by low flow conditions which are more prominent in systems with intermittent water supply. Because of intermittent supply people install water tanks and this may worsen the situation of under-registration. Hence a good approach is to use your data base to identify and map your consumers. Several entries will be useful including the age of the water meter, the number of persons in the household and the presence of water storage tanks connected to the system. By mapping these data you can find out which users show ‘abnormal’ consumption patterns and particularly low consumption of larger families with storage tanks. You may also detect high consumption in small families which may imply that the consumer has problems with the system in the house, or may be selling water to others. This exercise will help you to prioritise interventions.

A main intervention is to check and test the water meters. A physical inspection of the meter may show situations where users have tampered or even ‘partially’ bypassed the meter. You may consider announcing that you will start a meter review campaign indicating possible fines in case meters are found that are tampered with or by-passed. This may make some customers to adapt their system before it is being checked. Hence in that case registered consumption will increase and so if your data base is well organized you can put an alert with those users and keep a close look at them in future as they may return to their old habit.

Larger problems you may be able to detect during a meter inspection particularly if you can manage to tap a volume of water say few hundred or even 1000 litres of water and see what the meter indicates. This may be easy if users have water tanks for water storage and then you can even check the meter under different flow conditions. In other cases it may be an option to ask one or more water vendors to help collect this water as they will be able to sell it. You can also replace the meter temporarily and take it to a test bank, or by putting a temporary additional calibrated meter after the existing one. Another option is to replace meters and check meter accuracy in the laboratory. The question if you need to make a deal with the customer depends on how meters are financed. If they are an integral part of the tariff meter replacement is not an issue of the customers, but if they pay separately for the meter, you may need to make an arrangement in that they need to pay in full for the new meter unless the meter test shows that it was still working properly. This type of arrangement you may want to apply particularly for young meters (less than 4 years).

4.2.2 Reducing billing errors

Reducing billing errors requires a good review, updating and possibly modernizing of your consumer data base. Ideally your data base will allow for the cross checking of consumers and consumption mentioned at the start of this section, but a good clean-up can already be very helpful. You may however need to do a customers’ survey to be able to verify your data base and this will take time. So in that case you may want to prioritise specific areas in your distribution system where you expect more problems. This is where you can benefit from dividing your network in different DMA’s as this will allow you to update your data base gradually one DMA at the time.

Uploading your data into a GIS is tempting as it will help you to visualize the problems. It should be noted however that this requires staff familiar with the application that should be quite stable in the organization. Having considerable staff turnover may make it difficult to apply such a system.

4.2.3 Reducing illegal connections

Reducing the number of illegal connections is not an easy challenge and you may need to be very strategic. At the heart of the solution is to make customers aware of the fact that people with illegal connections steel from their fellow customers and not from the company as water tariffs need to compensate the revenue loss from illegal connections. This may help to put social pressure on those having illegal connections.

The reality is that illegal connections may have been made by staff from the water company and this may imply that they are of good quality. Furthermore disconnecting an illegal connection implies that the people have an unsolved water problem which they will have to solve possibly by making another illegal connection. So in that case you may consider a campaign aiming at legalizing illegal connections which is a good thing to do as it increases your income without large investments. Also in this case peer pressure will help particularly if a grace period is given to legalize the connection at ‘relatively low’ cost, with the indication that thereafter control will be increased and cost will be considerably higher, possibly including ‘social cost’ of being exposed as a person with an illegal connection. A good data base again will be helpful in combination with area maps of housing as this will allow you to identify houses that are not in your data base and thus may have an illegal connection.

4.3 Interventions to reduce physical losses

The strategy to reduce physical losses requires 4 main interventions: pressure management, speedy and quality repairs, active leakage control, and pipeline and asset management (Figure 4.1).

