PalestinePolytechnicUniversity

College of Engineering and Technology

Civil & Architecture Engineering Department

Project Title

Estimation of Non-revenue Water in the Water Distribution Network of SourifTown

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December, 2017

Certification

PalestinePolytechnicUniversity

Hebron- Palestine

The Senior Project Entitled:

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In accordance with the recommendations of the project supervisor, and the acceptance of all examining committee members, this project has been submitted to the Department of Civil and Architectural Engineering in the College of Engineering and Technology in partial fulfillment of the requirements of the department for the degree of Bachelor of Science in Engineering.

Department Chairman **Project Supervisor**

Abstract

Estimation of Non-revenue Water in the Water Distribution Network of SourifTown

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The water supply utilities should fulfill the water requirement with quantitatively and qualitatively. Drinking water systems exposed to manmade hazards that are common in Palestine. Among manmade risks is the water loss, which remains a major concern in Palestine. Levels of water losses estimated to be approximately 45 to 50 percent, high by international standards.

High levels of water losses reflect huge volumes of water being lost through leaks, not being invoiced to customers, or both. It seriously affects the financial viability of water utilities through lost revenues and increased operational costs. The waste of resources resulting from high water loss levels in developing countries like Palestine is considerable.

SourifTown is one of the Palestinian towns which has a big problem in its water distribution through a high level of water loss. the water distribution system in the town is old and it is suffering from bad operating and management conditions. The water losses in these water network is at increasing trend. This is expected to make the management of these water network at risk or being failed and instead of being a financial resource for municipalities. Thisstudy is concern with estimating and analyzing the non-revenue water in the water distribution network at SourifTown.

The result of this study shown that the non-revenue water in Sourif water distribution system reaches 38.46% in year 2016 with 140000$ this is because the water distribution system is old and weak.

إهداء

إلى من جرع الكأس فارغاً ليسقيني قطرة حب

إلى من كلت أنامله ليقدم لنا لحظة سعادة

إلى من حصد الأشواك عن دربي ليمهد لي طريق العلم

إلى القلب الكبير..... (والدي العزيز)

إلى من أرضعتني الحب والحنان

إلى رمز الحب وبلسم الشفاء ..... (والدتي الحبيبة)

إلى القلوب الطاهرة الرقيقة والنفوس البريئة إلى رياحين حياتي

الى من يحملون في عيونهم ذكريات طفولتي وشبابي ..... إخوتي وأخواتي

الى من سرنا سويا ونحن نشق الطريق معا نحو النجاح والإبداع.....زملائي وزميلاتي

الى من ضحوا بحريتهم من اجل حرية غيرهم..... الاسرى والمعتقلين

الى من هم اكرم منا مكانة..... شهداء فلسطين

إلى هذه الصرح العلمي الفتي والجبار..... جامعة بوليتكنك فلسطين

الى من احتضنتني كل هذا الكم من السنين ..... فلسطين الحبيبة

شكر وتقدير

(قل اعملوا فسيرى الله عملكم ورسوله والمؤمنون)

صدق الله العظيم

إلهي لا يطيب الليل إلا بشكرك ولا يطيب النهار إلا بطاعتك .. ولا تطيب اللحظات إلا بذكرك .. ولا تطيب الآخرة إلا بعفوك .. ولا تطيب الجنة إلا برؤيتك الله جل جلاله.....

لابد لنا ونحن نخطو خطواتنا الأخيرة في الحياة الجامعية من وقفة نعود إلى أعوام قضيناها في رحاب الجامعة مع أساتذتنا الكرام الذين قدموا لنا الكثير باذلين بذلك جهودا كبيرة في بناء جيل الغد لتبعث الأمة من جديد...

وقبل أن نمضي نقدم أسمى آيات الشكر والامتنان والتقدير والمحبة إلى الذين حملوا أقدس رسالة في الحياة...

إلى الذين مهدوا لنا طريق العلم والمعرفة...

إلى جميع أساتذتنا الأفاضل.....

"كن عالما ... فإن لم تستطع فكن متعلما ، فإن لم تستطع فأحب العلماء ،فإن لم تستطع فلا تبغضهم"

ونخص بالتقدير والشكر الى من قدمت لنا يد العون وكانت لنا سندا والتي علمنا التفاؤل والمضي إلى الأمام، إلى من رعتنا وحافظت علينا ، إلى من وقفت إلى جانبنا عندما ضللنا الطريق..... المهندسة سماح الجعبري .....

الذي نقول لها بشرائ قول رسول الله صلى الله عليه وسلم:

"إن الحوت في البحر ، والطير في السماء ، ليصلون على معلم الناس الخير "

وكذلك نشكر بلدية صوريف وطاقمها التي لم تبخل علينا بتزويدنا بالمعلومات اللازمة ومدت لما يد العون بكل اخلاص .

Acknowledgement

We would like to express our thanks and gratitude to Allah, the Most Beneficent, the most Merciful who granted us the ability and willing to start and complete this project. We pray to his greatness to inspire us the right path to his content and to enable us to continue the work started in this project to the benefits of our country.

We wish to express our deep and sincere thanks and gratitude to PalestinePolytechnicUniversity, the Department of Civil & Architectural Engineering, College of Engineering & Technology. We wish to express our thanks to Eng.Samah Al-Jabari, for a valuable help, encouragement, supervision and guidance in solving the problems that we faced from time to time during this project.

We can find no words to express our sincere, appreciation and gratitude to our parents, sisters and brothers, for their endless support and encouragement, we are deeply indebted to you and we hope that we may someday reciprocate it in someway.

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List of Acronyms

Acronym	Description
PWA	Palestine water Authority
NRW	Non –revenue water
GIS	Geographic Information Systems
˚C	Celsius
PCBS	Palestine Central Bureau of Statistics
UNEP	United Nations Environment Program
UFW	Unaccounted for Water
IWA	International Water Association
WHO	World Health Organization
AWWA	American Water Work Associated
PRV	Pressure Reducing Valves
ILI	Infrastructure leakage Index

Chapter One

Introduction

1.1 General

1.2 Problem Definition

1.3 Technical Objectives

1.4 Study Question

1.5 Methodologies

1.6 Phases Of The Project

1.7 Structure Of The Report

1.1 General

Water is the most important and valuable resource not only for human life but also for all living things in this world. The water supply utilities should fulfill the water requirement with quantity and quality in developing countries like Palestine water supply utilities still running by government authority namely Palestine water Authority (PWA).

Drinking water system is essential in ensuring the health and well-being of the population. Drinking water systems are exposed to both natural and man-made hazards that are common in Palestine.

Among man-made risks are the water loss or not –revenue water (NRW). Which remains a major concern in Palestine. Levels are estimated at approximately 40-50 percent, which is high by international standards.

High level of NRW reflects the huge volume of water being lost through lacks not being invoiced to cost or both it seriously affects the financial viability of water utilities through last revenues and increase operational cost .

This study is carried out to investigate the state of the existing water distribution systems in terms of uncounted for water in Sourif Town in Hebron district

1.2 Problem Definition

The water system in Sourif Town faces many problems: low services levels, high NRW frequent pipeline bursts, problems with billing and collection of revenue, and stopped or frequently water meters, one of the existing problem is the presence of polyethylene lines in the network.

The wide expansion and accelerated development of Sourif town had led to an increase in the amount of water consumption for domestic, public and irrigation uses , this is due to the loss of a large part of the water in the distribution pipeline.

Sourif faces great difficulties and different problems in water supply and water services due to population growth, And therefore non-arrival of the amount of water is enough to meet the needs of the population, compared with the continuous population growth. Hence, a number of water supplies to the town is very little and the existing water supply network is very old and does not satisfy the needs of water so, the number of water losses are increasing.

And as mentioned earlier, the municipality faces some difficulties that delay any improvement in the existing water distribution network or reduce the number of water losses.

1.3 Technical Objectives

The overall objective of this project is to identify and the study's the total losses of water in the distribution systems in Sourif Town in Hebron district and how these problems may be reduced, More specifically, the main objectives of this project may be classified as follows:

1- study the gap between water demand and supply capacity.

2- calculate losses in the Sourif water distribution system.

3- categorizing each loss type.

4- calculate a water balance for each network.

5- putting solutions to reduce losses

1.4 Study questions

In order to complete the objectives of the study and follow-up must be formulated the following questions:

1. What is the existing situation in the water distribution system at the project area?
2. What is the level of water losses in the project area?
3. What is the management strategy in the project area?
4. To what extent has NRW affected the overall performance of the water utility in the project area?
5. How can the NRW levels be improved in the project area?

1.5 Methodologies

The main tasks, which will be taken for the development of this project are as follows:

1. Data collection of the current situation of the project area.
2. Site visits and field work for estimating the water distribution system, leakage detection data, and location in the project area.
3. The design of data sheet and questioner and conducting interviews.
4. Analysis and calculating the water losses, and the NRW in the water distribution system using software.
5. Evaluate the import of NRW on the performance of water systems , in the project area.

1.6 Phases of the project

The project will consist of five phases as shown in **Table** (1.1)

1.6.1 First phase is Data collection: In this phase, available data information maps, drawings, statistical studies and previous studies from different sources were collected.

1.6.2 Second Phase is Data sheet and questioner: in this phase, data sheets prepared to achieve goals and prepare questions for complete the objectives of the study.

1.6.3 Third Phase is softwark application: focus on Site visits and field work for estimating the water distribution system.

1.6.4 fourth phase is study and analysis: In this phase, analysis for the non-revenue water using Software.

1.6.5 fifth phase is Writing the report: After finishing all of the above three phases, the project team prepared a complete report.

Objectives	Second Semester(2016) ٤	First Semester(2017)

	2/2017	3/2017	4/2017	5/2017	9/2017	10/2017	11/2017	12/2017
Literature review and data collection.								
Data sheet and questioner.								
softwark application								
Study and analysis.								
Writing the report.								

Table (1.1): Tasks and duration of the project.

1.7 Structure of the Report

The project report has been prepared in accordance with the objectives and scope of work. The report consists of six chapters:

The title of ***Chapter One "Introduction"*** outlines the general background, problem definition, technical objectives project question , work plan and structure of the report

Chapter Two entitled***" characteristics of the project area "*** which deals with the location, geographic data, and climate characterization of project area ,and maps.

Chapter Three entitled ***"literature review"*** which deals with the researches, studies and articles written for water losses NRW meanings , components, measuring, causes and management , strategy for reducing them

Chapter Four entitled ***"materials and methodology "*** which is deals with material used and methods follows for studying and analysis.

Chapter five entitled ***"Analysis and discussion of the results "*** is devoted to the analysis and discussion of results, and development of future plans and appropriate management technology for reconstruction and upgrading of the existing water network in Sourif town

Chapter six entitled ***"conclusions and recommendations"*** which is deals with the final conclusions and the usfull recommendations.

Chapter Two

Literature Review

2.1 General Background

2.2 What Is Water Loss And What Is Non-Revenue Water

2.3 The Challenge At Sourif Water Distribution System

2.1General Background

Water is a valuable resource, critical to economic development (Horne, 2013). However, developing countries worldwide face significant challenges in managing increasing demand for urban water because of industrialization, urbanization and the potential impacts of global warming on freshwater supply (Araral & Wang, 2013). Moreover, not all water produced reaches the customers to generate revenue for water companies. Instead, a significant portion of it is lost, due to leakage from water mains and unauthorized water use (Wu et al., 2010). The loss of treated water occurs by leakages and overflows from the pressurized pipes and fittings in water undertaker distribution systems and customers' private supply pipes (Lambert, 1994). Increasingly, water loss via leakage is acknowledged as one of the primary challenges facing water distribution system operations. The consideration of water loss over time as systems age, physical networks grow, and consumption patterns mature should be an integral part of effective asset management (Giustolisi et al., 2008). For this, the use of planning and management tools for water management in urban environments became a promising area of study (Tabesh et al., 2014).

With the international trends increasingly leaning toward susceptibility, economic efficiency, water shortages and protection of the environment, the problem of water loss from supply systems is of major interest world-wide, as it affects water companies and their customers (Covas et al., 2005; Holnicki-Szulc et al., 2005; Puust et al., 2010; Wu, 2009). Moreover, the demand for water is rising steadily (Mesquita & Ruiz, 2013).

Historically, when there are high losses in the supply system, it becomes more economical to improve the system, ration water use and perform continuous maintenance to keep the system efficient than to build new systems, which certainly will lead to high installation costs and environmental impact. Issues relating to loss of water must be treated and managed with preventive measures aimed to improve the procedures for maintenance and operation of networks (Trojan & Morais, 2012).

Many studies have been done with the aim of reducing leaks and improving services (Abu-Shams & Rabadi, 2003). However, the leakage reduction problem as a whole is complex and requires coordinated actions in different areas of the water network management, such as the direct detection and repair of existing leaks, general pipe rehabilitation programs and operational pressure control (Morais & Almeida, 2007). While pipes are designed and constructed to maintain their integrity, it is difficult to avoid leakages completely in a pipe system during its entire lifetime. Often, accurate leak detection, which enables a quick response, is necessary to minimize damage (Wang et al., 2002).

