ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL & ENVIRONMENTAL ENGINEERING

GRADUATE STUDIES PROGRAM

URBAN WATER SUPPLY PERFORMANCE ASSESSEMENT - THE CASE OF HOSSANA TOWN IN HADIYA ZONE, SNNP REGIONAL STATE OF ETHIOPIA

By

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A Thesis Submitted to the School of Civil & Environmental Engineering of Addis Ababa Institute of Technology of Addis Ababa University in Partial Fulfillment of the Requirements for the Master's of Science Degree in Civil Engineering with Specialization in Hydraulic Engineering

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AAiT=Addis Ababa Institute of Technology
ADB=Africa Development Bank
AWWA=American Water Works Association
BH=Borehole
BS=Booster station
CCP=Circuit Control Panel
CSA= Central Statistics Authority
DCI =Ductile Cast Iron
DN=Nominal Diameter
EEPCo=Ethiopian Electric Power Corporation
EWWCA=Ethiopian Water Works Construction Agency
Fig= Figure
GIS =Geographical Information System
GPS=Global Positioning System
HDR=Henningson Durham and Richardson (Architecture and Engineering Firm)
HH=House Hold
HWSS=Hossana town Water Supply Service
LCB=Lahore Cantonment Board
Masl=meter above sea level
Mg/l=Milligram per litre
Ml=Mililitre
NB=Note
NRW=Non-Revenue Water
NTU=Nephelometric Turbidity Units
PLC=Private Limited Company
PVC =Polyvinyl Chloride
SNNP=Southern Nations Nationalities and People
SPSS=Statistical Package for Social Science
SWWCE=South Water Works Construction Enterprise
TP=Treatment Plant
UfW=Unaccounted for Water
WHO =World Health Organization

ABSTRACT

The provision of adequate and reliable water supply in developing countries is becoming a challenge for most water utilities especially public service providers. Water demand has been increasing drastically in these countries due to many factors including population growth as a result of rural to urban migration. As a consequence, in many countries public service utilities have failed to provide consumers with adequate water supply and sanitation services. Apart from service coverage, there are other problems that affect public service providers such as high Unaccounted for Water (UfW) and poor services, poor consumer records and inefficient billing practices.

This study tried to assess the performance of Hossana town water supply system based on four main performance indicators namely water loss, water quality, customers satisfaction and operation and maintenance. Poor water quality which is not in accordance with the national standard, high water loss, presence of customer complaints and operation and maintenance problems indicates that there are deficiencies on the quality of the service and contribute to low performance of the water supply system. Methods used in the study included, previous studies and documentary review, water production and consumption recording and analysis, household interviews, key stakeholders interview, conducting water quality tests, and field observations.

The result of the research show that there are water quality problems and the water supply accessibility and reliability is also inadequate. The operation and maintenance timely response towards customers was also a matter of concern. Moreover, the UfW for the year 2014 was found to be 50.55% which is very high loss and needs reduction.

In conclusion, the quality of service delivered by the HWSS for the customers was not found satisfactory and also the UfW was higher than the generally accepted value of 25% suggested by the World Bank. It is recommended that the reduction of UfW through appropriate water demand management strategies should be given priority and HWSS should engage in environmental conservation at main water sources of water supply. In order to improve the quality of services, the HWSS should improve customer relation and care by expanding the branch offices in the town as the town is currently expanding fast in every corner of the town.

Key Words: Water Supply, Water Loss, Water Quality, Operation and Maintenance, Customer Satisfaction, Hossana, Ethiopia

CHAPTER ONE

1.0. INTRODUCTION

1.1. BACKGROUND INFORMATION

Water is the primary need to sustain life; every citizen in the country has the right to have access to potable water. Provision of safe and adequate water supply services is necessary components for sustainable development. The estimated water supply service level of Ethiopia in terms of coverage, quantity, quality and reliability is very low.

The provision of adequate and reliable water supply in developing countries is becoming a challenge for most water utilities especially public service providers. Water demand has been increasing drastically in these countries due to many factors including population growth as a result of rural to urban migration. As a consequence, in many countries public service utilities have failed to provide consumers with adequate water supply and sanitation services. Apart from service coverage, there are other problems that affect public service providers such as high Unaccounted for Water (UfW) and financial problems due to a combination of low tariff, poor services, poor consumer records and inefficient billing practices (Victor Kimey, 2008).

The provision of adequate supplies potable water for use in urban areas in developing countries is crucial for the well-being of the people. The demand for such supplies in the developing countries has been on the increase over time as a result of rising standards of living that occur with economic progress and population increase resulting from natural growth, and rural urban migration and rising per capital income (Rewata and Sampath, 2000).

Access to safe and adequate water supply is a universally recognized human right, which has special significance to the survival of humanity. Adequate water supply may be defined as having reasonable access to safe water supply, Performance of water utilities can be assessed by many factors including accessibility and reliability of water supply, affordability of services, and customer satisfaction. In many developing countries, however, the public service providers have failed to provide consumers with adequate water supply and sanitation services (Nickson, 2002). The existing problems of inadequate service provision is exacerbated by the fact that population growth and mounting pressure of increasing urbanization have offset much of the gains in service coverage (Gentry *et al* 1997). Service coverage can be one of the indicators of accessibility of water supply that can have an effect on the performance of water utilities. Apart from serving coverage there are other problems that affect the performance of the public water utilities, for example, many public utilities in developing countries, experience high unaccounted for water (UfW) rates, which often average between 40% - 60%, meaning that about half of the potable water produced is lost somewhere in the supply process (Schwartz, 2007). Moreover the public utilities often face financial challenges due to a combination of low tariffs, poor services, poor consumer records and inefficient billing and collection practices (World Bank, 1994).

A well performing urban water supply system should provide water supply for human being and livestock consumption, for industrial and other uses in terms of coverage, quantity, reliability and acceptable quality taking the existing and future realities of the city in to consideration. This research paper will assess and evaluate the performance of Hossana water supply system in terms of four main performance indicators such as water supply coverage, water quality, water loss, operation and maintenance and customer satisfaction and recommend solutions for improving the water supply service.

1.2. SCOPE OF THE STUDY

This study is limited to existing water supply system and do not include the sanitation part. Besides the assessment of the performance of the water supply system do not include tariff, billing system and management and financial aspect of the Water Service.

1.3. STATEMENT OF THE PROBLEM

Assessment of the performance of urban water supply system is important for identifying weakness and strengths of the system and to improve the water supply service level. A best performing system should provide safe, sufficient and affordable water supply service, with low water loss and good quality of water which fulfills national and international standards. The major challenges of urban water supply systems in developing countries are low water supply service coverage, unavailability sufficient water at all times, very high amount of water loss which ranges up to 50% of amount of water produced (World Bank, 2006) and absence of quality water which meets national or international drinking water standards.

As there is shortage of water supply provision in the Hossana town and also a complaint regarding service provision from customer side, knowing the real problem and dealing with it was what motivates me to do this research. Hence in doing so suggesting what measures to be taken by the HWSS to improve the quality of service was the focus of the research.

1.4. OBJECTIVES OF THE RESEARCH

1.4.1. GENERAL OBJECTIVE

The general objective of this research was to assess the performance of the Hossana town water supply system and suggests appropriate measures to improve the water supply for the town population.

1.4.2. SPECIFIC OBJECTIVES

1. To determine the factors contributing to the water loss, water quality, and operation and maintenance

2. To assess customer /consumer perception towards the service provided by the Water Supply Service.

3. To indicate and suggest corrective measures to the town Water Service on areas of service improvements which leads to increased access to sustainable water supply service and doing so assure the customer satisfaction.

1.5. RESEARCH QUESTIONS

1. What is the amount of water produced, consumed and lost in the supply system?

2. What are the main causes of water loss? What measures to be taken to reduce or minimize it?

3. What is the present water supply coverage of the town?

4. How is the water quality compared with national and international standards?

5. What are the main operation and maintenance problems? What is the level of customer satisfaction?

1.6. SIGNIFICANCE OF THE STUDY

From the study it is expected that the deficiencies of the water supply system and causes for the high water loss will be assessed and known, water supply coverage and water quality level will be determined. The assessed and analyzed results and estimates will in turn contribute to know the overall performance level of the system. Besides the results help decision makers and especially the town Water Supply Service in planning of future expansions and to know areas of water loss and develop corrective measures to reduce the high water loss, improve coverage and water quality so as to make the system more efficient and increase water supply service level. It may also give a clue for further research.

CHAPTER TWO

2.0. LITERATIURE REVIEW

2.1. EXISTING WATER SUPPLY SYSTEM

Construction of existing water supply was completed at the end of 1974 GC. It had two phases. Phase one was designed for 10 years from 1975 –1985 GC and phase two for 10 years from 1985 – 1995 G. C. However the second phase was not implemented. The existing water supply system comprised of 6 bore holes, two springs ,a dam with the capacity of 460,000m^3 and reservoirs with two 150m^3 capacity each,500 m^3 and 2000 m^3.

Table 1: Existing Water Sources

No.	Source	Location	Yield	Remark
1	BH-1	0372842 N, 0836670 E @2280 masl Elevation	5l/s	Constructed in 1984 EC. Working properly, Pump replaced before eleven years. Water meter not working
2	BH-2	0371615 N, 0836364 E@2235 masl Elevation	5l/s	Constructed in 1984 EC. Working properly
3	BH-3	0371615 N, 0836364 E@2235 masl Elevation	3l/s	Drilled in 1993 EC. Abandoned due to decrease in yield.
4	BH-4	0370059 N, 0837058 E@2212 masl Elevation	7l/s	Constructed in 1998 EC. And commissioned in 2000EC.Working properly.
5	BH-5	0375358 N, 0836966 E@2260 masl Elevation	11l/s	Constructed in 1998 EC. And commissioned in 2000EC.Working properly.
6	BH-6	0369826 N, 0836593 E@2199 masl Elevation	12l/s	Constructed in 2000 EC. Not connected to the system
7	Dam and TP	Location of TP 0374615 N, 0835160 E@2288 masl Elevation	~ <5l/s	Constructed in 1974 EC. Initial capacity of the treatment plant was 6.27l/s
8	Sheshar Spring	0394630 N, 0870251 E@2556 masl Elevation	70l/s	Constructed in 2005 EC.
9	Mosheshe Spring	0393559 N, 0869377 E@2548 masl Elevation	37.8l/s	Constructed in 2005 EC.

The dam was designed to yield 627L/second (541.73m3/day). However as a result of encroaching settlement and erosion, the catchments area of the dam and run off to the dam is decreasing there by decreasing the capacity of the dam. Currently it is not in use and abandoned.

The water meters installed at BH-2, BH-4 and the combined measurement for BH-5 and the treatment plant are working properly. During the site visit the yield of BH-4 was 11.4l/s, BH-2 was 10l/s and BH-5 and the dam was 15.3 l/s (data obtained from the last 24 days daily records). BH-1 is estimated to have a yield of 5l/s. BH-3 is abandoned because of the decrease in yield which has dropped to about 3l/s. BH-6 is not working as there no pump is installed. The service has a plan to put it in to operation very soon. Here below is shown the existing water supply sources of the town.

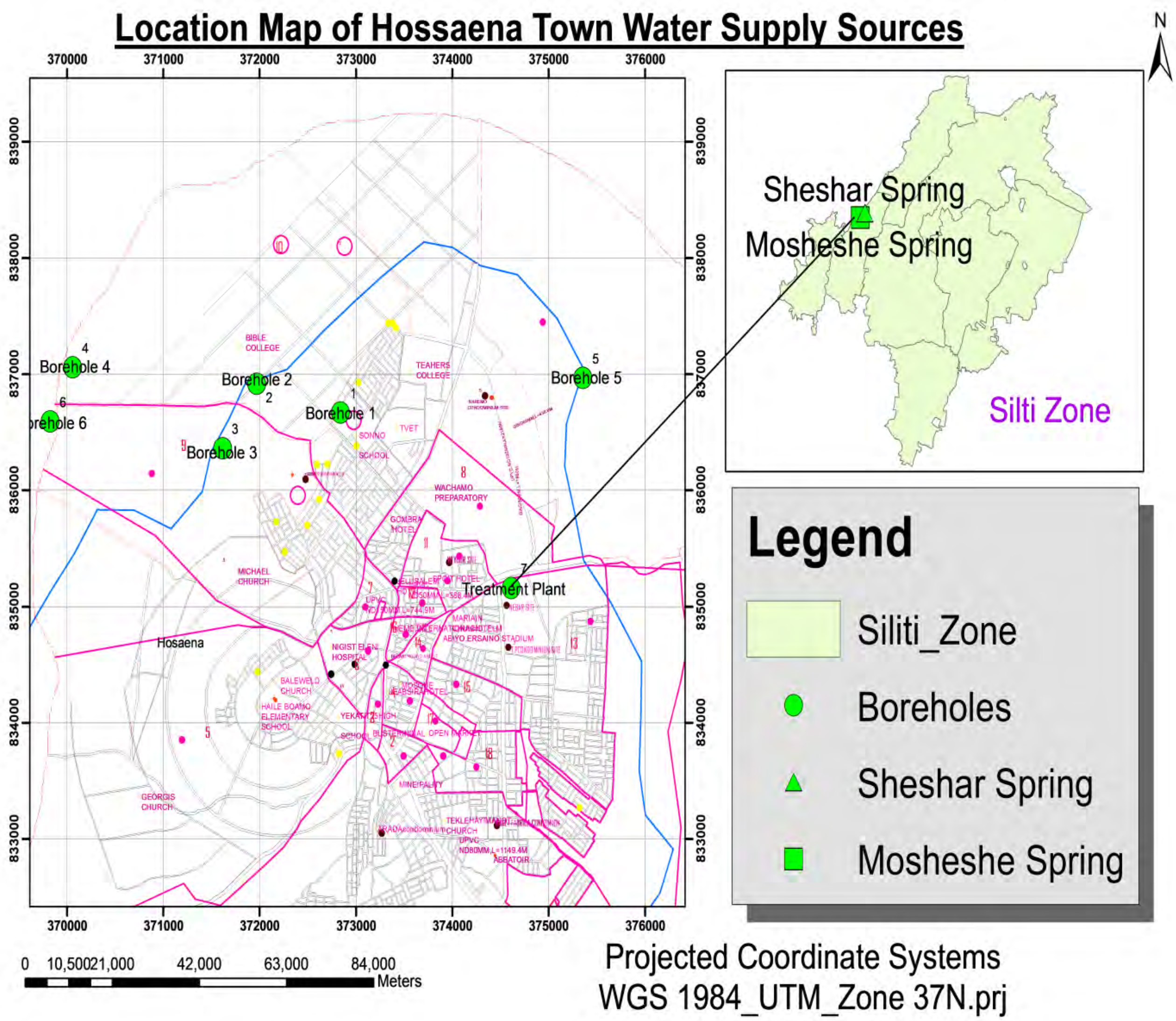

Figure 1: Location Map of Existing Water Supply Sources for Hossana Town

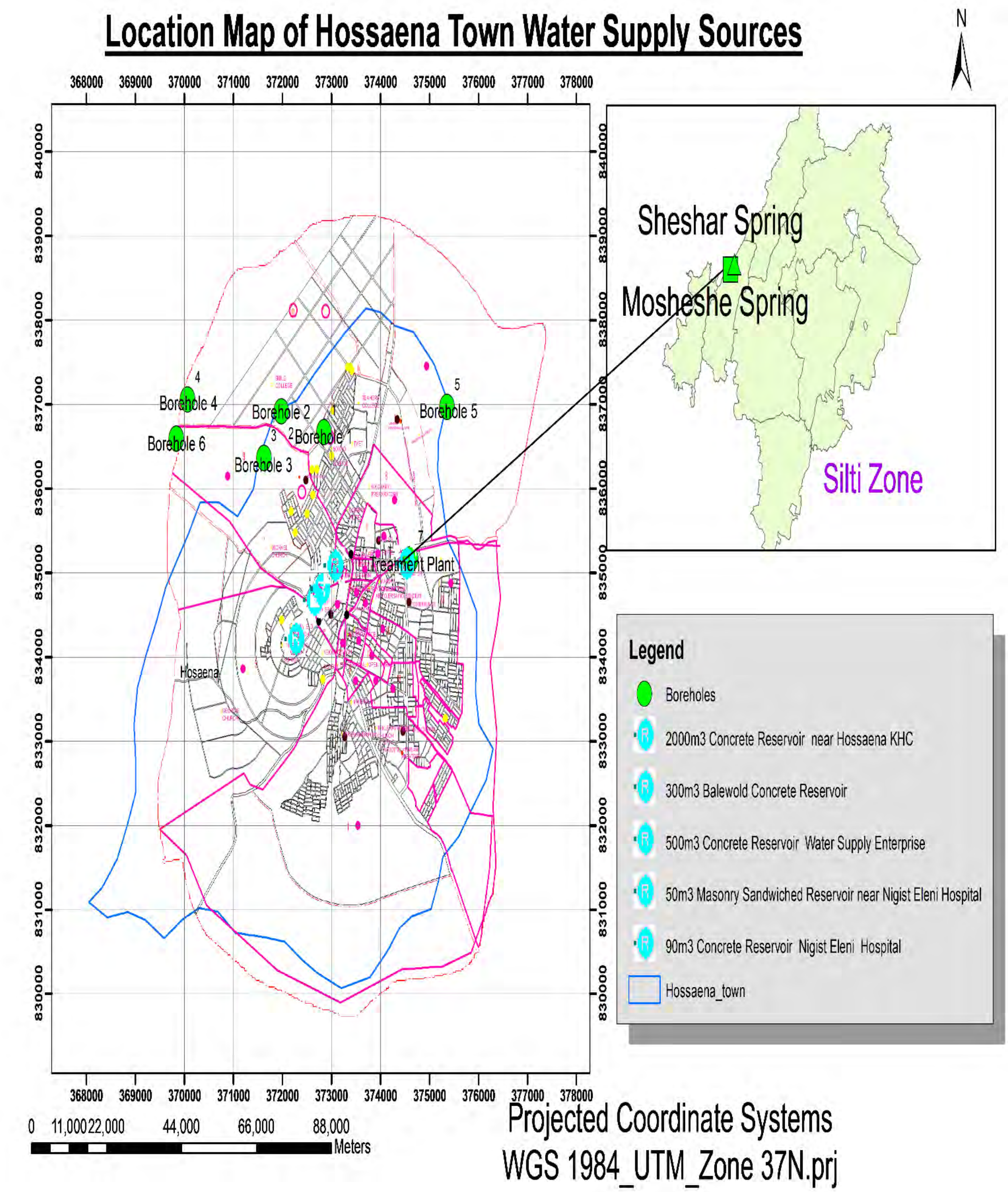

Figure 2: Location Map of Existing Water Supply Sources including Reservoirs for Hossana Town

The capacity of the water sources and their yields are not well known due to absence of raw water meters. However, estimates of the operation section reveals annual capacity ranging from 310,000 to 360,000 M^3 per year.

According to the last three years (2006-2008) data collected from Hossana Town Water Supply Enterprise, the water production is 62.88 m^3/hour for 18 hrs. Pumping or 1132 m^3/day. The average annual water production is calculated to be 413,228 m^3 showing a per capita production of 16 l/c/d.

But currently the newly constructed water supply from the spring water source in the Silti Zone is supplementing the above borehole yields and the total water supply from both springs is 91l/s. The distribution system consists of PVC to DCI pipes of various sizes for about 45km from Hossana.

The disinfection with chlorine is done in such a way that powder chlorine is added to the chlorine tankers placed at top of the reservoirs and mixed with water and the chlorine solution flows by gravity to the reservoirs through a hose which extends from the chlorine tanker to the reservoirs through the reservoir manholes. The liquid chlorine flows to the reservoirs continuously in form of droplets in parallel with the water pumping to the reservoirs and is terminated when pumping stops. The chlorine consumption per day of Hossana Town Water Treatment system can be seen in two ways depending on the water quality from the various sources: Maximum and Minimum. The maximum amount is 50 litre of chlorine in the form of Sodium hypochloride and the minimum one is half of the maximum which is 25litre of Sodium Hypochloride(NaOCl). Other than this disinfection of the line is done using 3kg of Calcium Hypochlorite per week and this amount may increase depending on the water quality scenario which can be identified through inspection by the utility or sometimes based on the information from beneficiary customers .

Relating to tariff the existing water tariff of Hossana town is a four-band system tariff and it also full cost recovery tariff as per the water resource policy for Urban Water Services. The current tariff for Hossana town is presented in table 1 below

Table 2: Current tariff rates of Hossana town water supply service

1st band	0-5m3	Birr 6.27
2nd band	5-10m3	Birr 7.83
3rd band	10-20m3	Birr 9.40
4th band	>20m3	Birr 10.97

2.2. PERFORMANCE INDICATORS FOR URBAN WATER SUPPLY SYSTEMS

Performance indicators are measures of the efficiency and effectiveness of the Water Utilities with regard to specific aspects of the Utility's activity and of the system's behavior.

Efficiency is a measure of the extent to which the resources of water Utility are utilized optimally to produce the service,

Effectiveness is a measure of the extent to which the targeted objectives (specifically and realistically defined) are achieved.