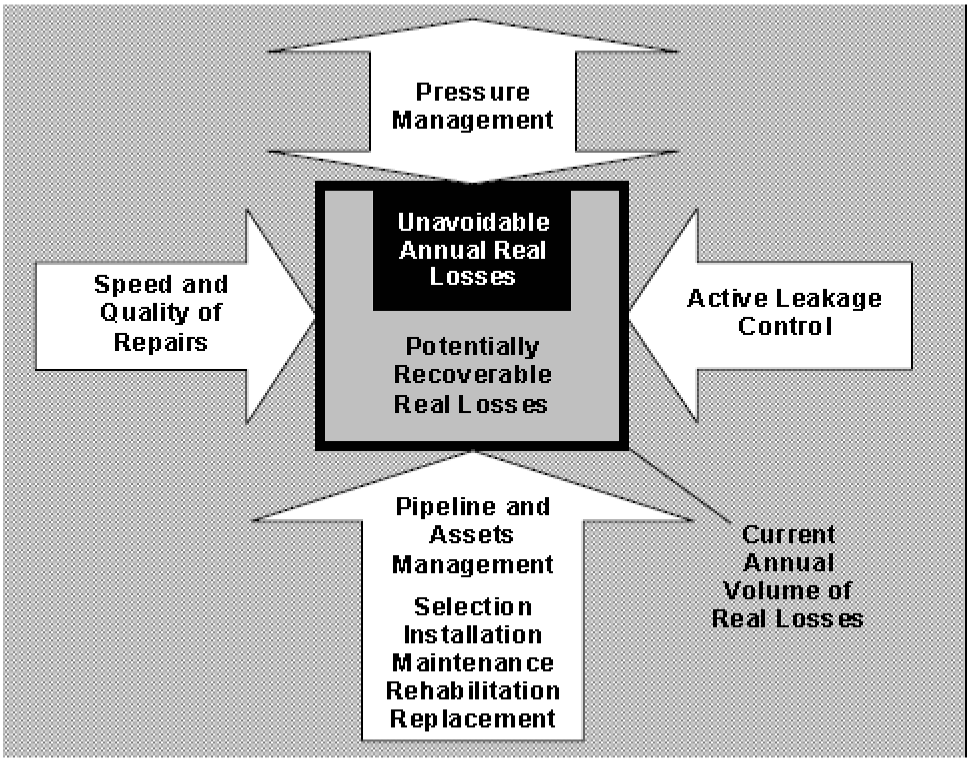

Figure 4.1 The four components of a successful leakage management policy (Liemberger and Farley, 2004)

4.3.1 Pressure management

Pressure management is considered as a cost effective leakage management strategy involving both reduction of water loss and in consumption of energy. There is a close relationship between applied pressure and the leakage flow rate. The approximate relationship is about 1:1, meaning a 10% increase of pressure, will cause a 10% increase of leakage. This relation may be different depending on the pipe material. In corroded iron pipes holes are often round whereas in PVC and asbestos pipes cracks may be more longitudinal which may give larger leakages. Reduction of the pressure where it is higher than needed is contributing a lot to reducing NRW and in this context it is good to take into account that water pressure during the day in general will be lower due to head loss from friction whereas in the night when less water flows through the pipes friction will be lower and pressure higher unless you take special measures at night. Pressure can be controlled by reducing the exit pressure at pumping stations and/or by installing Pressure Reducing Valves. Different examples exist where investments related to the introduction of this type of measures where easily reclaimed from reduction in water loss (Baghdali et al. 2013).

When looking at a gravity system with a water storage tank the normal pressure distribution without interventions would look as indicated in Figure 4.2. What would be needed in this case would be to start with the reduction of the pressure in the lower part of the system, which may be relatively easy by introducing a pressure break chamber or a pressure reducing valve in the last part of the system. Reducing the pressure indicated as higher pressure in Figure 4.2 may be more difficult as pressure is needed to bring the water to the highest point in the network which happens to be in the middle section. So the question in this case is whether the part with the higher pressure can be isolated without affecting the pressure for the water to reach the highest point.

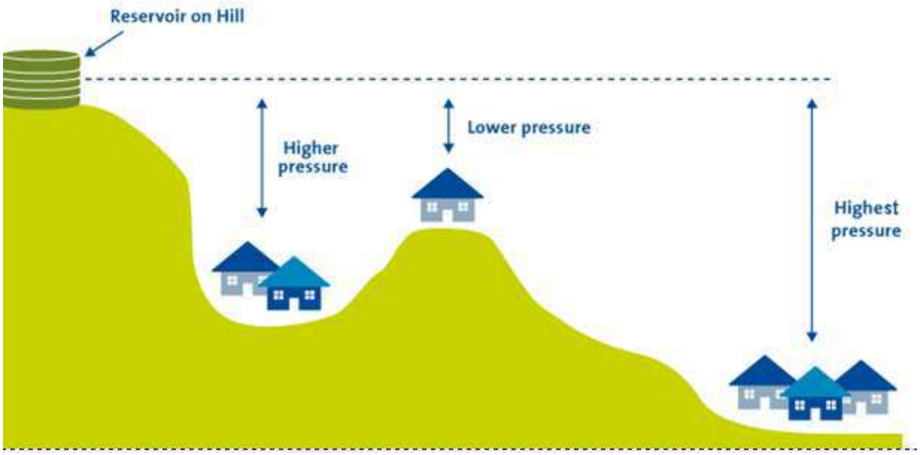

Figure 4.2 Water pressure distribution in a gravity system (Baghdali et al, 2013)

In pumped systems it may be an option to reduce the inflow in the system by having for example different sizes of pumps, including one pump or a set of pumps that can provide the flow that is required at night

4.3.2 Active leakage control

Active leakage control by staff from the utility in close consultation with customers forms an important part of physical losses' management. Special staff can visit the area where the system is located and go try to identify leakages themselves or with help of residents. The visual inspection needs to include looking at leaking valves, wet spots in the ground or differences in vegetation. The staff can carry a toolkit to repair leakages or report leaks to the office. Customers can also be encouraged to report leaks possibly through a free phone service that people can call to report leaks or other problems including illegal connections. It is essential that there is a good response on notifications on leakages, whether they come from utility staff or customers, so that people not become demotivated to report.

The physical inspection should be extended to checking reservoirs for overflow or leakage. Especially at night, when consumer demand drops to a minimum, reservoirs may overflow. The latter can be prevented by valves that close when the reservoir fills up.