There are different solutions for leakage reduction in water distribution networks. One technique for leakage reduction is pressure management, which considers the direct relationship between leakage and pressure (Nazif et al., 2010; Nicolini & Zovatto, 2009). This is because pipe pressure affects leakage in a number of ways, and pressure management can realize a substantial reduction in leakage. The lower the pressure, the lower the frequency of pipe breaks. Additionally, frequent pressure fluctuations may cause fatigue failure in pipes, particularly with plastic pipes (Hunaidi & Wang, 2006).

2.2 What is Non-Revenue Water (NRW)

2.2.1 Introduction

Non-Revenue Water (NRW) can be defined as water that is produced for consumption and lost before it reaches the customer. The amount of NRW is typically represented as a percentage, and is made up of both real and apparent losses, as well as unbilled authorized consumption. Real losses refer to water lost from leaks and water main failures, while apparent losses come from theft and metering inaccuracies. Unbilled authorized consumption comes from water that is provided for public services that is not billed, such as fire hydrants.

One of the major issues affecting water utilities in the developing world are Unaccounted for Water (UFW) now better known as Non-Revenue Water (NRW). According to the International Water Association Task Force on Water Loss (IWA, 2003), non-revenue water is the difference between the volume of water put into a water distribution system and the volume that is billed to customers. NRW is usually expressed in a number of different ways such as:

- Percentage of the water produced from the raw water source which is not accounted for (MWAC, 1999).
- The difference between water delivered to the distribution system and water sold (Yepes, 1995)
- The term NRW refers to an accumulated range of losses that will be experienced by a Water Utility when comparing the system demand of a hydraulic water network with the quantity of water that is acknowledged as consumed by the water consumers residing within the network (UNEP, 2000)
- Lambert (2003) goes further, and defines non-revenue water, as the difference between the system input volume and billed authorized consumption.

Although the above definitions seem to have differences, all have in common that they took the water produced and distributed to the system as an input and the water consumed or exported from the distribution system as an output. From the local context, the UFW has been defined as the water loss calculated as the difference between the amounts of treated water produced and supplied and the total amount of water billed and collected. The volume of water consumption due to the inaccuracy of the water meters as well as the lump sum payments made by the customers when their meters cannot be repaired are also taken in to account for the determination of the NRW (AAWSA,1997).

2.2.2 Components of NRW and Water Losses

In the IWA methodology, all water that enters and leaves the distribution system can be classified as belonging to one of the categories in the water balance table shown in Figure (2.1). Based on table, NRW comprises three components: physical (or real) losses, commercial (or apparent) losses, and unbilled authorized consumption; each of these terms is defined below (Adu Yeboah, 2008).

<table>
<tr><td rowspan="6">System Input Volume</td><td rowspan="3">Authorized Consumption</td><td>Billed Authorized Consumption</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td></td><td>Billed Non-metered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="5">Non-Revenue Water</td></tr>
<tr><td>Unbilled Non-metered Consumption</td></tr>
<tr><td rowspan="3">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to Customers' Meters</td></tr>
</table>

Figure (2.1): The IWA Best Practice Standard Water Balance (Mcintosh, 2003)

- **Authorised Consumption**: the annual volume of metered and/or non-metered water taken by registered customers, the water supplier and others implicitly or explicitly authorised to do so. It includes water exported, and leaks and overflows after the point of customer metering.
- **Water Losses**: the difference between System Input Volume and Authorised Consumption, consisting of Apparent Losses and Real Losses.
- **Commercial(or apparent Losses)** : consists of Unauthorised Consumption and Metering Inaccuracies
- **Physical (or real) losses**; this comprise leakage from all parts of the system and overflows at the utility's storage tanks. These occur as a result of poor operations maintenance, the lack of active leakage control, and poor quality of underground assets. It is "any leakage downstream of a production source and upstream of the consumer revenue meter" (UNEP/IETC, 1999).

- **Unbilled authorized consumption**; these include water used by the utility for operational purposes, water used firefighting, and water provided for free to certain consumer groups.

The first two of these components constitute Water Loss (IWA, 2003). Normally it is the water loss indicators that reflect the level of efficiency of management of the water supply system (Butler and Mamon , 2006). To be able to effect effective reduction in water loss, issues of

technical, operational, institutional, planning, financial and administrative need to be coherently addressed (WHO, 2000 as cited in Butler and Mamon, 2006).

2.2.3 Measuring NRW

The steps for calculating NRW using water balance calculations are as follows (Balkaran and Wyke, 2004):

- Step 1: Obtain System Input Volume
- Step 2: Obtain Billed Metered Consumption and Billed Unmetered Consumption and add together to calculate Billed Authorized Consumption and Revenue Water
- Step 3: Calculate the volume of Non-Revenue Water as System Input Volume minus Revenue Water
- Step 4: Obtain Unbilled Metered Consumption and Unbilled Unmetered Consumption and add together to calculate Unbilled Authorized Consumption
- Step 5: Add volumes of Billed Authorized Consumption and Unbilled Authorized Consumption to calculate Authorized Consumption
- Step 6: Calculate Water Losses as the difference between System Input Volume and Authorized Consumption
- Step 7: Assess components of Unauthorized Consumption and Metering Inaccuracies by best means available, and add these to calculate Apparent Losses[2].

2.2.4 Causes of Water losses

Leakage is usually the major component of water loss in developed countries, but this is not always the case in developing or partially developed countries, where illegal connections, meter error, or an accounting error are often more significant (Farley and Trow, 2003). The other components of total water loss are non-physical losses, e.g. meter under registration, illegal connections and illegal and unknown use (WHO, 2001). There are several reasons for the level of NRW. These are briefly discussed below.

a) Leaks in Water Distribution Systems

The leaks in water systems vary depending on the nature of the soil, the quality of construction, the materials used, the pressure levels and the utilities operating and maintenance

practice (AWWA, 1987). Leakage is often a large source of NRW and is a result of either lack of maintenance or failure to renew ageing systems. Leakage may also be caused for poor management of pressure zones, which result in pipe or pipe-join failure. Although some leakage may go unnoticed for a long time, detection of visible leakage also requires good reporting which also needs a strong public participation[4].

Leakage is one of the components of total water lost in a network, and comprises the physical losses from pipes, joints and fittings and also from over flowing service reservoirs (WHO, 2001). The amount of leakage from a reticulation system varies from location to location, due to differences in construction methods, age, and condition. The condition of the reticulation system is affected by soil movement, corrosive conditions, flow regularity, pipe material, workmanship, age, supply pressure, number of joints and connections, and the occurrence of bursts/cracks result from overburden loading or water hammer. Leakage reduction as a whole is a complex task which requires coordinated actions in different areas of the water network management such as direct detection and repair of existing leaks, pipe rehabilitation program, pressure control system, etc. and many companies use a mixture of these.

b) Pressure and Leakage

Pressure distribution system on the one hand contributes to the increase of leakage, when it is more, and on the other hand when it is low contributes to the shortage of water that as a result causes for unequal distribution of water among residents. To alleviate such problems, some water authorities develop a zoning scheme whereby the complete water distribution network is broken down in to manageable segments that can be easily metered and monitored and analyzed. Pressure variation in distribution network is caused, among others, by changes of demand of users.

Frequent starts and stops of pumps, closure and openings of control valves that induce water hammer are also some of the causes to be mentioned for pipe breakage and water loss. The position of reservoirs also has a great impact on the pressure distribution.

The elevation at which it is desirable to position a service reservoir depends upon both the distance of the reservoir from the distribution area and the elevation of the highest buildings to be supplied. If the served area varies widely in elevation it may be necessary to use two or more service reservoirs at different levels, so that the lower areas do not receive an unduly high pressure. Generally, 45 to 75 meters static pressure is that which best suits the domestic

distribution systems. Pressure below 45 meters will be likely to cause trouble in supplying extensive distribution areas; pressure above 90 meters, tend to result in excessive leakage losses (Twort. et al., 1994).

Pressure control valves are sometimes installed in outlet mains from service reservoirs in order to reduce the pressure to low lying zones, or to limit increases of pressure at night to reduce leakage. Pressure reducing valves (PRVs) throttle automatically to prevent the downstream hydraulic grade from exceeding a set value, and are used in situations where high downstream pressures could cause damage (Walski et al., 2003).

In making a decision to install pressure control devices it should be kept in mind that if the device fails to operate, which usually happened if the equipment is not properly maintained, then the downstream mains will be subjected to a sudden increase. Reducing pressure on the other hand may make existing leaks more difficult to find, because they make less noise, or do not come up to the surface. Therefore, pressure reduction should be coordinated with leakage detection and repair operations (Farley and Trow, 2003).

c) Ages of Pipes and Leakage

Although there are no scientifically based criteria for defining the useful life for water mains, there has been a growing concern that many older urban water distributions are deteriorating that as a result massive rehabilitation will be required to replace mains older than some predetermined number of years in age or “useful life”.

Pipe age and material are important factors contributing to the burst probability of pipes that as a result cause lots of water loss. However, as this information is mostly not available especially for aged pipes, it is usually estimated using the history of the urban development. Reports from undertakings collected by different agencies suggest that

leakage rates from mains are of the order of 100 to 200 L/hr per km for newer mains and 150 to 300l/hr per km for older mains. Assuming an average of 100 connections per km these figures would represent 1.0 to 3.0 L/hr per connection (Twort et al., 1994).

There is a general correlation between the age of a system and the amount of NRW. Newer systems may have as little as 5 percent leakages, while older systems may have 40 percent leakage or higher (Walski et al., 2003). Although age is considered as an indicator for predicting the

break rate of mains, some studies have shown that it is not the major determinant factor for main water break rates. Poor design, deterioration of pipe material and unanticipated load condition will also result in pipe breakage.

d) Effects of Corrosions on Leakage

Corrosion is the problem that is created as water supply pipelines are in continuous contact with soil surrounding it and the water moving through it. The water itself or the surrounding soil may cause problems that will affect the performance and life of the distribution pipes in the system. The majority of the main breaks occur at locations where the pipe wall has been weakened due to corrosion of metal pipes. Corrosion of the external surfaces of cast-iron or steel pipes can, under some conditions, be a significant problem. Therefore, ductile-iron or steel pipelines placed in aggressive soils must be protected by coatings with corrosive resistant materials. The characteristics of the soil in which a pipe is placed affect the rates of corrosion.

Some soils such as clays and other highly organic soils can be extremely corrosive, though corrosive condition can exist in non-corrosive soils too. Soil conditions are responsible for the exterior corrosion of metal structures under or in contact with the ground. On the other hand, internal corrosion of pipes in unlined pipes walls may be caused by intermittent flow conditions.

e) Meter Error and Water Loss

Under registration of customer meters is also one of the causes of water loss. Like the ages of pipes, ages of meters also has an impact to the increase of water loss. Customer meter errors include errors due to accounting procedure and errors due to under or over registration of the metering units. Many countries especially developing countries are experienced losses of water due to under registration of meters that many of them put meter replacement policies to alleviate the problem.f

The selection of customer meter types and classes may be limited by water quality considerations, as well as technical and economic considerations. Economic replacement policies for residential meters based on selective testing programs in the National Reports generally indicate changeover periods between 5 and 10 years. Where customers are served by way of roof tanks, the probability of customer meter under-registration is increased, because of the tendency for a greater part of the consumption to pass through the meter at rates less than the Q minimum specified for the meter (Lambert, 2003).

Domestic water meters tend to under register for two reasons, i) malfunctioning due to deterioration with use, and ii) inability to measure low flows accurately. Much larger under registration can occur where maintenance of meters is poor. An under registering meters and any meter stoppage could be noted immediately if meter readers are alert to compare readings of one specific meter with its past readings, but in reality this situation doesn't happen (Twort et al.,1994).

2.2.5 Benefits of Reducing NRW

a) Improvement in demand management policies

NRW reduction and control is one area of demand management where the objective is to limit the demand for water services by users. The utility is one such user, a major one at that, and continued water loss impacts negatively on the effort to limit demand. This can be translated into economic terms, as more efficient use of existing supplies becomes an increasingly cost effective alternative to supply augmentation and management (Versteeg and Tolbom, 2003).

There are several economic benefits of reducing NRW:

- It costs money to produce water - in terms of chemicals, energy, staff and maintenance of the infrastructure. Reduced NRW means increased savings in these areas;
- Capital costs for expansion works to meet the demands for uncontrolled water use can be deferred. These savings can be applied elsewhere;
- With the attendant increase in revenue water, additional income is available to the utility for its use;
- There will also be reduced costs to the treatment of wastewater due to reduced flows to the treatment works.

b) Improved public perception of utility

Once a programmer for NRW reduction and control is instituted, this should redound to the benefit of the Authority as the public sees its efforts bearing fruit. Improved service, fewer leaks and extension of the distribution system are some of the positive outcomes of reducing NRW. However, there is need for the programmer to be properly communicated nationally so that the good work is not viewed as disruptive, and without any information being provided as to the long-term benefits.

2.2.6 Strategy for Dealing with Water Losses

Undoubtedly leakage detection and control is more and more an up-to-date issue that water utilities have to deal within the management of water distribution systems, in order to increase the profits, as well as to satisfy the customer needs. The obvious answer to this problem is not to wait till it increases and ends up in significant and locatable ruptures, but to solve it with the implementation of an integrated strategy of action.

