Utility Management Series for Small Towns

Water Audit Manual

Volume 4

UN-HABITAT
FOR A BETTER URBAN FUTURE

Water Audit Manual

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Disclaimer

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FOREWORD

Municipal authorities and urban service providers are being increasingly challenged to deliver sustainable services in a rapidly urbanizing world with complex problems resulting from the interplay of climate change, resource constraints and the adverse effects of a sluggish world economy. The need to improve the coverage and efficiency of urban basic services, such as water supply, sanitation, energy, drainage and transportation, has never been greater.

It is now well recognized that the essential pre-condition for improvements in the delivery of urban services, is to establish effective and well run institutions within the framework of a policy environment that promotes investment, a commercial approach to service delivery, managerial autonomy and accountability to key stakeholders, including customers and the Government.

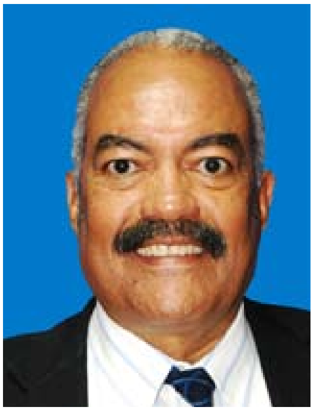
With its mandate to promote sustainable urbanization, UN-Habitat has been in the forefront of international efforts to build the capacity of urban water utilities to face the challenges of expanding access to water and sanitation while improving the efficiency of service delivery. Through its regional and national programmes and the Global Water Operators Partnership Alliance, UN-Habitat provides capacity building for urban water utilities with a focus on business planning, water demand management, improving billing and revenue efficiency, energy audits and planning for climate change adaptation.

The Lake Victoria Region Water and Sanitation Initiative is one of the regional programmes in Africa that has demonstrated the effectiveness of integrating capacity building for urban water utilities with modest investments to improve infrastructure. The first phase of the Initiative has now been completed with impressive improvements in extending access to water and sanitation while enhancing the managerial capacity and operational efficiency of the utilities in the ten pilot towns in Kenya, Uganda and Tanzania. The utilities which have benefited from the capacity building programme have experienced significant improvements in performance in key areas such as revenue enhancement, an expanded customer base and reductions in non-revenue water.

The six training manuals which are included in this Compendium of Training Materials are based on the practical experience of delivering the capacity building programme for urban water utilities in the Lake Victoria Towns. They encompass the key areas of utility management and operations and it is hoped that they will contribute to the knowledge base of training approaches and best practices in the water utility sector in small urban centers.

Joan Clos
Under-Secretary-General, United Nations
Executive Director, UN-Habitat

PREFACE



Small water utilities face unique challenges in delivering water and sanitation services to their customers. With a limited revenue base and few opportunities to benefit from economies of scale, they often suffer from severe skill shortages and a long legacy of underinvestment in infrastructure and capacity enhancement. To overcome these challenges, the small utilities need to maximize their operating efficiencies and ensure optimum utilization of their assets.

Since the year 2006, UN-Habitat has been working with national and regional partners in East Africa to implement the Lake Victoria Water and Sanitation Initiative (LVWATSAN) which seeks to address the water and sanitation needs of small secondary towns in the Lake Victoria Basin. A capacity development programme in utility management and operations has become an integral component of this Initiative, which was started in 10 towns and is now being expanded to another 15 towns in the 5 East African Countries which share the Lake Victoria Basin.

The implementation of LVWATSAN has generated a solid body of knowledge and experience in enhancing the capacity of small utilities to improve their financial viability and operating efficiencies. This experience has been applied to produce a series of Manuals which can be used as training materials to improve the operating performance of small utilities.

The Block Mapping Procedures Manual is part of a Compendium of Training Manuals for Small Water Utilities, produced by UN-Habitat in six (6) volumes, as follows:

Volume 1: Finance Policies and Procedures Manual
Volume 2: Customer Services User Manual
Volume 3: Block Mapping Procedures Manual
Volume 4: Water Audit Manual
Volume 5: Leakage Control Manual
Volume 6: Reduction of Illegal Water Use Manual

The Manuals were produced through a collaborative effort between UN-Habitat and the National Water and Sewerage Corporation of Uganda within the framework of a fast track capacity building programme in utility management and operations which targeted seven small utilities in the towns around Lake Victoria.

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ABBREVIATIONS AND ACRONYMS

M	Meter
NRW	Non Revenue Water
NWSC	National Water and Sewerage Corporation
UFW	Un-accounted for Water
QMS	Quality Management Systems
L	Litre
Hrs	Hours
No.	Number
%	Percent

GLOSSARY

Non Revenue Water

This is the difference between volume of water delivered to the distribution system and the volume of water sold (as a % of water delivered).

Water Audit

Refers to a periodic exercise of determining the water supplied, consumed and lost in the distribution system thus providing a utility with information to make effective O&M as well as investment decisions.

Water Balance

This is a schematic chart showing the different components of water supplied into the distribution system as well as water lost and/or used within the distribution system.

CONTENTS

CHAPTER 1

Background

Repairs in the water pump house. Photo © UN-Habitat

Water Utilities have an important responsibility to provide safe and reliable supplies to their customers. The Water Audit manual gives guidance on all aspects from when water gets to the distribution system to when water finally gets to the consumer.

The Lake Victoria Region Water and Sanitation Initiative has provided many useful lessons on the procedures and systems to be followed in addressing the problem of Non revenue water, water audit and water balance. Key lesson learnt is that water balance can effectively reduce Non revenue water. It is a framework for assessing a utility's water loss situation, gives direction for improvement, serves as a communication tool tool and gives guidance required in prioritization and investment of limited resources.

Small urban utilities, with all the challenges that they face, cannot afford to lose water through illegal connections, meter tampering and other forms of illegal water use. They are encouraged to systematically confront this problem by adopting the procedures outlined in this Manual.

1.1 Rationale

The rationale for preparation of the manual is to have documented and streamlined procedures for implementation of activities. The documented procedures are to ensure that staff carries out their roles and responsibilities with minimum supervision and new staff quickly copes up with the requirements for their jobs. This conforms to the overall water sector perspective of designing and implementing Quality Management Systems (QMS).

1.2 Scope and Objectives

The scope of this water balance manual shall cover all aspects from the water supplied to the distribution system as well as water losses and/or used with the distribution system and what eventually reaches to the customer's premises and is billed/converted into revenue for the utility. The manual covers the procedures for determination of the various components of the water balance.