As indicated, quick repair of leaks is needed. This includes repairing cracks in storage tanks that often may be feasibly done by local masons if tanks are made in concrete but also other types of tanks need to be repaired quickly. Sometimes a quick way to repair is to put chicken mesh wire with a cement coating of some three centimetres on the inside wall and floor of a tank. If cracks in tanks are large you will need to check for structural problems which may be the result of design mistakes or to inadequate supervision of construction. The latter may allow contractors to use poor quality materials or to put, for example, less cement and iron rods in the concrete. Leakages may also arise from poor preventive maintenance.

Another action is to check water loss in sections of the system. This can be done as indicated earlier by establishing different DMAs, but a first approach depending on the system may be to just check the overall water loss by comparing production and consumption (water balance) that is if you have bulk water meters. An alternative in systems with overhead tanks may be to fill the tank with all valves closed and then try to isolate the first part of the system also asking users to close their taps and then check the drop of the water level in tanks. Doing this with the outlet valves closed allows you to check the water tightness of the tank. Then opening the valve of the storage tank the drop in water level relates to water loss in the part of the system that you could isolate, but also may include some consumption of people that did not cooperate.

A similar approach is to undertake Minimum Night Flow (MNF) measurements which is measured when most consumers are asleep (i.e. between 2 and 4 a.m.) and consumption has dropped to a minimum. If water consumption in the area during that time is higher than the expected ‘background flow’ (i.e. usage by those few people awake and storage tanks that may be filling up), this indicates leakage. Monitoring of these consumption levels on a daily or weekly basis can also serve as a leakage warning tool.

This information can be used to identify the level of leakage in section of the distribution system, but then leaks need to be localized. This can then be done by step-testing: isolating portions of the network with (portable) water meters, and checking them for leaks or by using leak noise correlators and/or ground microphones (the latter at night when there is not too much background noise) as even smaller leaks produce a sound. If you do not have access to listening devices you may use an alternative by closing all outlet taps and ‘to listen to flowing water’ by putting a wooden stick through the ground to touch the pipes. This device you can call a ‘local listening device’ because when you put your ear to the stick you will hear water flow if there is considerable leakage. You follow the pipe upstream and repeat the listening and this may help you to detect leakages.

Another key point is to measure water pressure at strategic locations. Low pressure may be an indication of a problem that may be caused by leakage but also by many people with open taps at the same time, distribution systems with too small pipes or inadequate pressure distribution for lack of control valves. Very high pressure at taps is also a problem as it will increase leakage and the number of locations where leaks may occur. It also leads to customers using more water than needed. This problem is quite common in gravity piped systems and may require the installation of pressure break chambers or pipe-reducers. If you find important variations in water pressures a detailed check is needed to explore the problem. This preferably needs to include running a computer model of the network.

Active leakage management includes the registering of leakages (date, time and location of leakage, repair team) to help to analyse the quality of the network and repairs. This will provide the overview that can indicate pipes with problems but also team that may provide insufficient quality in repairs (repeated leakage).

Household level interventions may be an issue to explore as well. The aim would be to improve water use efficiency by looking carefully at the habits of people. In a way it seems like a contradiction for a utility as water use efficiency implies that consumption is reduced which may have an impact on the income of the company. On the other hand it may allow you to sell water to other (new) customers and possible increases in tariffs may be (partly) compensated for the consumer by reduced water consumption.

4.3.3 Speed and quality of repairs

Once a leak has been identified or reported it should be repaired as quickly as possible in order to reduce water loss, but also to show that action is taken when leaks are being reported or identified. This will motivate both the consumers and staff to actively report leakages.

The quality of repair is of great importance as substandard repairs may quickly deteriorate and leakage may continue. Some examples of poor repairs include:

- Using bicycle tire to fix leakages
- Using poor quality PVC connections and/or working without appropriate fittings
- Gluing under wet conditions (not closing valves before doing repair work)

The work of plumbers (repair teams) should at times be verified by qualified technical staff and if needed refreshment training needs to be provided. Another issue is that proper standard operating procedures should be available and applied (section 4.4).

4.3.4 Asset management

Asset management needs to be organized. Although preventive maintenance including replacement of parts of the network will cost money (materials, staff contractors), it is in the end less expensive than corrective maintenance when problems occur. Also it reduces inconvenience to the user. For example replacing an old pipe line will require one interruption of the supply whereas repairing it several times implies repetitive interruptions. A good preventive maintenance strategy will save a utility money and work, and will improve customer satisfaction

The assets include the water system and all the equipment, buildings, land, people, and other components needed to deliver safe and clean water. The most costly assets of a water company may be the mains and distribution network. Fortunately these assets normally last pretty long as replacing them can be very expensive. So the challenge is to keep them in good shape, which implies that you need to know where the assets are and particularly the part that is below ground. In this respect it is important to ensure that good quality materials are being purchased and installed. In terms of purchases you may need to carefully review your procurement policy to ensure that quality materials are being bought. Installation thereafter needs clear supervision as it may be tempting to replace good quality (more expensive) pipes, fittings and valves with low quality (cheaper) material. This implies that good supervision is needed to ensure that contractor do not use this kind of practice. Here it may be a good option to involve the community as they will be in the area where construction is going on and can easily spot when materials reach the works. Another point where clear instructions (standard operating procedures) and monitoring can help is to safeguard that installations are made properly. For example installing pipes at too shallow depth, in unprepared trenches and if back-filling is poorly done then pipes may be easily damaged particularly at road crossings.