Perhaps the two most important components of NRW are the real losses and the apparent losses. These two components need much resource in terms of logistics, staffing and finance in order to control water losses. The third component, unbilled authorized consumption can be controlled fairly well without much resource. It is therefore important to develop the appropriate strategies for controlling water losses especially through real and apparent losses if meaningful achievements are to be made and the outcome would justify the efforts put in. The starting point to deal with water losses in any water utility, according Butler and Mamon (2006), is to understand the network system of the utility.

Butler and Mamon (2006), suggest that certain questions should be posed about the water utility with regard to the characteristics, the production process, and the operating practices, and using the available tools and mechanisms within the water utility to answer these questions as the first step in the right direction to deal with the prevailing situation. Butler and Mamon (2006) suggest the following questions

- How much water is being lost?
- Where is it being lost from?
- Why is it being lost?

Table (2.1) below is a summary of the tasks required to address the above questions.

According to Butler and Mamon (2006), the first two questions, “how much” and “where from”, can be answered by conducting water balance referring to Figure (2.10), which shows the components of water losses from a network, “the difference between system input volume and authorized consumption”, water balance can be conducted.

Table (2.1): Tasks and Tools for Developing Strategies for the Management of NRW (Butler and Mamon, 2006**)**

Question/Solution	**Task**
How much water is being lost? - Measure components	Water Balance: - Improve estimation/measurement techniques - Meter calibration policy - Meter checks - Identify improvements to recording procedures.
Where is it being lost from? - Quantify leakage - Quantify apparent losses	Network Audit: - Leakage studies (reservoirs, transmission mains, distribution network) - Operational/customer investigations
Why is it being lost? - Conduct network and operational audit	Review Network Practices: - Investigate. - Historical reasons. - Poor practice. - Quality measurement. - Procedure. - poor materials/infrastructure. - Local/political influences.
How to improve performance? - Upgrade the network - Design a strategy and action plans	Strategy Development: - Update record systems. - Introduce zoning. - Introduce leakage monitoring. - Address causes of apparent losses - Initiate leak detection/repair policy. - Design short/medium/long-term action plans.
How to sustain performance? - Ensure sustainability with appropriate staffing and operational structures.	Training and Operation and Maintenance (O&M) - Improve awareness. - Increase motivation. - Transfer skills. - Introduce best practice/technology. - Community involvement. - Water conservation/demand management programmes. - Monitor action plan recommendations. - Introduce O&M procedures.

The third question “why is it being lost” can be answered by reviewing the management practices of the water system. The reviewing processes should identify the policies and procedures that need reviewing and those which are being done well. Having addressed the first three questions, “how? where? and why? "of the losses in the system, it then becomes possible to address the last two questions which have to do with issues of strategies, policies and methodologies that need to be formulated and adopted to address the system’s losses and improve performance and how these strategies be maintained or sustained?. According to Butler and Mamon (2006), the strategies, methodologies and policies referred to above do not only entail “introducing equipment for measurement and monitoring flows, leakage control equipment and leak repair policies, but also education and awareness programmes and a fully operational policy”.

The two tools; water balance and network review, would enable priority areas to identified and tackled. According to Thornton (2002), the above tools would enable the utility to identify the priority areas and this would mean tackling apparent losses first or vice versa depending upon the outcome of the processes so far described.

At last, after decreasing the level of leakage to a satisfactory rate, it must be implemented a continuous monitoring system that permanently assesses the performance of the system and induces location of areas with problems in the future. The monitoring system is a computer based system in order to gather, to process and to analyze the greatest amount of data in the shortest period of time. Computer simulation of the hydraulic system would help significantly at this stage. It will be emphasized expert methods, techniques and instrumentation related with the implementation of each stage (Coves and Ramos, 2000).

2.3 The Challenge at Surif Water Distribution System

The need for efficient management of water resources and the accurate metering of water flows are specific issues that require high priority attention in today’s international climate of environmental sustainability and conservation of natural resources.

It is commonly accepted that any water network cannot avoid losing water throughout its path, it is vital and of high priority to ensure that these level of losses are known and controlled, and that they do not exceed the pragmatic level that is technically and economically manageable on given infrastructures. It is worth noting that it is particularly true in cases where the production cost of water is high (as is the case in the most Palestinian cities and towns), the requirement of transporting water over long distances and of water scarcity, with customers with low financial capabilities.

The available data indicate that the level of water loss is above 40%. The data most properly is both incomplete and the cause of considerable concern regarding its accuracy. Most cities and towns in Palestine have a water loss in their distribution systems between 36% and 50 % depending on the source of data and its deficiencies. The reasons for these deficiencies include: Inaccuracies in billing volumes and the method of estimating consumptions through faulty meters; and the differences in volumes dispatched from tanker filing stations as recorded by meters and the payment system. However the available data highlight the areas that need urgent attention and provide an indication of the magnitude of the problem.

The definition and implementation of a strong Metering and Non-Revenue Water Strategy will supply a starting point for Surif Municipality to allow for the proper assessment of losses within technical and economical limitations.

The main regions in Surif (Bekaa , Wadi-Ain Surif , Batan Al-hawa , Habala, Wadi-Jdur, Aqaba , Der-Enell , Qurna, Dafa Alzahoh ,Qlava, Der-Mousa, Al-Bustan) is supplied with water from the municipality network. via transfer pipelines with diameters ranges from 0.75 inch to 12 inch , shown on the figure(2.2). The water is provided to the town from the PWA with quantity varies from 1400 to 1500 m3 per day , this quantity is variable from one month to another depending in many factors such as season, politics.

Chapter Three

Characteristics Of The Project Area

3.1 General

3.2 project area

3.3 metrological data

3.4 population

3.5 Water supply

3.6 Water Distribution System

3.1 General

In this chapter, basic data of Sourif town will be discussed, location of the project, Topography, meteorological data, Population data, water consumption, and description after water distribution networks, supported by maps and figure .

3.2 Project Area

Sourif is a town in Hebron Governorate located 18 km north of Hebron city in the southern part of the West Bank. Located between Hebron and Bethlehem Governorates, the town is bordered by Beit Ummar and Safa to the east, Al Jab'a to the north (Bethlehem Governorate), the 1949 Armistice Line (the Green Line) to the west, and Kharas to the south (See figure 3.1) which shows the Location of Sourif town and(See Figure 3.2) which shows the Aerial photograph of Sourif town .

Sourif town extends over a mountainous area west of the Halhul Mountains, at an elevation of 575 – 600 m above sea level , Its lands lie south-east to the northwest. Some of the upper reaches of the wadis that descend north-west toward Bab al-Wad pass from Sourif. Sourif consists of dwellings built of stone, concrete or mud. They are overcrowded, separated by narrow alleys, and their outline takes the form of a rectangle extending from west to east. The urban extension of Sourif runs along the road leading to Beit Ummar and the Hebron-Jerusalem road, it creeps eastward and north-east. figure (3.3) shows the DEM (digital elevation model) for Sourif town.

3.3 Meteorological Data

The hydrology of region depends basically on its climate, and secondary on its topography. Climate is largely dependent on geographical position of the earth surface, humidity, temperature, and wind .These factors are affecting on evaporation and transpiration. So this study will include needed data about these factors , since they play big role in the determination of water demand.

The climate of Sourif town tends to be cold in winter with limited amount of rain , and warm in summer and relatively humid .

Climate can be divided in general for two seasons:

A) Rainfall season ,usually start in October and reach its peak in February then decrease gradually in May month .This climate consist of three seasons winter season, and part of spring, autumn season .

B) Dry season consist of summer and part of spring, and autumn seasons .It start from May till September and sometimes continue to October month.

The climatological data presented in the following section were obtained from survey carried out by the meteorological station of Hebron city.

3.3.1 Rainfall

The average annual rainfall in Sourif town is about 450 mm per year and the relative humidity varies Almost (64)% this information from Sourif municipality . The driest month is June, with 0 mm of rainfall. The greatest amount of precipitation occurs in January, with an average of 204mm.The monthly rainfall of Sourif town is shown in table (3.1) .

3.3.2 Temperature

The temperature is characterized by considerable variation between summer and winter times . The mean temperature values at Sourif town are given in table (3.1).The following minimum and maximum values were shown :

- The mean maximum temperature : (28) ˚C
- The mean minimum temperature : (13) ˚C

Table (3.1) :Meteorological Condition At Sourif Town Weather Station for (2011- 2016). The climatological data presented in the following section were obtained from survey carried out by the meteorological station of Hebron city.

Month	Rainfall (mm)	Maximum Temperature (˚C)	Minimum Temperature (˚C)	Relative Humidity (%)
January	110.5	13.2	5.3	74.4
February	97.8	14.7	7.1	69
March	48.2	17.5	8.4	64.9
April	50.4	28	13.8	47.9
May	10.3	24.8	14.5	55.4
June	0	27.2	17.2	57.2
July	0	28.8	18.7	56.6
August	0	29.9	19	63.6
September	3.6	27.3	16.4	69.9
October	28.6	24.4	14.7	65
November	48.3	19.1	10.9	67.6
December	155.7	13.8	6.5	76.6

3.4 Population

3.4.1 Population projection

The base for the forecast is the 2016 population for Sourif town obtained from Municipality of Sourif of 18200 parsons. The annual growth rates is 3.2%Which is high when compared to the rate of population growth in the West Bank(See figure 3.4) .

To calculate the population for the coming 25 year, a geometric increase is assumed, represented by the following equation.

$P_f = P0 * (1+ r)^n$ ……...(equation 1)

Where :

P : Future population.

P_o : Current population.

n : Time period (25 years).

r : Population growth (rate).

based on the previous data for Sourif population

3.4.2 Population Forecast for Sourif Town

The population forecast for the year 2043.Is shown in table (3.2) . The data show that the population of Sourif town is estimated to be 40000 in year 2042 by equation 1.

Table(3.2) : Presents the population projection up to the year 2042 to Sourif

Year	**2017**	**2022**	**2027**	**2032**	**2037**	**2042**
Population(capita)	**18200**	**21304**	**24938**	**29192**	**34172**	**40000**

3.5 water supply :

The main source of water in the town is the Israeli Water Company (MEKOROT), though alternative sources of water in the town exist, including cisterns, water tanks and springs. The town has seven springs, though only Al Mezra'a, "Ein Kalafa, and Wad Helwas springs are currently in use. These springs are used solely as watering holes for livestock. In addition, the town has a water reservoir of 1000 cubic meters.

The water services in Sourif are suffering from many problems such as:

1. Lack of water accessibility in the higher regions of the towns.

3. Insufficient capacity of water reservoir in the town.

3.6 Sourif water networks

3.6.1 Description of Sourif water network :

The Sourif water network has been established since 1973 and extends from the beginning of the town until its end and nearly 95% of the housing units are connected to the network , the rest is supplied with water by tanks . figure (3.5) shows the water distribution network and figure(3.6) shows the distribution of the water with the contour.

In addition of that there is a storage tank its located in Al-aroq store and distribute water from Beit Ummar with capacity 1000 m^3 it is elevation is(850 m) See figure (3.7) Which shows pictures of Sourif tank.

Water was distributed throughout the year as the available amount of water was insufficient to provide all areas at the same time

3.6.2 pipelines situation :

The pipe lines at Sourif water network is of various life spans, some parts of the network have been changed and improved and the others need to be improved because its life span have been expired, while some lines exceed 30 years in its life span , and became scratched.

The situation these pipelines varies between good ,medium and bad conditions, it can be classified as follows :-

• pipelines have been changed from 2"(inch) to 4"

• New pipelines have been added and some old pipeline improved from 2" to 4".

• Improvements and changing are still done on network.

3.6.3 Water Network problems :

1. Life span of the network is irregular .
2. insufficient amount of water supplied by the Water Authority .
3. The pressure is uneven in the network due to absence of pumps.
4. The difficulty of the terrain in the town .
5. Many regions are away from the city canter.
6. Very high quantity of the water losses

figure (3.7): pictures of Sourif tank

3.6.4 Water network future plan

Jaba-Nuba Transmission Main Phase II Project

With funding from the American people, and in cooperation with the Palestinian Water Authority and Sourif Municipality, Kharas Municipality, Nuba Beit Ula Municipality and Hatta village council, Arab Brothers is implementing the second phase of Jaba Nuba Transmission Main Pipeline Project .

The objective of this project is to improve the water system and expand services to new customers in order to bring clean water to the northwest villages of the Hebron Governorate, this project includes.

Constructing new transmission pipelines, Rehabilitating of the existing transmission pipeline, Constructing new distribution pipelines, Constructing new service connection chambers, Improving existing water reservoirs, and constructing new booster pump stations. Project implementation is expected to last 390 days, ending in December 2017.

Chapter Four

Materials And Methodology

4.1 General Background

4.2 Data Collection

4.3 AWWA Water Audit Software

4.1 General Background

The study of the quantity of water losses is an important indicator of the positive or negative evaluation of water distribution efficiency, both in individual years and as a trend over a period of time. High and increasing annual volumes of water losses, which are an indicator of ineffective planning and construction, and low operational maintenance activities, should be the trigger for initiating an active leakage control program.