The objectives of preparation of the water balance are to:

- i ease assessment of the utility's water loss situation
- ii. improve understanding and identification of problems/issues pertaining to reduction of unaccounted for water and enhance effectiveness of its improvements through more reliable data
- iii enhance meaningful benchmarking with other service providers

iv deepen understanding of the water balance for purposes of prioritising attention and investments

1.3 Manual outline

Chapter one contains the background, rationale, scope and objectives of the manual.

Chapter two details the operating procedures which is the main purpose of this manual and

Chapter three entails the key result areas and the performance indicators that help the management to set realistic targets for the implementing team, and aid decision making as well.

Chapter four details the logistics required for implementation, this also includes the human resource, equipment and or skills and abilities required for the key team.

CHAPTER 2

Operating Procedures

Routine maintenance in the water pump house. Photo © UN-Habitat

2.0 The Water Balance

Whereas water audit refers to the conducting of periodic exercises to determine water supplied into the distribution system as well as water lost and/or used within the distribution system, the water balance chart is the tool used to enhance a meaningful water audit report.

2.1 Definition of key variables in the water balance

i. System Input Volume

The volume of treated water input to that part of the water supply system to which the water balance calculation relates.

ii. Authorized Consumption

The volume of metered and (or) unmetered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so for residential, commercial and industrial purposes. Authorized consumption may include items such as fire fighting and training, flushing of mains and sewers, these may be billed or unbilled, metered or unmetered.

iii. Water Losses

The difference between System Input Volume and Authorized Consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as transmission or distribution

Figure 1 | An illustration of a meter by pass

System Input Volume (1)	**Authorized Consumption (13)**	Billed Authorized Consumption (10)	Billed Metered Consumption (2)	**Revenue Water (17)**
			Billed Unmetered Consumption (3)	
		Unbilled Authorized Consumption (11)	Unbilled Metered Consumption (4)	**Non-Revenue Water (18)**
			Unbilled Unmetered Consumption (5)	
	Water Losses (14)	Apparent (Commercial) Losses (15)	Unauthorized Consumption (16)	
			Metering Inaccuracies & Data Handling Errors (6)	
		Real (Physical) Losses (12)	Leaks (7)	
			Bursts (8)	
			Leakage & Overflows at storage Tanks (9)	

schemes, or individual zones. Water Losses consist of Physical Losses and Commercial

iv. Billed Authorized Consumption

Those components of Authorized Consumption which are billed and produce revenue (also known as Revenue Water)

Billed Authorized Consumption = Billed Metered Consumption + Billed Unmetered Consumption

v. Unbilled Authorized Consumption

Those components of Authorized Consumption which are legitimate but not billed and therefore do not produce revenue.

Unbilled Authorized Consumption = Unbilled Metered Consumption + Unbilled Unmetered Consumption

vi. Apparent (Commercial) Losses

Includes all types of inaccuracies associated with customer metering as well as data handling errors (meter reading and billing), plus unauthorized consumption (theft or illegal use). Commercial losses may also be referred to as Apparent Losses or Non-Technical Losses.

vii. Real (Physical) Losses

Physical water losses from the pressurized system and the utility's storage tanks, up to the point of customer's meter. Physical losses are also referred to as Real losses or Technical losses.

viii. Billed Metered Consumption

All metered consumption which is also billed. This includes all groups of customers such as domestic, commercial, industrial or institutional.

ix. Billed Unmetered Consumption

All billed consumption which is calculated based on estimates or norms but is not metered.

x Unbilled Metered Consumption

Metered Consumption which is for any reason unbilled

xi. Unbilled Unmetered Consumption

Any kind of Authorized Consumption which is neither billed nor metered

xii. Unauthorized Consumption

Any unauthorized use of water. This may include illegal water withdrawal from hydrants (for example for construction purposes), illegal connections, bypasses to consumption meters or meter tampering.

xiii. Customer Metering Inaccuracies and Data Handling Errors

Commercial water losses caused by customer meter inaccuracies and data handling errors in the meter reading and billing system

xiv. Leaks

Water lost through leaks

xv. Bursts

Water lost through bursts

xvi. Over flows and leaks at Storage Tanks

Water lost through overflows and/or leakage of water storage facilities.

xvii. Revenue Water

Those components of Authorized Consumption which are billed and produce revenue (also known as Billed Authorized Consumption)

Revenue Water = Billed Metered Consumption + Pilled Metered Consumption

xvii. Non-Revenue Water

Those components of System Input which are not billed and do not produce revenue.

Non Revenue Water = Unbilled Authorized Consumption+Physical Losses +Commercial Losses

2.3 Importance of Computing the Water Balance

Developing a water balance is of paramount importance for the following reasons:

- i It serves as a framework for assessing a utility's water loss situation
- ii Calculating the water balance
  - ❑ Reveals availability/reliability of data and level of understanding
  - ❑ Creates awareness of problems/issues
  - ❑ Gives direction of improvements
- iii. It also serves as a tool for communication and benchmarking
- iv. Above all it provides significant guidance required for purposes of prioritizing attention and investments of limited resources.

As one Technical Manager in NWSC once said '*fighting NRW without a clear indication of where the problem is like a patient who goes to the hospital and simply tells a Doctor that He/She is not well without highlighting what or where the problem is*'

2.4 Benefits of Non Revenue Water Reduction

The primary objective of developing the Water Balance is to be able to effectively prioritize investments and effectively reduce NRW. The following benefits accrue from the reduction of NRW:-

i. Cleaner database and increased revenues
ii. More water available for consumption
iii. Cost reduction – less chemicals and electricity – optimized production
iv. Deferred need for investments to increase production capacity
v. Reliable demand projections
vi. Optimized operation of the distribution system

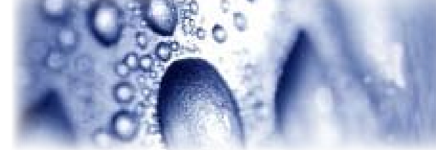


Figure 2 Water Balance Flow Chart

System Input Volume 363,000m^3 (1)	**Authorized Consumption 2,179,502m^3 (2)**	Billed Authorized Consumption 2,140,294m^3 (4)	Billed Metered Consumption 2,134,134m^3 (8)	**Revenue Water 2,140,294m^3 68.7% (17)**
			Billed Unmetered Consumption 6,160m^3 (9)	
		Unbilled Authorized Consumption 39,208m^3 (5)	Unbilled Metered Consumption 23,693m^3 (10)	**Non-Revenue Water 973,594m^3 31.3% (18)**
			Unbilled Unmetered Consumption 15,569m^3 (11)	
	Water Losses 934,386m^3 (3)	Apparent (commercial) Losses 687,629m^3 (6)	Unauthorized use=(6)-(10) 612,922m^3 (12)	
			Metering Inaccuracies 74,707m^3 (13)	
		Real (physical) Losses 246,757m^3 (7)	Leaks 103,673m^3 (14)	
			Busts 143,084m^3 (15)	
			Leakage and Overflows at storage tanks 0m^3 (16)	

2.5 Practical Water Audit Report Writing and understanding The Water Balance

In computing a water audit it is preferred to follow the sequence as indicated above i.e. (1) to (18).