You can think of asset management as “A process for maintaining a desired level of customer service at the best appropriate cost (Brubaker, 2015).

The asset management strategy needs to include a good maintenance plan for technical staff to check the status and clean assets (such as valves, meters, pumps, and hydrants on a regular basis. It also needs funding so a good approach is to make an infrastructure gap analysis establish the potential magnitude of increase in investment needed to: renew the aging infrastructure and to address growing population or growing consumption.

To develop the asset management strategy you need to know:

- The current state of the assets and their expected future performance
- Which assets are critical for achieving the long-term service levels
- What are the best minimum lifecycle cost improvement programs and operation and maintenance strategies

And this knowledge you have to connect to the proposed long term service levels and a sustainable financing strategy.

4.4 Standard operating procedures

A Standard Operating Procedure (SOP) is a set of written instructions that document a routine or repetitive activity that is to be implemented by an organization (EPA, 2007). SOPs are important to ensure the quality of the day to day activities of the organization as it provides staff with the information to perform a job properly, and facilitates consistency in the quality and integrity of a product or end-result. Organizations may also use other terms for this type of procedures such as protocols and instructions, and they may also use worksheets.

SOPs document the way activities are to be performed to facilitate that they conform to technical and quality system requirements and to ensure proper data management. They may be very important to reduce the risk involved in different hazards. They may detail for example how to go about water disinfection including steps to be taken when some of the equipment fails. SOPs are intended to be specific to the water company whose procedures are described and aim to assist the company to maintain their quality control, ensure compliance with prevailing regulations and ensure provision of good quality water.

SOPs need to be written properly and need to be followed. This implies that management needs to ensure that they are readily available at the place of work and they need to review and re-enforce their implementation. It is important to include in the SOP how its effectiveness will be monitored as an input to the regular monitoring system that is needed for a water company.

The problem may be that these procedures may have been developed by consultants perhaps even without staff consultation and may in fact be just text on paper. It may well be that whereas procedures exist responsibilities may not have been clearly allocated. Hence it is essential to review the actual implementation of these SOP and to explore where they are effective and were they can be made more efficient to ensure that the utility can respond quicker to incidences.

4.4.1 Developing standard operating procedures

It is very important that SOPs are simple, short and unambiguous. In the development of SOPs it is necessary to take into account that they should provide detailed work instructions and therewith can also be used in staff training. SOPs may relate to routine operations such as water treatment, disinfection, disinfection of systems after repair etc. but may also include a number of emergency related procedures for example in case of a flooding event.

SOPs need to be written by individuals or a team knowledgeable with the activity and the organization's internal structure and who may actually perform the work or use the process (see for the SOP format Box 4.1). The procedure should have sufficient detail to allow it to be implemented by someone with limited experience but with a basic understanding. The minimum experience for performing an activity should be mentioned in the procedure.

The draft SOP needs to be tested by involving individuals other than the original writer. The most convenient approach is to give the draft SOP to staff that have to implement the procedure asking them to put it in practice. The finalized SOP should be approved by the immediate supervisor of the procedure and by management. To remain current SOPs need to be reviewed perhaps every 1 to 2 years and also whenever procedures are changed. In the latter case SOPs should be updated (possibly only the section that deals with the part of the process that is adjusted) and reapproved. An SOP should be withdrawn if it describes a process that is no longer followed.

Box 4.1 Annotated outline of an SOP

- Title and date of issue
- Registration number and number of pages (so it is easy to check if document is complete)
- Introduction (purpose of the work or process, appropriate regulatory information or standards, scope to indicate what is covered and links to other SOPs)
- Responsibility (who is / are responsible for implementation)
- Procedure (The steps and materials involved in the procedure including as needed a possible recovery process after the intervention)
- Monitoring (how to know that procedure was effective – including indicator to monitor)
- Reporting / registration of the event (official report to the appropriate person / unit)

4.4.2 Monitoring and reporting

One common problem is that SOP and other safety measures are developed, but not necessarily implemented properly. This implies that it is important to have some key indicators that can be monitored in relation to the SOPs. This may concern indicators that measure the outcome of the SOP or the safety measure, for example the chlorine content of the clean water storage is always above the minimum acceptable level. It may also relate to reports being prepared on SOP implementation in combination with occasional spot-checks. It needs to be clear to whom reports need to be submitted and staff should also be aware of the possibility that their activity may be evaluated which may include repeating the procedure under supervision to ensure that they follow all the steps.

Effective monitoring needs to be simple and need to lead to effective and timely action. Crucial issues to be shown in the monitoring procedure include:

- What will be monitored and how this will be done (including frequency and location)
- Who will monitor
- Who will analyse the result and propose that action is taken
- The person that will take action

For each of the relevant risks routine monitoring needs to be instated preferably based on simple observations and tests, such as volume of spare parts in store, pressure, and absence of cracks. For some control measures, ‘critical limits’ may need to be

defined and for these measures it will need to be clear, as much as possible, what action needs to be taken if results are not within these critical limits.
Monitoring needs to be reported properly to allow for internal and external audits, but reports need to be very simple comprising a minimum number of data to avoid bureaucracy and additional workload. So better to use simple forms where boxes can be ticked. We can distinguish between operational monitoring, the checking of key indicators related to system performance, such as residual chlorine, turbidity, pH, integrity of screens, stock of spares etc. and monitoring of the control measures.