International Water Association (IWA) defined performance indicator as a ratio between variables of the same nature (e.g., %) or of different natures (e.g., Birr/m3 or liters per service connection).

Before evaluating the performance of urban water supply system it is important to develop appropriate performance indicators. The following are suggested performance indicators for evaluating urban distribution systems (Water Utility Journal 1:31, 2011).

Water resources performance

- Inefficiency of use of water resources, Water resources availability, Own water resources availability

Physical performance

- Raw water storage capacity, Transmission and distribution storage capacity, Standardized energy consumption
- Energy recovery, Customer meter density, Metered customers

Operational performance

- Network inspection, Leakage control, Active leakage control repairs, System flow meters calibration
- Meter replacement, Vehicle availability, Mains rehabilitation, Mains renovation, Mains replacement
- Replaced valves, Service connection rehabilitation, Water losses per connection, Water losses per mains length
- Pump failures, Main failures, Service connection failures, Customer reading efficiency, Residential customer connection efficiency, operational meters, and unmetered water.

Quality of service performance

- Households and business supply coverage, Building supply coverage, Population coverage, Population coverage with service connections
- Pressure of supply adequacy, Continuity of supply, Water interruptions, Interruptions per connection, Days with restrictions to water service
- Microbiological tests compliance, Physical-chemical tests compliance, New connection efficiency
- Time to install a customer meter, Connection repair time, Service complaints per connection, Service complaints per customer, Pressure complaints, Continuity complaints, Water quality complaints, Interruption complaints,Billing complaints and queries, Other complaints and queries, Response to written complaints.

Table 3: List of Key Performance Indicators with their unit of measurement (WSP, 2012)

No.	Category of Indicators	Key Indicators	Units
1	Technical Indicators	1. Water Supply Coverage 2. Per Capita Consumption 3. Unaccounted For Water 4. Continuity piped water supply	1. % 2. l/c/d 3. % or l/d/km 4. Hr/day
2	Personnel Indicators	1. Number of staff per 1000 connection 2. labor cost as a proportion of operational costs 3. staff costs as a percentage of utility expenditures	1. #/1000 connection 2. % 3. %
3	Operational Indicators	1. length of distribution piped water system 2. number of pipe breaks 3. Maintenance cost against total operating cost	1. km 2. No. 3. %
4	Financial Indicators	1. Water production cost per cubic meter 2. Average Tariff (in to supply) 3. Operating ratio:[annual O&M cost (Birr)] / [annual revenue (Birr)] 4. Revenue collection efficiency: [total annual collections (Birr) / total annual billings (Birr)] x 100 5. Energy vs O&M cost 6. Account receivable (month's equivalent) = [accounts receivable at end of the fiscal year] / [total annual billings/12]	1. Birr/m^3 2. Birr/m^3 sold 3. % 4. % 5. % 6. %
5	Customer Management Indicators	1. Annual Number of Complaints 2. Response time to complaints	1. No. 2. No.

A study set out to assess the performance of two urban water supply utilities in Tanzania shows there are serious water supply problems in the districts under study. The assessment was based on two main indicators which are the quality of service and unaccounted for water. The quality of the service and UfW has been cited as some of the major factors which reflect the performance of many water utilities. Poor service quality as measured by the water quality, billing efficiency and customer care, affects consumer willingness to pay and consequently the performance of the water supply utility. Methods used in the study included documentary review, household questionnaires, key informant interviews and field observations. The results show that accessibility and reliability of water supply in Muheza town is inadequate compared to Korogwe town. On average customers receive water for 8 hours per day in Korogwe and 5 hours per day in Muheza. Water supplied by the respective utilities in the two districts is far below the total demand. More than 80% of customer complaints in both towns were about water quality, water shortage and customer relations. Poor billing practices and old infrastructure have resulted in high UfW of 42% in Korogwe and 47% in Muheza. The conclusion, therefore, was that the customers were not satisfied with quality of services and that the UfW was higher than the generally accepted value of 25% suggested by the World Bank (Victor Kimey, 2008).

The quality of service can also be assessed by assessing the accessibility of water, reliability of water services, water quality, customer-operator relations and the affordability of the service provision. Factors that should be considered in assessing the accessibility of water supply include supply coverage and production capacity to meet consumer demand. The type of household main water source and per capita water use are also needed to study. The reliability of the service can be studied by investigating the duration of water supply and downtime period (Victor Kimey, 2008).

The performance of the Hossana town water supply conducted based on four main indicators which are service coverage and water loss (unaccounted for water), water quality, Customer satisfaction and operation and maintenance contextualizing the indicators in regard to data availability situation, i.e. Financial indicator and other cost related criteria are not considered as these are out of the scope of the study part stated earlier in this research.

2.2.1. WATER LOSS

Another factor to be considered to assess the performance of urban water supply systems is amount and causes of water loss.

The general steps to be followed for understanding and managing Losses in Water Distribution Networks the general steps to be followed are: Analysis of network characteristics and operating practices, Quantification of water losses and Use of appropriate tools and mechanisms to suggest appropriate solutions (Saroj Sharma, 2008).

Quantifying and characterizing water loss and leakage in a city water supply is by its nature a complex task. Leakage identification needs detailed field investigation sometimes using sophisticated equipment (Shimeles Kabeto, 2011).

Non-Revenue Water: Non-revenue water (NRW) represents the difference between the volume of water delivered into a network and billed authorized consumption.

NRW = "Net production" – "Revenue water"

= UfW + water which is accounted for, but no revenue is collected (unbilled authorized consumption)

Unaccounted for Water

Unaccounted-for water (UFW) represents the difference between "net production" (the volume of water delivered into a network) and "consumption" (the volume of water that can be accounted for by legitimate consumption, whether metered or not).

UFW = "net production" – "legitimate consumption" (Saroj Sharma,2008).

System Input Volume	Authorised Consumption	Billed Authorised Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorised Consumption	Unbilled Metered Consumption	Non-Revenue Water
			Unbilled Unmetered Consumption	
	Water Losses	Commercial Losses	Unauthorised Consumption	
			Customer meter Inaccuracies and Data Handling Errors	
		Physical Losses	Leakage on Transmission and Distribution Mains	
			Leakage and Overflows from the Utilities Storage Tanks	
			Leakage on Service Connections up to the Customer Meter	

Figure.3: Water Balance Showing NRW Components(IWA,2000)

Calculating Water Loss

Water loss is expressed as: a percentage of net water production (delivered to the distribution system) and also as m^3/day/km of water distribution pipe system network (specific water loss)

Other way of calculating water loss is m^3/day/connection, m^3/day/connection/m pressure. Of all the above, water loss as % of net water production is the most common way of expressing it.

Magnitude of Water Losses

Water loss levels (UfW or NRW) vary widely per country and within one country per city. UfW values ranging from 6% to 63% have been reported.

(*Source:* Water and Wastewater Utility Data, 1996)

A certain level of water losses cannot be avoided from a technical point of view and /or is considered acceptable from an economic point of view.

What is an Acceptable Water Loss?

1. It is a compromise between the cost of reducing water loss and maintenance of distribution system and the cost (of water) saved.

2. AWWA Leak Detection and Accountability Committee, (1996), recommended 10% as a benchmark for UfW.

3. UfW levels and action needed :< 10% Acceptable, monitoring and control, 10-25% Intermediate, could be reduced,> 25% Matter of concern, reduction needed

Controlling Water Loss

The controlling of water loss is very important task to be given due attention and in this regard measures as per the specific situation can be taken. Among them some are: Meter testing and repair/replacement, improving billing procedure, Leak detection and control program(Network evaluation, leak detection in the field and repair),Rehabilitation and replacement program(Corrosion control, Pressure reduction), Public education program(Legal provisions, Water pricing policies encouraging conservation, Human resources development, Information system development).

2.2.2 WATER QUALITY

Water quality refers to the chemical, physical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. It is most frequently used by reference to a set of standards against which compliance can be assessed. (Wikipedia, the free encyclopedia)

To be safe for human consumption, drinking water must be free from microorganisms capable of causing disease. It must not contain minerals and organic substances at concentrations that could produce adverse effects. Drinking water should be aesthetically acceptable; it should be free from apparent turbidity, color, and odor, and from any objectionable taste (HDR Engineering Inc., 2003).

Another performance indicator to be used for assessment of urban water supply system is water quality. Water quality of urban water supply may affected by different factors like urban storm or urban runoff, flood intrusion to water supply sources, intrusion of pollutants through pipe leaks, connection of faulty sewerage line with water supply pipe line, industrial wastes etc. The water quality of urban drinking water should satisfy standards set by WHO (world health organization) and National standards.

In this research the existing practices of the water utility to check the water quality of Hossana town water supply and the treating system will be assessed. Besides water sample will be taken from sources, reservoirs, distribution network pipe line and from house connection and water quality analysis will be done for different water quality parameters and the results will be checked against international and national guidelines and based on the result recommendation will be given to improve the water quality. Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all. Improving access to safe drinking-water can result in tangible benefits to health. Every effort should be made to achieve drinking-water that is as safe as practicable. Safe drinking water, as defined by the Guidelines, does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. In other direction, the nature and form of drinking-water standards may vary among countries and regions and there is no single approach that is universally applicable. In the development and implementation of standards it is essential to consider the current or planned legislation relating to water, health and local government and the capacity of regulators in the country. Additionally approaches that may work in one country or region will not necessarily transfer to other countries or regions (WHO, 2011). For this work WHO and Ethiopian guidelines values for drinking water are presented in the following table.

Table 4: Water Quality Standard –WHO and Ethiopian

S/N	Parameter	WHO Standard(1993)	Ethiopian Standard(1998)
1	Total Coliform	0Col/100ml	0Col/100ml
2	Faecal Coliform	<3Col/100ml	<3Col/100ml
3	Turbidity(NTU)	<5NTU	Low Turbidity
4	Residual Chlorine(mg/l)	0.3-1.5mg/l	0.5mg/l
5	pH	6.5-8.5	6.5-8.5

Source: http://www.lenntech.com

2.2.3. OPERATION AND MAINTENANCE

Operation and maintenance is the main challenge of urban water supply system.

Operation

Operation refers to the everyday running and handling of a water supply. This involves:

- Major operations required to convey safe drinking water to the users, e.g. starting and stopping a motorized pump, the supply of fuel and the control of valves.
- The correct handling of facilities by users to ensure long component life (Jan Davis and Francois Brikké,1995).

The proper operation of a supply results in its optimum use and contributes to a reduction in breakdowns and maintenance needs

Maintenance

Maintenance refers to the activities required to sustain the water supply in a proper working condition. Maintenance can be divided into:

- **Preventive maintenance** - regular inspection and servicing to preserve assets and minimize breakdowns.

- **Corrective maintenance** - minor repair and replacement of broken and worn out parts to sustain reliable facilities.
- **Crisis maintenance** - unplanned responses to emergency breakdowns and user complaints to restore a failed supply (Jan Davis and Francois Brikké, 1995).

Maintenance costs money and a policy of crisis maintenance alone may appear cheap in the short term. However, continuing crisis maintenance leads to frequent breakdowns, an unreliable supply, poor service levels, and a lack of user confidence. Reliance on crisis maintenance may ultimately lead to complete system failure.

Rehabilitation entails the correction of major defects and the replacement of equipment to enable a facility to function as originally intended. Rehabilitation becomes necessary when it is no longer technically feasible or economically viable to maintain a facility in good working order. Maintenance will become uneconomic if the long term cost of rehabilitation and subsequent operation is more favorable than continued repair and maintenance.

Water supply statistics often give the number of people served by improved water supplies. Unfortunately, the actual number of people served is far less because many supplies do not function reliably due to the neglect of operation and maintenance. Unless operation and maintenance is properly implemented then continued investment in the development of water supplies is not worthwhile. In this study the existing operation and maintenance practice of Hossana town water supply system is assessed and suggestions will be given to improve the operation and maintenance practice. Besides as stated before there is very high water loss in water supply system and this can also be reduced by improving the operation and maintenance system. In summary, the Technical performance (Water coverage, Water Production and consumption and Non-Revenue water) evaluation will be highly assessed and other performance indicators like human resource utilization and capacity building, Customer care and Service Affordability will also be assessed.

2.2.4. CUSTOMER SATISFACTION

It is the very nature of this commodity that makes the customer satisfaction so important. Water is a lifeline whose importance is felt only when people cannot get enough of it. It is keeping this in mind that urban water distribution networks are designed to supply water for household customers as well as industrial concerns twenty four hours a day, three sixty five days of the year. Any disruption or inconsistency in this service even though for a short while has an unpleasant effect on all sorts of customers. There is a great pressure on the water delivering agencies to ensure customer satisfaction.

One of the most relevant aspects of water services therefore is the important role of customers. Water supply agencies as well as their regulators are becoming increasingly sensitive to customer protection issues and customers' opinions about the service quality and performance (Omar Saeed, 2011). The research made by Omar Saeed to check whether the residents are satisfied or not with clean drinking water provided by Lahore (Pakistan) Cantonment Board (LCB) used main research questions that summarize the main aspects of clean drinking water. The research questions were overall satisfaction of people with the clean drinking water, aspects of the water that the customers have complaints against such as quality, quantity, continuity and price and on the satisfaction of the customers with the responsiveness of LCB to their complaints (Omar Saeed, 2011).

In this study of Hossana town existing water supply System performance assessment Sample Household interviews using prepared questionnaires for the customers located in three different Sub cities is carried out to collect information about customers' satisfaction towards the water supply service.

The following indicators were considered for the satisfaction of customer survey: Availability of water, quality of water, daily consumption amount, sufficiency of water pressure, maintenance response by the Service, functionality of water meters, and availability of other sources of water, availability of home water treatment and affordability of water tariff. The standard for the satisfaction depends as per the perception of customers and in general it lies with the delivery of quality service to the customer by the utility and the degree of customer –operator relations in responding to the customer complaints.

CHAPTER THREE

3.0. RESEARCH METHODOLOGY

3.1 .DESCRIPTION OF THE STUDY AREA

3.1.1. LOCATION

Hossana Town, capital of Hadya Zone is found in Southern Nations and Nationalities Regional Government Administration Region of Ethiopia. Hossana town is located between 7º53'000''N and 7º55'000''N latitudes and 37º30'00''E and 37º40'00''E longitudes in UTM coordinates. The town is located in between 2140m and 2380m elevated lands above mean sea level & 230 km away from the Country's Capital city Addis Ababa to the southern direction via Alemgena&Butajira Road and 168km from the Regional town Hawassa via Alaba-Angacha Road.

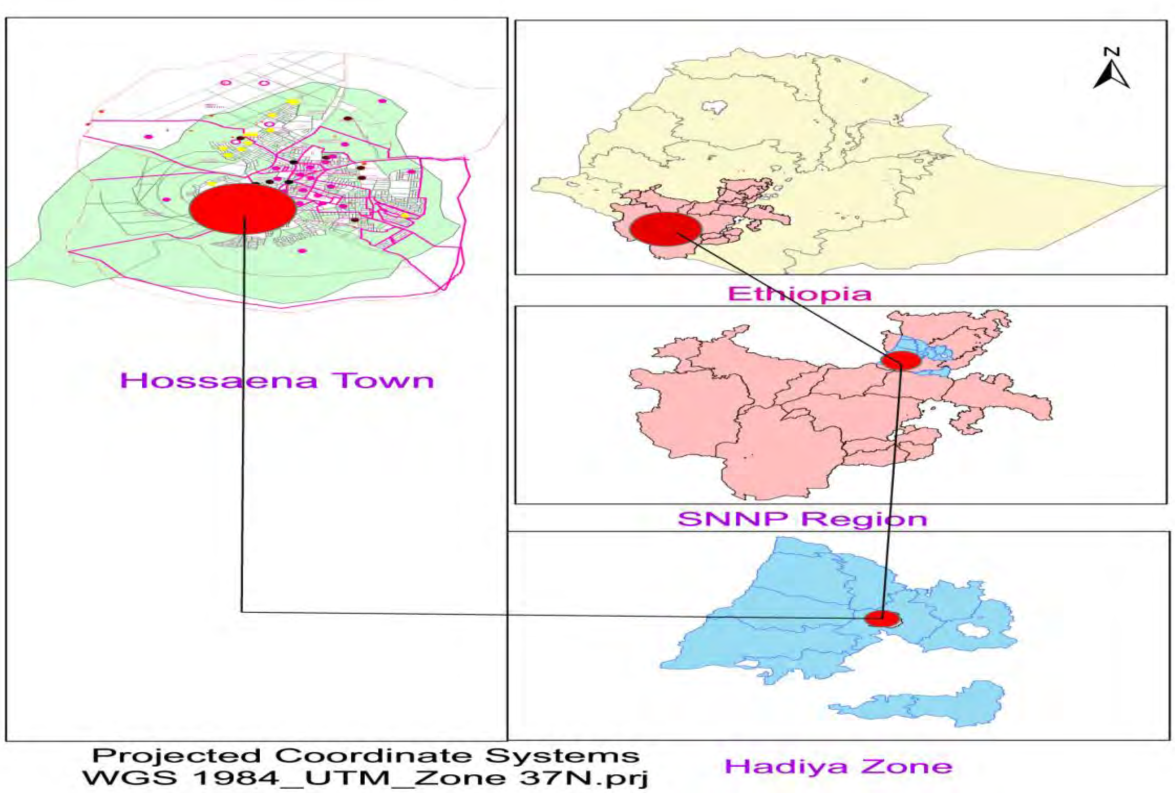

Figure 4: Location Map of Hossana town

3.1.2. CLIMATE AND HYDROLOGY

The altitude of the town ranges from 2140m and 2380m above mean sea level. This shows that the study area is mainly characterized by highland ('dega') climatic conditions. There is one rain gauge station in Hossana at a specific location of 374900E, 832800N UTM coordinates. The annual average temperature is 16^0 - 17^0 C

There are also other gauge stations at relatively closer proximities namely Durame, Gimbicho, Fonko and Shone as well. Using the rainfall data collected for over 36 years at the Hossana meteorological station, the mean annual rainfall at and around Hossana is 1179.27mm/year. The other nearest station is Durame station which is located at about 36.9km South of Hossana, at a specific location of 38 º40’00’’E, 79º59’00’’N UTM has the mean annual rainfall of 1083mm/year. Shone station located at 124km South of Hossana at a specific location of 37º58’00’’E, 7º08’000’’N UTM has a mean annual rainfall value of 1563.52mm/year.

3.1.3. GEOLOGY

Hossana is located on the edge of the western escarpment west of the Great Ethiopian Rift Valley. The rock formation in the region is predominantly composed of volcanic rock known as the Magdala group. The Magdla group unlike the Trap Series (pre-Rift Volcanic) is essentially composed of Acidic rocks such as Ignimbrites, Rhyolites, Tuffs and Trachytes. These rocks are however intercalated or inter bedded with basaltic rocks.The thickness of these rocks as inferred from the two boreholes (bore hole 1 & 2) drilled in the town is over 200 meters. The well log exhibit an inter bedding of ignimbrites and volcanic sand for over 200 meters.

Since Hossana town is located near the Rift margin it has suffered from tectonic activities. NE-SW lineaments which most probably can be fault structures and which run parallel to the Great Ethiopian Rift System are prevalent. This fault structures which runs parallel to the rift system which extends further to Butajira is assumed to be the source of the two springs namely Sheshara and Mosheshe (fracture spring).

3.1.4. HYDROGEOLOGY

Groundwater occurring or reservoir characteristics of the rocks is governed by two factors; fracture and Weathering. The Ignimbrites impound groundwater when they are fractured and/or weathered. The Tuff or volcanic ashes in most cases have very poor permeability and thus are insignificant from groundwater point of view. Thus the chance of striking groundwater or even the quantity available varies from place to place depending on the degree of fracturing and weathering. This fact can vividly be proved from recently drilled wells around Hossana town.

Two wells which have been drilled in 1992 by EWWCA Central Region show the following characteristics. The wells are located about 2-3 kms North of the town in a topographically depressed land. The distance between the wells being less than 0.5 kms however the hydraulic properties of the aquifer show significant variation.

Table 5: Hydraulic properties of boreholes

Well Name	Well Depth (meter)	S.W.L. (meter)	D.W.L. (meter)	Tested Yield	Aquifer Type
Well No. 1	208	124.34	157	5 l/sec	Weathered and fractured volcanic
Well No. 2	153	70.93	96.98	10 l/sec	Fractured ignimbrites and volcanic sand

Hossana town and its surrounding area obtain quite considerable amount of average rainfall (about 1195mm) per year. Since Hossana more or less lies on or very close to the water divide which separate the Omo and Bilate-Lake Abaya catchments, major surface water (perennial) may not be expected. However there are some smaller perennial streams like Bilate River in the closer vicinity.

The average transmissivity is calculated to be 17.6 and 98.8 m^2/day for Well No. 1 and No.2 respectively.

Maximum yield of the wells are estimated based on the knowledge of specific capacity and available draw-down. The available draw-down is taken to be two third of the water column and the specific capacity is the ratio of the discharge and draw-down after 24 hours of pumping. Thus the maximum yield is the product of the available draw-down and the specific capacity.