System Input Volume (1)

Volume of **treated water sent to the systems network.** Note: **Not water produced**. Always subtract service and back wash water and ensure that your system input Volume is equal to the water you send from the plant to the distribution system.

Metered System (May be surface water, gravity water source, borehole etc.)

If your water sent to the system is metered, simply take readings at the beginning of month and end of month (System input Volume = Reading at end of month – Reading at beginning of month). Note that the meters should be checked to ensure that the efficiency is within acceptable error i.e. +/- 8%. Otherwise you must invoke the correction factors.

Un metered system (May be surface water, gravity water source, borehole etc.)

If the water sent to your system is not metered, then use the estimates of pump production capacities.

Water sent to system = Production capacity of pump per hour x hours run through the month

Note: the efficiency of the pumps must be put into consideration. The most commonly used pumps are the Reciprocating and centrifugal pumps. The Reciprocating Long stroke engine pumps have an efficiency of 85% while the smaller pumps of the same category have only up to 40% Efficiency. The Centrifugal pumps have efficiency between 40% and 85% and are more efficient if the head and discharge are maintained within narrow limits.

Therefore assuming an efficiency of 80% for instance gives you; a production;

Production = 80/100 x Capacity of production pump(s)

i.e. System Input Volume = ((Capacity of pump/hour) x (Hours run through the month) x (80/100)) – (Service water if any) **m^3**

System Input Volume ={[Pump Capacity per hr x Hours run through the month] x 80/100 -[Service Water if any]}m^3

Billed Metered Consumption (8)

This is the water that has been metered and billed for the month. It is paramount to always liaise with the billing / commercial department to acquire this information on a monthly basis. If none of your customers is metered simply write a zero in the water balance sheet and proceed.

Billed Unmetered Consumption (9)

This is water that is billed though not metered. **Water billed on flat rate or estimate**. Quantify this water in cubic meters.

Revenue Water (17)

= Water from which revenue is realized which = Billed Metered Consumption (8) + Billed Unmetered Consumption (9)

Non Revenue Water (18)

= Water from which revenue is not realized which = System Input Volume (1) - Revenue Water (17)

Unbilled Metered Consumption (10)

This is water that is not billed but is metered. It could include metered fire hydrants (Used by the Police Fire fighting Department), water that is metered and is supplied to staff houses yet not billed, water that is metered and supplied to the water service providers premises and is not billed etc.

Unbilled Unmetered Consumption (11)

This is water that is not billed and is not metered as well. It is lost during repairs and while effecting new connections.

Water lost through new connections

= Water lost per connection (in litres) x Number of new connections e.g. 6 litres x 10 connections = 60 litres

Water lost through repairs

= Average Water lost per repair (litres) x Number of repairs e.g. 40 litres x 100 repairs = 4,000 litres

Total Water lost = 60 litres + 4,000 litres = 4,060 litres

Divide the total number of litres by 1000 to convert the loss into cubic meters. = 4060/1000 = 4.060m^3

Metering Inaccuracies (13)

This has two aspects (Meter under registration and under estimation of consumption for un-metered customers)

Meter under registration

In general meters like any other machine depreciate with time. It is therefore important to sample a number of your meters to be able to know the average efficiency of your meters. If you have ultrasonic flow meters, go ahead and use them to sample the efficiency of your water meters. If you do not have assorted equipment, use a 20 liter jerry can to determine the efficiency of your metering.

Using the 20 liter Jerry can to determine efficiency of a water meter

- Ensure that all other taps are closed
- Take initial reading of meter in litres
- Let water into a 20 liter jerry can up to the 20 liter mark
- Take reading of meter again in litres.
- Subtract Initial reading from final reading

Efficiency of meter = (final Reading - Initial Reading) x 100/20

If you find that the average efficiency is for instance 80%, it implies that the billed metered consumption in (2) above is only 80 % of actual water consumed.

Billed Metered Consumption divide by Actual Water Consumed = 80 over100

Actual Water Consumed = Billed Metered Consumption(100/80)

Therefore Water lost due to meter under registration

Actual Water Consumed - Billed Metered Consumption

Under estimation of consumption for un-metered customers

Most times we under estimate consumption from un-metered accounts or from customers billed on a flat rate. Imagine if you had to pay a flat rate for your mobile phone services! How much would you talk? The same applies to the water consumer!

Estimating water lost through under estimation

- ❑ Select a number of customers who are on flat rate.
- ❑ Install meters on their service lines without their knowledge
- ❑ Take readings at the end of one month to determine the customer's actual consumption.

Water lost through under estimation

= (Average Customer's actual consumption - Flat Rate) x Number of customers on Flat Rate

Total water lost through metering inaccuracies = total of the two aspects above

Leaks (14)

The volume of the water lost by leakage will depend largely on a number of factors i.e.

- ❑ The pressure in the network.
- ❑ whether the soil allows water to be visible at the surface
- ❑ The "awareness" time (how quickly the loss is noticed);
- ❑ The repair time (how quickly the leakage is repaired)
- ❑ The size of leak hole.

Determining water lost therefore requires significant record keeping. A leak record book is a handy requirement under these circumstances. The information captured should include the following;

- ❑ Leak No – This is a sequential number given to the leaks. This enables one to easily tell the number of leaks per month.
- ❑ Zone (Area) – to back up decision making in future.
- ❑ Area of Leak mm^2 – Water lost is dependent on the area; small holes will let out less water under the same pressure than a bigger hole. This can be by simply measuring the diameter of a hole in mm then used the calibrated table in Appendix one to determine area. If the hole is square then one has to calculate the area manually. Water lost is then got from the table by matching area against pressure in bars. Note that 1Bar = 10 water meter height.
- ❑ Average Pressure. If you have equipment to establish pressure in the area then do so per zone/area. Otherwise use estimates of height of supply reservoirs per zone. 1bar = 10m
- ❑ Date and Time of occurrence – The date and time when the leak was first noticed (Note: Not date reported)
- ❑ Date Time of repair of leak – The date and time when leak was repaired.
- ❑ Water loss time – The time through which water was lost = Hours between occurrence and repair.
- ❑ Water lost in litres / minute from the table *(See Appendix I)*
- ❑ Water Lost in Cubic Meters

It is normally tedious to calculate water lost per leak. It is therefore advisable to establish some helpful assumptions i.e.