Monitoring of control measures in first instance implies that they are reported upon by the actor that is to take the action. For example for the control measure: ensuring proper stock of valves, fittings, glue etc. it needs to be checked from the operational data whether the levels were outside the prescribed limits. If that is the case the responsible person as indicated in the SOP has to take action and report. In addition management needs to check at times if prescribed limits were passed and whether appropriate action was taken.

4.5 Self evaluation

This is an individual evaluation of your understanding of the information presented in this module. Answer the (multiple choice) evaluation questions and check your own answers. In case your answers had many mistakes it is suggested that you review the module again before doing the assignment.

Q1. An experienced water professional can assess water leakage in a water supply system without asking information from the water users.

A: Yes
B: No

Q2. Water leakages may occur and can be detected by (indicate which answer is correct (multiple answers possible):

A: Observing leaking taps;
B: Making a water balance
C: Visual inspection of the area where the network is installed;
D: Making a detailed inspection of the network including the use of a 'local listening device'

Q3. Indicate which of the following statement is correct. (Several statements may be correct)

A: Strategic water metering practice is a very component to reduce commercial water loss as meters may show considerable errors;
B: To reduce the number of illegal connections it is important to consider legalizing them instead of disconnecting them
C: Water storage tanks at household level have no influence on commercial water loss

Q4. Indicate which of the following statement is correct. (Several statements may be correct)

A: Pressure management is not very important in reducing water loss
B: SOPs are control measures to ensure that water loss is reduced
C: An SOP needs a registration number, a date, and needs to be updated at least every two years

4.6 Assignment

Make a brief description of

1. The customers data base and how this is being updated
2. Measures that have been taken to control physical water loss
3. Review the SOP on repairing leaking water pipes; if not existing make a proposal for such an SOP (See box 4.1)

4.7 References and further reading

- Baghdali, L., Yinon, Y., Nasereddin, M., and Nadifi, K. (2013). Documentation of best practices in non-revenue water in selected mediterranean countries – Algeria, Israel, Jordan & Morocco.
- Brubaker, S. (2015) Asset Management 101 Basics for Small Water and Wastewater Systems. EPA
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- Liemberger, R., and Farley, M. (2004). Developing a Non-Revenue Water Reduction Strategy; Part 1: Investigating and Assessing Water Losses
- Mazoud, H. (2013) SOP (Standard Operating Procedures) for Water Treatment Facilities http://sop-ghapwasco.blogspot.com/
- Town of Fort Francis (2004) Standard Operating Procedure for the disinfection of water mains

4.8 Answers to self-evaluation questions

Q1. Answer B is correct. Communication with the consumers using the piped system living in the area is an important part of finding leakages. They know about activities that take place in the area, which may be related to specific seasons. They know if they receive water intermittently or at low pressure, they can see and report the leaks etc.

Q2. All answers need to be marked. All four options can provide information on water loss, but leaking taps may in fact be water that is lost by consumers which may be included in their water bill, unless the flow is too low for the meter to mark it. Just as an experience put a bucket under a dripping tap and come back an hour later. The water balance will give insight in the level of the water loss, the visual inspection may show some problem areas, and the listening device will help you to find mayor leakages. If you did not mark all answers then you also need to review module 3 again.

Q3. Answer A and B. Strategic water metering is indeed essential as it may be the most important component of commercial water loss as meters may show considerable errors. Answer B is also correct as illegal connections represent a water need and if disconnected the users will need to find water and so reconnection may be the easiest option. So instead of disconnecting it is better to explore options for legalization. Answer C is not correct. Water storage tanks at household level may have an important effect on under registration in water meters and so may contribute considerably tp commercial water loss

Q4. Answers B is correct. Answer A is not correct because pressure management often is the very first step in reducing physical water loss. Answer B is wrong as some SOPs may facilitate this but in general SOPs are a description of different type of routine as well as emergency activities, including for example pipe repairs, registration of a new connection but also controlling the chlorination process. Answer C is correct as SOPs need to be properly registered and carefully managed and updated.

If you failed to provide several of the correct answers, then review this module again.

Module 5 *Towards water and financial efficiency*

This module completes the steps involved in developing and implementing a WFEP which includes completing of the plan, monitoring measures and a management and support programme.

At the end of this module the participant will have:

- *Developed an improvement plan to overcome the priority hazards and risks that were identified*
- *Identified possible support programs that need to be implemented*
- *Completed de WFEP document*

5.1 Introduction

Planning and management are perhaps the most neglected aspects of water supply systems in many parts of the world. It is very common that breakdown management is applied combined with the collection of a fee to meet operational cost. As a result many water supply systems show substandard performance. The consequences are severe with non-revenue water levels of 40% in Ethiopia (OWNP, 2018) or even higher. This implies that water utilities do not generate enough revenues to make the necessary investments to sustain their systems. This in turn, implies that they will further deteriorate, as shown in the vicious circle indicated in module 3.