The main objective of this chapter is to explain the methodology carried out to estimate the quantity of water losses from the water network in the study area, in order to determine the efficiency of the water distribution systems in the project area. The works require collecting data from the municipality. The type of data required should be of best available quality and cover five years. Any missed data will be covered by measurements, estimation or assumption.

4.2 Data Collection

Before data collection, several visits were made to the Surif municipality in order to screen and investigate the current situation of the water distribution networks and to check the availability of data needed for fulfilling the purpose of the study. The researcher met and interviewed the chief engineer for the water network and other engineers and technicians from the water operation department in the municipality and discusses with them the issue of water losses.

For the purpose of the present study and in order to estimate and audit the water losses in the water distribution network of the study area, data sheet presented in table (4.1) were prepared in order to collect the data and information necessary for water auditing using American Water Works Association (AWWA) free Water Audit Software. The data sheet includes also some questions regarding the policy for reducing water losses.

The data sheet is divided into three sections. In the first section, we have to fill basic information about the name of the city or utility with full address and year of reporting. Section two is reporting worksheet which includes the data of water supplies, authorized consumption, apparent loss, system data, and cost data. Water loss reduction management questions are given in section three that includes questions in procedures and policy, and obstacles for fighting water losses.

4.3 AWWA Water Audit Software

The level of water losses can be determined by conducting a Water Audit with the results shown in a Water Balance consistent with the international terminology. A Water Balance is based on measurements or estimations of water produced, imported, exported, used and lost. Being aware of the problem of different water balance formats and methods, the International Water Association (IWA) was established a standard water balance shown in Figure (2.1).

American Water Works Association developed Water Audit Software based on the standard water balance. The software has capable of analyzing losses in it is different categories and calculating the revenue and non-revenue water and other parameters.

Table (4.1): Data Sheet for Water Loss Information.

A- Basic Information

Name of City or Utility:			**Country:**		
Reporting Year:		**Start Date (MM/YYYY):**		**Start Date (MM/YYYY):**	
Name of Contact Person:			**E-mail:**		
Telephone:		**Fax:**		**Mobile:**	
Reporting Units for Water Volume:					

B- Reporting Work Sheet

1.	Water Supplies	2012	2013	2014	2015	2016
1.1	Volume from Own Sources					
1.2	Master Meter Error Adjustment					
1.3	Water Imported					
1.4	Water Exported					
2.	**Authorized Consumption**	**2012**	**2013**	**2014**	**2015**	**2016**
2.1	Billed Metered					
2.2	Billed Unmetered					
2.3	Unbilled Metered					
2.4	Unbilled Unmetered					

3.	Apparent Losses	2012	2013	2014	2015	2016
3.1	Unauthorized Consumption					
3.2	Customer Metering Inaccuracies					
3.3	Systematic Data Handling Errors					
4.	**System Data**	**2012**	**2013**	**2014**	**2015**	**2016**
4.1	Length of Mains					
4.2	Number of Active and Inactive Service Connections					
4.3	Average Length of Costumer Service Line					
4.4	Average Operating Pressure/Bar					

5.	Cost Data	2012	2013	2014	2015	2016
5.1	Total Annual Cost of Operating Water System (₪)					
5.2	Costumer Retail Unit Cost (Applied to Apparent Losses) (₪)					
5.3	Variable Production Cost (Applied to Real Losses (₪)					

C- Water Loss Reduction Management

1.	Procedures and Policy	Yes	No
1.1	A National Water Policy Exists Which Aims At Reducing Water Losses		
1.2	A Water Loss Reduction Program is Implemented		
1.3	Pressure Management is Used to Reduce Water Losses		
1.4	A Network Maintenance/ Rehabilitation Program is Implemented		

1.5	Measures to Fight Illegal Connections are Applied		
2.	**Obstacles for Fighting Water Losses**	**Yes**	**No**
2.1	Institutional Situation		
2.2	Lack of Financial Means		
2.3	Lack of Appropriate Technologies		
2.4	Maintenance System		
2.5	Personnel capacities		
2.6	Personnel Awareness		
2.7	Public Acceptance / Awareness		

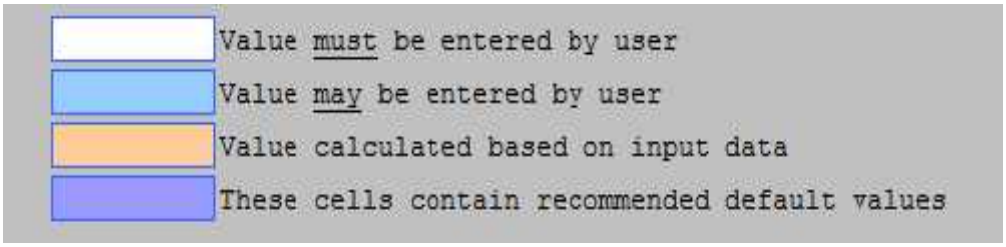
Determination of water losses is a complicated operation; it needs a clear methodology to obtain the necessary information efficiently. Water losses has been evaluated using AWWA software. Methodology determining water losses as of follows:

1. obtained Sourif data sheet contained data about network of water distribution from 2012 to 2016, these data help in determining water losses .

2. In order to determine real water losses AWWA software has been used by interring data from municipality. These software has more than one spreadsheet PURPOSE:

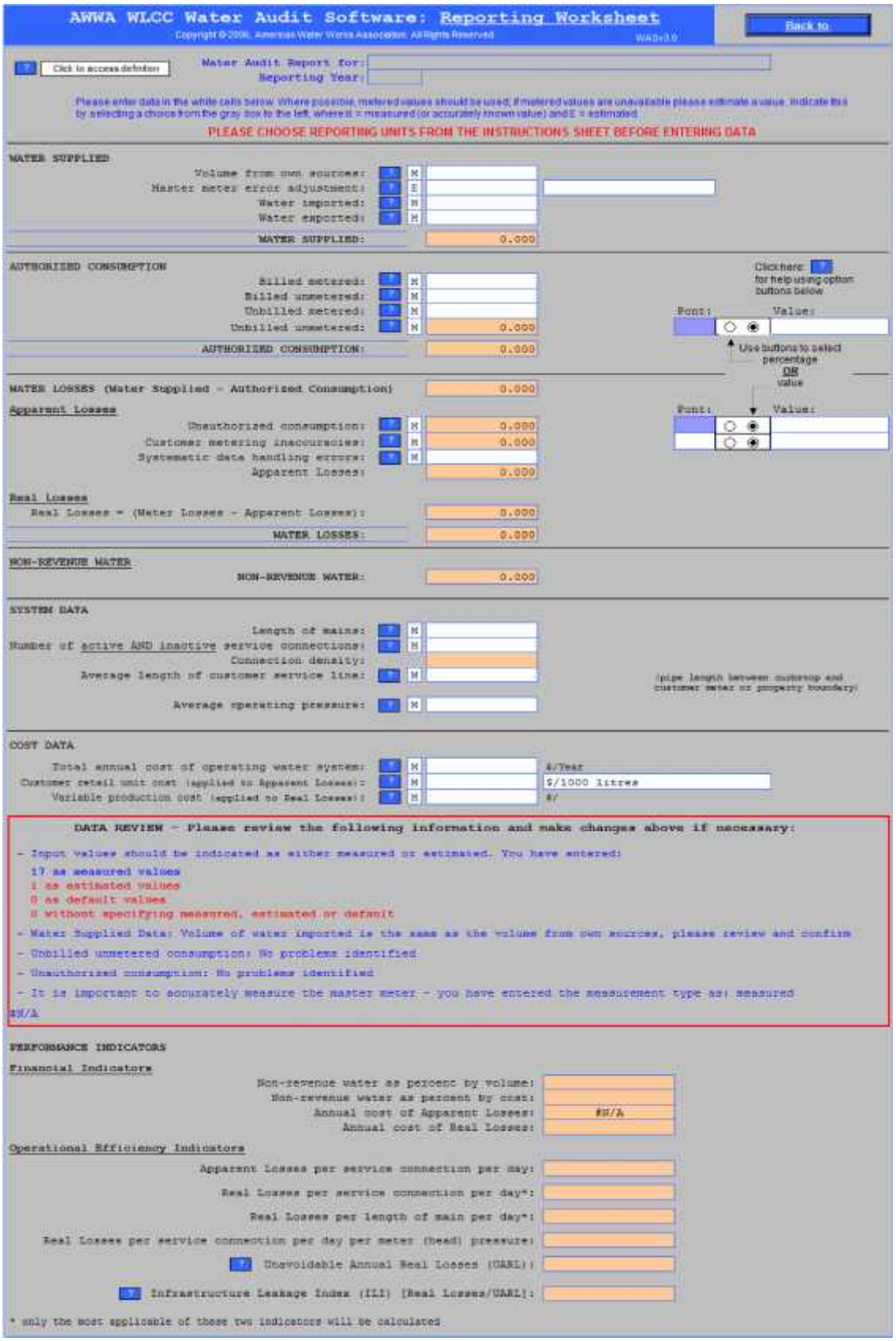
This spreadsheet-based water audit tool is designed to help quantify and track water losses associated with water distribution systems and identify areas for improved efficiency and cost recovery as follow:

- **Instructions**: The spreadsheet contains several separate worksheets. Sheets can be accessed using the tabs towards the bottom of the screen, or by clicking the buttons on the left below. Descriptions of each sheet are also given below.



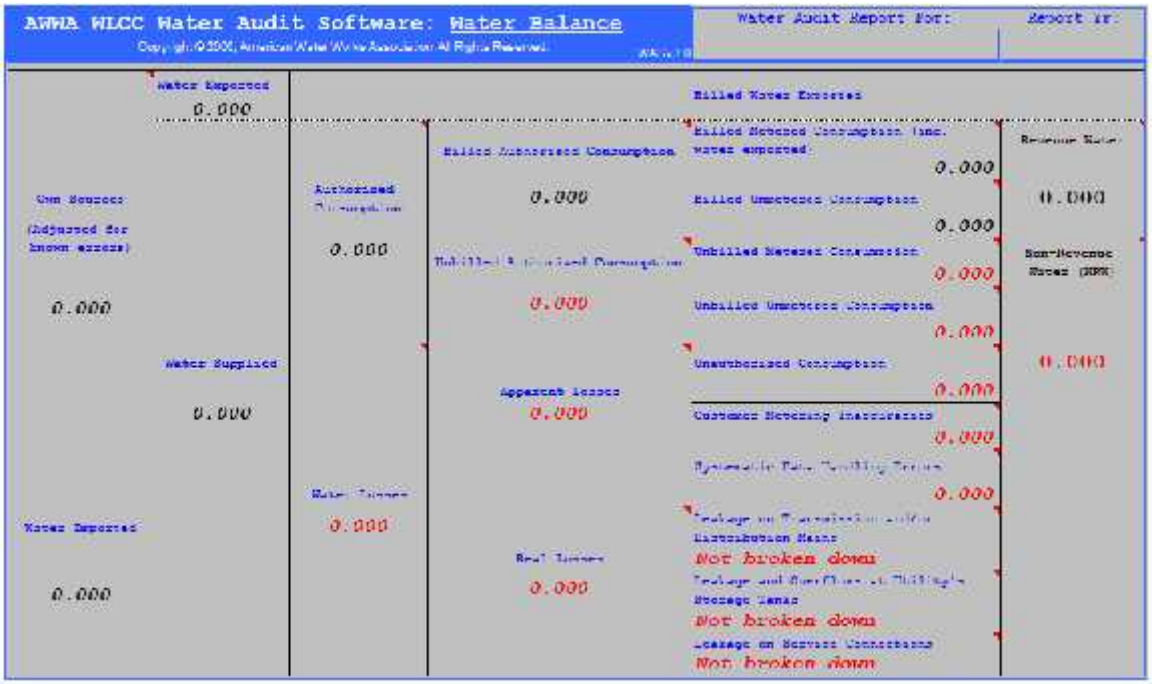
Fig(4.1): Explain each box what it means.

- **Reporting worksheets**: Metered value should be interred in the white cells (measured), if metered values are unavailable, an estimate data should be use. In this study only measure data used. The below figure is a part from reporting worksheet.



Fig(4.2): Part of reporting worksheet from AWWA.

- **Water balance** : In this part contain from revenue and non-revenue water. revenue water is known value which interred by the user. While the non-revenue water measured by the software.



Fig(4.3): Part of water balance from AWWA.

- **Definitions :** This part explains terminologies and their descriptions it is filled in the table (4.2) as follows:

- **Water losses standing:** Once data has been entered into the reporting worksheets, the performance indicators are automatically calculated. The AWWA water loss control committee provided the following table to assist water utilities is gauging an approximate infrastructure leakage index (ILI) that is approximate for their water system and local condition as shown in table (4.3)

  This table offers an approximate guideline for leakage reduction target-setting. The best means of setting such target include performing an economic assessment of various loss control methods.