Table 6: Bore hole yields

Well Name	Available Draw-down	Specific Capacity	Maximum Yield (l/sec)
Well No. 1	55.7	0.15	8.4
Well No.2	54.72	0.38	20.7

NB: Available draw-down = Water column x 2/3 and Specific capacity = l/sec/mt

Hydro-chemistry - Data of chemical analysis available for the two boreholes has been analyzed.

- The content of the cations and anions are within the limit of acceptable standard.

- The respective total hardness as $CaCO_3$ for Well No. 1 and 2 is 60 and 52 mg/l and thus fall in the "Soft Water" group according to the standard classification made by Freeze and Cherry 1979. The pH of water for Well No. 1 and No.2 is 7 and 7.3 respectively which shows that the groundwater in the region is neutral or slightly basic.The General and Physical quality of water is satisfactorily fit for drinking and household use (Hywas Engineering Consultants et al, 2009).

3.1.5. POPULATION AND WATER DEMAND PROJECTION

According to CSA population count of May 2007, the total number of Hossana town population was 69,959 for the year 2007/8. Out of this the male population were 35505 (50.75%) and the females were 34454 (49.25%).

Since the preliminary population count result is not more disaggregated, population distribution by sub-cities and number of households as well as housing units in the town could not be shown.

The Municipality source show very consistent estimate to that of CSA count and well disaggregated by sub-cities. According to this data source the total population of Hossana Town as of 2008 is estimated to 70,470 and as per the population projection done by the Hywas Engineering Consultants the total population of the town for the year 2014 and 2015 is estimated to 91,341 and 95,269 and the distribution by localities and gender as of 2008 is summarized below.

Hossana town comprises of three KifleKetema and eight sub kebeles. It is one of the economically and Scio-politically dynamic towns in the region and supposed to have adequate supply and availability of all development infrastructures including safe water supply

Table 7: Population distribution by sub-cities as of 2008

No	Sub-City	Head of households			Family members			Total population		
		M	F	T	M	F	T	M	F	T
1	SecheDuna	2162	2169	4331	11679	13602	25281	13841	15771	29612
2	Addis Ketema	941	725	1666	7244	8624	15868	8185	9349	17534
3	Gofer Meda	5322	728	6050	6102	11172	17274	11424	11900	23324
	Total	8425	3622	12047	25025	33398	18423	33450	37020	70470

Source: Hossana Town Finance and Economic Development Office, 2008)

Table 8: Population Projection and Water Supply Demand Forecasting

Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Growth rate		4.60%	4.30%	4.30%	4.30%	4.30%
Population, no	73,790	77,184	80,503	83,965	87,575	91,341
Proportion of Population Served						
Public taps Urban	39%	36%	33%	29%	24%	20%
Private yard connection	26%	26%	27%	30%	34%	38%
Private house connection	4%	7%	10%	11%	12%	13%
Private yard shared	31%	31%	30%	30%	30%	29%
Domestic demand, m^3/day	2416.6	2632.0	2845.80	3018.5	3205.3	3388.8
Demand of Animals, m^3/day	123.0	128.6	134.2	139.9	146.0	152.2
Institutional + Commercial(20% of Dom. D), m^3/day	483.3	526.4	569.2	603.7	641.1	677.8
Industry, m^3/day	146.5	175.8	205.1	732.5	820.4	908.3
Hadiya University Demand, 14500 community(60l/c/d), m^3/day	0	87.0	87.0	261.0	261.0	261.0
Total Daily Demand, m^3/day	3169	3550	3841	4756	5074	5388
UfW %, *	30%	30%	38.13%	33.71%	55.44%	50.55%
UfW, m^3/day *	951	1065	1465	1603	2813	2724
Total daily Demand, m^3/day*	4,120	4615	5306	6359	7887	8112
Max Daily Demand, m^3/day(1.1xaverage demand) *	4532	5077	5837	6995	8676	8923

(Source: Hywas Engineering in association with AG Consult, & EDM Consultants 2009) ,*=amendment made for % of the UfW for Year 2011 to 2014 which was 30%,29%,28% & 27% respectively and replaced with %ages based on the finding of this research .

3.2. CONCEPTUAL FRAMEWORK

Descriptive and Experimental study designs were applied for the completion of the research. Descriptive study design was applied to examine the customer satisfaction regarding water availability, affordability and pressure and response for customer complaint and operation and maintenance. While Experimental study design was used for assessing physicochemical and bacteriological quality of drinking water at sources, reservoirs and consumers tap. The water demand projection, water production and consumption data was used to assess the coverage of demand and the amount of UfW of the Hossana town.

3.3. MATERIALS

3.3.1. SOURCE OF DATA

The research was conducted various data and the source of data were both primary and secondary.The primary data was obtained from field observation, checklists, questionnaires and laboratory results. Water sample was taken at selected sampling site for microbiological and physico-chemical water quality analysis. Water sample collected was analyzed for different parameters at the laboratory of Hossana Town Water Supply Service (HWSS). After checking parameters which indicate quality status of drinking water it was compared to the Ethiopian and WHO guideline values. Secondary data were collected from published and unpublished literatures and from the sub-city reports.

3.3.2. EQUIPMENTS USED

The laboratory of Hossana town Water Supply Service was used to conduct water quality test. pH meter were used for chemical water quality inspection. Microbiological analysis was also undertaken in the same laboratory, using validated multiple tube fermentation technique. The main procedure was incubating sample water in media which selectively promote growth of total coliform bacteria and fecal coliform. Sampling bottle, taste tubes, Diurnal tubes , Knife/spoon, Distilled water, Incubation machine, Sterilization machine, Refrigerator, pH meter, Pipet were used when microbiological and physico-chemical water quality analysis were done.

For microbiological water quality assessment (total and feacal coliform) the following reagents were used for each consecuitive stages: Lactose broth,used for analysis of total coliform at the presumptive stage,BGB(Brilliant green bile) used for fecal coliform analysis at conformative stage and DPD(Diethyl-Phenylene-Diamine) was used for physico chemical water quality determination-for determination of free residual chlorine.

Interview questionnaires were used for customer satisfaction survey and Water supply service performance indicator checklist for Water Supply Service authorities, water production and consumption data collected from the record of the HWSS for the past four years (2011-2014).

3.4. METHODS

3.4.1. DATA COLLECTION

3.4.1.1. DATA COLLECTION TECHNIQUES

The data collections techniques used in order to achieve the objectives of this study were a collection of comprehensive literature review from published and unpublished sources and the assessment of customer perception regarding the quality of service through questionnaire and informal discussion by enrolling three data collectors. Additionally, Household head means the person who plays the main role in the decision-making process of a family were selected to answer the questionnaire and in absence of the household head, the second important adult member of the family was selected. In doing so, the study objectives were clearly explained to the households and each household was assured that the information provided would be kept confidential. In addition laboratory analyses of water sample were done to characterize the quality of drinking water in the town. The detail methodology is presented as follows:

1. Sample Household interviews using prepared questionnaires for the customers is carried out to collect information about customers' satisfaction towards the water supply service. Site visits is conducted for all water sources, transmission pipes, reservoirs, and distribution systems to collect information through observations and measurements. Water meter readings are taken to estimate yield of boreholes.

2. Previously studied documents and the town's water supply system layouts are reviewed

3. Customer records, water production and water consumption records are reviewed

4. In order to determine the total water loss and trend of the loss, daily water production records of all sources for the past four years (2011-2014) are taken from the utility office records and monthly water production is calculated for all sources. And monthly water consumption records of all kebeles' private, public, institutions, commercial and industrial customers of the past four years (2011-2014) are taken from the utility office records and analysis is made for four years water production and consumption. And also the four consecutive year's water loss is calculated from the water production and consumption data. For missing data of water production and consumption average of the available records is taken.

5. Water samples are collected from water sources, reservoirs and household connections and water

quality tests are carried out for parameters such as Residual chlorine, pH, turbidity, total coliform and faecal coliform. GPS reading of all water sources is taken and GIS map is produced accordingly.

3.4.1.2. SAMPLE SIZE

Total number of customers in the town for 2014 was 7232; from these beneficiary customers, sample population was determined by using the following statistical formula (Cochran WG, 1977).

$$n(i) = (N*Z^2*P*Q) / ((W^2*(N-1)) + (Z^2*P*Q))$$

Whereas n (i)......sample household (Sample size)

N……total number of house hold

P…… proportion of population, (50%)

Q…….1-P

Z……..95% confidence interval (1.96)

W……..Absolute error or precision,5%

$$n(i) = (7232*1.96^2*0.5*0.5) / ((0.05^2*(7232-1)) + (1.96^2*0.5*0.5)) = 365 \text{ household.}$$

However due to the financial and time constraint, in this research only a total of 60 households were used for interview. After sorting house-number in ascending order the first house were selected by lottery means and the next were elected by interval of 25.

3.4.1.3. SAMPLE SELECTION FOR WATER QUALITY ANALYSIS

For water quality analysis from a total sample 5% was taken as a representative sample. As the basic assumption that Water quality may not vary at a nearby distance (WHO, 1999).

Sample size =5%*365 households=18.25 which is rounded to 19 sampling points.

Accordingly 15 household sampling points, 1treatment reservoir in connection with BH5, the newly built spring source around Mugo, Borehole4 of Ajo area and Collection of Borehole 1 and Borehole2 which is a total of 19 sampling points were used for water quality assessment. The water quality analysis was done following appropriate water quality sampling methods.

3.4.2. SAMPLE HANDLING

3.4.2.1. SAMPLING TIME, STORAGE AND TRANSPORTATION

Water samples were collected starting from mid of May-mid of June, during morning hours. Residual chlorine analyses were taken at time of sampling by taking water sample directly from tap to the sampling tubes in the comparator. For other parameters, water samples were collected by using water sampling kit from HWSS for microbiological parameters and using plastic bottles for physico-chemical water quality analysis. The collected samples were made to reach to laboratory within less than 8 hours.

3.5. DATA ANALYSIS

1. The water production and consumption data collected were analysed using Microsoft Excel.

2. Unaccounted for Water was calculated by taking the averaging of monthly total UfW for the past four years (2011-2014).

3. Water quality laboratory results were summarized and compared with the local and international (WHO) standard.

4. The customer satisfaction survey questionnaire was analysed using Microsoft Excel and Percentages and frequency distributions were main analytical methods. The results of the questionnaires were calculated in percentages according to the higher number of the same answer.

5. Tables and graphs were used to display the results.

CHAPTER FOUR

4.0. RESULT AND DISCUSSION

4.1. WATER PRODUCTION, CONSUMPTION AND WATER LOSS ANALYSIS

4.1.1. INTRODUCTION

In order to determine the total water loss and trend of the loss, water production and consumption records of the past four years (2011-2014) are taken from the utility office records and analysis is made for four years water production and four years (2011-2014) consumption and four consecutive years (2011-2014) water loss is calculated from the water production and consumption data. Water production, consumption and loss analysis and findings are indicated on the tables and graphs mentioned below.

4.1.2. WATER PRODUCTION

The existing water supply for Hossana town is obtained from six boreholes located at the periphery of the town (though one borehole is abandoned due to low yield and the other BH-6 is still not functional due to relay system not installed) and two springs located around Mugo ,Siltie Zone, 45km away from the Hossana town. The annual water production from the water supply service is collected on the monthly base and then converted to yearly base for the evaluation purpose. The production of the water for distribution purpose is from the boreholes and the newly constructed spring sources. Here below are presented the production for the year 2011-2014 both in tabular and in chart form.

4.1.3. WATER CONSUMPTION AND WATER SUPPLY COVERAGE

4.1.3.1. WATER CONSUMPTION

The annual water consumption from the water supply service is collected on the monthly base and then converted to yearly base for the evaluation purpose. The consumption of water is combined consumption of private, commercial, Government & public and industry consumption. Here below are presented the consumption for the year 2011-2014 both in tabular and in chart form and also refer Tables 20-27 in the Annex III.Statistical analysis was used to evaluate the distribution of the supply coverage in the town and the domestic water supply coverage is evaluated using the annual consumption data and the result has been converted to average daily per capital consumption using the number of population. The average daily per capital consumption calculated as:Capital consumption (l/person/day) =(Annual consumption in m^3*1000litre/m^3)/ (Population number * 365)

Hossana Town Water Supply Production (m^3) from Ethiopian Year 2003 Yekatit-2007 Tahisas (2011-2014 GC)

Table 9: Monthly Water Production (m^3) for the Years 2011-2014

S/N	Year	2011	2012	2013	2014
1	January	39,720.00	38,235.00	91,600.00	110,420.00
2	February	38,585.00	40,820.00	133,890.00	100,970.00
3	March	50,345.00	40,484.00	86,840.00	118,973.00
4	April	48,770.00	39,210.00	113,170.00	105,100.00
5	May	48,148.00	33,819.00	123,150.00	122,800.00
6	June	45,348.00	36,680.00	148,700.00	92,335.00
7	July	42,219.00	38,300.00	118,410.00	160,490.00
8	August	49,939.00	37,335.00	115,306.00	124,505.00
9	September	46,848.00	37,414.00	159,535.00	132,300.00
10	October	48,469.00	39,620.00	118,220.00	139,340.00
11	November	38,308.00	89,474.00	120,120.00	156,710.00
12	December	35,095.00	105,975.00	133,270.00	165,470.00
	Total	**531,794.00**	**577,366.00**	**1,462,211.00**	**1,529,413.00**

Hossana Town Water Supply Consumption from Ethiopian Year 2003 Yekatit-2007 Tahisas (2011-2014 GC)

Table 10: Monthly Water Consumption (m^3) for the Years 2011-2014

S/No.	Year	2011	2012	2013	2014
1	January	25627.34	38116.51	54989.00	61386.00
2	February	21244.90	30566.00	57235.00	58944.00
3	March	31515.97	32612.16	55721.00	74589.00
4	April	30593.42	30443.38	55621.00	64533.00
5	May	28436.21	28739.11	51274.00	62097.00
6	June	27444.61	30800.60	56413.00	55083.00
7	July	25020.75	26007.00	40361.00	63270.01
8	August	26842.89	24585.00	44966.00	63270.01
9	September	28425.89	27331.00	54388.12	63270.01
10	October	26371.00	27464.00	50874.00	63270.01
11	November	30078.00	39880.00	65841.72	63270.01
12	December	27418.16	46181.00	63827.50	63270.01
	Total	**329019.14**	**382725.76**	**651511.34**	**756252.06**

Table 11: Summarized Water Production and Consumption for the Years 2011-2014

Year	Total production (m^3)	Total Billed data ,Consumption(m^3)	Total population	Water Production l/person/day	Water Consumption l/person/day
2011	531,794.00	329,019.14	80,503	18.10	11.20
2012	577,366.00	382,725.76	83,965	18.84	12.49
2013	1,462,211.00	651,511.34	87,575	45.74	20.38
2014	1,529,413.00	756,252.06	91,341	45.87	22.68

4.1.3.2. WATER SUPPLY COVERAGE

The distribution of the domestic water coverage has been evaluated using the above statistical tools. The distribution of the production has been first reviewed using the descriptive statics. Taking the mean production as shown in above the average domestic water Production of the town is found to be 45.87 l/person/day and the consumption of the town are 22.68 l/person/day in 2014. The average daily per capital consumption of the town is low because from this production more than 50% are loss due to leakage from corroded, old, defective and broken pipe lines, water loss caused by metering inaccuracies or non- functional water meters and leakage from transmission and distribution pipes sudden breaks.

Water supply coverage can be defined as the percentage of people in access of water supply service in the town. To address the need of highly rising water supply needs in the urban population, the water supply service utilities has to manage the existing water supply systems in a manner to efficiently address the need .It is observed that the financial constraint, poor management of the water supply system and the low capacity of human resource has a great impact in the low coverage of water supply provision. Moreover the problem is not only of the low supply coverage but also the supply variation existing in various localities of the population.

The coverage of water supply can also be evaluated based on the quality, quantity, paying capacity of the people, distance, etc. In this study effort is made to evaluate the coverage related to the quantity of the supply and level of connection that are related to the water loss. In this part of the analysis, the number of domestic connection per family and the average daily per capital consumption is used to analysis the domestic water supply coverage for the town in relation to the water produced. The level of coverage has been also compared with other towns/cities of developing countries.

The water supply coverage of the town has been evaluated based on the average per capital consumption and level of connection per family. The average water production is taken from the record of the water utility and the average per capital consumption has been derived from the yearly consumption aggregated from the individual domestic water meters. Statistical analysis was used to evaluate the supply coverage for the town. Number of population as forecasted to the year 2014 has been used to evaluate the average per capital consumption and also of the water coverage.

Table 12: Water Supply Coverage of Hossana Town for the Years 2011-2014

Year	Annual Water Consumption (m^3/yr)	Total Population (No)	Annual Production (m3/yr)	Consumption l/person/day	Total Annual Demand(m^3/yr) *	%of coverage **
2011	329,019.14	80503	531,794.00	11.20	1,936,690.00	27.46
2012	382,725.76	83965	577,366.00	12.49	2,321,035.00	24.87
2013	651,511.34	87575	1,462,211.00	20.38	2,,878,756.00	50.79
2014	756,252.06	91341	1,529,413.00	22.68	2,960,880	51.65

* Annual Demand taken from Hywas Engineering Consultants Design Report for Hossana Town, 2009, which is amended for its value of UfW based on this research result for years 2011-2014 (Refer Table 8: Population Projection and Water Demand Forecasting).

** Percentage of Water Supply Coverage is computed as: (Annual Production/Annual Demand)*100

In 2010 the Ethiopian Government presented the equally ambitious Growth and Transformation Plan (GTP) 2011-2015, which aims at increasing drinking water coverage, from 68.5% to 98.5%. In comparison with this plan, the water supply coverage is behind the plan (Ministry of Finance and Economic Development, 2010) and also in comparison, the Ethiopia's capital city, Addis Ababa water supply coverage during 2009 was found to be 60.67% (Shimelis Kabeto, 2011).

The above table shows that the annual production for the year 2013 is almost nearly tripled (2.5325 times the annual production for the year 2012) and as well the coverage also nearly doubled (2.04 times the coverage for the year 2012) as compared to the production and coverage for the year 2012. This is due to the newly built water supply from the two springs located around Mugo area in Silti zone with a yield of 107.8l/s which was made to function in 2013

As clarified earlier the water supply coverage of the town, both in quantity and level of connection is low while compared to the other towns and cities in Africa. The above table (Table12.) shows that the water production per capita of Hossana town as of 2014 as per this research finding was 16.74m3/person /yr which is equivalent to nearly 46 l/person/yr and the consumption was 22.68l/person/day. While that of African cities like Maseru of Lesotho in which the water production and consumption in 2000 was found to be 81l/person/day and 67l/person/day respectively and the water production and consumption of Port Luis of Mauritius Island in the same year was found to be 200 l/person/day and 135 l/person/day respectively which clearly tells that a big effort is expected from utilities and government to address the demand in this regard (HR Wallingford and DFID,2003).

In areas where water supply coverage is sufficient, volume of domestics water consumption is expected to be linear related to the level connection. Areas having better level of connection are expected to consume more water as they can easily get it within their building or compound. A detail demand study in Africa found that average water carried was about 22 l/day per capital over a long distance rising to about 30 l/day per capital where water was obtained from the consumer own stand pipe. Of course distance is not a big problem in urban areas rather than rural areas (ADB, 1993) on the other hand in areas having insufficient supply, some areas may have better level of connection but may not necessarily mean they are consuming more volume of water as the possibility of getting the water does not depend only on the location. There are number of places that get low volume of water due to their topographic location. As the town mainly uses gravitational supply system, topography has a great impact on the per capital consumption.

Table 13: Southern African Capital Cities of Water Production

Country	Largest City	Population of largest city(million)	Water Production for the largest city(l/person/day)
Angola	Luanda	4	30
Botsowana	Gaborone	0.13	286
Democratic Republic of Congo	Kinshasa	5.7	86
Lesotho	Maseru	0.27	81
Mauritius	Port Luis	0.15	200
Tanzania	Dar Es Salaam	3	150
Zambia	Lusaka	1.21	225
Zimbabwe	Harare	2.38	156

(Source: HR Wallingford and DFID, 2003)

4.1.4. WATER LOSS

Unaccounted-for water (UfW) represents the difference between "net production" (the volume of water delivered into a network) and "consumption" (the volume of water that can be accounted for by legitimate consumption, whether metered or not).

UfW = “net production” – “legitimate consumption” and it can be put in percentage as:UfW, %=((net production-Legitimate consumption)/net production)*100.

Accordingly, the averaged UfW, % for year 2011-2014 was found 38.13%, 33.71%, 55.44% and 50.55% respectively (refer: Annex III of this research for Tables 20 -27 and Figures 5-17). In comparison the loss of other towns like Addis Ababa was 37% in 2009 (Shimelis Kabeto,2011), and the loss (NRW as % of system input volume for the year 2001) record of developed countries/cities was as follows Malaysia,36.4%,Korea 29.3%,Bangkok of Thailand, 38.8%,Taipei of Taiwan 41.8%, Denmark 7.6%,Norway 40%,Murcia of Spain 18% to 58% and France Urban 10% to 30%(A.O. Lambert (UK),2001).