Developing a NRW Reduction Strategy may be a turning point in the life of the utility. The essence to developing such a strategy is to start with gaining a better understanding of the situation and the factors which influence the different NRW components. An NRW strategy needs to be tailored to the specific local conditions clearly setting practical priorities that can be achieved. This implies a diagnostic approach, followed by the practical implementation of practical and achievable solutions. The two pillars are 1) reducing commercial/ apparent losses which will help to significantly increase revenue and 2) reducing physical/ real loss reduction which reduces production cost or makes more water available to sell and allows utilities to postpone capital investments to increase their production capacity.

The key issue to problem solving is to get a good understanding of the situation and remedy problems or predict and prevent them before they occur. An essential activity is to discuss the situation with operators and knowledgeable persons in the community. You can learn a lot from these discussions and you may find for example that monitoring is not part of the routine and that breakdown maintenance is common, with the big disadvantage that this cannot be planned and so repair may take more time and may come at an inconvenient moment. You may also find out about the presence of illegal connections and the random connection of new customers without network calculations.

It is important to take an action oriented approach from the beginning. The review of the systems will show a number of problems which sometimes may be very serious. It does not seem fair to just leave the community and write a report instead of already exploring possible 'emergency' improvements that can be implemented. The key issue to problem solving is to get a good understanding of the situation and predict and prevent problems before they occur. An essential activity is to discuss operation and maintenance routines with the operator. You can learn a lot from these discussions and you may find for example that monitoring is not part of the routine and that breakdown maintenance is common, with the big disadvantage that this cannot be planned and so repair may take more time and may come at an inconvenient moment.

It is important to take an action oriented approach from the beginning. The review of the systems will show a number of problems which sometimes may be very serious. It does not seem fair to just leave the community and write a report instead of already exploring possible ‘emergency’ improvements that can be implemented. In systems with a lot of pressure problems it may be considered for example to temporary set up additional safe water selling points (perhaps even supplied by tankers) so customers at least have access to some good quality water.

A crucial point is to be realistic and to understand that NRW management comes at a cost that needs to be compared with the gains that can be made by losing less water. If you invest little in NRW management you will have more losses than if you invest a lot. Hence you need to find the combination where sum of the total cost of water lost plus cost of NRW management is lowest (Figure 5.1)

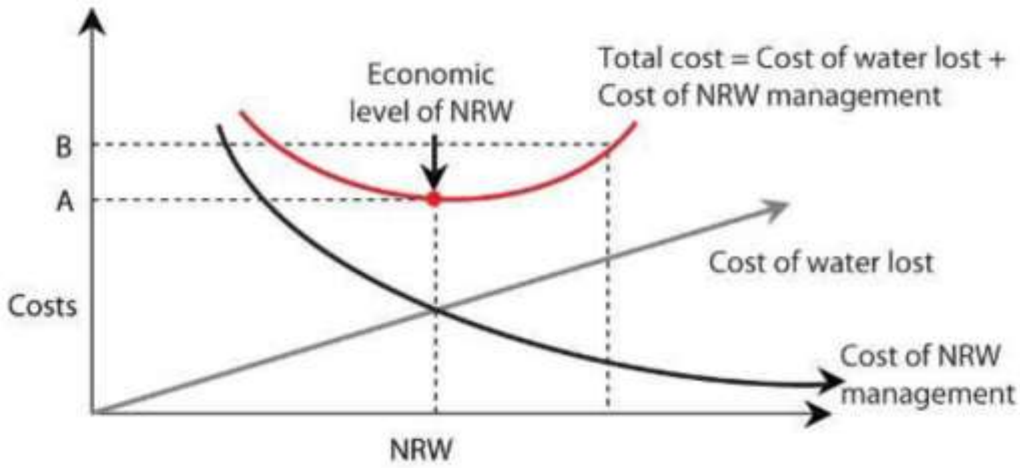

Figure 5.1 Identifying the economic level of NRW (DAI, 2010)

The water and financial efficiency improvement plan needs to be prepared with clear activities, responsible actors, a time frame and (financial) resources. This may include simple action in relation to improving and organizing procedures to capital investment to improve the infrastructure. The plan may include short-, medium- as well as long-term activities which need to be planned with management and may require external support which in turn may have an impact on timing. When resources are scarce careful prioritization should be made taking into account the cost involved and benefits that can be achieved. Implementation of the plan needs to be monitored, including the timely introduction of new or improved SOPs. Some improvements may be rather easy to implement and at no or very low cost. Even if these are not a priority it may be considered to implement these pretty quickly in order to show quick results.

5.2 Development of the improvement plan

The development of a Water and Financial Efficiency improvement plan involves a number of steps:

- ***Establishing of a small NRW team*** that directly reports to management. The team needs a clear TOR that includes assessing and describing the situation, proposing objectives and concrete actions for NRW reduction with clear cost estimates, and proposing an approach to enhance the interest of staff and customers in NRW

- ***Making a description of the utility and the network*** which needs to include the basic data presented in module 1. You may also want to include a checklist on key issues that may be in place in the utility (Table 5.1) as presented by InWEnt (2010)

  Having a detailed drawing of the water mains and distribution system is crucial as it forms the bases for planning interventions. If such map does not exist is should be developed initially in the form of sketches, but these should be put into computer based maps (GIS) where gradually much more details can be added. Important data to be collected early in the process is the size and age of the different parts of the system. Making the map may include fieldwork to inspect the network, which than can be also used to look for signs of leakage.