Table (4.2):.AWWA WLCC water audit software definitions.**Error! Not a valid link.**

Table (4.3): General guidelines for setting a target ILI.**Error! Not a valid link.**

Chapter Five

Analysis and results

5.1 General

5.2 Results for Sourif Town

5.3 strategy of water losses in Sourif Town

5.1 General

In this project an attempt is made to study and evaluate the problem of non-revenue water through public water network in Sourif Town that effects the operating of water systems and how these problems may be reduced through effective mitigation measures develops planes and procedures in accordance with PWA corporate policy to deal with this problem that effect PWA (Palestine water Authority) ability to provide the best water services to the people in Palestine.

The study was carried out for Sourif Town in the north of Hebron city, where the water distribution network is old and the water losses is high. All the necessary data are collected using a design data sheet and the analysis was carried out using water losses and auditing software developed by American water work Association (AWWA). In this chapter, the analysis and discussion of result are presented along with the strategy of waster losses in Palestine.

5.2 Results for Sourif Town

5.2.1 Description of water network

At present, the existing water supply system of Sourif Town is almost entirely supplied mainly by water coming from Palestine Water Authority (PWA).

The water in the area is distributed directly by a network of steel pipes, most of them are very old and some of them are exposed traffic. The pipelines range from 0.75" to 12" in diameter as listed in table (5.1) and mentioned earlier , many of the pipes are in bad state of (main tranke). The total length of the network pipe is about 60 Kilometer and it includes other components as air valves, pressure reduce valves and non-return valves.

The existing water distribution network of Sourif Town was shown in figure (3.5) in chapter three.

Table (5.1): The components of Existing Water Distribution Network.

Component	Length	Number
0.75 (inch)	2.66 Km	-
1 (inch)	16.11 Km	-
2 (inch)	19.13	-
4 (inch)	15.8	-
6 (inch)	3.1 Km	-
12 (inch)	3.2 Km	-
Pressure Valve	-	5
Air valve	-	10
Non return Valve	-	6
Tanks	-	1

5.2.2 Water losses and water Balance

The analysts of water losses in the study area was carried out using water loss and auditing software developed by American water works Association (AWWA) version 3.0 . The data obtained for Sourif Town was entered in the reporting sheet of the software for each year from 2012 to 2016 and the results of water losses and water balance were predicted as shown in table (5.2).

The sample of reporting sheet amounts for years 2012 to 2016 are presented in Fig(5.1) to fig(5.5).The results of water balance percentages for years 2012 to 2016 is illustrated in Fig (5.6) to Fig(5.10).

The percentage values of apparent losses, real losses and total losses, along with non- revenue water, for Sourif Town are presented table (5.3), and the same data are shown in Figure (5.11) and (5.12).

Table (5.2): Data Sheet for Water Loss Information.

A- Basic Information

Name of City or Utility:	**Hebron city**			**Country:**	**Sourif**
Reporting Year:	**2017**	**Start Date (MM/YYYY):**	**2/2017**	**Start Date (MM/YYYY):**	**----------**
Name of Contact Person:	**Fida Al-Qadi**			**E-mail:**	**Fida.alqadi@yahoo.com**
Telephone:	**2523001**	**Fax:**	**2523002**	**Mobile:**	**0599888259**
Reporting Units for Water Volume:	**m^3/ Year**				

B- Reporting Work Sheet

1.	Water Supplies	2012	2013	2014	2015	2016
1.1	Volume from Own Sources	613039.72	557430.63	730389.04	816806.54	699298.85
1.2	Master Meter Error Adjustment	1	1	1	1	1

1.3	Water Imported	0	0	0	0	0
1.4	Water Exported	0	0	0	0	0
2.	**Authorized Consumption**	**2012**	**2013**	**2014**	**2015**	**2016**
2.1	Billed Metered	373387	364209	358420	378346	430326
2.2	Billed Unmetered	0	0	0	0	0
2.3	Unbilled Metered	0	0	0	0	0
2.4	Unbilled Unmetered	0	0	0	0	0
3.	**Apparent Losses**	**2012**	**2013**	**2014**	**2015**	**2016**
3.1	Unauthorized Consumption	1533.45	1394.5	1826.3	2042.2	1748.5
3.2	Customer Metering Inaccuracies	13543	13210	13000.3	13722	15608
3.3	Systematic Data Handling Errors	28327.07	16432.54	20463.50	21495.71	18935.30
4.	**System Data**	**2012**	**2013**	**2014**	**2015**	**2016**
4.1	Length of Mains	53 km	54 km	55 km	58 km	60 km

4.2	Number of Active and Inactive Service Connections	2568	2672	2751	2930	3017
4.3	Average Length of Costumer Service Line	15	18	20	22	25
4.4	Average Operating Pressure/Bar	(9 – 15)	(8 – 15)	(12 – 15)	(13 – 15)	15
5.	**Cost Data**	**2012**	**2013**	**2014**	**2015**	**2016**
5.1	Total Annual Cost of Operating Water System (₪)	102279	78219	100678	390453	226022
5.2	Costumer Retail Unit Cost (Applied to Apparent Losses) (₪)	20616	35166	67703	79797	48953
5.3	Variable Production Cost (Applied to Real Losses (₪)	219929	150713	290136	341993	209783

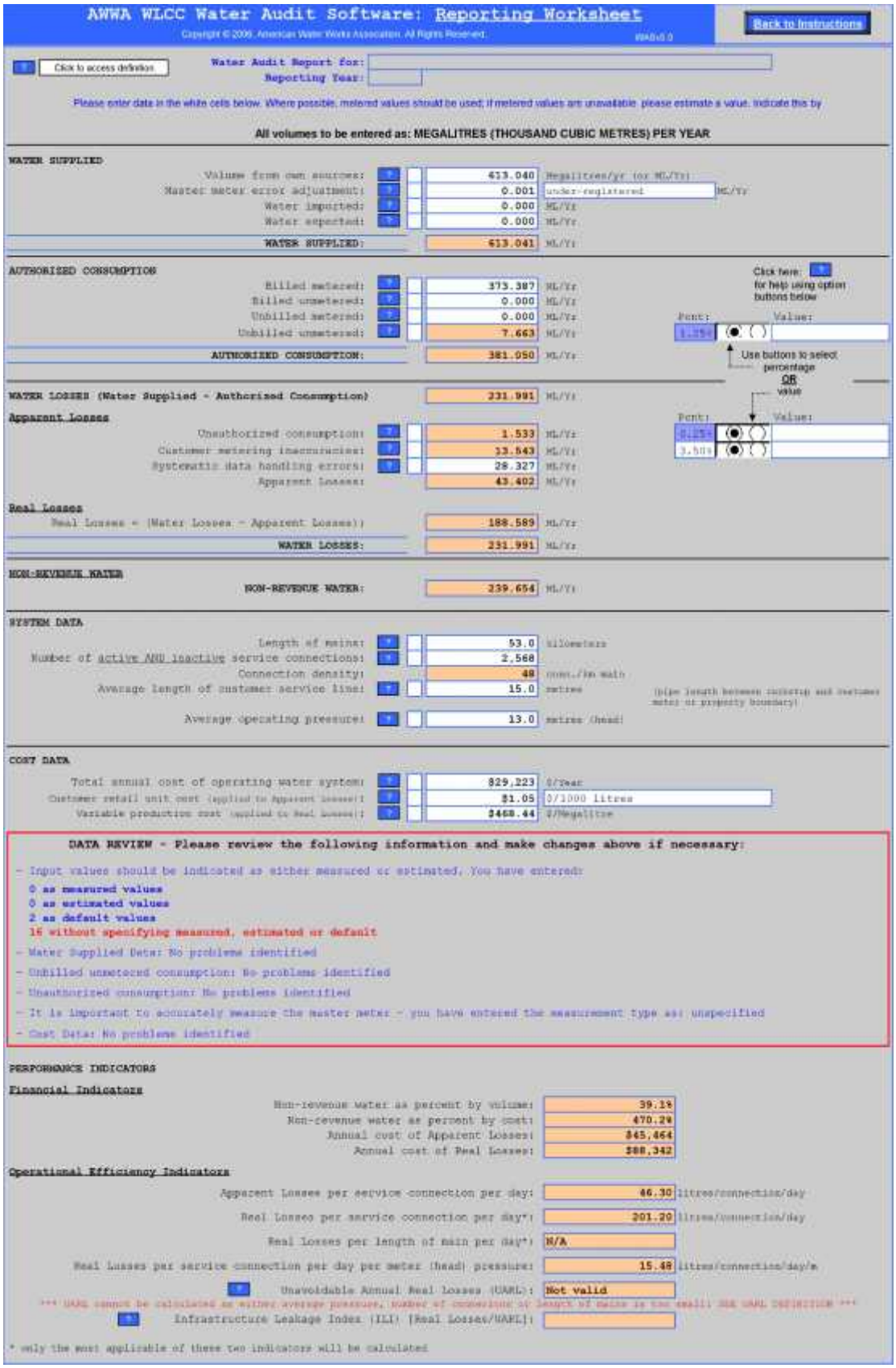


Figure (5.1): Reporting worksheet for year 2012 of Sourif Area.

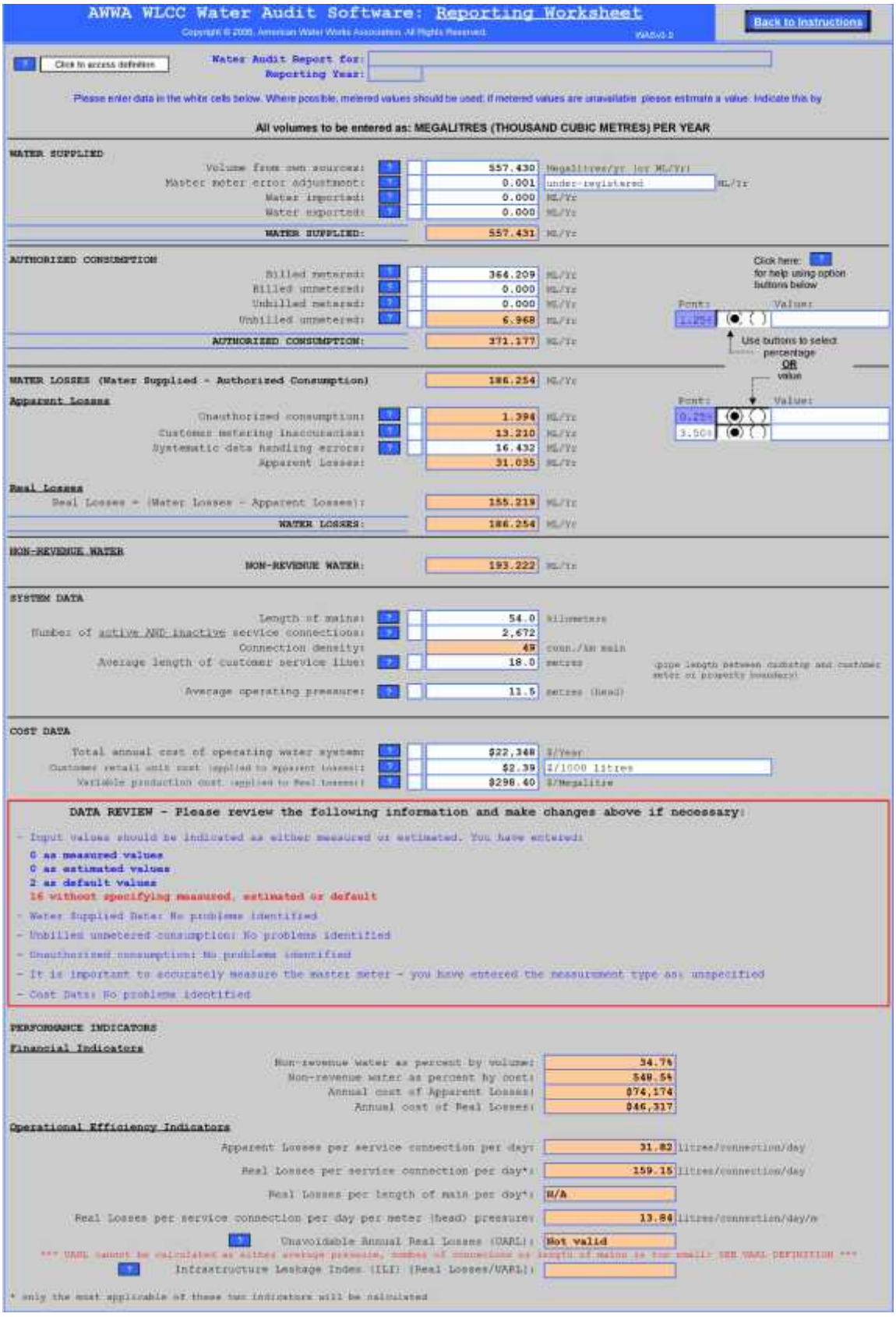


Figure (5.2): Reporting worksheet for year 2013 of Sourif Area.