As per the analysis on Table 27 and Fig.12 the average water loss for the year 2014 is calculated to be 50.55% of the average water production which is very high and a matter of concern.

In other words, out of the average monthly water production in 2014 which was 127,451.08m^3 the amount consumed was 63,021.01m^3 and the water loss was 64,430.08m^3. As per the analysis on Table 26 and Fig.11, the average water loss for the year 2013 is calculated to be 55.44% of the average water production. Out of the average monthly water production in 2013 which was 121,850.92m^3 the amount consumed was 54,292.61 m^3 and the water loss was 67,558.31m^3. Similarly the water loss (UfW) for year 2012 was 33.71% and for the year 2011 was 38.13% as per this research finding.

The Table 20, Table 21, Table 22 and Table 23 and also the corresponding charts in Fig 14, 15, 16 and 17 shows amount of water loss in the year 2011-2014 respectively in amount and percentages. In other words, out of the average monthly water production in 2014 which was 127,451.08 m^3 the amount consumed was 63,021.01 m^3 and the water loss was 64,430.08 m^3 which means UfW is 50.55%. Out of the yearly 1,529,413 m^3 water production in 2014 the amount consumed was 756,252.06 m^3 and the amount of water loss was 773,160.94 m^3

To express daily water loss in terms of daily water production, out of the average daily water production which was 4,248.37 m^3 the water loss was 2,147.67 m^3. Considering the average tariff of birr 8.62 per m^3 of water consumption the loss in monetary term can be calculated. Accordingly the water loss in 2014 is 773,160.94 m^3 or it is equivalent to birr 6,664,647.30 which is huge amount of money. If loss is minimized say by 50%, about birr 3,332,323.65 will be collected on average and this money can be used for various purposes to address the demand of the population.

4.1.4.1. REASONS OF HIGH WATER LOSS

During the study of Hossana town water supply system, it was observed that leakages have been observed and the main reasons among others were:

- Leakage from transmission and distribution pipes sudden breaks
- Water loss caused by metering inaccuracies
- Leakage on service connections up to point of customer metering
- Leakage due to high pressure at transmission and distribution pipes and leakage caused by connecting distribution pipes on pressure lines
- Leakage due poor workmanship and using of nonstandard pipes and fittings.

4.1.4.2. RECOMMENDATIONS TO REDUCE THE HIGH WATER LOSS

In order to minimize the above water loss observed in the Hossana town water supply system, the following measures has to be taken:

- Better data collection regarding the amount of non-revenue water due to technical losses (leaking pipes, etc.) and administrative losses (illegal connections, etc.) to enable better targeting of NRW reduction resources

- Development of an asset management plan that identifies the condition of assets and plans for the operation, management and repairs needed to maintain the infrastructure annually and over the longer term.

- Water meters should be installed at all sources, reservoirs and collection chambers inlet and out let pipes main district or zonal distribution pipes and proper water production recording should be in place.

- Old and corroded pipes should be replaced and faulty water meters need to be maintained or replaced to minimize leaks from pipes and errors of water production recording

- There has to be planned and regular routine inspection for leakage from water supply system components such as transmission and distribution pipes, reservoirs, collection chambers and pump houses. And there should be immediate rehabilitation and maintenance when leaks are observed.

- Maintenance and rehabilitation needed to be done for pumping station collection chamber and surface pumps and for inlet pipes from boreholes routine base and when leaks are observed. Immediate Rehabilitation and replacement of old pipes is also to be done regularly.

- Float valves and water level indicators should be installed at all ground and elevated tanks, at all reservoirs and collection chambers inlet pipes and those float valves which are not function should be maintained

- There has to be regular water meter testing or functionality of all types of installed water meters should be checked frequently and improvement of the billing system.

- Maintenance of the base and walls of the Masonry Sandwiched Reservoir near the Nigist Eleni Hospital compound to reduce leakage and also the service life of the reservoir to get revenue from unbilled metered consumptions and to minimize illegal connection and also to avoid further destruction of the reservoir.

- Corrosion control and pressure reduction systems need to be developed
- Water audit or assessment of the capacity of total water produced by the water supply utility and the actual quantity of water distributed through the area of service of the water utility, thus leading to estimate the losses.

4.2. WATER QUALITY ANALYSIS RESULTS AND DISCUSSION

Water is essential to life and a nominal supply of clean-safe drinking water is required for the sustenance of life. Concern regarding safe-clean drinking water commenced at the turn of the 20th century, when science coupled with technology unraveled the implications associated with contaminated drinking water. Today, in developed nations, it is standard practice to provide the populace with safe-reliable drinking water, as safe drinking water in most industrialized countries is recognized as a basic human right and a cost effective measure of reducing disease (i.e., preventative medicine). In developed countries, drinking water quality guidelines and regulations are based on current, published-scientific research related to health effects, aesthetic effects, and operational considerations. All these important parameters aim at providing potable and palatable drinking water to reduce water borne diseases and foster healthy living.

Briefly, the purpose of having drinking water quality guidelines and regulations is to ensure that all human beings within a country have access to safe drinking water. In developing countries, it is estimated that over 80% of disease is caused by contaminated drinking water and as a consequence, over 30% of work productivity is lost. Meaning, water is largely the cause of most disease and a considerable amount of work potential is compromised because of this.

In order to say a water supply system is performing well the system should provide potable water supply to the customers in addition to other factors like quantity , continuity etc. To check Hossana town water supply water quality status, thirty eight water samples are taken from all existing water supply sources, reservoirs, pumping stations and selected households. After the samples are taken water quality test is carried out in the HTWSS laboratory for the parameters which are coliform (Total &Faecal), turbidity, residual chlorine and pH. The results of the water quality tests are indicated in comparison with the international (WHO) and national (Ethiopian) standards on Table 14, Table 15, Table 16, Table 17 and Table 18 respectively here below.

Table 14: Water Quality Test Result for Total Coliform

SN	Sample Sites	No.of Samples	Average Result	WHO Standard	Ethiopian Standard
1	Treatment Reservoir +BH5	2	0/100ml	0/100ml	0/100ml
2	Mugo Spring	2	0/100ml	0/100ml	0/100ml
3	BH4-Ajo	2	0/100ml	0/100ml	0/100ml
4	BH1+BH2	2	2/100ml	0/100ml	0/100ml
5	Nigist Eleni Hospital	2	2/100ml	0/100ml	0/100ml
6	Gombora Hotel	2	3/100ml	0/100ml	0/100ml
7	Sidone Café Meliamba Kebele	2	0/100ml	0/100ml	0/100ml
8	Around Lemma International Hotel	2	5/100ml	0/100ml	0/100ml
9	AG Flour Factory – Wolaita Ber	2	0/100ml	0/100ml	0/100ml
10	Belay Flour Factory	2	0/100ml	0/100ml	0/100ml
11	Yekatit 25/67 School	2	1/100ml	0/100ml	0/100ml
12	Grime Bekele Kutir 5 School	2	0/100ml	0/100ml	0/100ml
13	Bobicho Primary School	2	0/100ml	0/100ml	0/100ml
14	Heto High School	2	0/100ml	0/100ml	0/100ml
15	Heto Kebele6 HH	2	10/100ml	0/100ml	0/100ml
16	NaramoKebele HH	2	15/100ml	0/100ml	0/100ml
17	Betel Kebele1-Z café Near Heme Hotel HH	2	>50/100ml	0/100ml	0/100ml
18	Bobicho Kebele HH	2	5/100ml	0/100ml	0/100ml
19	Abera Sefer Public Fountain-Village 19	2	0/100ml	0/100ml	0/100ml

Table 15: Water Quality Test Result for Faecal Coliform

SN	Sample Sites	No.of Samples	Average Result	WHO Standard	Ethiopian Standard
1	Treatment Reservoir +BH5	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
2	Mugo Spring	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
3	BH4-Ajo	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
4	BH1+BH2	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
5	Nigist Eleni Hospital	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
6	Gombora Hotel	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
7	Sidone Café Meliamba Kebele	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
8	Around Lemma International Hotel	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
9	AG Flour Factory – Wolaita Ber	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
10	Belay Flour Factory	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
11	Yekatit 25/67 School	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
12	Grime Bekele Kutir 5 School	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
13	Bobicho Primary School	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
14	Heto High School	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
15	Heto Kebele6 HH	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
16	Naramo Kebele HH	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
17	Betel Kebele1-Z café Near Heme Hotel HH	2	3/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
18	Bobicho Kebele HH	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli
19	Abera Sefer Public Fountain-Village 19	2	0/100ml	<3Col/100ml/Coli	<3Col/100ml/Coli

4.2.1. COLIFORM

Total Coliforms

Total coliforms are a group of closely related bacteria (family *Enterobacteriaceae*) that has been used for many decades as the indicator of choice for drinking water. The group is defined as aerobic and facultatively anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria that ferment the milk sugar lactose to produce acid and gas within 48 h at 35°C. Few bacteria other than coliforms can metabolize lactose; for this reason, lactose is used as the basis for identification (the hydrolysis of *o*-nitrophenyl-β-*d*-galactopyranoside, or ONPG, is also used for identification in some coliform tests).

The total coliform group includes most species of the genera *Citrobacter, Enterobacter, Klebsiella,* and *Escherichia coli.* It also includes some species of *Serratia*and other genera. Although all coliform genera can be found in the gut of animals, most of these bacteria are widely distributed in the environment, including water, and wastewaters. A major exception is *E. coli,* which usually does not survive long outside the gut, except perhaps in the warm water associated with tropical climates. Total coliforms are used to assess water treatment effectiveness and the integrity of the distribution system. They are also used as a screening test for recent fecal contamination.

Treatment that provides coliform-free water should also reduce pathogens to minimal levels. A major shortcoming to using total coliforms as an indicator is that they are only marginally adequate for predicting the potential presence of pathogenic protozoan cysts/oocysts and some viruses, because total coliforms are less resistant to disinfection than these other organisms. Another shortcoming is that coliforms, under certain circumstances, may proliferate in the biofilms of water distribution systems, clouding their use as an indicator of external contamination. Coliforms are also often not of fecal origin. Despite these drawbacks, total coliforms remain a useful indicator of drinking water microbial quality, and the group is regulated under USEPA's Total Coliform Rule (USEPA, 1989e).

Fecal Coliforms and *E. coli*

Fecal coliforms are a subset of the total coliform group. *E. coli* is the major subset of the fecal coliform group. They are distinguished in the laboratory by their ability to grow at elevated temperatures (44.5°C) and by the ability of *E. coli* to produce the enzyme glucuronidase, which hydrolyzes 4-methyl-umbelliferyl-β-*D*-glucuronide (MUG). Both fecal coliforms and *E. coli* are better indicators for the presence of recent fecal contamination than are total coliforms, but they do not distinguish between human and animal contamination. Moreover, fecal coliform and *E. coli* densities are typically much lower than are those for total coliforms; thus, they are not used as an indicator for treatment effectiveness and post treatment contamination. *E. coli* is a more specific indicator of fecal contamination than is the fecal coliform group. Under the Total Coliform Rule, all total coliform-positive samples must be tested for either fecal coliforms or *E. coli* (WHO, 2011).

As it is indicated on the above Table 14 and Table 15, water samples are taken from different household connections, sources and reservoirs and checked for total Coliform bacteria, PH and turbidity and the result shows that there is high turbidity and Coliform bacteria existence beyond allowable limit both from WHO and National Standard around BH1+BH2, Lemma International Hotel,Heto HH, Nigist Eleni Hospital, Gombora Hotel HH ,Naramo Keble 6 HH and Betel Kebele1-Z café near Heme Hotel HH. The reason for this has been the leakage from old pipelines which pave the way for intrusion of contaminants and also no or very low residual chlorine. Specifically during this research period, the latrine line around the Betel Kebele1- Z café near Heme Hotel HH has joined the supply line and due to this high total coliform count encountered. Later the problem was solved by disinfecting the distribution lines by concentrated, 65% calcium hypochlorite(CaOCl). The possible reason of presence of coliform bacteria in the existing sources is there is no sufficient dosage of chlorine added or absence of continuous chlorination relative to the amount of water entering the reservoirs. The reason of no coliform on the water samples of other sample sites is presence of enough residual chlorine which is near to the national guideline. This shows that the reason for coliform bacteria existence on most water samples is due to old pipe lines which allow leakages through which contaminants can enter the distribution line easily and also due to lack of sufficient and continuous chlorination (disinfection with chlorine).

Table 16: Water Quality Test Result for Turbidity

SN	Sample Sites	No.of Samples	Average Result	WHO Standard	Ethiopian Standard
1	Treatment Reservoir +BH5	2	5NTU	<5NTU	Low Turbidity
2	Mugo Spring	2	5NTU	<5NTU	Low Turbidity
3	BH4-Ajo	2	5NTU	<5NTU	Low Turbidity
4	BH1+BH2	2	5NTU	<5NTU	Low Turbidity
5	Nigist Eleni Hospital	2	5NTU	<5NTU	Low Turbidity
6	Gombora Hotel	2	5NTU	<5NTU	Low Turbidity
7	Sidone Café Meliamba Kebele	2	5NTU	<5NTU	Low Turbidity
8	Around Lemma International Hotel	2	5NTU	<5NTU	Low Turbidity
9	AG Flour Factory – Wolaita Ber	2	5NTU	<5NTU	Low Turbidity
10	Belay Flour Factory	2	5NTU	<5NTU	Low Turbidity
11	Yekatit 25/67 School	2	5NTU	<5NTU	Low Turbidity
12	Grime Bekele Kutir 5 School	2	5NTU	<5NTU	Low Turbidity
13	Bobicho Primary School	2	5NTU	<5NTU	Low Turbidity
14	Heto High School	2	5NTU	<5NTU	Low Turbidity
15	Heto Kebele6 HH	2	5NTU	<5NTU	Low Turbidity
16	NaramoKebele HH	2	5NTU	<5NTU	Low Turbidity
17	Betel Kebele1-Z café Near Heme Hotel HH	2	5NTU	<5NTU	Low Turbidity
18	Bobicho Kebele HH	2	5NTU	<5NTU	Low Turbidity
19	Abera Sefer Public Fountain-Village 19	2	5NTU	<5NTU	Low Turbidity

4.2.2. TURBIDITY

Turbidity is a general measure of water ‘cloudiness’ created by particles suspended in a water sample. It has been used to assess drinking water quality for a century and is still the most widely used particle measurement in water treatment. These particles may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, and plankton and other microscopic organisms. Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern as it may provide food and shelter for pathogens.

The World Health Organization (WHO,2011) Guidelines for drinking-water quality states turbidity in water is caused by colloidal matter or suspended particles that obstructs light transmission through the water which may be caused by inorganic or organic matter or a combination of the two. Microorganisms (bacteria, viruses and protozoa) are typically attached to particulates, and removal of turbidity by filtration will significantly reduce microbial contamination in treated water. Turbidity in surface waters may be the result of particulate matter of many types and is more likely to include attached microorganisms that are a threat to health whereas turbidity in some groundwater sources is a consequence of inert clay or chalk particles or the precipitation of non-soluble reduced iron and other oxides when water is pumped from anaerobic waters.

Turbidity in distribution systems can occur as a result of the disturbance of sediments and biofilms but is also from the ingress of dirty water from outside the system. In addition, turbidity can seriously interfere with the efficiency of disinfection by providing protection for organisms, and much of water treatment is directed at removal of particulate matter before disinfection. This not only will increase the efficacy of disinfection by chemical disinfectants such as chlorine and ozone, but is an essential step in ensuring the effectiveness of physical disinfection processes such as ultraviolet irradiation, because light transmission through water is impaired by particulates. Removal of particulate matter by coagulation and sedimentation and by filtration is an important barrier in achieving safe are emerging that show an increasing risk of gastro intestinal infections that correlates with high turbidity and turbidity events in distribution.

This may be because turbidity is acting as an indicator of possible sources of microbial contamination. Therefore, turbidity events should be investigated and the causes corrected, whereas turbidity should be minimized as far as is possible within the constraints of the type of system and the resources available as one part of the management of distribution to achieve water safety. Turbidity is also an important consideration when investment decisions are made regarding sources and treatment for water supplies and should be identified in the water safety plan as a hazard that needs to be controlled.

Turbidity is measured by nephelometric turbidity units (NTU) and can be initially noticed by the naked eye above approximately 4.0 NTU. However, to ensure effectiveness of disinfection, turbidity should be no more than 1 NTU and preferably much lower. Large, well-run municipal supplies should be able to achieve less than 0.5NTU before disinfection at all times and should be able to average 0.2 NTU or less.

The possible reasons for turbidity above the national standard may be contamination of the water sources by surface water flooding, contamination by storm water from urban areas or may be absorption of mud or soil particles during pumping and even due to over pumping.

The water quality test result is shown on Table 16. As it is clearly shown, there is high turbidity which is almost near to exceed the minimum standard set. The main source of high turbidity is the turbid water that is pumped from boreholes even though further detail study need to be conducted to identify the main cause of the problem, the possible causes of high turbidity are contamination by surface water runoff containing mud or silt during rainy season due to formation of pond around the boreholes area, percolation of surface water containing silt due to over pumping as it is seen on the soil formation surrounding borehole areas which is seen cracked during field observation. It may also due to problem on the casing installation during construction of the well.

Table 17: Water Quality Test Result for Residual Chlorine

SN	Sample Sites	No.of Samples	Average Result	WHO Standard	Ethiopian Standard
1	Treatment Reservoir +BH5	2	1.36	0.3-1.5mg/l	0.5mg/l
2	Mugo Spring	2	1	0.3-1.5mg/l	0.5mg/l
3	BH4-Ajo	2	0	0.3-1.5mg/l	0.5mg/l
4	BH1+BH2	2	0	0.3-1.5mg/l	0.5mg/l
5	Nigist Eleni Hospital	2	0	0.3-1.5mg/l	0.5mg/l
6	Gombora Hotel	2	0.5	0.3-1.5mg/l	0.5mg/l
7	Sidone Café Meliamba Kebele	2	0.7	0.3-1.5mg/l	0.5mg/l
8	Around Lemma International Hotel	2	0	0.3-1.5mg/l	0.5mg/l
9	AG Flour Factory – Wolaita Ber	2	0	0.3-1.5mg/l	0.5mg/l
10	Belay Flour Factory	2	0	0.3-1.5mg/l	0.5mg/l
11	Yekatit 25/67 School	2	0.2	0.3-1.5mg/l	0.5mg/l
12	Grime Bekele Kutir 5 School	2	0.5	0.3-1.5mg/l	0.5mg/l
13	Bobicho Primary School	2	0	0.3-1.5mg/l	0.5mg/l
14	Heto High School	2	0.2	0.3-1.5mg/l	0.5mg/l
15	Heto Kebele6 HH	2	0	0.3-1.5mg/l	0.5mg/l
16	Naramo Kebele HH	2	0	0.3-1.5mg/l	0.5mg/l
17	Betel Kebele1-Z café Near Heme Hotel HH	2	0	0.3-1.5mg/l	0.5mg/l
18	Bobicho Kebele HH	2	1.36	0.3-1.5mg/l	0.5mg/l
19	Abera Sefer Public Fountain-Village 19	2	0.2	0.3-1.5mg/l	0.5mg/l

4.2.3. RESIDUAL CHLORINE

Chemical Symbol or Formula: Cl2. Units Used for Analytical Results: mg/l Cl. Normal Method(s) of Analysis: Colorimetric (DPD) [A; in-situ test Occurrence/Origin: Water treatment processes, industrial effluents, chlorinated sewage and other effluents. Health/Sanitary Significance: No direct significance at the relatively tiny levels used in water treatment processes.

Background Information: Water supplies are disinfected to destroy or deactivate microorganisms which can produce diseases such as cholera, typhoid and so on, and the process is the most important in water treatment. Disinfection maybe achieved in various ways but the vast majority of supplies are treated with chlorine which is a powerful oxidizing agent and an extremely efficient disinfectant. It is relatively easy to handle and is also cost-effective, hence its almost universal use. Chlorine is very reactive and will only remain, as discussed below, in treated waters of high quality. It is not a constituent of unpolluted natural waters.

The primary effects of chlorination are extremely beneficial and for many minor water supplies the process may be the only treatment deemed necessary. Quite low levels are effective for disinfection in normal circumstances, but should the ammonia or organic content of the water be high then the water may have an appreciable "chlorine demand" and a higher chlorine input may be needed to achieve a given degree of protection.

As in many cases the treatment works for a public water supply may be a considerable distance from the ultimate consumers, it is essential that continuing protection be afforded along the distribution system, particularly if it is old and prone to leaks and/ or infiltration of extraneous matter. The philosophy underlying chlorination is therefore to ensure that there is chlorine residual which will protect against recontamination. Dosage, contact time and other factors in the chlorination process will be adjusted so that a concentration of 0.1-0.3 mg/l Cl remains after 30 minutes' contact. Chlorine reacts with water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl). The former is a weak acid which dissociates to give hypochlorite ions (OCl–) and there is a chemical equilibrium between the dissociated and the undissociated forms (the latter actually effects the disinfection) but it is very common to add the chlorine as hypochlorite solution. The free chlorine residual is taken to include chlorine, hypochlorous acid and hypochlorite, irrespective of form.