- ❑ Average area of leak - measure area of leaks for at least two month and come up with average
- ❑ Average water pressure - come up with average pressure

Total Water Lost (litres) = (Water lost per minute x average number of minutes between occurence and repair) x number of leaks that occured during the month

You must state the average pressure used in the computation.

Bursts (15)

Similar to leaks above but water loss must be calculated for each burst. Water losses through bursts can vary significantly.

Leaks and Overflows at Storage Facilities (16)

This component has two aspects

- ❑ **Water loss through leakage at Storage tank**: This can be achieved by simply estimating water lost per hour through leakage at the storage tank(s). Thereafter, multiply this by 24 hours a day and then by 30 days a month.
- ❑ **Overflows at Storage Tanks**: Note the hours when you had over flows at the tank and estimate water loss per hour. Water lost

= estimated loss per hour X total number of hours of over flow through the month.

Water Lost = Estimated loss per hour x total number of hours of over flow through the month

Note: Components 4 – 7, 15 and 16 are arrived at by simply adding up the components they constituted.

Unauthorized Consumption (12)

This is the water stolen either through illegal connection, by-passing the meter, Removal and fetching water before the meter and/or reversal of water meter. This one is difficult to estimate that is why it is got by subtracting the now known UFW/NRW components from the total NRW/UFW figures i.e. 18 – (10 + 11 + 13 + 14 + 15).

2.6 Example of a Typical Water Balance of Water Balance Report

A Monthly Water audit report by use of Water Balance sheet should look like the one below with three main aspects:-

- ❑ Volumes of water per component.
- ❑ Corresponding percentages as well.
- ❑ A back up report (water balance report) explaining how you reached at each of the figures above (in i and ii).

2.6.1 Typical water balance report – Input data

System Input Volume (1)

Assume we have two water supply plants A and B. A is metered while B is not metered.

Treatment Plant A

- ❑ The meter reading taken reflected a production of 30,000 m^3. The water used for backwashing is taped after the bulk production meter. For the month of September we used 3,000 m^3 for back washing. The total volume of water sent to the network from plant A = 30,000 – 3,000 = 27,000 m^3.

Treatment Plant B

- ❑ This plant has two pumps. The capacity of each pump is 500 m^3 per hour. The pumps are run for 16 hours each per day.

Assume the efficiency of the pumps is about 70%. This implies that these pumps can only produce 70% of their capacity.

70% of the 500 capacity = X; X/500=70/100 i.e X = (70/100) x 500
Actual Production = 350 m3 x 2 pumps x 16 hours a day x 30 days = 336,000 m^3

Figure 3 | Typical Water Balance Chart

System Input Volume 363,000m^3	**Authorized Consumption 153,480m^3**	Billed Authorized Consumption 150,000m^3	Billed Metered Consumption 142,000m^3	**Revenue Water 150,000m^3 42%**
			Billed Unmetered Consumption 8,000m^3	
		Unbilled Authorized Consumption 3,480m^3	Unbilled Metered Consumption 3,000m^3	**Non-Revenue Water 213,000m^3 58%**
			Unbilled Unmetered Consumption 480m^3	
	Water Losses 209,520m^3	Apparent (commercial) Losses 208,998m^3	Unauthorized use169,298m^3	
			Metering Inaccuracies 39,700m^3	
		Real (physical) Losses 552m^3	Leaks 432m^3	
			Busts 90m^3	
			Leakage and Overflows at storage tanks 0m^3	

Billed Metered Consumption (8)

Assume that only 400 of our customers are metered, 100 of which are commercial. The total volume of water consumed by the metered accounts for the month of September 2007 = **142,000 m^3**

Billed Unmetered Consumption (9)

The largest number of our customers are billed on flat rate i.e. 1000 customers. Of the 1000, 300 are commercial while 700 are domestic.

Flat rate for domestic is 5 m^3 per month while the flat rate for commercial is 15 m^3 per month.

Revenue Water (17)

Non Revenue Water / Unaccounted for Water (18) = 363,000m^3 – 150,000m^3 = 213,000m^3

Unbilled Metered Consumption (10)

Assume your staff consumed water and were not billed. In total they consumed 2000m^3 of water for the month of September 2007. Assuming we also serve the police fire department through one metered fire hydrant; they consumed 1000 m^3 for the month of September

Total Unbilled metered = 2,000 + 1,000 = 3,000m^3

Unbilled Unmetered Consumption (11)

Assuming you also serve the police fire department through 4 unmetered fire hydrants. One week we hired someone to record the number of truck fetched from these fire hydrants. It was noted that up to 15 trucks are fetched from each of these fire hydrants per week. Each truck has a capacity of 2 m^3; =15 truck x 4 fire hydrants x 4 weeks = 240 trucks per month

Total water consumed = 2m3 x 240 trucks = **480m^3**

Metering Inaccuracies (13)

Meter Performance inefficiency

We sampled our meters in the field and got to know that they are about 80% efficient. That means that the water measured by the water meters i.e. Billed metered consumption of 142,000 m^3 is only 80% of the actual water consumed.

142,000/Actual consumed = 80/100
Actual consumed = 142,000 x 100/80
Actual consumed = 177,500m^3
Water Lost = 177,500 -142,000 =35,500m^3

Water lost due to under registration

We quietly installed meters at premises that are on flat rate recently and noted that the domestic customers were consuming 8 units on average and not 5 units as assumed, commercial customers were consuming 22 units and not 15 as assumed. This means that for each domestic customer on flat rate we lose 3 m^3.

Water Lost = $3m^3$ x 700 domestic customers = $2,100m^3$

For each commercial customer on flat rate we lose 22-15 = 7 units.