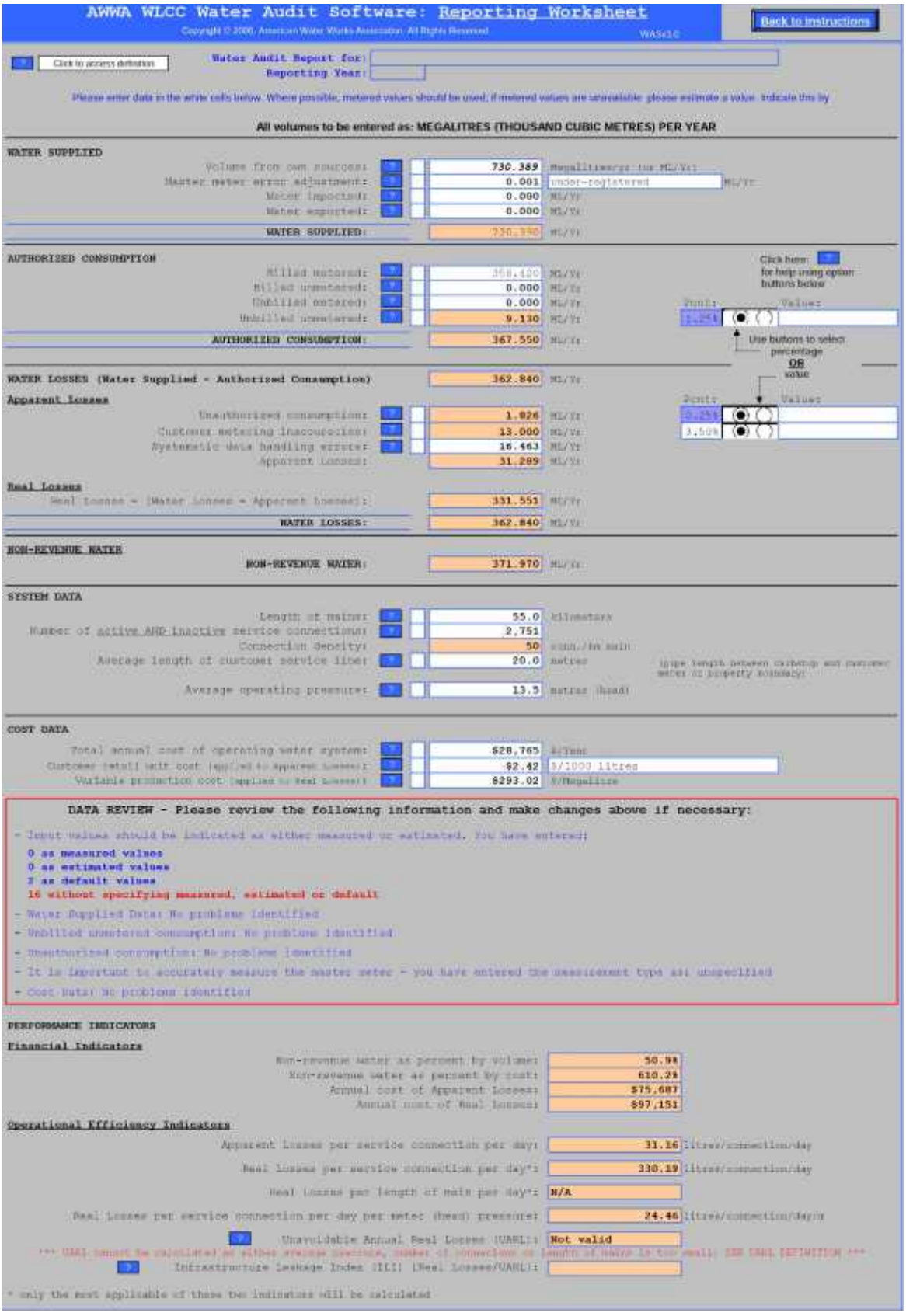


Figure (5.3): Reporting worksheet for year 2014 of Sourif Area.

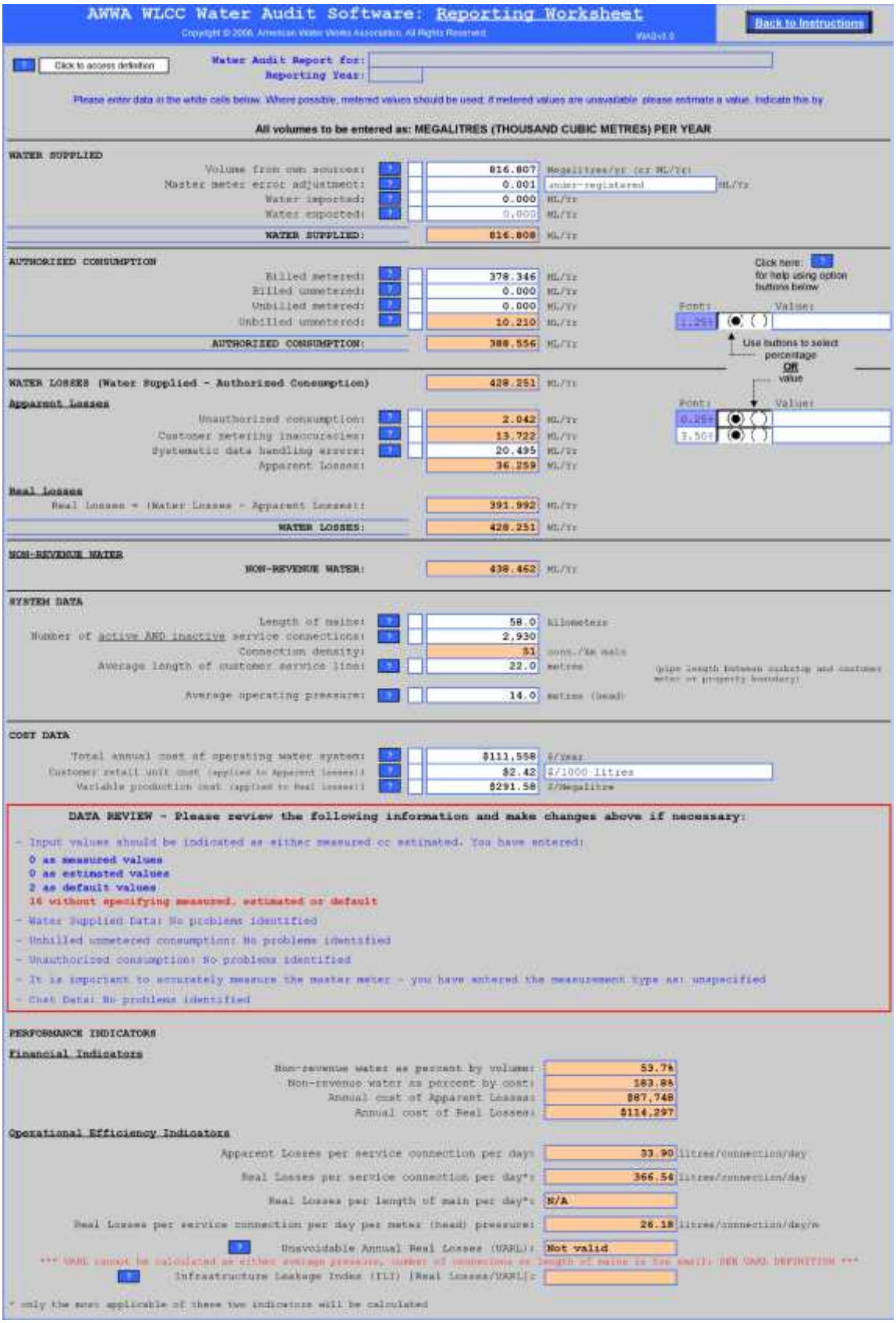


Figure (5.4): Reporting worksheet for year 2015 of Sourif Area.

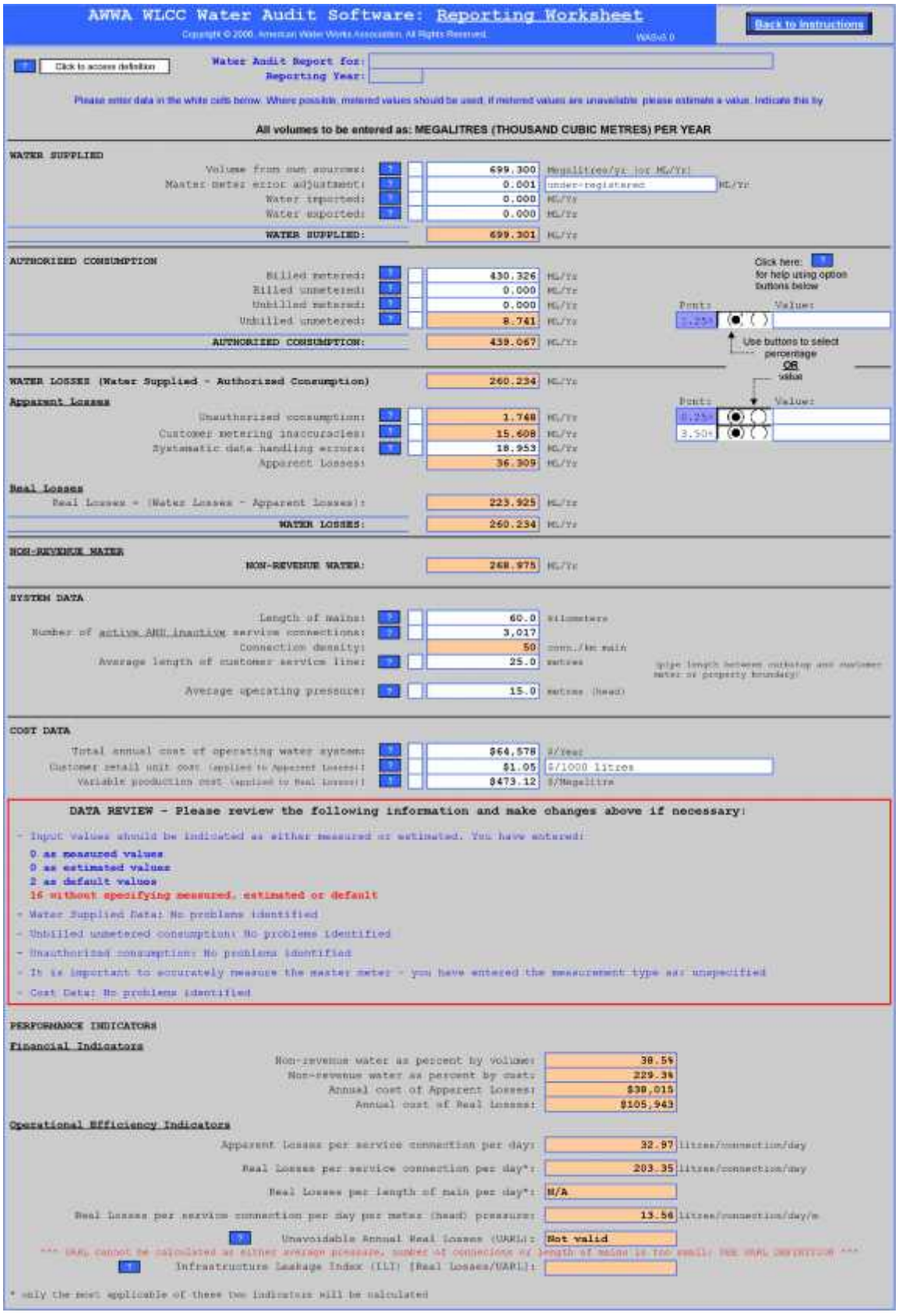


Figure (5.5): Reporting worksheet for year 2016 of Sourif Area.

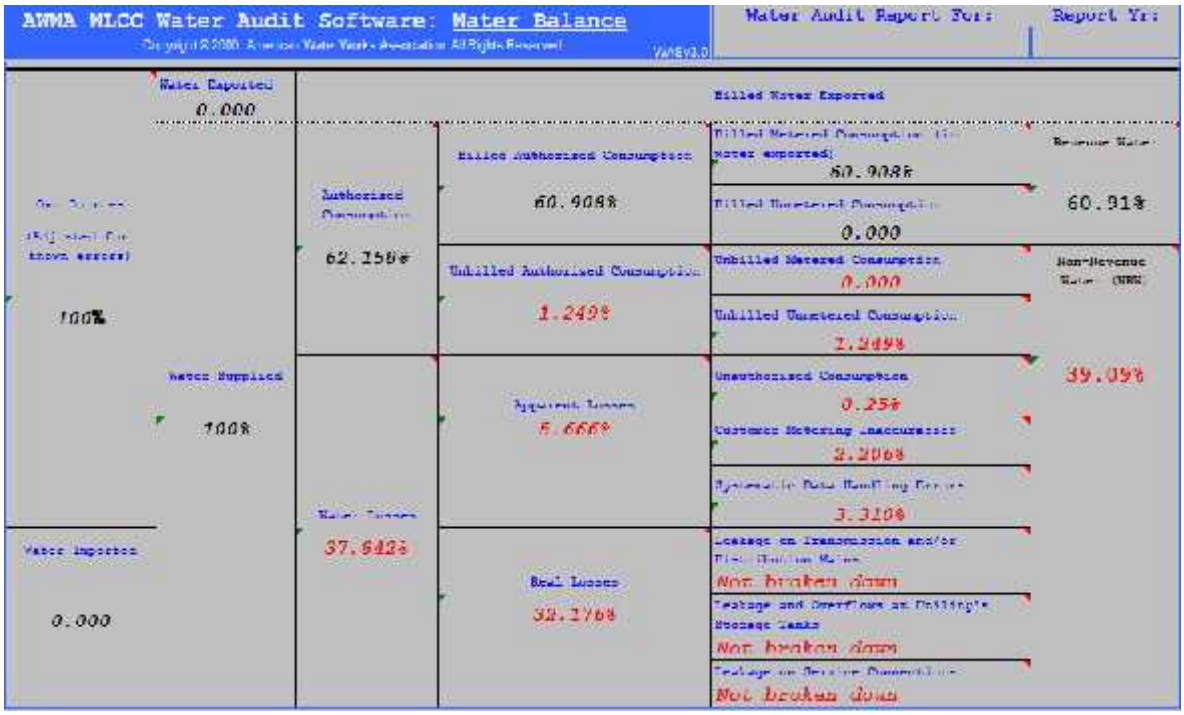


Figure (5.6): Water Balance for year 2012 of Sourif Area.