Parameters of Water Quality - Interpretation and Standards: Because of the reactivity with reducing agents and organic matter these free residual forms may not persist and there may not therefore be continuing protection. Ammonia will also react with chlorine forms to give mono-chloramine (NH2Cl), di-chloramine ($NHCl_2$) and tri-chloramine (NCl_3), depending on relative concentrations and pH. The mono- and di-chloramines have significant disinfection power which persists. Because of this it is sometimes the practice to add ammonia in the chlorination stage to give a combined residual rather than a free residual. The results of a complete analysis will therefore show from the relative proportions of free and combined residuals the extent to which disinfection can be maintained during distribution of a supply. Free chlorine is a more efficient disinfection agent than the chloramines but, being more reactive, it is more likely to disappear fairly quickly from solution; the combined chlorine, on the other hand, gives longer-lasting protection.

Two further points should be noted about the use of chlorine. First, if water is polluted by phenols or by trace organic compounds released from decaying algal growths, chlorination can give rise to very severe taste and odour problems, rendering the water unfit to drink. Second, it should also be noted about chlorination that where a water contains even small amounts of organic (humic) colouring matter, the reaction between it and the added chlorine will give rise to undesirable chlorinated by-products [e.g. trihalomethanes; q.v.] which are also subject to restriction.. Comments: Although chlorine is a poisonous gas, its toxicity to humans is not a consideration in drinking water supplies as water would be unacceptable on organoleptic grounds long before the onset of directly toxic effects. There are, however, strict limits on its concentration in fishery waters as its toxicity to aquatic life forms is much more marked.

Chlorine: Recommended or Mandatory Limit Values: As per the publication by water research center, the chlorine that does not combine with other components in the water is free (residual) chlorine, and the break point is the point at which free chlorine is available for continuous disinfection. An ideal system supplies free chlorine at a concentration of 0.3-0.5mg/l (WHO, 2011). As shown on the Table 17,the reason for low amount of residual chlorine presence at most of the water samples is due to low amount of chlorine dosage added to the sources and reservoirs. As previously discussed and indicated there no coliform bacteria presence in the water samples taken in which residual chlorine from these samples are not very far from the national standard. This shows that if there is sufficient chlorination and residual chlorine amount of 0.3-0.5mg/l in the system, the chance of coliform existence will be zero.

Table 18: Water Quality Test Result for pH

SN	Sample Sites	No.of Samples	Average Result	WHO Standard	Ethiopian Standard
1	Treatment Reservoir +BH5	2	7.5	6.5-8.5	6.5-8.5
2	Mugo Spring	2	7.1	6.5-8.5	6.5-8.5
3	BH4-Ajo	2	7.4	6.5-8.5	6.5-8.5
4	BH1+BH2	2	7.3	6.5-8.5	6.5-8.5
5	Nigist Eleni Hospital	2	6.7	6.5-8.5	6.5-8.5
6	Gombora Hotel	2	6.8	6.5-8.5	6.5-8.5
7	Sidone Café Meliamba Kebele	2	7.8	6.5-8.5	6.5-8.5
8	Around Lemma International Hotel	2	6.3	6.5-8.5	6.5-8.5
9	AG Flour Factory – Wolaita Ber	2	7.2	6.5-8.5	6.5-8.5
10	Belay Flour Factory	2	7.4	6.5-8.5	6.5-8.5
11	Yekatit 25/67 School	2	6.8	6.5-8.5	6.5-8.5
12	Grime Bekele Kutir 5 School	2	7.3	6.5-8.5	6.5-8.5
13	Bobicho Primary School	2	6.9	6.5-8.5	6.5-8.5
14	Heto High School	2	7.4	6.5-8.5	6.5-8.5
15	Heto Kebele6 HH	2	6.95	6.5-8.5	6.5-8.5
16	Naramo Kebele HH	2	7.5	6.5-8.5	6.5-8.5
17	Betel Kebele1-Z café Near Heme Hotel HH	2	7.5	6.5-8.5	6.5-8.5
18	Bobicho Kebele HH	2	7.3	6.5-8.5	6.5-8.5
19	Abera Sefer Public Fountain-Village 19	2	7.4	6.5-8.5	6.5-8.5

4.2.4. pH AND CORROSION

As per Guidelines for drinking-water quality by World Health Organization, although PH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection. For effective disinfection with chlorine, the pH should preferably be less than 8; however, lower-pH water (approximately pH 7 or less) is more likely to be corrosive. The pH of the water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems. Alkalinity and calcium management also contribute to the stability of water and control its aggressiveness to pipes and appliances. Failure to minimize corrosion can result in the contamination of drinking-water and in adverse effects on its taste and appearance. The optimum pH required will vary in different supplies according to the composition of the water and the nature of the construction materials used in the distribution system, but it is usually in the range 6.5–8.5. Extreme values of pH can result from accidental spills, treatment breakdowns and insufficiently cured cement mortar pipe linings or cement mortar linings applied when the alkalinity of the water is low (WHO,2011). As shown on Table 18 above, the pH value of all taken water samples is within the range of the National(Ethiopian) and WHO Standard.

4.2.5. CONCLUSIONS

The presence of coliform bacteria in most of the water samples tested is due to lack of proper and continuous chlorination and low amount of chlorine dosage added compared to water volume pumped and this has resulted in low residual chlorine below the national standard.

Even though there is water quality laboratory at Hossana town water utility office compound bacteriological and chemical water quality test is conducted biannually in which the frequency is not sufficient and sanitary inspection for existing water supply system and newly developing sources is not carried out periodically as per the Ethiopian Guideline for Drinking Water Quality.

4.2.6. RECOMMENDATIONS

It is recommended that appropriate amount, dosage and continuous chlorination in accordance with the quantity of water pumped to the reservoirs are used to avoid presence of coliform so as to meet the national standard. The chlorination should be done in such a way that the residual chlorine in the distribution system to be in the range of 0.3 -0 .5mg/l. There should be continuous chlorination at each reservoir in line with volume of water entering the reservoir so as to disinfect the water that is produced and pumped from boreholes before it is distributed to consumers.

To identify the main cause of high turbidity at boreholes further detail study should be conducted and to alleviate the customers suffering from lack of potable water during summer other water source should be developed(borehole should be drilled) or alternative measure has to be taken without delay.

As per Ethiopian Guideline for Drinking Water Quality, sanitary survey and water quality analysis are complementary activities that should be conducted by both the water supply agency as well as surveillance agency. Hence no new water supply should be approved without a sanitary inspection and routine surveys of existing supplies should be undertaken periodically by the community, water supplier and surveillance agency.

It is recommended that bacteriological and chemical water quality test be conducted periodically (at least four times a year). And as it is indicated on the water quality guideline the bacteriological test should be accompanied with turbidity and free residual chlorine and pH where chlorination is applied.

4.3. CUSTOMER SATISFACTION SURVEY ANALYSIS AND RESULT

4.3.1 INTRODUCTION AND PURPOSE OF THE SURVEY

Any water supply service providers should strive to satisfy its customers in all aspects of service it provide. In this regard customers have also a right to get appropriate service as they are also responsible to compensate in return for the service delivered by the service providers.

Customers' satisfaction regarding service in all its aspect is the aim to do this survey and accordingly following the procedure described in the methodology part of this research, customers were selected for an interview and an interview have been done about the water sources, quality, tariff, water availability including the time travel to get water, maintenance service etc. The number of customers of HWSS in Hossana town in 2014 were 7232 and the below table (Table 19) shows customers number in 2014 by category.

Table 19: Customer Type vs Number for the year 2014

S/N	Customer Category	Number of Customers	Percentage (%) by category
1	Private	6694	92.56
2	Commercial	351	4.85
3	Government & Public	163	2.25
4	Industry	24	0.33
6	Total	7232	100.00

4.3.2. RESULTS

Out of the total 60 respondents asked for second source of water, 57 or 95% said they have no second source of water and only 3 or 5% said that they have second source other than the pipe water.

Out of the total 60 respondents asked for sufficient pressure on their household taps, 44 or 73.3% said that they get sufficient pressure at their taps while 16 or 26.7% said the pressure at the water tap is not enough.

Out of the total 60 respondents asked for satisfaction on the water quality, 50 or 83.33% said that they are satisfied with the water quality and 5 or 8.35% said that they are not satisfied with the water quality while 5 or 8.35% said that the quality depends on the season

Out of the total 60 respondents asked on home water treatment method,6 or10% said that they have home water treatment method and 50 or 90% said that they have no any water treatment method at home.

Out of the total 60 respondents asked on water tariff, 42 or 70% said that the current water tariff is affordable while 18 or 30% said that the current water tariff is not affordable.

Out of the total 60 respondents asked for functionality of their water meter, 59 or 98.33% said that their water meter is functional and 1 or 1.77% said that their water meter is not functional

Out of the total 60 respondents asked for daily water consumption, 15 or 25% said that they use less than 50litre per day and 28 or 46.67% said that they use 5 1-100 liter per day and 14 or 23.33% said that they use 101-500 liter per day and 3 or 5% said that they use greater than 500litre per day.

Out of the total 60 respondents asked for availability of water per day, 9 or 15% said that water available less than 6 hours per day and 11 or 18.33% said that water available for 7-12 hours per day and 6 or 10% said that water is available for 13-18 hours per day and 34 or 56.77% said that water is available more than 19 hours per day.

Out of the total 60 respondents asked for length of time taken to get maintenance, 30 or 50% said that the water utility answer their request less than three days and 18 or 30% said they get maintenance within 4-7 days and 12 or 20% said that they get maintenance after 8 days.

4.3.3 RECOMMENDATIONS

The water utility need to respond immediately to maintenance requests of customers to avoid complaints from customers

The water utility need to work towards increasing the pressure in the distribution system in the way that do not cause leakage and pipe damage but satisfies customers need. Detail study and surveying work need to be conducted before distribution network expansion so as to avoid pressure reduction in the system

As per the conducted household survey, it is only about 57% of the total customers that are getting water supply for 24 hours per day. Hence the water utility should work towards making water to be available for the whole day by developing additional sources to increase the water production and by reducing the high water loss and also as the current water supply is very reliable it is better to construct reservoirs at peak elevation of the town and use relay system to reach very peak area like Arada area and its surrounding.

The water utility need to have planned and regular discussions with the customers and should conduct a regular survey to know customers satisfaction level and the service deficiencies and should make improvements on its service to increase the customers satisfaction.

4.4. OPERATION AND MAINTENANCE

4.4.1. INTRODUCTION ON OPERATION AND MAINTENANCE

The existing water supply source for Hossana town is from boreholes drilled around and Spring Sources from Silti Zone namely Sheshar & Mosheshe Springs.

The rising main from these spring sources to reservoir site is 46.5 km which is gravity transmission line. After joining the treatment plant in the Water Supply Enterprise office compound and collected and disinfected in the 500m3 Reservoir located in this compound the water is pumped to the new 2000m3 Concrete circular reservoir located at an elevation of 2358masl near Hossana Kaleheyewot Church compound on the way to Nigist Eleni Hospital to be distributed. The total length of the Pumped 300mm DCI pipe is 1703m. The other boreholes BH4-Ajo pumped to Balewold Reservoir. Under the existing system, a booster station, BS-2 with a deep well submersible pump installed in a collection tank boosts the supply from BH-5, to the Hospital Reservoir, through a DN 100 transmission Pipe. The new borehole, BH-6, also pumped to the collection tank (500m3 reservoir in the Water Supply office compound).

Under the existing system, a booster station, BS-1, two surface pumps in a 1+1 configuration, boost the supply from BH-1, 2&3, to the Balewold reservoir through a DN 150 transmission pipe. In general BH-1, 2, 3& 4 are functioning with the existing equipments.

The HWSS have got with about 49 km transmission lines and more than 36km distribution lines, four pumping stations (old treatment,3ne treatment ,Bobicho collection chamber and Adjo collection chamber).

The total number of staffs is 7232 and when this considered with performance indicator criteria, number of staffs/1000 connections are around 1. This shows a big gap in operation and maintenance service.

The HWSS got with four band tariff and an average water tariff to be considered as an indicator can be taken as the average value of the four bands which is around Birr8.62/m^3 of water supply.

Pump Control

In regard to Pump control, the borehole & booster pumps are controlled from a CCP installed in the borehole switch house /booster pump house. It will normally start and automatically controlled from high and low level controlled probes installed in their sources and pressure switches installed on the delivery line. The motor control panels are provided with a start stop switch as well as provision for the installation of general fault and operation status.

The pumps are provided with the following automatic cut outs, to stop the pump and indicate a fault, at the local panel. These are:

-Low Source level,-High delivery pressure (closed valve),-Phase failure,-Over Current,-Under voltage, or,-Over Voltage.

The operating sequence of the pumping units is as shown below:

1. Source level…not low, discharge pressure switch…..closed (delivery line pressure below pressure switch low setting)…Pump starts

2. Source level…not low, discharge pressure switch…..open (delivery line pressure above pressure switch high setting)…Pump stops

3. Source level… low, discharge pressure switch…..any…Pump stops

Pump Control Panels

Starters capable of operating the relevant motor a minimum 15 times per hour and suitable for remote, automatic and local button manual operation are provided. Star-delta type starters of a current limiting type suitable for remote, automatic and local manual operation are provided.

Power Sources

The equipment at the TP are operating from EEPCO's grid. All motors above 7Kw are of the star/delta starting type. A stand by generator sufficient to run one booster pump mat new TP booster house and TP utility electrical loads is installed in the generator house constructed for this purpose. The diesel generators installed include the following: Diesel generator pipe works, Fuel tanks and pipe work, Switchgear, Cables, Earthling, All accessories and other necessary items.The primary source of power for running the pumps is electric power from EEPCo grid and standby generators are installed where they are necessary at the sources.

Disinfection

With regard to operation of the chlorination system which is the only water treatment method used as mentioned before, there are chlorine mixing tanks installed at top of reservoirs. The disinfection with chlorine is done in such a way that powder chlorine is added to the chlorine tankers placed at top of the reservoirs and mixed with water and the chlorine solution flows by gravity to the reservoirs through a hose which extends from the chlorine tanker to the reservoirs through the reservoir manholes. The liquid chlorine flows to the reservoirs continuously in form of droplets in parallel with the water pumping to the reservoirs and is terminated when pumping stops. The chlorine consumption per day of Hossana Town Water Treatment system can be seen in two ways depending on the water quality from the various sources: Maximum and Minimum. The maximum amount is 50 litre of chlorine in the form of Sodium hypochloride and the minimum one is half of the maximum which is 25litre of Sodium Hypochloride(NaOCl). Other than this disinfection of the line is done using 3kg of Calcium Hypochlorite per week and this amount may increase depending on the water quality scenario which can be identified through inspection by the utility or sometimes based on the information from beneficiary customers .

Maintenance

Corrective maintenance is done for the different water supply system components by the water supply service office. The common maintenance problems include leakage on pipes, damage of pumps and control panel boards, malfunctioning of water meters installed at the sources.

Regarding maintenance of generators, surface pumps, submersible pumps and pump control panel boards when damage is occurred maintenance work including replacement of pumps is done by the utility. The utility did replacement for submersible pumps by borrowing drilling (service) rig from regional water bureau.

There is one branch office currently under operation except collecting bills. The enterprise planned to open more in the near future to serve the need of the town appropriately which will do operation and maintenance works like follow up the proper operation of different water supply system components under their area, monthly water meter readings of private customers, bill collection, receiving maintenance requests from customers and carry out maintenance, doing maintenance works for the pipelines under their custody, distribution pipeline expansion works for new villages and house connection for new customers.

The enterprise have currently around 72 employees(Master's degree 1,Bachelor degree 7,Diploma 28, Grade 10+2 are 3, Grade10 & 12 completed are 10 , Grade 8-10 are 19 and Grade 1-7 are 4 employees). Gender wise out of 72 employees 19.4% which is 14 of them are females (Bachelor degree 3, Diploma 8, Grade 10&12 complete 2 and Grade 8-10 complete 1).

4.4.2. OBSERVED PROBLEMS ON THE OPERATION AND MAINTENANCE

The following problems are observed on the operation and maintenance of the existing Hossana town water supply.

There are no readily available updated maps showing location of sources, reservoirs, pumping stations, transmission pipe routes and valves, distribution network pipes sizes, length, ages, location of fire hydrants, and gate valves.

There are no district water meters or flow meters installed at the major distribution system pipelines and because of this it is difficult to estimate the amount of leakage and locate the area of high leakage to take corrective actions..

There are no water level indicators in almost all reservoirs and because of this it is difficult to know the water level inside the reservoir.

In most of the reservoirs there are no float valves installed at inlet pipes. Hence the water pumped to reservoirs may overflow and cause high leakage.

The water meters installed in almost all boreholes (specifically BH-1, 3 and 6) are not functional and hence there is no water production recording at the boreholes.

Each source is not provided with standby generator hence the water production will be reduced and there will be water supply shortage during main power failure.

There is no planned and regular routine inspection and preventive maintenance for the water supply system components.

Water production recording at most sources is not done on permanent ledger or book. Rather it recorded on piece of paper and some of the hand writing of the operators is not visible and this may lead to difficulty in knowing the exact water production from the sources.

Most of the transmission pipes that carries pumped water from the boreholes to reservoirs are not aligned along a road and this creates difficulty on routine inspection of the systems for checking of leakages and other problems and carry out the required maintenance.

There is no full, summarized and well organized readily available data of water production and consumption. It is with great effort made that data of water production and consumption of some years is found for this research work.

It is not possible to find borehole history of the existing six wells, feasibility studies, and detail designs and as built drawings of reservoirs, and transmission and distribution pipelines.

4.4.3. RECOMMENDATIONS

The transmission pipes that carries pumped water from the boreholes to reservoirs are need to be aligned along a road and to ease the difficulty on routine inspection of the systems, for checking of leakages and other problems and carry out the required maintenance.

There should be permanent water production recording book at the sources and pumping stations

The utility should give immediate response to customers' maintenance requests.

The installed water meters which are not functional should be maintained or replaced.

Periodic surveillance should be conducted for all water supply system components (sources, reservoirs, and transmission and distribution pipes) to check for problems of leakage and to check for damage of pipes

Routine inspection should also be done for transmission pipes and for main distribution pipes for assessing damage of the transmission system after flooding along the alignment following a heavy storm, unauthorized construction activity near or on the utility pipeline.

Pipeline bursts and breaks can occur at any time and the water utility shall have a plan for attending to such events.

Flushing should be done on the transmission pipe lines to remove impurities or sediment that may be present in the pipe.

The water utility has to establish procedures where by the population residing along the transmission mains and distribution system pipes can notify the visible leaks, to the utility.

Preventive maintenance should be carried out by the utility before reporting of problems such as visible leaks and pipe breaks to the utility by the residents. The preventive maintenance need to include works that are planned and carried out on a regular basis to maintain and keep the water supply system components in a good condition. Some of the works are pressure lines and distribution network inspection, cleansing and greasing of mechanical parts and replacement of equipment with limited life span such as pumps, generators, switch boards, water meters, valves, pipes and fittings.

Connection of distribution pipe from the transmission mains should be avoided so as to reduce high leakage and frequent pipe breaks.

All relevant documents, feasibility studies, borehole history, manufacturer manuals and detail designs, as built drawings of all existing water supply system components(sources, collection chambers, reservoirs, pump houses etc.) need to be find and documented in a well-organized way and should be available in the water utility office for future reference.

Water level indicator used to read and control the water level in the reservoirs need to be installed on the reservoirs so that whenever the reservoirs reach the maximum water level the operators working at the reservoirs inform the operator at the pump house to stop pumping. In addition to this automatic float valves should be fixed on the inlet pipes inside the reservoirs to stop flow to the reservoirs when the reservoirs are full.

The age of pipes laid within the water supply transmission and distribution systems need to be registered and old and corroded pipes need to be replaced with new pipes as age and corrosion cause reduction in carrying capacity of the pipes.

Distribution pipeline expansion should not be done without knowing the pressure (head) in the distribution system and doing surveying work.

Updated water supply system map which provide an overall view of the water supply system components like distribution and transmission pipes layout, sizes and length, location of valves, flow meters, fire hydrants ,reservoirs, pumping stations, sources should be prepared and be available in the water utility office for proper operation and maintenance of the system

Skilled operators need to be assigned at all pumping stations and training program on a continuous basis need to be given for those operators, mechanics plumbers and other water utility staffs who could eventually get involved in the operation and maintenance activities

Manufacturer's instructions on operation and maintenance of mechanical and electrical equipments should be kept in an appropriate manner for reference purpose to be used when a need arise to do so.

Summarized and well organized data of water production and consumption should be available both in soft and hard copy which can easily be referred when need arises.