Total Water lost due to metering in accuracies = 35,500 + 2,100 + 2,100 = $39,700m^3$

Leaks (14)

The number of leaks reported for the month of September 2007 was 90. The average diameter of the leaks was 3mm. The average time between awareness and repair was about 8 hours = 480 minutes – this is attributed to lack of repair materials and limited transport. The average pressure in the network was about 35 meters = 3.5 bars.

From table in appendix one;

Estimated water loss = 10l/min x 90 leaks x 480 minutes at an average pressure of 2.7 bars = 432,000 litres
Convert litres to m^3 = 32,000/1,000 = $432m^3$

Bursts (15)

There was only one burst in the month of September 2007. The burst lasted three hour and the estimated water loss was **30 m³ per hour.**

Total Water lost = 30 x 3hrs = 90m^3

Leaks and Overflows at Storage Facilities (16)

Unlike the previous month someone was hired to monitor water levels at the storage tanks. The leaks were all repaired in august 2007 and hence there were no over flow and leakage at the water storage tanks.

Total Water lost = 0 m^3

2.6.2 Typical water balance report – Results

From the computations made from figure 3 - Typical water balance chart the result are as follows:

Water Balance Computations	
Component (No.)	**Value computed (m^3)**
Un authorized Consumption (12)	169,298
Billed Authorized Consumption (4)	150,000
Un billed Authorized Consumption (5)	3,480
Real (Physical Losses) (7)	522
Authorized Consumption (2)	153,480
Water Losses (3)	209,520
Apparent Losses (6)	208,998

2.7 Making use of the water balance

As one develops the water balance report loop holes/ critical areas of improvement in the water supply system should right away be identified and corrective activities or projects initiated. For instance;

System Input Volume

It is desired that all system input volume be metered with meters being regularly calibrated. If your system input volumes are not fully metered, then initiate a project to accurately meter all your production and ensure regular calibration of water meters.

Billed Metered Consumption

100% metering is the most desired position. If some of your customers are not metered then initiate to have that done.

Billed Unmetered Consumption

The desired position is to have 0 cubic under this category. If you are billing your customers on flat rate, it's high time you initiate a project to meter all your customers. Otherwise it is difficult to pin point a figure to where your water may be going.

Unbilled Metered Consumption

It is desired that you meter all your unbilled authorized consumption. For purposes of accountability and full knowledge of how much of your water is where and consumed by whom. If you are serving unmetered water to the police fire department, your staff quarters etc. you better start by metering this water.

Unbilled Unmetered Consumption

It is desired that you have zero unbilled unmetered consumption.

Metering Inaccuracies

It is desired that you replace all meters which are 5 to 7 years old, since the level of inaccuracy increases with the meter age. The Oldest meters in your network should therefore be between 5 and 7 years at most.

Leaks

It is desired that you check your entire network at least twice a year – by leak detection equipment. Conduct visible leak searching at least twice a month for the entire pipe network if the leak in a given area is so frequent. You may consider pipe replacement and/or reduction of pressure through network balancing or installation of pressure reducing valves.

Bursts

Is the pipe design suitable for the pressure?

Leaks at Storage Facilities

This is not expected to contribute to NRW every month. Simply monitor the condition of the storage reservoir and carry out remedial works whenever the need arises.

Overflows at Storage Facilities

You may have to replace Ball valves. You may have to keep an attendant stationed at the storage tanks or inspecting the levels at intervals, and communicate to the pumping station staff on to stop pumping and hence minimize loss.

Unauthorized Consumption / Water stolen

The desired position is to have a fully flagged team and/or unit that addresses the issue of illegal usage on full time basis.

CHAPTER 3

Key Results and Performance Indicators

Checking the pump perfomance. Photo © UN-Habitat

3.1 Key Result Areas

- ❑ Streamlined system of determination of Non Revenue Water (NRW)
- ❑ Streamlined system of identification of problem areas in the water supply system for targeted remedial measures
- ❑ Accurate determination of Non Revenue Water (NRW)
- ❑ Implementation of the procedures highlighted in the manual will result in reduction of Operations and Maintenance costs

3.2 Performance Indicators

To effectively carry out water audits and a water balance the following performance indicators need to be determined: -

Performance Indicators for Water Balance		
No.	**Performance Indicators**	**Unit**
1	UFW/NRW= ((production-Billed)/Production))*100	%
2	Water Produced	m^3
3	Service Water	m^3
4	Backwash water	m^3
5	Water Supplied	m^3
6	Production capacities for each pumps	m^3/hr
7	Hours of operation for each pump	Hrs
8	Efficiency of each pump	%

Performance Indicators for Water Balance continuation...		
No.	**Performance Indicators**	**Unit**
10	New Water Connections Made	No
11	No. of Leakages Reported	No
12	Average response time to Leakages	Hrs
13	No. of bursts Reported	No.
14	Average response time to bursts	Hrs
15	Meter Accuracy	%
16	Inaccuracies due to flat rate billing	%
17	Average Pressures in the Network	Bars
18	No of overflows from reservoirs	No
19	Average duration of overflows from reservoirs	Hrs

3.3 Monitoring and Evaluation of Indicators

The monitoring and evaluation (M & E) during the implementation of the water balance manual shall be through M&E sub-committees established within the utility. The sub-committees will regularly move, at an interval to be determined by management, around the network to take measurements for determination of qualitative data. Records of quantifiable performance indicators should be maintained to facilitate accurate assessment and determination of variables for NRW computation.

The sub-committees will then meet on a weekly basis to discuss constraining issues and strive to find solutions. The entire M&E team will then meet bi-weekly to have a holistic overview of the implementation status. At each stage of the meeting, the agreed way forward on the constraints and achievements will be communicated to the respective operating sections.

The evaluation of the performance of the water balance system shall be carried out at the end of each month and each sub-committee shall highlight constraints experienced and proposed way forward, which are then discussed in a meeting chaired by the Technical In-charge.

CHAPTER 4

Requirements for Successful Implementation

Community joint effort in digging trenches for water pipes. Photo © UN-Habitat

4.1 Equipment

Flow meter – for measuring flow if the production is not metered. Flow meter for checking accuracy of the production meters if metered. If you can not own the equipment then hire a service provider to help you measure production or determine accuracy of the production meters. Relying on the capacity of pumps is most often misleading as the pumps' actual capacity may be much lower or higher.

Consumer meters are very important in determining the billed metered.

4.2 Human Resource & Responsibilities

The task of preparing a water audit report is better done by someone with a supervisory role. One with an overall understanding and responsibility over the network. However where there isn't sufficient capacity an available responsible staff can be assigned the task of preparing the water balance report. The bottom line is that the person preparing the report MUST have an understanding of Water Audit and the water balance.