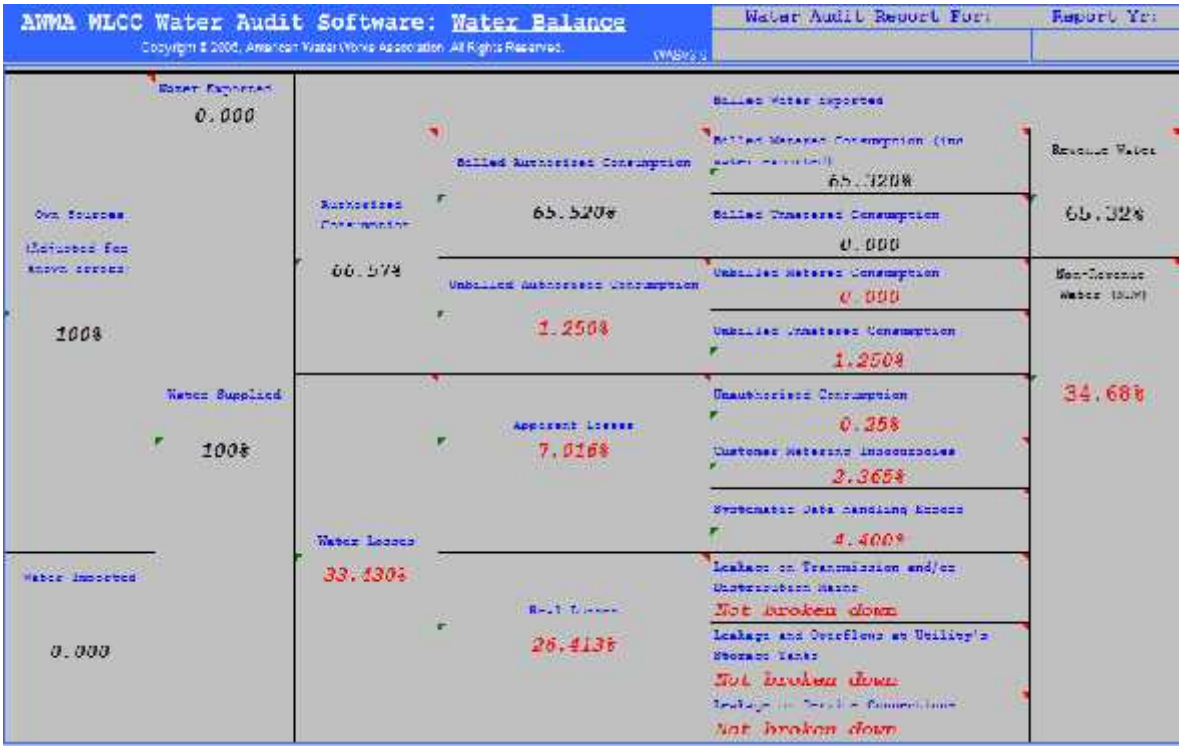


Figure (5.7): Water Balance for year 2013 of Sourif Area

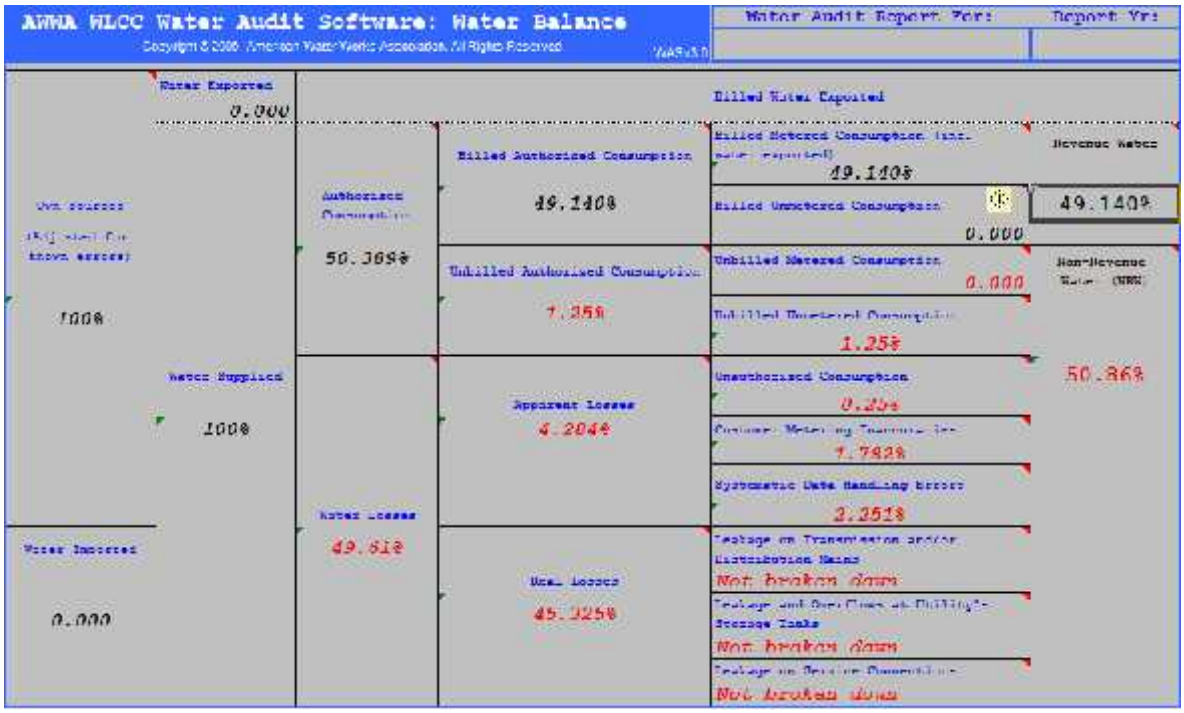


Figure (5.8): Water Balance for year 2014 of Sourif Area.

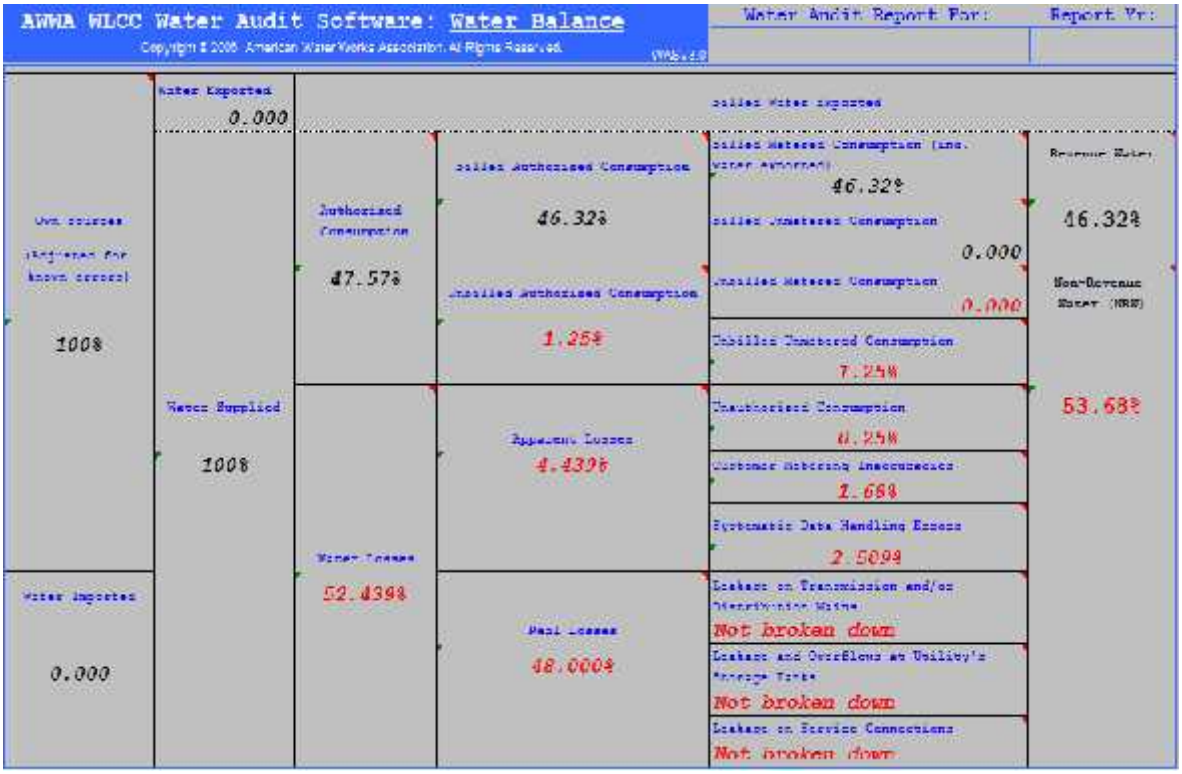


Figure (5.9): Water Balance for year 2015 of Sourif Area

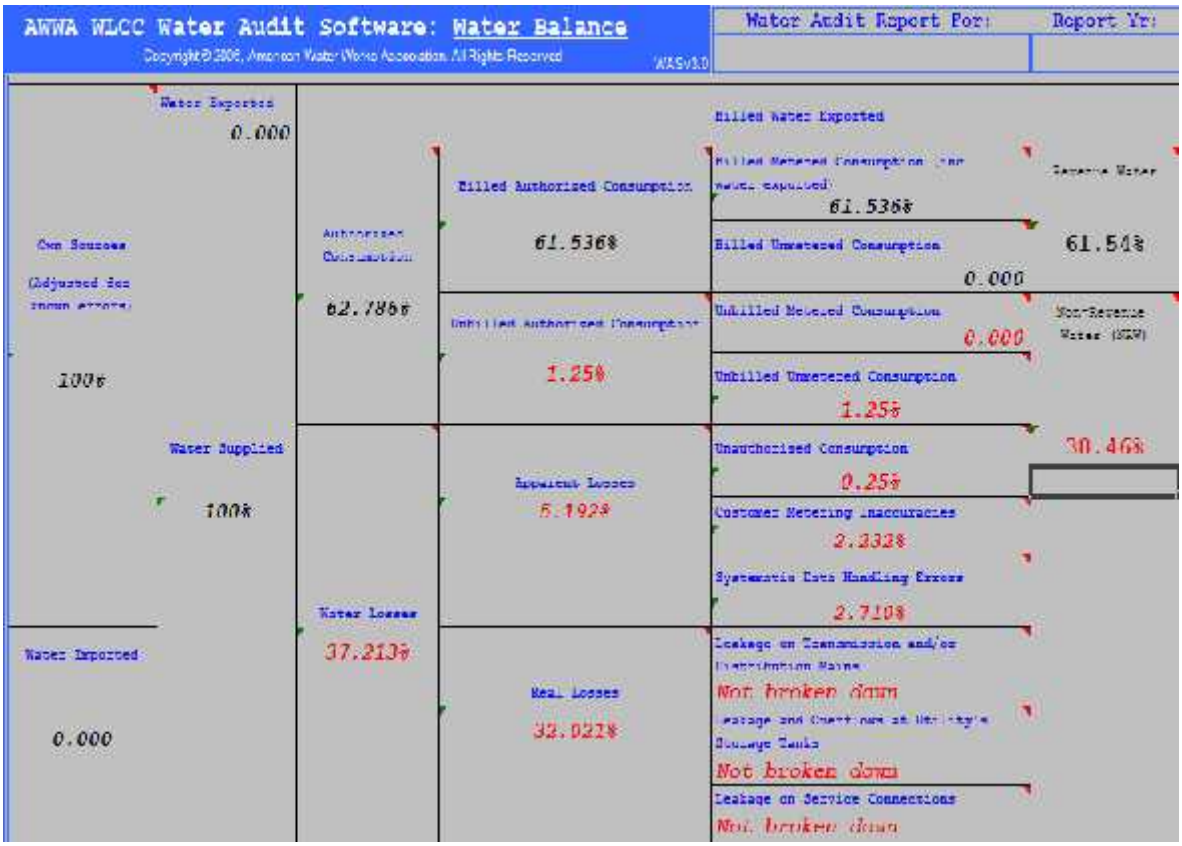


Figure (5.10): Water Balance for year 2016 of Sourif Area.

Table (5.3) : The value of water loses and Non-Revenue water as percentage of volume of water supplies for Sourif Town.