Appropriate actions should be planned, included in the operation and maintenance plan and undertaken by the water utility to periodically check that Maintenance of Sources and Catchments protection is effective (prevention of farming in the catchment areas, cutting grass and overgrowth in the vicinities of structures, regular inspections at collection chambers of spring intakes, cleaning and greasing of locks, repairs to cracked slabs or leaks, etc.). As periodical coliform bacteria counts provide the best indicators on the evolution of bacteriological water quality, they should be performed on a regular basis, appropriate actions should be immediately taken to locate and eliminate any source of pollution thus detected.

CHAPTER FIVE

5.0. GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

High water loss , water quality problem, very high turbidity from boreholes especially during summer time which leads to high complaint by customers show that there is operation and maintenance problem.

Presence of water quality problem which shows existence of coliform, turbidity, low residual chlorine in the tested water samples, very high water loss as compared to water production, customers' complaints towards water quality, availability, residual head etc. and mentioned operation and maintenance problems in the previous sections of this research shows that Hossana Town Water Supply System Performance is not satisfactory.

Lack or shortages of skilled man power regarding operation and maintenance, record keeping, Service deliveries etc. are significant gaps observed.

A significant amount (50.55%) of the water produced and distributed is lost before reaching to residents.

Most of the customers are not satisfied in the delivery of the water supply service with regard to quality, water pressure, availability time, and maintenance response.

There is gap between existing water supply and demand. Currently as per this research finding, the existing water supply satisfies only 51.65 % of the demand.

5.2. RECOMMENDATIONS

As new water supply scheme is joining the existing system from the Silti zone travelling almost more than 45 km, management of the Gravity line ,supply system in general should be given due consideration. In this regard mutual understanding for mutual benefit between the people of the two zones should be created and there should be bilateral agreement, laws and regulations in all aspects of using the system in a sustainable manner is the primary assignment of both zones in a win-win approach and keeping in mind that the people of the two zone's share common border and have values shared in common from the very long time.

The 500m^3 reservoir is situated in a low elevation than the peak elevation in the town. In this regard it is also recommended that another sizable volume of reservoir can be built in a relatively high elevation than this reservoir which can collect and distribute water from this reservoir to peak areas of the town suffering water shortage or with no access to water.

Immediate actions and corrective measures which are recommended in previous sections should be implemented to reduce water loss to acceptable level, improve the water quality, provide good quality service to satisfy customers and to improve the operation and maintenance to raise the water supply system performance to satisfactory level.

Pressure zoning with appropriate consideration should be done and implemented in ground.

Professionals in all aspects of the service required should be fulfilled or existing staffs' capacity should be upgraded by any means possible.

Additional branches should be opened so as to serve the town's need as the population of the town increasing and both government and private institutions are also expanding unexpectedly.

Further detail study should be conducted to identify measure causes of high water loss which is a matter of concern and needs to be reduced to the intermediate level (below 25%) by taking immediate action.

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ANNEXES

ANNEX–I INTERVIEW QUESTIONNARIES FOR CUSTOMER SATISFACTION SURVEY

1. From where do you get water?

2. For which purposes you use the water from the household tap?

3. Do you have other water source rather than the household tap?

4. How many liters of water you consume per day?

5. How many hours per day is water supplied?

6. Does the water you get from tap have sufficient pressure?

7. Is the water you get from tap clean? (colour,odour,taste)

8. Are you satisfied with the water quality?

9. How do you report for maintenance?

10. Does the utility respond for maintenance request immediately? Within what time or day?

11. Do you have household water treatment method?

12. Is the water tariff affordable? How many birr per liter are you willing to pay?

13. How often is water meter reading taken? Is the water meter functional? Do you have any complain on the amount of water you consumed and pay for it?

14. What do you suggest for improvement of the water supply service? Or what things should be improved on the water supply service?

15. Is there any other problem you want to state?

ANNEX-II WATER SUPPLY SYSTEM PERFORMANCE INDICATOR CHECKLIST

1. Is the Capacity of the source sufficient for current and future demands?
2. What is the Amount of water produced and sold for the past five years?
3. What are the different current Demand amounts and types and (domestic, industrial, commercial, public institutions, fire hydrants etc.)
4. Is there water quality problem and how is the monitoring done?
5. What is current water treatment method?
6. How old are the old system pipes and total length?
7. What is the magnitude of Unaccounted for water for the past five years?
8. What are the total no of different types of household connections?
9. Is the water supply available for 24 hours?
10. What is the current tariff? Is the tariff affordable?
11. How the Operation and maintenance condition is looks like? Is there scheduled preventive maintenance?
12. Are there Villages without water supply?
13. Does the Distribution system cover all part of the town?
14. Are all bills paid?
15. How is the Sanitation condition of the sources?
16. Is there regular routine inspection for the water supply system from source to distribution?
17. How is Leakage detected and controlled?
18. What is the average available head in the distribution system?

19. Is water meter installed at all the sources and reservoirs and are all functional?

20. How old are the water meters? Are all household water meters functional?

21. Are there any connections without installed water meters?

22. Are there regular recordings at all the sources and reservoirs?

23. Are there standby generators at the pumping stations and boreholes?

24. Is leakage observed at storage tanks?

25. How is overflow controlled? Are float valves or automatic closing valves installed at service reservoirs?

26. How is maintenance carried out? Are there sufficient equipments, experts and vehicles for maintenance for the system in times of damage?

27. Are there sufficient spare parts in the stock for different electromechanical equipments?

28. For how many hours is the electromechanical equipments (pumps and generators) working per day?

29. Are there industries or institutions which develop their own water source and not paying for the water?

30. What are the possible causes of water loss and which part of the system has high loss?

ANNEX III Tables & Figures related with Water production, Consumption and Loss

Table 20: Monthly Water Loss for the Year 2011

S/No.	Year	Production(m3)	Consumption (m3)	Water Loss(m3)
		2011	**2011**	**2011**
1	**January**	39720.00	25627.34	14092.66
2	**February**	38585.00	21244.90	17340.10
3	**March**	50345.00	31515.97	18829.03
4	**April**	48770.00	30593.42	18176.58
5	**May**	48148.00	28436.21	19711.79
6	**June**	45348.00	27444.61	17903.39
7	**July**	42219.00	25020.75	17198.25
8	**August**	49939.00	26842.89	23096.11
9	**September**	46848.00	28425.89	18422.11
10	**October**	48469.00	26371.00	22098.00
11	**November**	38308.00	30078.00	8230.00
12	**December**	35095.00	27418.16	7676.84
	Total	**531,794.00**	**329,019.14**	**202774.86**
	Average	**44,316.17**	**27,418.26**	**16,897.91**

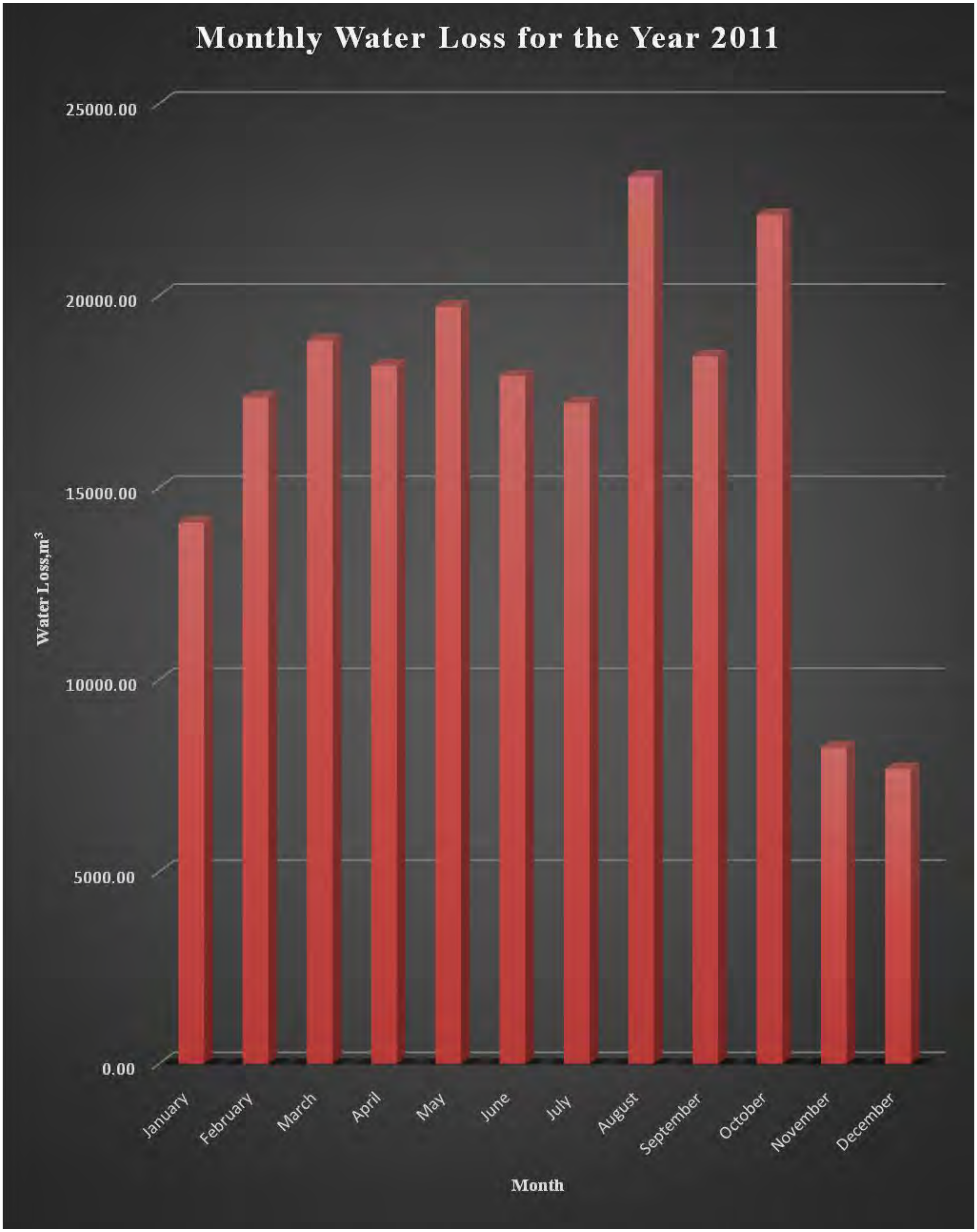

Figure 5: Monthly Water Loss for the Year 2011

Table 21: Monthly Water Loss for the Year 2012

S/No.	Year	Production(m3)	Consumption(m3)	**Water Loss(m3)**
		2012	**2012**	**2012**
1	**January**	38235.00	38116.51	118.49
2	**February**	40820.00	30566.00	10254.00
3	**March**	40484.00	32612.16	7871.84
4	**April**	39210.00	30443.38	8766.62
5	**May**	33819.00	28739.11	5079.89
6	**June**	36680.00	30800.60	5879.40
7	**July**	38,300.00	26,007.00	12293.00
8	**August**	37,335.00	24,585.00	12750.00
9	**September**	37,414.00	27,331.00	10083.00
10	**October**	39,620.00	27,464.00	12156.00
11	**November**	89,474.00	39,880.00	49594.00
12	**December**	105,975.00	46,181.00	59794.00
	Total	**577,366.00**	**382,725.76**	**194640.24**
	Average	**48,113.83**	**31,893.81**	**16,220.02**

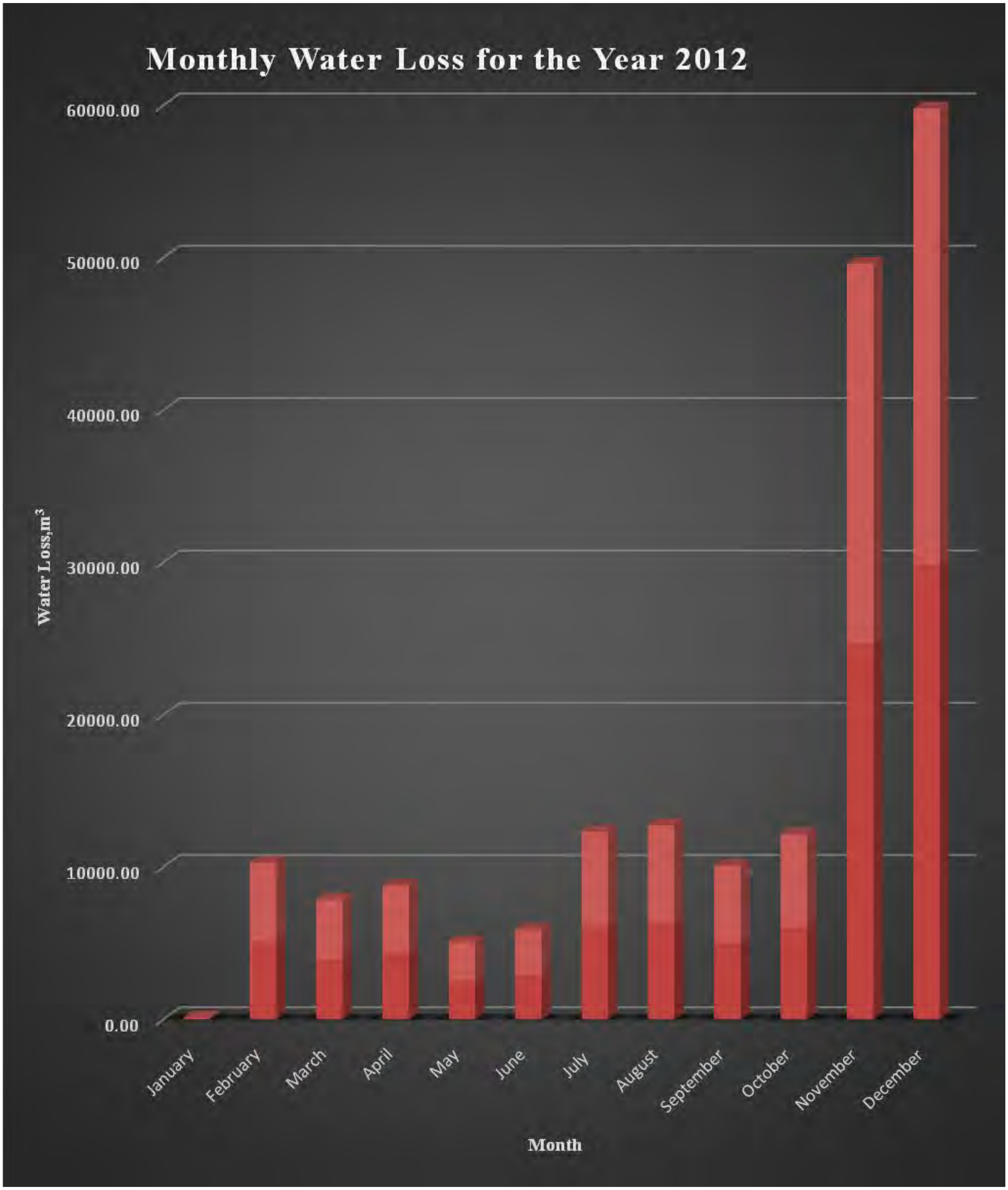

Figure 6: Monthly Water Loss for the Year 2012

Table 22: Monthly Water Loss for the Year 2013

S/No.	Year	Production(m3)	Consumption(m3)	Water Loss(m3)
		2013	**2013**	**2013**
1	**January**	91,600.00	54,989.00	36611.00
2	**February**	133,890.00	57,235.00	76655.00
3	**March**	86,840.00	55,721.00	31119.00
4	**April**	113,170.00	55,621.00	57549.00
5	**May**	123,150.00	51,274.00	71876.00
6	**June**	148,700.00	56,413.00	92287.00
7	**July**	118,410.00	40361.00	78049.00
8	**August**	115,306.00	44966.00	70340.00
9	**September**	159,535.00	54388.12	105146.88
10	**October**	118,220.00	50874.00	67346.00
11	**November**	120,120.00	65841.72	54278.28
12	**December**	133,270.00	63827.50	69442.50
	Total	**1,462,211.00**	**651,511.34**	**810699.66**
	Average	**121,850.92**	**54,292.61**	**67,558.31**

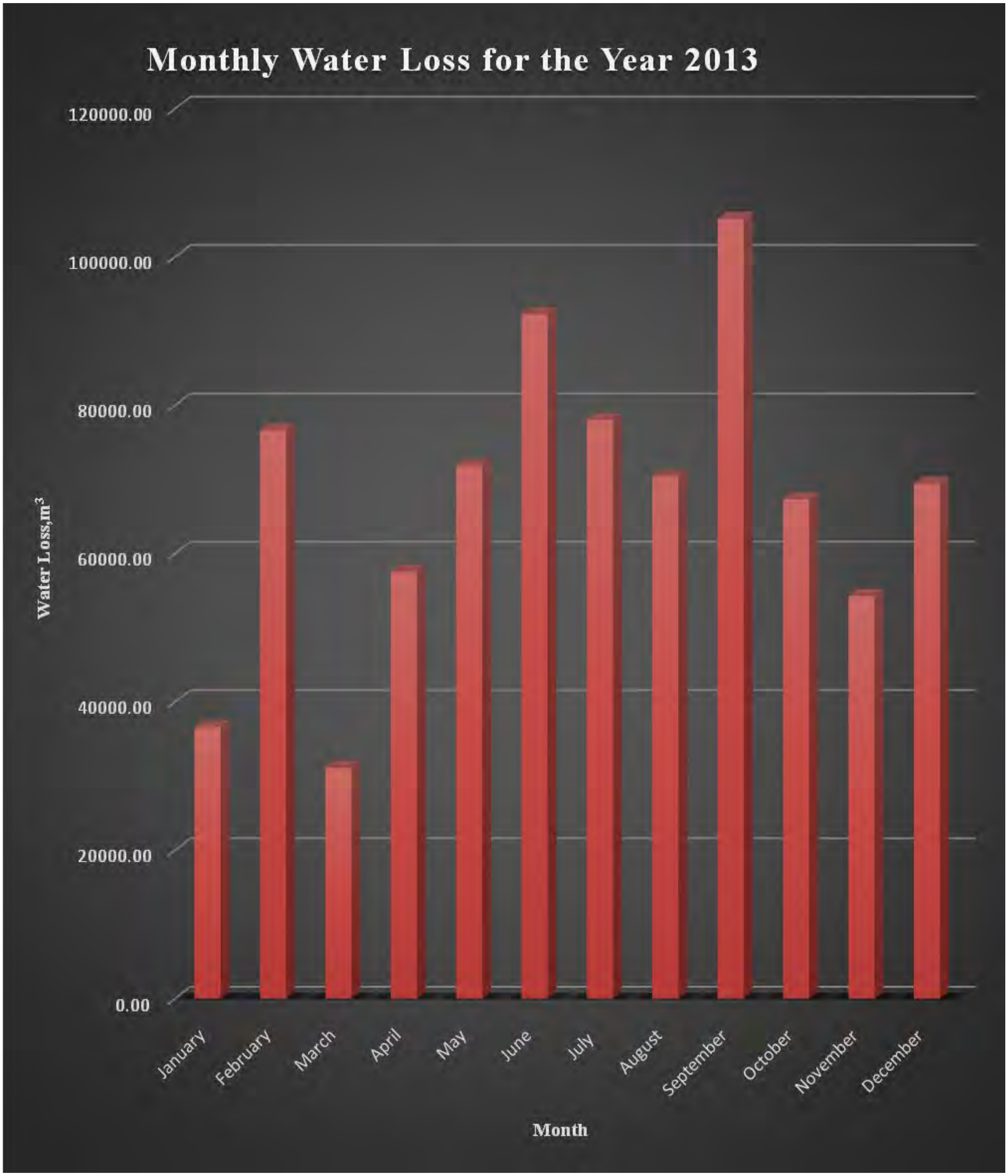

Figure 7: Monthly Water Loss for the Year 2013

Table 23: Monthly Water Loss for the Year 2014

S/No.	Year	Production(m3) 2014	Consumption(m3) 2014	Water Loss(m3) 2014
1	**January**	110,420.00	61386.00	49034.00
2	**February**	100,970.00	58944.00	42026.00
3	**March**	118,973.00	74589.00	44384.00
4	**April**	105,100.00	64533.00	40567.00
5	**May**	122,800.00	62097.00	60703.00
6	**June**	92,335.00	55083.00	37252.00
7	**July**	160,490.00	63270.01	97219.99
8	**August**	124,505.00	63270.01	61234.99
9	**September**	132,300.00	63270.01	69029.99
10	**October**	139,340.00	63270.01	76069.99
11	**November**	156,710.00	63270.01	93439.99
12	**December**	165,470.00	63270.01	102199.99
	Total	**1,529,413.00**	**756,252.06**	**773160.94**
	Average	**127,451.08**	**63,021.01**	**64,430.08**