Table 5.1. Checklist related to NRW activities in a water utility

	Activity	Situation
1	Water balance in place	
2	Bulk water metering and management	
3	Pressure metering and management	
4	Availability of maps (GIS)	
5	Household water metering and management	
6	Leak repair records (mains, distribution system)	
7	Active leakage control	
8	District Meter Areas	
9	Customer data base	
10	Customer metering (checking and replacement)	
11	Disconnecting illegal connections	
	Based on InWEnt and KWI, (2010)	

- ***Making a situation analysis (water audit)*** including the development of a water balance and an overview of NRW reduction activities that have been implemented.

- ***Exploring commercial water loss*** to get insight in the volume that is lost looking at the three main components: water meter under registration, billing errors and water theft. This activity needs to include a description of the customer data base.

- ***Exploring physical water loss*** to get insight in the volume that is lost looking at: reported leaks and breaks (which should all have been repaired), unreported leaks and breaks (some of which you may identify when inspecting the lines – small very green area suggesting abundance of water, clean water flowing in drains), and background leakage.

- ***Providing and overview of implemented NRW activities*** as already different actions may have been with different rates of success

- ***Prioritising problems*** particularly based on the loss they represent to the utility including anticipated losses due to for example inadequate repairs (absence SOP).

- ***Prioritise and describe interventions*** which should look at costs and benefits, improved service, experience with earlier interventions, encouraging consumers and staff to get involved (e.g. quick repair after leakages are reported). For each of the specific improvement actions that is developed it needs to be clear what benefit it may achieve, who will be the person that will be responsible to implement the action, what budget is available and when the action needs to be completed (Table 5.2). Preferably the actions are listed in order of importance. Actions may be very diverse and may include technical interventions, control measures, setting up DMAs, training, as well as the development or improvement of SOPs. A difficulty may be the availability of (financial) resources, but with a good plan in hand it may be easier to convince external actors that resources are needed. It will also be important to clarify the gains that may be obtained by each action in terms of reducing water loss and therewith possibly reducing pumping and chemical cost which represents cost reductions. In this case it may be that management can reorient some resources for that specific action. Other actions may not require financial support such as SOPs but may need staff time to ensure that they can be developed.

Table 5.2 Elements that may be included in an improvement plan

	Specific improvement action	**Goal**	**Responsible party**	**Budget (Birr)**	**Due date**	**Status** *(not yet started, actions undertaken to date, etc.)*
1	Improving customers data base	Creating the basis for improved billing (increasing revenue)	Mr. Y	……….	………….	……………….
2	Water metering pilot	Obtaining a clear picture of possible meter under registration	Mr. X	……….	………….	……………….
3	Development of an SOP on pipe repair	Avoid future leakages	Mrs. Y	……….	………….	……………….
4	Initiating pressure reduction and active leakage control project	Reducing physical water loss				

5.3 Verification monitoring

With the improvement plan being implemented the water supply system should score better in terms of verification monitoring that assesses whether the system as a whole meets its objectives (Figure 5.2).

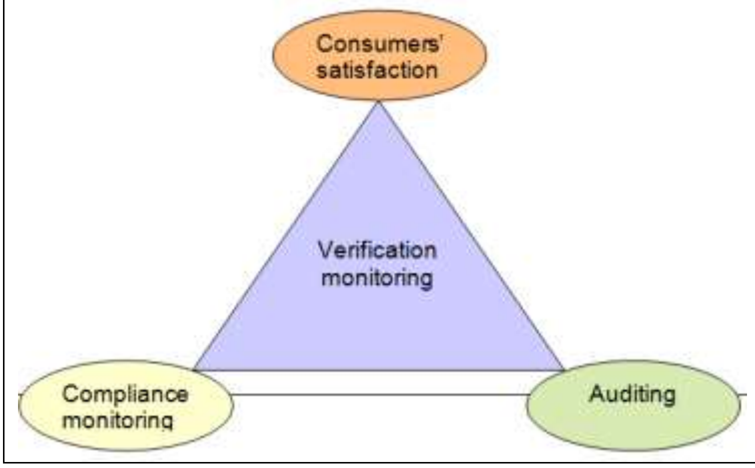

Figure 5.2 Components of verification monitoring based on WHO (2009)

Verification monitoring includes; compliance monitoring being the checking that the system provides water according to standards, and that the targets for NRW reduction are being met. Internal and external auditing which includes checking the information that is provided, the compliance of operational activities and the effectivity of the plan. The third element concerns consumer's satisfaction which is very important as it will determine the willingness of the users to support the water company and to pay for the service that is being provided.

5.4 Management and communication

At this stage we can combine the different elements that have been developed and fit these in an overview of the management procedures that apply to the system. It is essential to understand the management that is in place and the way the roles and are being implemented. What are the rules of engagement that are in place? A few key aspects can be distinguished in management

- Who are the actors and what is their role
- Who operates the system
- Who monitors and controls the system (technically and financially)
- Who carries out repairs

This needs to be briefly described in the plan and may include the roles and responsibilities of the actors involved in the different system components. In addition the SOPs can be listed per activity, under normal operating procedures, including events that may be more complicated but can be managed without interrupting the water supply. Part of the management procedures concern communication with the users and possibly other actors.