The responsibilities of such a person should entail;

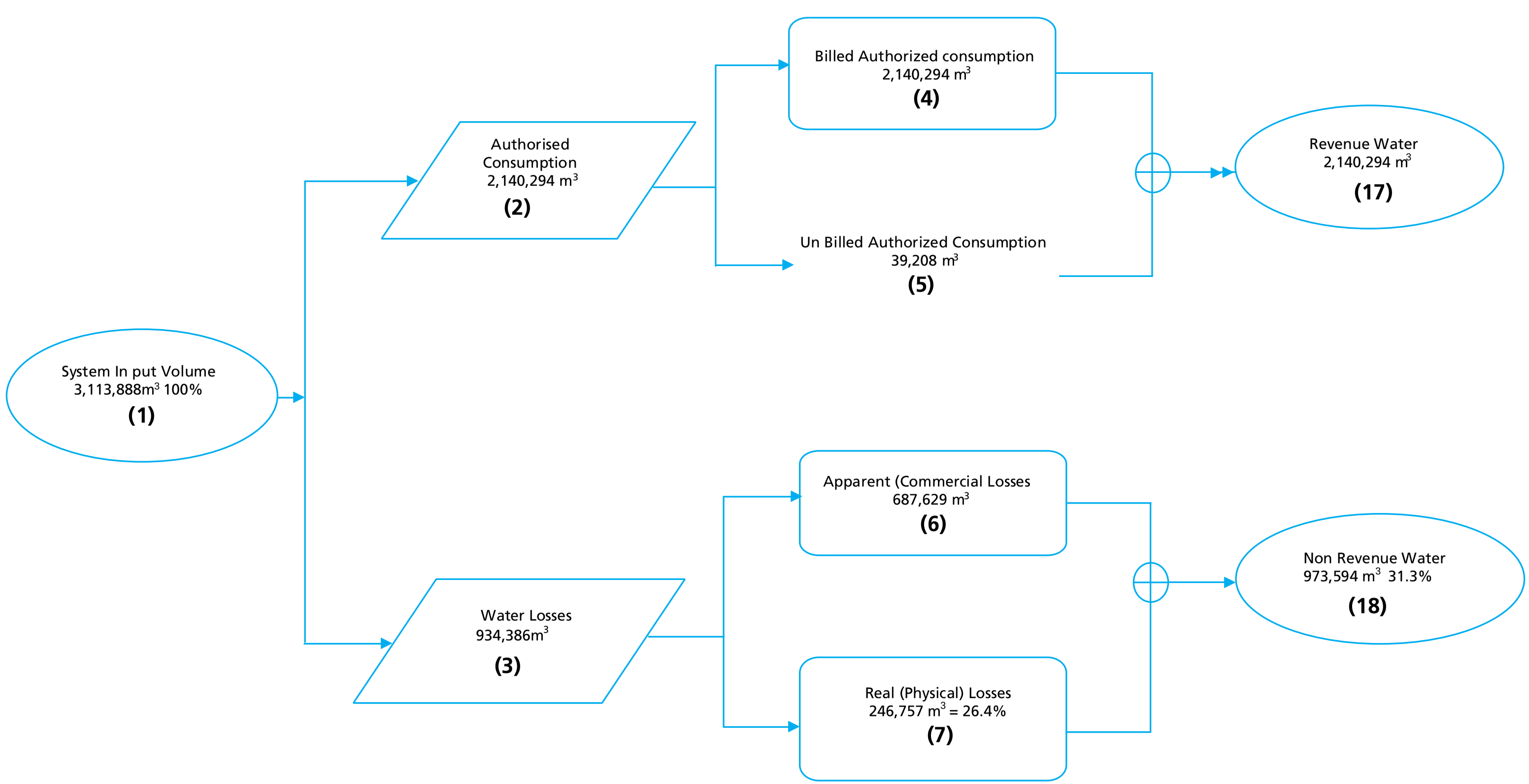
- ❑ Collecting data on the different components of the water balance i.e.
  - Total production of the month (with clear understanding on how the figures were reached at)
  - Total volume Metered and Billed
  - Total volume billed though unmetered (Billed on estimate for unmetered accounts) etc.
- ❑ Compare the NRW/UFW contributing factors and inform management on trends observed.
- ❑ Conceptualize / identify, develop and ensure quality implementation of Non Revenue Water projects.
- ❑ Advice and or make recommendations to management concerning NRW reduction