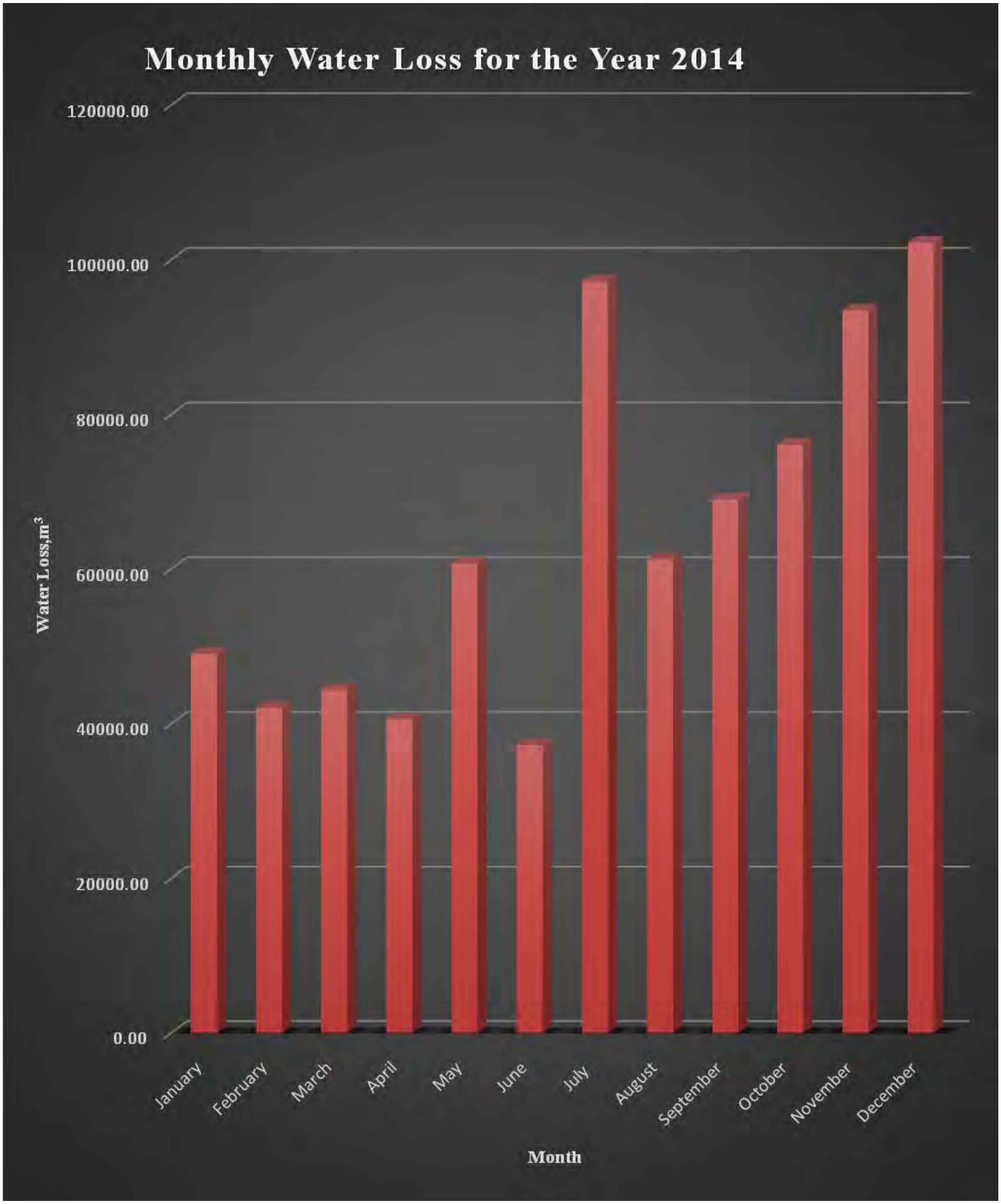

Figure 8: Monthly Water Loss for the Year 2014

Table 24: Monthly Water Production, Consumption and Loss for the Year 2011

		Production(m3)	Consumption(m3)	**Water Loss(m3)**
S/No.	**Year**	**2011**	**2011**	**2011**
1	**January**	39720.00	25627.34	14092.66
2	**February**	38585.00	21244.90	17340.10
3	**March**	50345.00	31515.97	18829.03
4	**April**	48770.00	30593.42	18176.58
5	**May**	48148.00	28436.21	19711.79
6	**June**	45348.00	27444.61	17903.39
7	**July**	42219.00	25020.75	17198.25
8	**August**	49939.00	26842.89	23096.11
9	**September**	46848.00	28425.89	18422.11
10	**October**	48469.00	26371.00	22098.00
11	**November**	38308.00	30078.00	8230.00
12	**December**	35095.00	27418.16	7676.84
	Total	**531,794.00**	**329,019.14**	**202774.86**
	Average	**44,316.17**	**27,418.26**	**16,897.91**

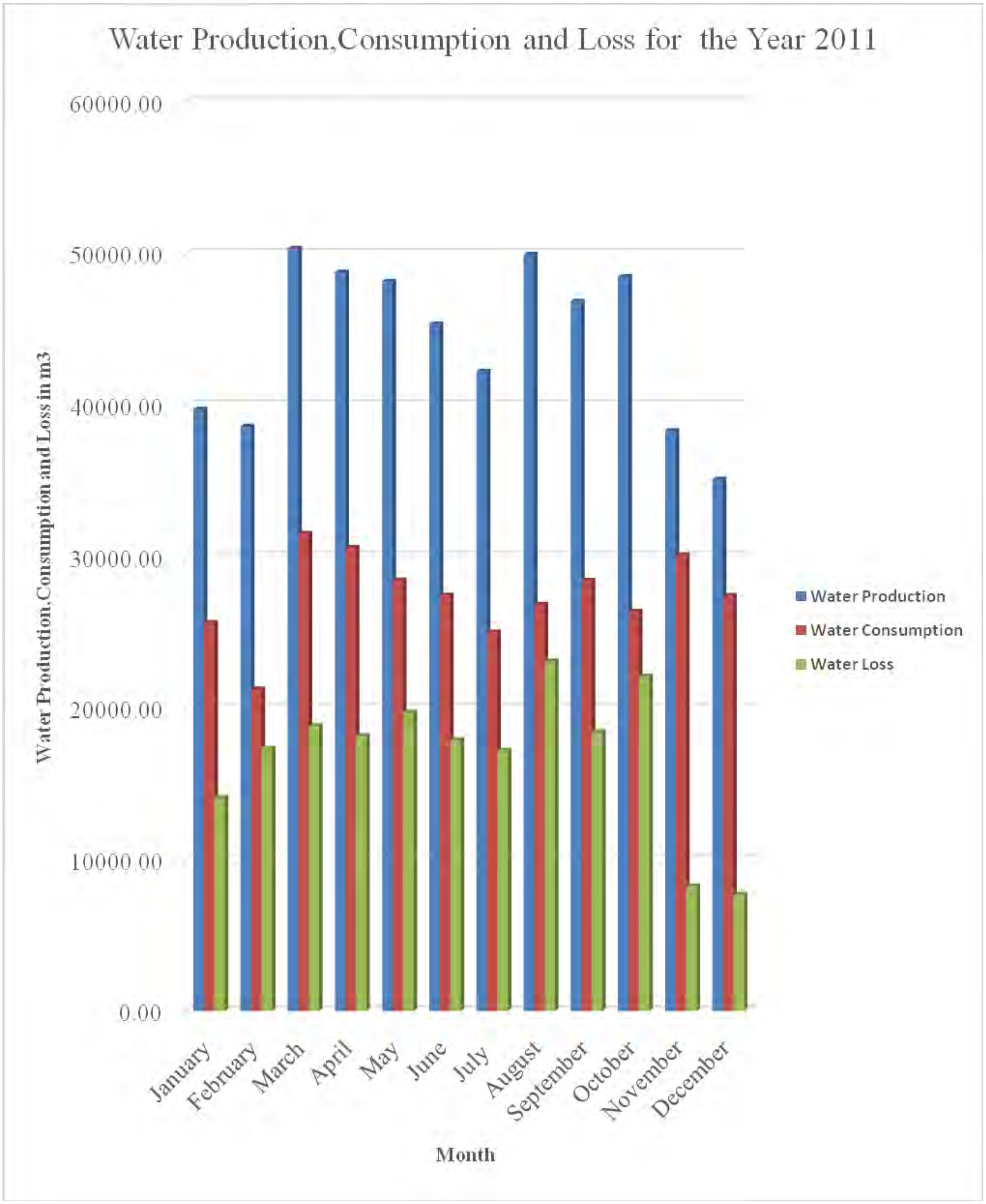

Figure 9: Monthly Water Production, Consumption and Loss for the Year 2011

Table 25: Monthly Water Production, Consumption and Loss for the Year 2012

S/No.	Year	Production(m3) 2012	Consumption(m3) 2012	Water Loss(m3) 2012
1	**January**	38235.00	38116.51	118.49
2	**February**	40820.00	30566.00	10254.00
3	**March**	40484.00	32612.16	7871.84
4	**April**	39210.00	30443.38	8766.62
5	**May**	33819.00	28739.11	5079.89
6	**June**	36680.00	30800.60	5879.40
7	**July**	38,300.00	26,007.00	12293.00
8	**August**	37,335.00	24,585.00	12750.00
9	**September**	37,414.00	27,331.00	10083.00
10	**October**	39,620.00	27,464.00	12156.00
11	**November**	89,474.00	39,880.00	49594.00
12	**December**	105,975.00	46,181.00	59794.00
	Total	**577,366.00**	**382,725.76**	**194640.24**
	Average	**48,113.83**	**31,893.81**	**16,220.02**

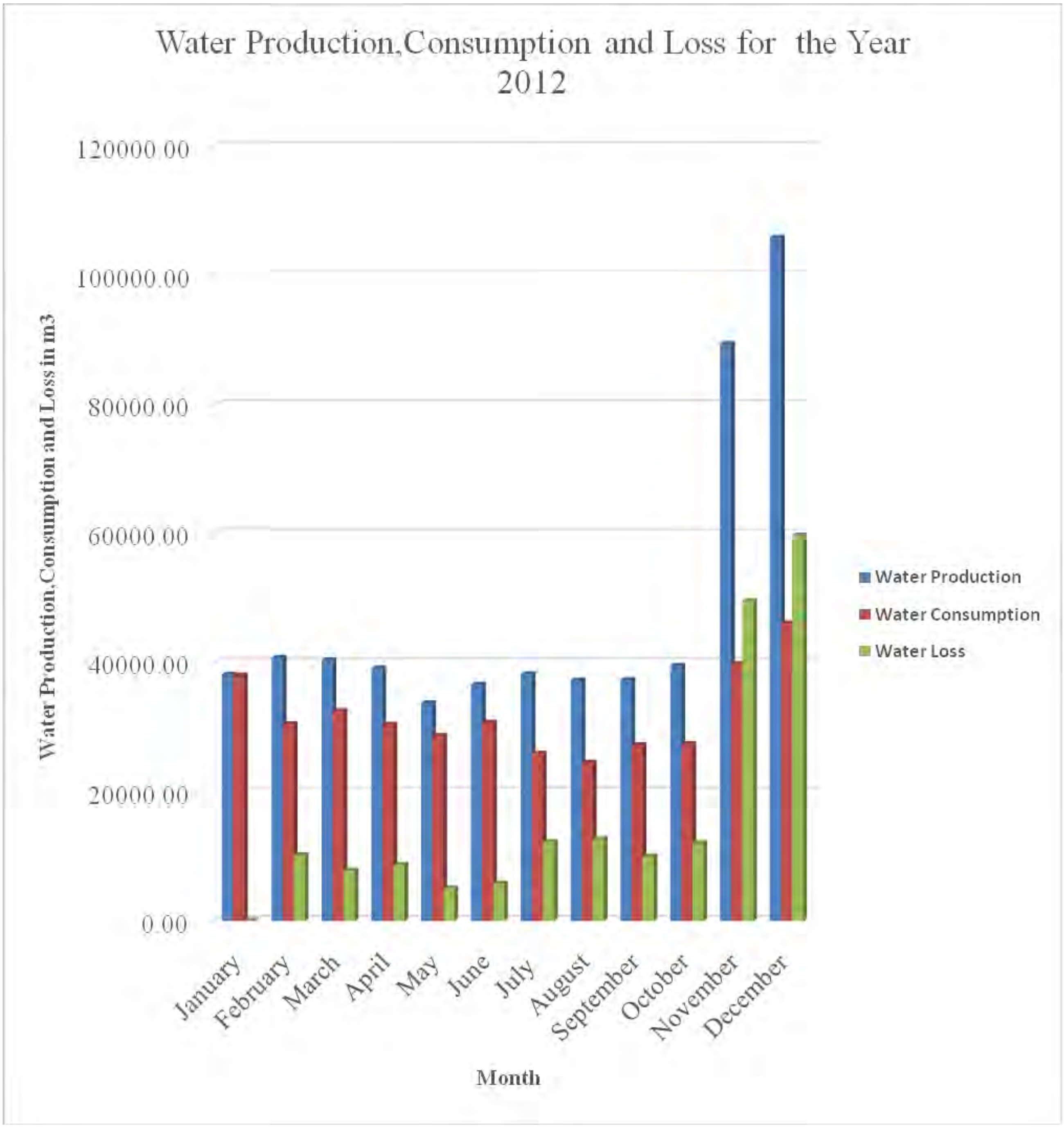

Figure 10: Monthly Water Production, Consumption and Loss for the Year 2012

Table 26: Monthly Water Production, Consumption and Loss for the Year 2013

		Production(m3)	Consumption(m3)	Water Loss(m3)
S/No.	**Year**	**2013**	**2013**	**2013**
1	**January**	91,600.00	54,989.00	36611.00
2	**February**	133,890.00	57,235.00	76655.00
3	**March**	86,840.00	55,721.00	31119.00
4	**April**	113,170.00	55,621.00	57549.00
5	**May**	123,150.00	51,274.00	71876.00
6	**June**	148,700.00	56,413.00	92287.00
7	**July**	118,410.00	40361.00	78049.00
8	**August**	115,306.00	44966.00	70340.00
9	**September**	159,535.00	54388.12	105146.88
10	**October**	118,220.00	50874.00	67346.00
11	**November**	120,120.00	65841.72	54278.28
12	**December**	133,270.00	63827.50	69442.50
	Total	**1,462,211.00**	**651,511.34**	**810699.66**
	Average	**121,850.92**	**54,292.61**	**67,558.31**

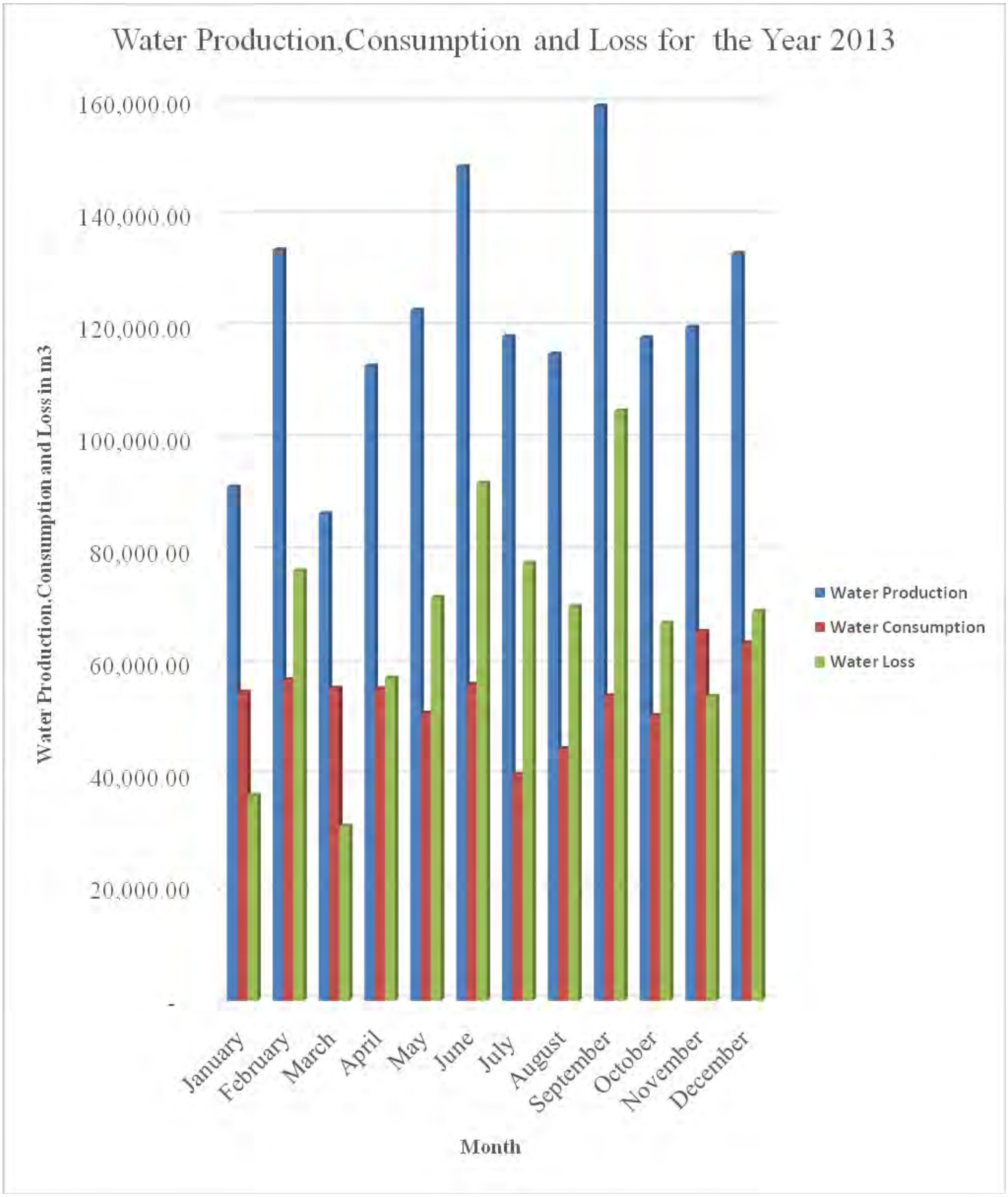

Figure11: Monthly Water Production, Consumption and Loss for the Year 2013

Table 27: Monthly Water Production, Consumption and Loss for the Year 2014

		Production(m3)	Consumption(m3)	**Water Loss(m3)**
S/No.	**Year**	**2014**	**2014**	**2014**
1	**January**	110,420.00	61386.00	49034.00
2	**February**	100,970.00	58944.00	42026.00
3	**March**	118,973.00	74589.00	44384.00
4	**April**	105,100.00	64533.00	40567.00
5	**May**	122,800.00	62097.00	60703.00
6	**June**	92,335.00	55083.00	37252.00
7	**July**	160,490.00	63270.01	97219.99
8	**August**	124,505.00	63270.01	61234.99
9	**September**	132,300.00	63270.01	69029.99
10	**October**	139,340.00	63270.01	76069.99
11	**November**	156,710.00	63270.01	93439.99
12	**December**	165,470.00	63270.01	102199.99
	Total	**1,529,413.00**	**756,252.06**	**773160.94**
	Average	**127,451.08**	**63,021.01**	**64,430.08**