A different issue that needs to be briefly addressed is how management will function under ***emergency conditions.*** This may include for example a massive pipe burst that may make it impossible to supply water to all consumers. It is good to reflect what can be done in such case so you will be prepared once this happens. In this case communication will be even more important as consumers will need to know what to do with the emergency situation at hand.

Another important issue is that a one-off NRW exercise is not useful as actions will become dated. So at least an annual review is needed to ensure that progress is being made over time and plans can be adjusted to changing conditions.

5.5 Develop supporting programs

To ensure a good implementation of the plan it is essential to establish what supporting programmes are needed for implementing the approach. This may entail capacity building, but also issues such as research to optimize system capacity, and calibration of equipment. The process needs to include a review, and as necessary, revision of existing supporting programs and development of additional ones.

Gaps in staff knowledge or skills may impede the timely implementation of the Water and Financial Efficiency Plan and this may be aggravated by staff turnover. This makes it even more important to clearly document operational procedures so new staff can quickly grasp the approach they have to follow. But equally important is to have training material available such as this manual that staff can consult and review including doing the exercises and discuss results with colleague that have already done the course. Supporting programmes are activities that support the development of people's skills and knowledge, and commitment to the NRW approach,

.
An issue that is often not being considered is how to deal with conflict. This is unfortunate because conflicts are normal and in fact may be having a great potential for growth if the negative energy can be transferred into joint action (Visscher, 2008). So the challenge is not to avoid conflict but to manage it. Conflict avoidance and neglect can worsen the situation. Let's take an illegal water connection as an example. This is a conflict as people steel water from the company (but in fact from their neighbours who indirectly pay for the theft through the tariff and possibly through a poorer service). The problem is not solved by just cutting (uprooting) the illegal connection as the consumer will need to get water from somewhere. So perhaps the approach to take in this case is to negotiate with the owner of the illegal connection and move towards legalization as this may serve the interest at both sides, more income for the company, sustained water supply for the consumer.

Many conflicts can be dealt with in a positive way through negotiation and joint problem solving. A few key aspects include:

- All parties need to understand the conflict and gain insight in the (subjective) views of the other parties
- Dialogue as the basis for problem solving in which actors listen to each other
- Separating the people (emotions) from the problem, but dealing with both. This aspect may require the involvement of a mediator to facilitate the process. Actors need to learn how to jointly face the problem instead of each other
- Focus on interests instead of positions to open dialogue
- Can problems be turned into opportunities by the actors allowing benefits to be enlarged and better shared?
- Develop multiple solutions to choose from and insisting on using objective criteria, independent of the will of either side, to choose the solution.

If conflicts were identified in the assessment then it is important to include actions that deal with these conflicts and that may include seeking external support.

5.6 Self evaluation

This is an individual evaluation of your understanding of the information presented in this module. Answer the (multiple choice) evaluation questions and check your own answers. In case your answers had many mistakes it is suggested that you review the module again before doing the assignment.

Q1. An adequate management model:
1. Requires a detailed analysis of the existing system and existing practices
2. Ensures that manuals with all technical specifications are available
3. Includes appropriate monitoring formats for the tasks to be performed

A: Answers 1 and 3 are correct
B: Answer 2 is correct
C: All three answers are correct

Q2. A written report is the most important aspect of a monitoring system.
A: Yes
B: No

Q3. The most important reason to establish a good monitoring format for a water supply system is:

A: The need to have reliable data and a good performance record
B: The need to be able to review the performance of the system over time
C: The need to be able to manage the system

Q4. Verification monitoring; indicate which of the following statement is correct. (Several statements may be correct)

A: Verification monitoring includes compliance monitoring, auditing and assessing consumers' satisfaction
B: The most important issue of verification monitoring is compliance monitoring
C: Compliance monitoring is the part of verification monitoring that includes monitoring of NRW

5.7 Assignment

Establish with your team:

- A Water and Financial Efficiency improvement plan for your water utility including suggestions for distribution of responsibilities, resources involved and timing
- A monitoring plan for NRW reduction

5.8 References and further reading

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And how to reach solutions. IRC International Water and Sanitation Centre, The Hague, The Netherlands. http://www.irc.nl/page/46285

5.9 Answers to self-evaluation questions

Q1. Answer A. An adequate management model requires that clear insight is obtained in existing systems and that a good overview is provided of all the tasks and responsibilities, but it is not necessary that all detailed specification of the different technologies are available locally as these will be only relevant for the technicians that will carry out repairs that go beyond the capacity of the company.

Q2. Answer B. In many locations reporting is strongly emphasized, but the main reason of a monitoring system is to generate action when needed. Recording of some data is useful, but it should not be made into a burden as many monitoring aspects do not need to be recorded. So the essence is to establish a monitoring system that clear shows which indicators need to be checked and depending on the results what action need to be taken.

Q3. Answer C. A good monitoring format that clearly describes the indicators to be monitored and the actions required if indicators do not fall into the prescribed levels is crucial to be able to adequately monitor the system. It may also be used for reporting and assessing the performance, but these are not the most important reason. A good monitoring format will help the operator to do his or her job and seek timely support when needed.

Q4. Answers A and C are correct; Based on answer B the system can perform very well, but if consumers are not satisfied the end result will not be satisfactory.

If you failed to provide several of the correct answers, then review this module again.