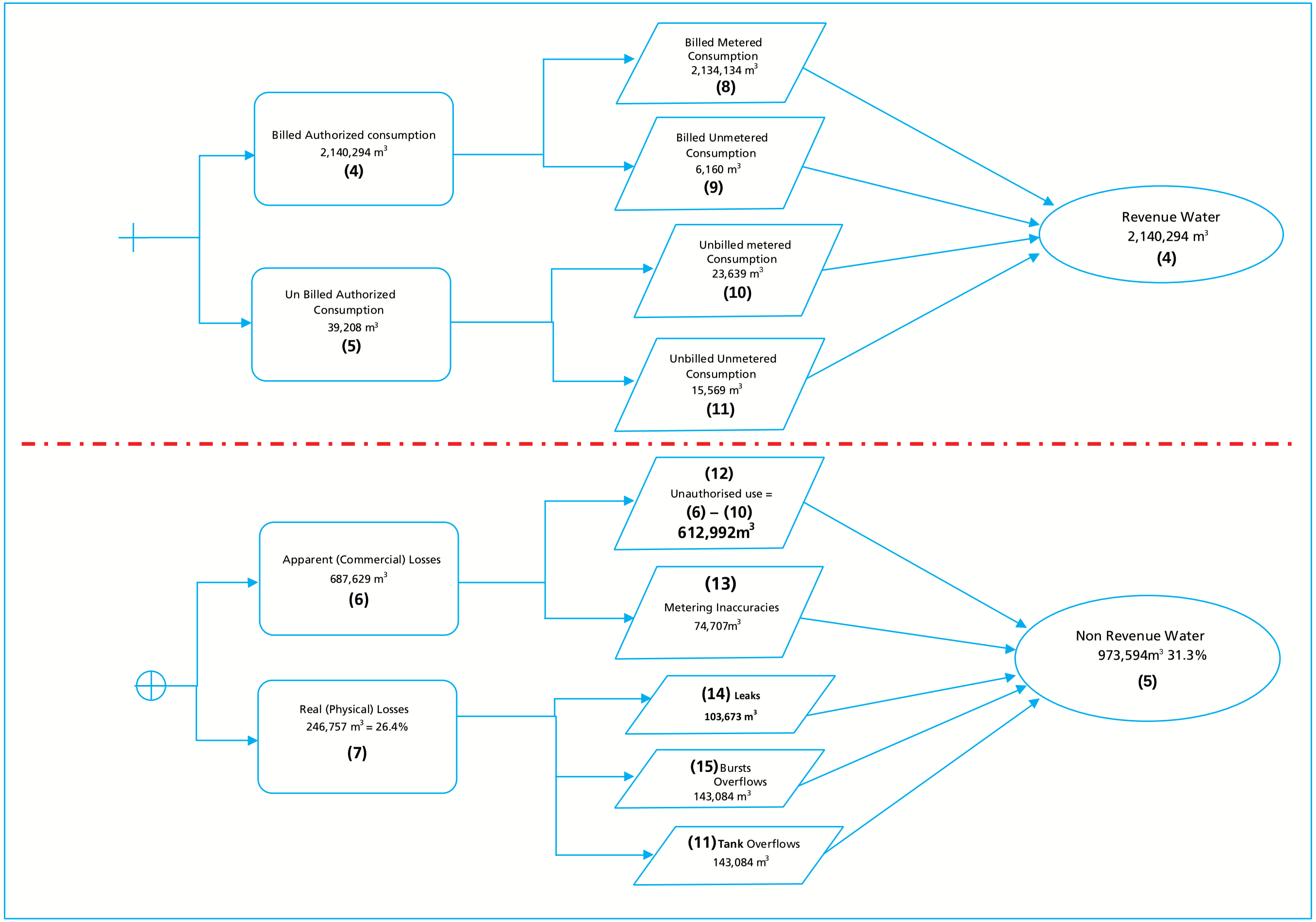
Appendices

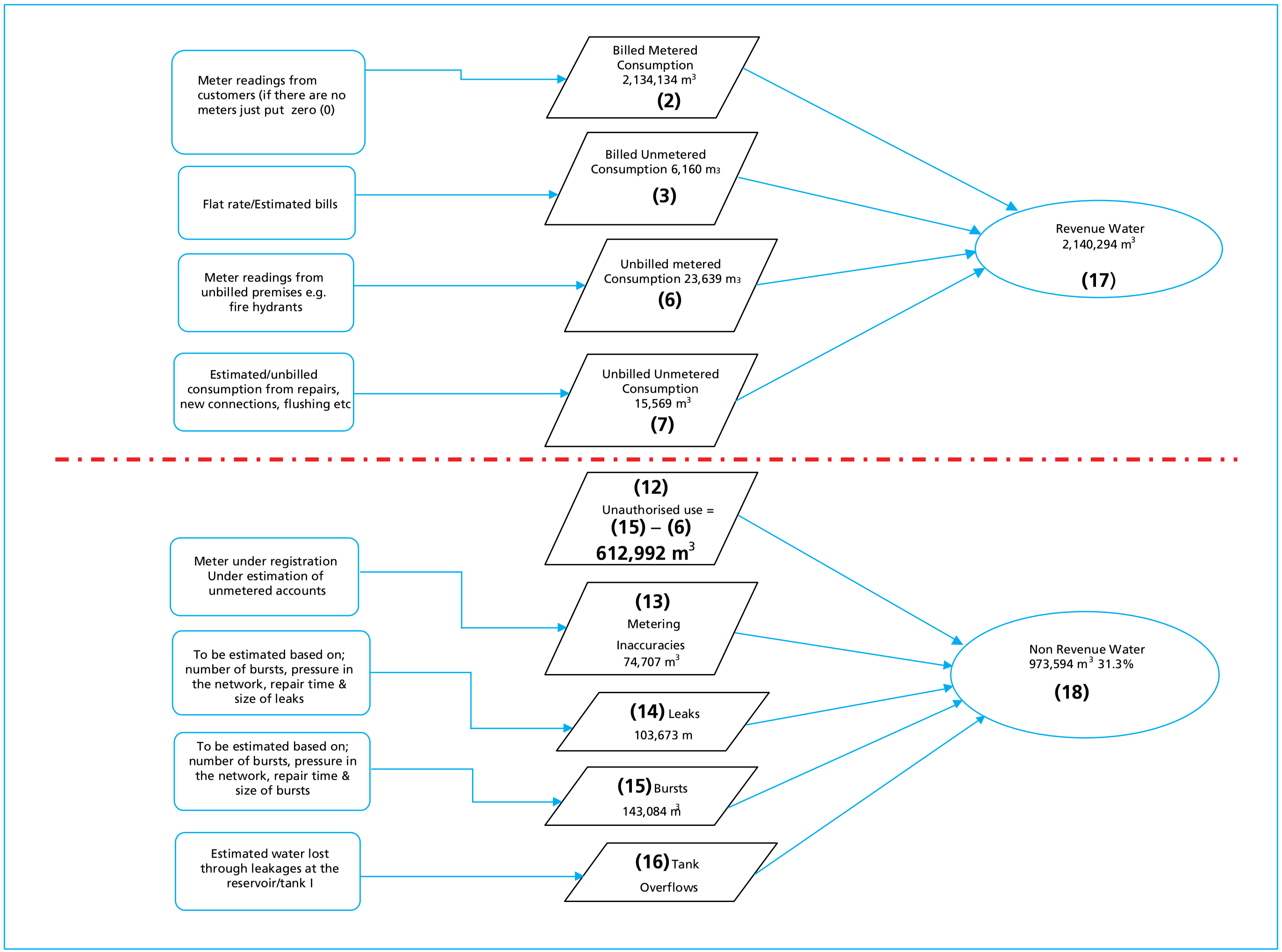
Formula Flow = 2.8xAreax square Root of (148x Preasure): Flow(gallons per minute), Area (Square inches) and Psi)