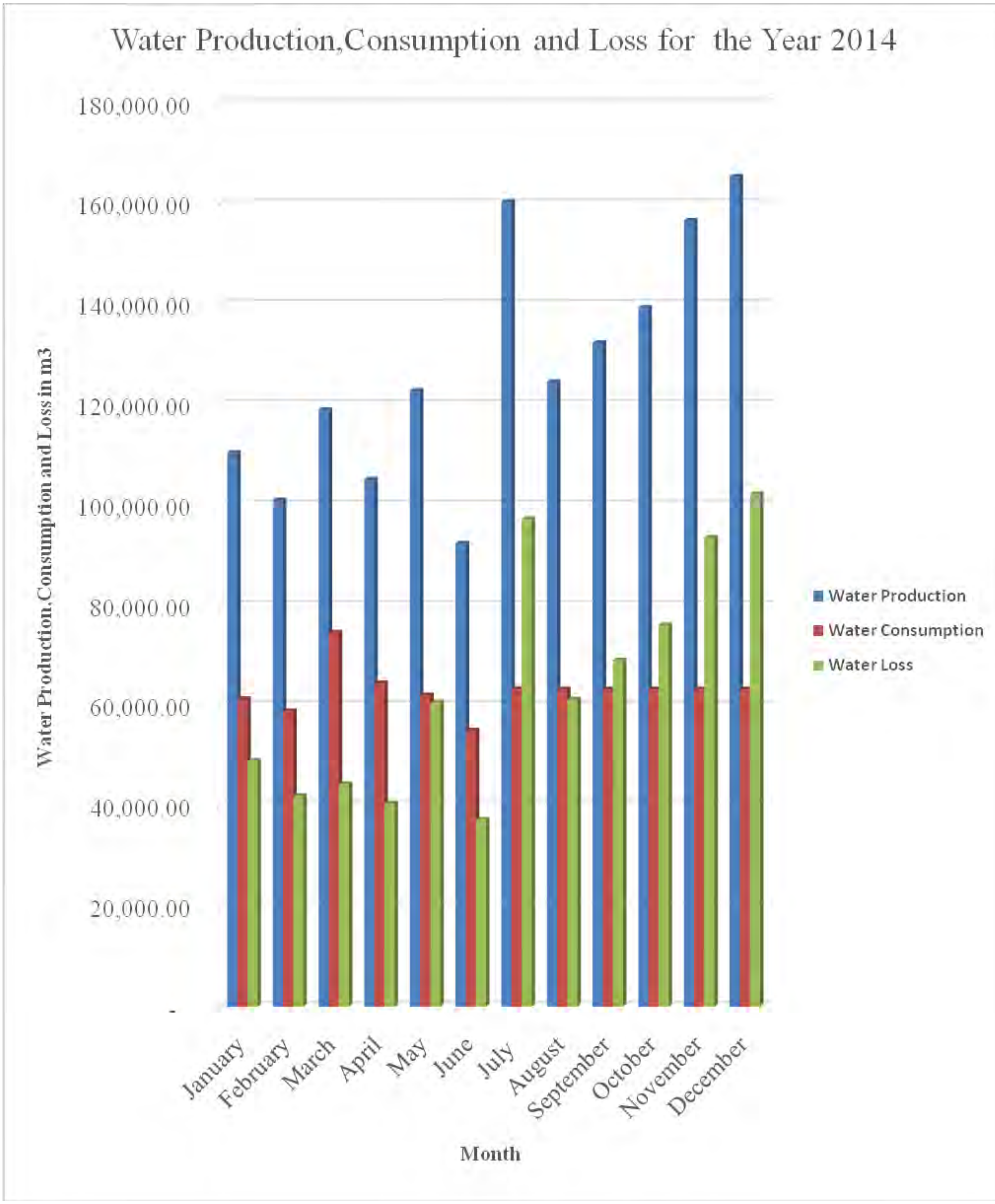

Figure 12: Monthly Water Production, Consumption and Loss for the Year 2014

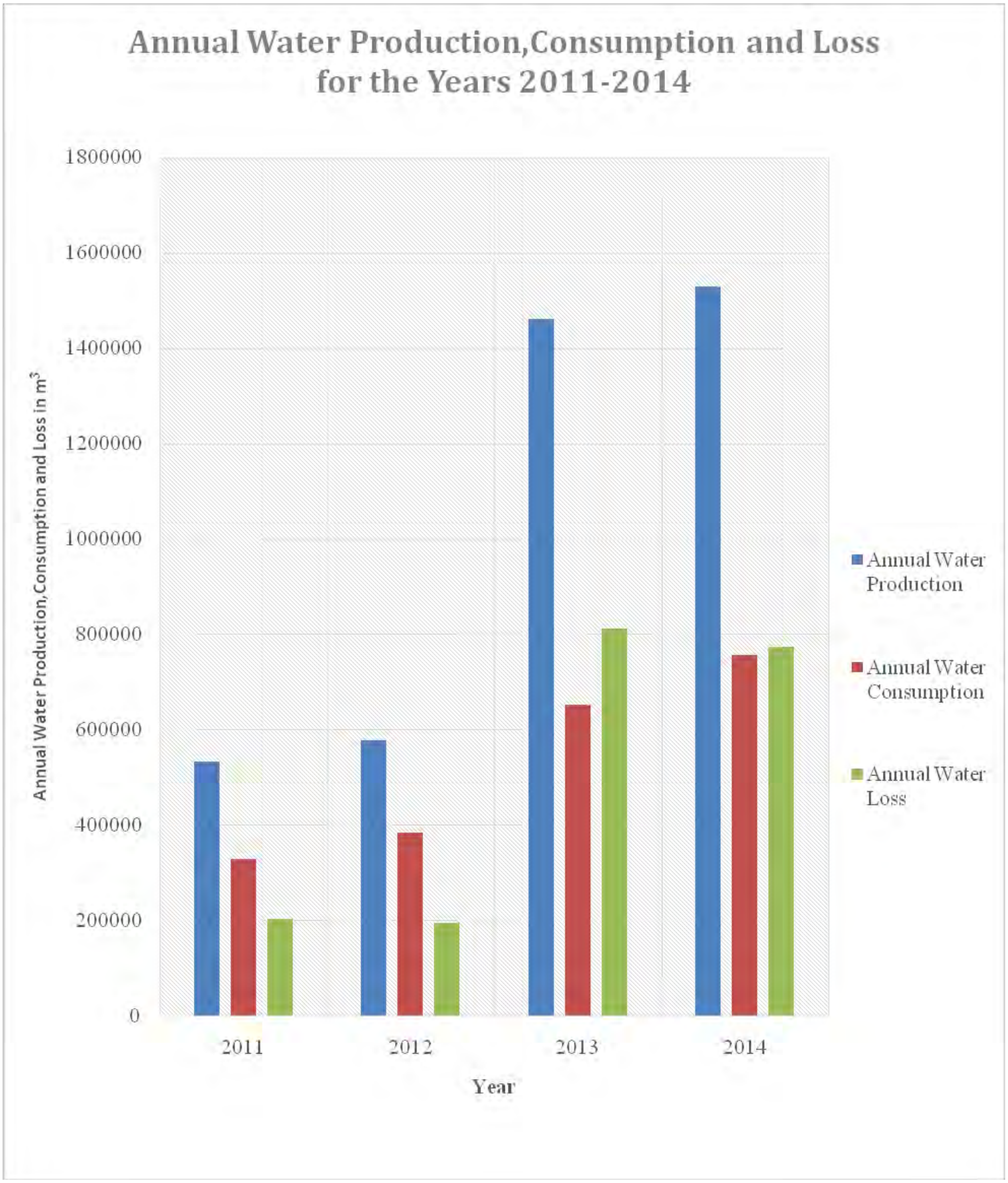

Figure 13: Annual Water Production, Consumption and Loss for the Year 2011-2014

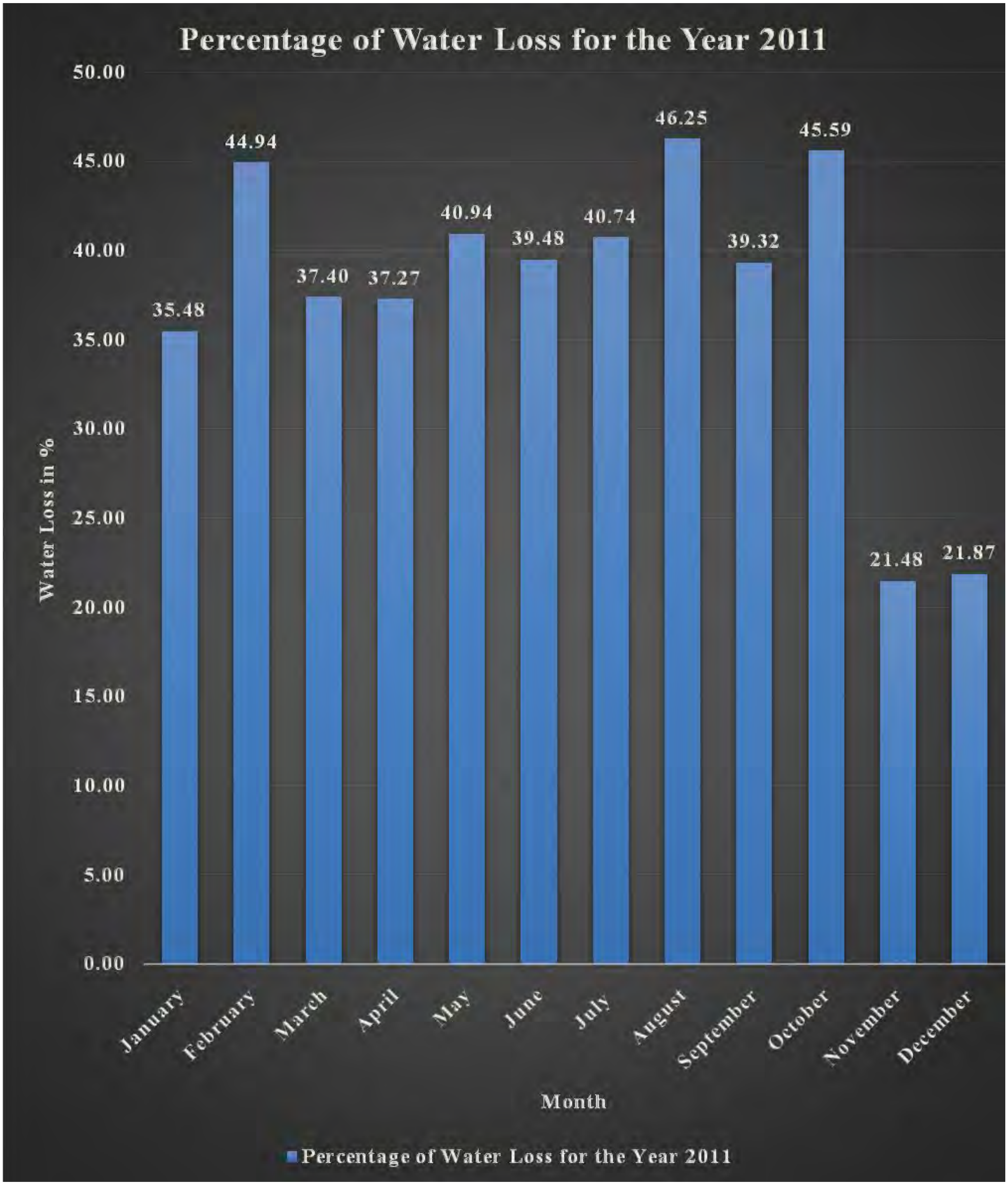

Figure 14: Percentage of Water Loss for the Year 2011

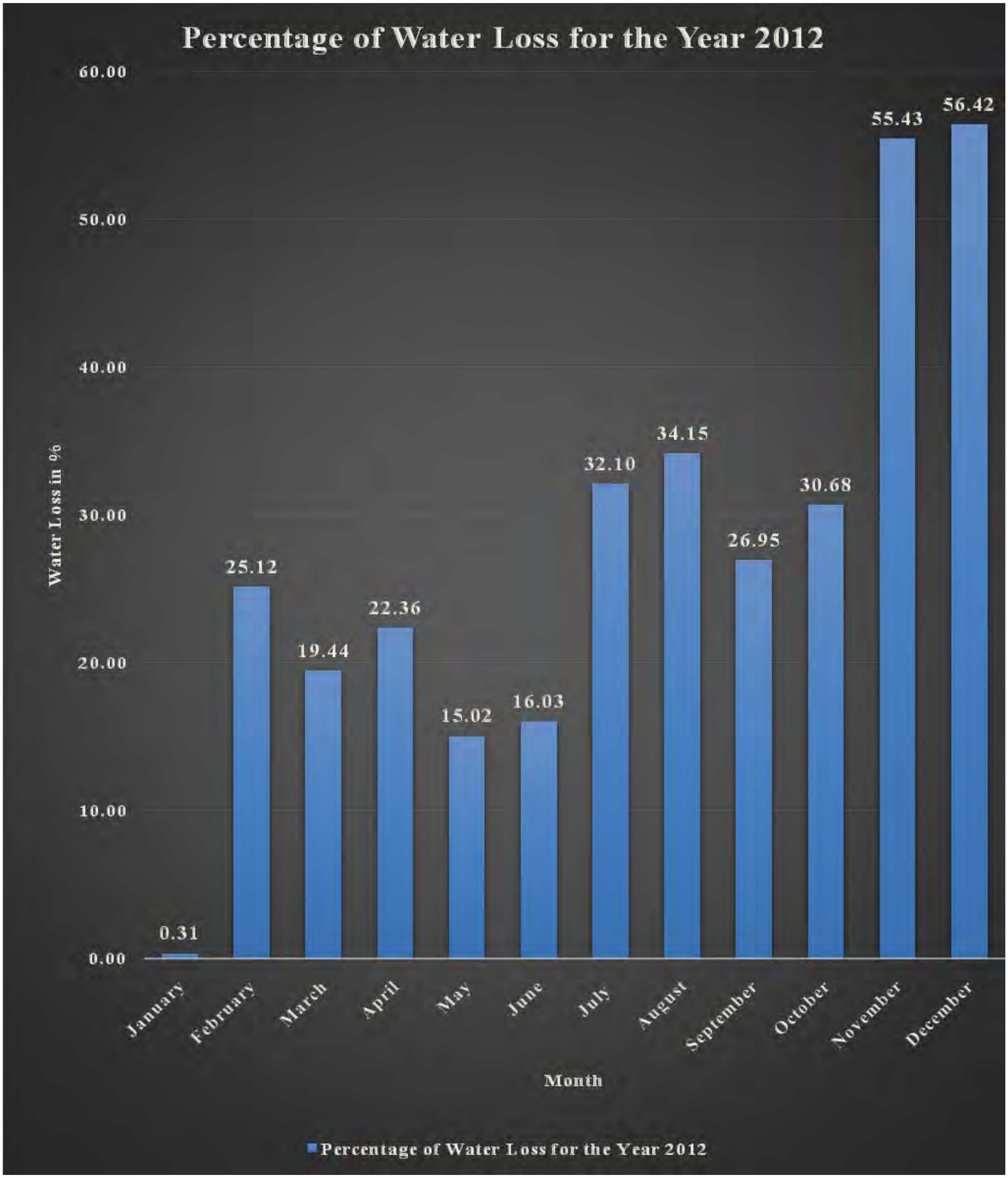

Figure 15: Percentage of Water Loss for the Year 2012

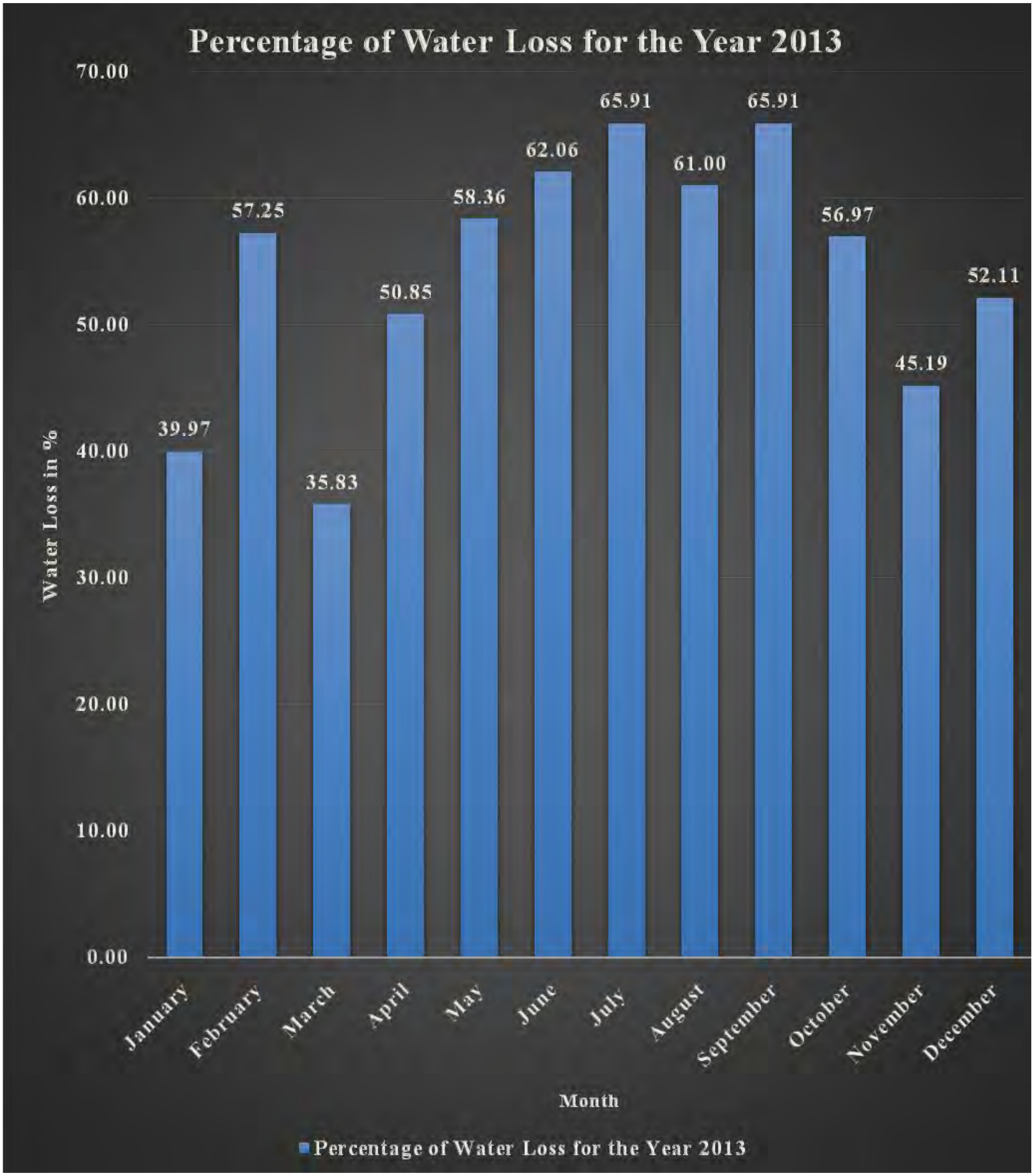

Figure 16: .Percentage of Water Loss for the Year 2013

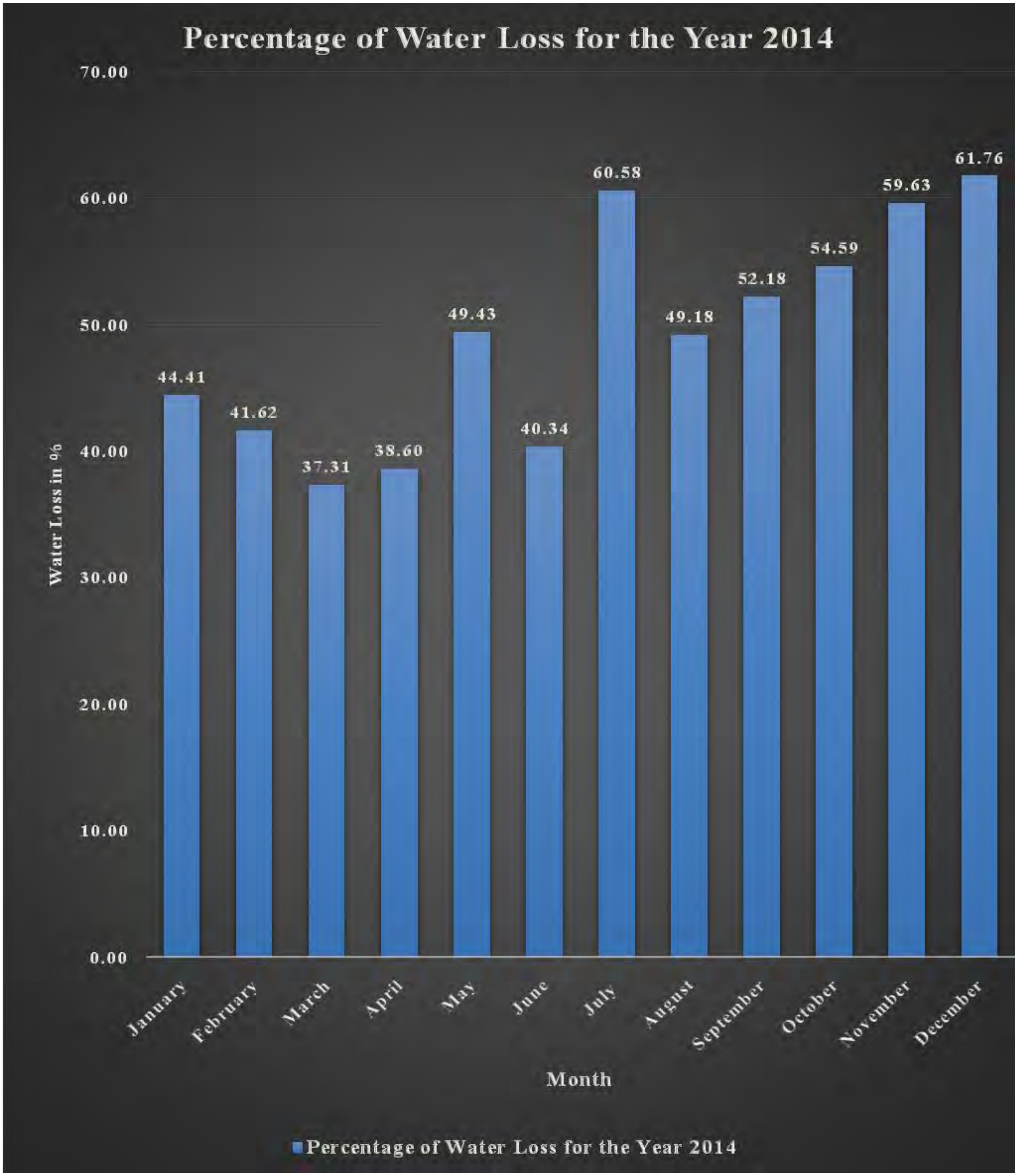

Figure 17: Percentage of Water Loss for the Year 2014