Years	Apparent losses (%)	Real losses (%)	Water losses (%)	NRW (%)
2012	5.67	32.18	37.84	39.09
2013	7.02	26.41	33.43	34.68
2014	4.28	45.33	49.61	50.86
2015	4.44	48	52.44	53.68
2016	5.19	32.02	37.21	38.46

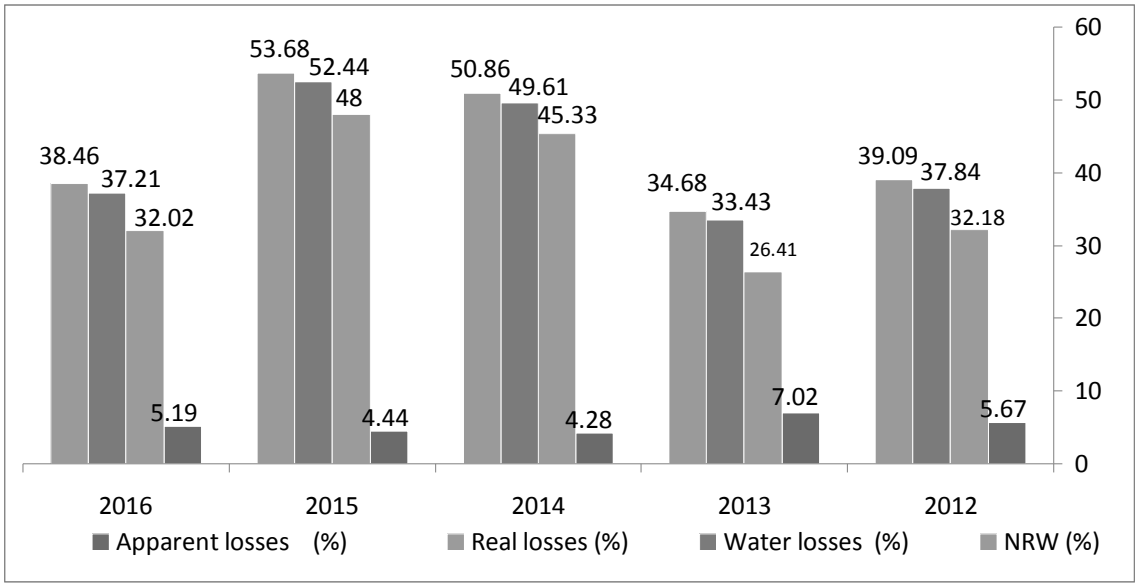


Fig (5.11): The values of different water losses and NRW for Sourif Town.

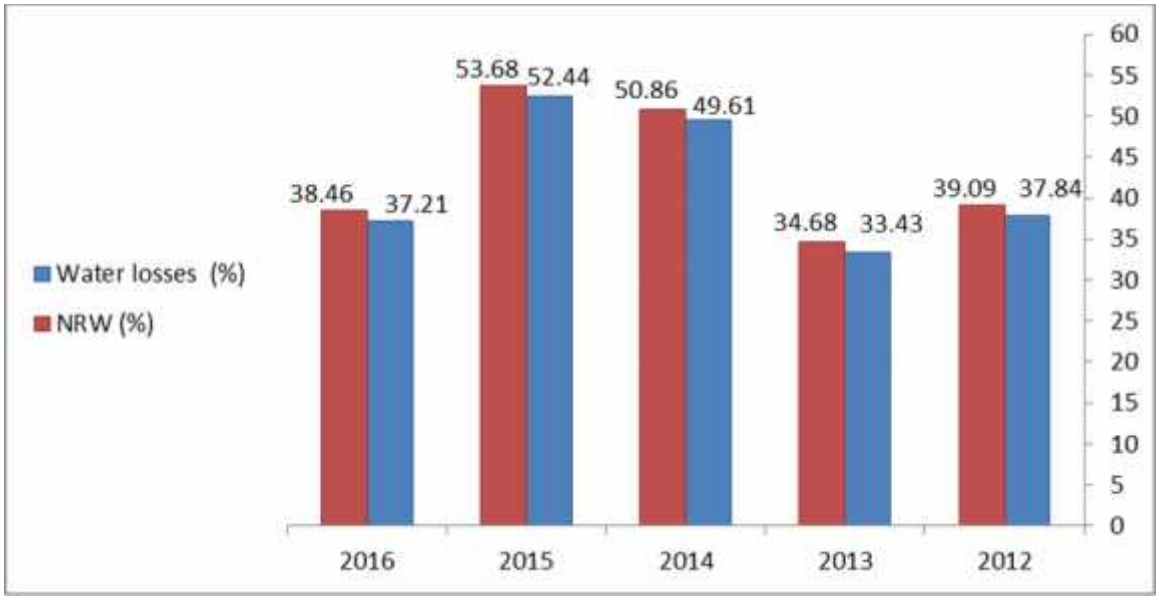


Fig (5.12): Water losses and NRW versus years for Sourif Town.

The performance indicators in terms of both financial and operational efficiency of the network are calculated in the software, the values obtained for financial indicator of water losses and NRW for Sourif Town are given in Table(5.3). The values of annual cost for apparent and real losses are plotted against each year and are presented in Fig (5.13).

Table (5.4): The financial indicator of water losses and NRW for Sourif Town.

years	Operating System ($)	Apparent losses($)	Real losses ($)
2012	29223	45464	88342
2013	22348	74174	46317
2014	28765	75687	97151
2015	11156	87748	114297
2016	64578	38015	105943

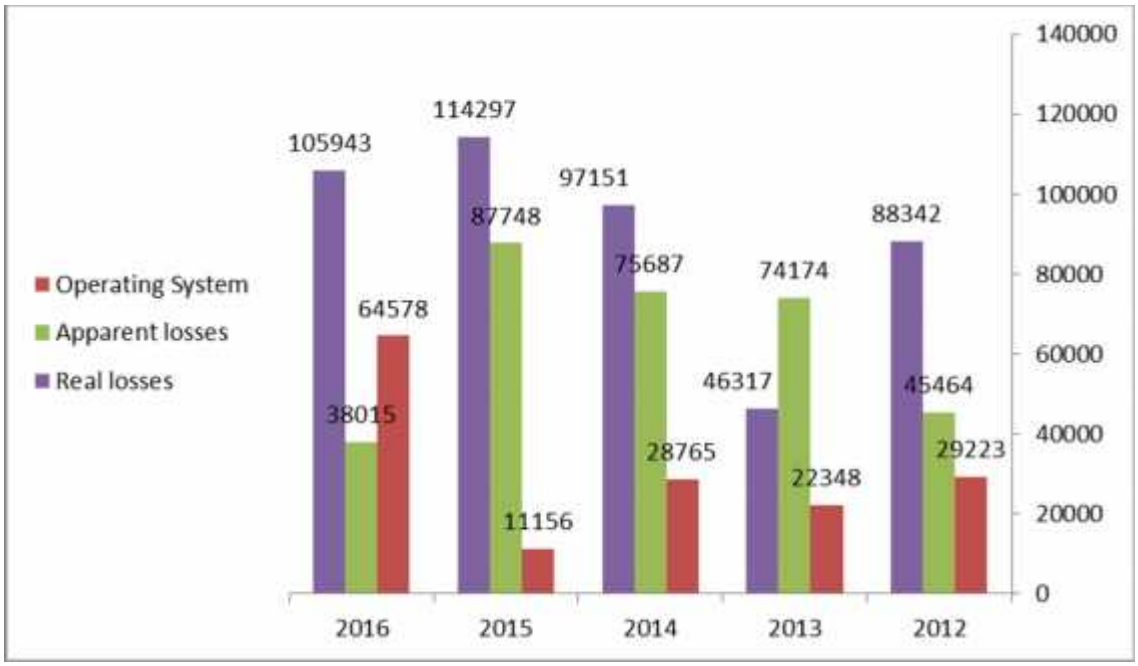


Fig (5.13): The Annual cost of apparent and real losses for Sourif Town

The apparent losses includes all types of inaccuracies associated with costumer metering as well as data handling errors (meter reading and billing), plus an authorized consumption incudes theft by illegal meter by-passes, vandalism, or unmetered hydrant use for construction or recreation. The results indicate that the values of apparent losses are ranges from 4.28% to 7.02% which means that the customer metering inaccuracies and illegal connecting in Sourif Town is low.

The values of real losses show that the value of real losses is increased from 26.41% in year 2013 to around 48% in year 2015 that may because the water network at Sourif Town was very old with many main trance and expansion works, become and pipe connections is increased, at the same time the areas supplied by the network is increased with intermittent supply and the excavation and maintains works of roads there is holes in pipes 2" from mechanical work, and excavation machine that cause losses of water from network. Due to use large amount of water for cleaning road after excavation works so the values of water losses keep on increasing.

As shown in Table (5.3), the values of water losses and Non-revenue water as percent by volume of water supplied for Sourif Town is increased appreciably during the last years, The values of total water losses and non-revenue water are 33.43% and 34.68% respectively in year 2013 and in year 2015 they are 52.44% and 53.68%.

The figures are very high and this due to old water system in the area and the absence of clear plan to overcome the water losses in water network.

Authorized consumption may include items such as training, flushing of main sewers, street cleaning watering of municipal gardens, public fountains, forest protection, The total annual cost corresponding to this losses as presented in table (5.4) and Fig (5.13). The Non- revenue water as percentage of cost is 39.09% for year 2012 and increased in year 2015 up to 53.68%.

We found the largest percentage of non-revenue water in year 2015 estimated at 53.68%, due to the expansion of the network, where the length of the network increased by 3 km in this year see table (5.2). Due to a breakage and leakage of the pipes during the excavations.

5.3 strategy of water losses in Sourif Town:

This section explains the finding and answer to the questions given in the data sheet regarding water losses reduction management and strategy in the study area. The team found that the answers to all questions for the area about water losses reduction management is as shown in table (5.5).

Table (5.5): The water losses reduction management.

	Procedures and Policy	**Yes**	**No**
1.1	A National Water Policy Exists Which Aims At Reducing Water Losses	✓	
1.2	A Water Loss Reduction Program is Implemented	✓	
1.3	Pressure Management is Used to Reduce Water Losses		✓
1.4	A Network Maintenance/ Rehabilitation Program is Implemented	✓	
1.5	Measures to Fight Illegal Connections are Applied		✓
2.	**Obstacles for Fighting Water Losses**	**Yes**	**No**
2.1	Institutional Situation		✓
2.2	Lack of Financial Means	✓	
2.3	Lack of Appropriate Technologies		✓
2.4	Maintenance System		✓
2.5	Personnel capacities	✓	
2.6	Personnel Awareness	✓	
2.7	Public Acceptance / Awareness		✓

The answers reveal that there is a national water policy exist which aims to reducing water losses and water losses program is implemented This means that policy water losses reduction is available in Sourif and the government is try to apply policy for different areas through water losses redaction program.

In the study area no pressure management is used to reduce water losses. At the s same the network main trance, re habitation and expansion program is implemented but in random way because of this the values of water losses and non-revenue are high add to that the water network is old.

The data sheet includes some questions regarding the obstacles that water depart faces for the purpose of water losses fighting. From the answers we can conclude the main obstacles for fighting water losses are Institutional situation, Lack of Financial Means, Lack of Appropriate Technologies, Personnel Awareness and public Acceptance.

Chapter Six

Conclusions and Recommendations

6.1 Conclusions

6.2 Recommendations

6.1 Conclusions :

In this project, an attempt is made to study and evaluate the existing water distribution networks at Sourif Town in terms of water losses and non-revenue water. The analysis of water losses in the study areas was carried out using water loss and auditing software developed by American Water Works Association (AWWA) version 3.0. The main conclusions drawn from the present study are:

1. The average values of water losses and non-revenue water in the study areas are high and reach more than 40% The figures are high because the water system is very old and in bad state of maintenance. At the same time, there is no clear plan to overcome the water losses in water networks.

2. The results indicate that in the project area, the values of apparent losses are less than 6% which means that unauthorized consumption (theft or illegal use) are little in Sourif Town and the customers metering are good status.

3. The results of the present study reveal that PWA adopted national water policy and strategy aims at reducing water losses and water losses program is implemented. But it seems no pressure management is used to reduce water losses, and the network maintenance and rehabilitation program is not implemented in the project area.

4. The main obstacles for fighting water losses are: the institutional situation, maintenance system, and the capacities of the people working with water losses. In the time the financials support and appropriate technology for water losses fighting is available, and the public people accept and aware of the problem.

6.2 Recommendation:

In order to increase the performance efficiency of the existing water networks in the project areas and reduce the percentage of water losses, project team recommended the following points:

1. Investigate pressure management pressure options in order to reduce the pressure in the networks to limited ranges and consequently the water losses will be less.

2. Speed the process of repairing the damages and water losses in the network pipes, quality of repair should be high.

3. Identify options for improved maintenance and introduce active leakage control

4. Development of human resources working in water losses, taking into consideration the deficiencies in manpower training and communications.

5. Review burst frequencies and asset management policy.

6. Rehabilitation and replacement of the old pipes in the network.

7. Improve the billing pricing.

8. Apply leak detection and control program.

9. Improve meters testing and repairer and replace inaccurate water meters.

10. Apply public education program.

11. Apply measures to fight illegal connections to water network and take legal actions.

12. A national water policy should be exists which aims at reducing water losses.