			Pressure in (Pounds per Square Inch (psi) and (Bars) ; 1 Bar = 14.5038 psi Flow in Gallons per minute and Litters per minute; 1 litter = 0.22 gallons									
			psi	Bars	psi	Bars	psi	Bars	psi	Bars	psi	Bars
			10.00	0.07	20.00	1.38	40.00	2.76	60.00	4.14	80.00	5.52
Area of leak Square Inches 1″ Sq=645.16 sq mm	Area of leak mm Squared 1″ = 25.4mm	Diameter of Circle (mm) A=(DSq)/4	Gallons per minute(gpm) or Liters per minute									
			Gallons	Liters	Gallons	Liters	Gallons	Liters	Gallons	Liters	Gallons	Liters
0.005	3.2258	2.00	0.50	2.27	8.00	36.36	1.10	5.00	1.30	5.91	1.50	6.82
0.010	6.4516	2.80	1.10	5.00	1.50	6.82	2.20	10.00	2.60	11.82	3.10	14.09
0.025	16.129	4.50	2.70	12.27	3.80	17.27	5.40	24.55	6.60	30.00	7.60	34.55
0.050	32.258	6.40	5.40	24.55	7.60	34.55	11.00	50.00	13.00	59.09	15.00	68.18
0.075	48.387	7.80	8.10	36.82	11.00	50.00	16.00	72.73	20.00	90.91	23.00	104.55
0.100	64.516	9.00	11.00	50.00	15.00	68.18	22.00	100.00	26.00	118.18	31.00	140.91
0.200	129.032	12.80	22.00	100.00	31.00	140.91	43.00	195.45	53.00	240.91	61.00	277.27
0.300	193.548	16.00	32.00	145.45	46.00	209.09	65.00	295.45	79.00	359.09	92.00	418.18
0.400	258.064	18.00	43.00	195.45	61.00	277.27	86.00	390.91	106.00	481.82	122.00	554.55
0.500	322.580	20.00	54.00	245.45	76.00	345.45	108.00	490.91	132.00	600.00	153.00	695.45
0.600	387.096	22.00	65.00	295.45	92.00	418.18	129.00	586.36	159.00	722.73	183.00	831.82
0.700	451.612	24.00	76.00	345.45	107.00	486.36	151.00	686.36	185.00	840.91	214.00	972.73
0.800	516.128	26.00	86.00	390.91	122.00	554.55	173.00	786.36	211.00	959.09	244.00	1109.09
0.900	580.644	27.20	97.00	440.91	137.00	622.73	194.00	881.82	238.00	1081.82	275.00	1250.00
1.000	645.160	28.70	108.00	490.91	153.00	695.45	216.00	981.82	264.00	1200.00	305.00	1386.36
1.100	709.676	30.08	119.00	540.91	168.00	763.64	237.00	1077.27	291.00	1322.73	336.00	1527.27
1.200	774.192	31.44	129.00	586.36	183.00	831.82	259.00	1177.27	317.00	1440.91	366.00	1663.64
1.300	838.708	32.70	140.00	636.36	198.00	900.00	280.00	1272.73	343.00	1559.09	397.00	1804.55
1.400	903.224	33.96	151.00	686.36	214.00	972.73	302.00	1372.73	370.00	1681.82	427.00	1940.91
1.500	967.740	35.00	162.00	736.36	229.00	1040.91	324.00	1472.73	396.00	1800.00	458.00	2081.82
1.600	1032.256	36.30	173.00	786.36	244.00	1109.09	345.00	1568.18	423.00	1922.73	488.00	2218.18
1.700	1096.772	37.42	183.00	831.82	259.00	1177.27	367.00	1668.18	449.00	2040.91	519.00	2359.09
1.800	1161.288	38.51	194.00	881.82	275.00	1250.00	388.00	1763.64	476.00	2163.64	549.00	2495.45
1.900	1225.804	39.56	205.00	931.82	290.00	1318.18	410.00	1863.64	502.00	2281.82	580.00	2636.36
2.000	1290.320	40.59	216.00	981.82	305.00	1386.36	431.00	1959.09	528.00	2400.00	610.00	2772.73
2.500	1612.900	45.38	270.00	1227.27	381.00	1731.82	539.00	2450.00	661.00	3004.55	763.00	3468.18
3.000	1935.480	49.71	324.00	1472.73	458.00	2081.82	647.00	2940.91	793.00	3604.55	915.00	4159.09
4.000	2580.64	58.42	431.00	1959.09	610.00	2772.73	863.00	3922.73	1057.00	4804.55	1220.00	5545.45

WATER BALANCE PROCESS FLOW CHART




Billed Authorized consumption
2,140,294 m3
(4)
Un Billed Authorized Consumption
39,208 m3
(5)
Billed Metered Consumption
2,134,134 m3
(8)
Billed Unmetered Consumption
6,160 m3
(9)
Unbilled metered Consumption
23,639 m3
(10)
Unbilled Unmetered Consumption
15,569 m3
(11)
Revenue Water
2,140,294 m3
(4)
Apparent (Commercial) Losses
687,629 m3
(6)
Real (Physical) Losses
246,757 m3 = 26.4%
(7)
(12)
Unauthorised use =
(6) – (10)
612,992m3
(13)
Metering Inaccuracies
74,707m3
(14) Leaks
103,673 m3
(15) Bursts Overflows
143,084 m3
(11) Tank Overflows
143,084 m3
Non Revenue Water
973,594m3 31.3%
(5)


Meter readings from customers (if there are no meters just put zero (0)
Flat rate/Estimated bills
Meter readings from unbilled premises e.g. fire hydrants
Estimated/unbilled consumption from repairs, new connections, flushing etc
Billed Metered Consumption 2,134,134 m3 (2)
Billed Unmetered Consumption 6,160 m3 (3)
Unbilled metered Consumption 23,639 m3 (6)
Unbilled Unmetered Consumption 15,569 m3 (7)
Revenue Water 2,140,294 m3 (17)
Meter under registration Under estimation of unmetered accounts
To be estimated based on; number of bursts, pressure in the network, repair time & size of leaks
To be estimated based on; number of bursts, pressure in the network, repair time & size of bursts
Estimated water lost through leakages at the reservoir/tank I
(12) Unauthorised use = (15) – (6) 612,992 m3
(13) Metering Inaccuracies 74,707 m3
(14) Leaks 103,673 m
(15) Bursts 143,084 m3
(16) Tank Overflows
Non Revenue Water 973,594 m3 31.3% (18)

This manual is part of a Utility Management Series for Small Towns. It can be used either as a training module to support the delivery of capacity building programmes in utility management and operations or as a reference manual to guide operations and maintenance staff in designing and implementing programmes to reduce the rate of Unaccounted-For-Water. When used by urban water utilities, the manual should be widely circulated to ensure that all staff and Supervisors involved/working in concerned Departments/Sections receive a copy. This will ensure a systematic and consistent approach to the implementation of an Illegal Water Use Reduction Strategy.

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