TECHNICAL ANALYSIS OF WATER DISTRIBUTION SYSTEM AND ASSESSMENT OF WATER SUPPLY COVERAGE: A CASE OF BESHENO RURAL TOWN, WERA DIJO WOREDA, HALABA ZONE, CENTERAL ETHIOPIA

MSc THESIS

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HAWASSA UNIVERSITY, HAWASSA ETHIOPIA

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A THESIS SUBMITED TO DEPARTMENT OF WATER RESOURCE AND IRRIGATION ENGINEERING INSTITUTE OF TECHNOLOGY, HAWASSA UNIVERSITY HAWASSA, ETHIOPIA

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ADVISORS APPROVAL SHEET

SCHOOL OF GRADUATE STUDY

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(Submission-I)

This is to certify that research study entitled as "Technical Analysis of Water Distribution System and Assessment of Water Supply Coverage: A Case of Besheno Rural Town, Wera Dijo Woreda, Central Ethiopia" and submitted in partial fulfillment of the requirement for degree of Master's with specialization in Water Resource Engineering and Management, the graduate program of Department of Water Resource and Irrigation Engineering, and has been carried out by Tariku Abebe Asfaw, ID.NO. PGWREMW/0020/2014, under our supervision. Therefore, we recommended that the student has fulfilled the requirement and hence hereby can submit the thesis to department.

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We, the undersigned members of the Board of Examiners of the final open defense by Tariku Abebe Asfaw have read and evaluated his thesis entitled "Technical Analysis of Water Distribution System and Assessment of Water Supply Coverage: A Case of Besheno Rural Town, Wera Dijo Woreda, Central Ethiopia'', and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Water Resource Engineering and Management.

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Final approval acceptance of the thesis is contingent upon the submission the final copy of the thesis to the School of Graduate Studies (SGS) through the Department/ School of Graduate Committee (DGC/SGC) of the candidate's department

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DEDICATION

I dedicate this thesis manuscript to my brother **Engida Abebe** and to my entire families for their unlimited care, support, encouragement and dedicated partnership in the success of my life.

DECLARATION

I hereby declare that this MSc thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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Date of submission: _______________________

ABBRERIVATION

BH	Borehole
CER	Central Ethiopia Region
CAD	Computer Aided Design
CSA	Central statistical Agency
CWS	Continuous Water Supply
DN	Diameter Nominal
DCI	Ductile Cast Iron
EPA	Environmental Protection Agency
FDRoE	Federal Democratic Republic of Ethiopia
FTU	Formazin Turbidity Unit
GI	Galvanized Iron Pipe
GEMS	Geographic Engineering Modeling System
GIS	Global Information System
GPS	Global Position System
GTP	Growth and Transformation Plan
HDPE	High Density Polyethylene
HHS	Households
IWA	International Water Association
JMP	Joint Monitoring Program
KM	Kilo Meter
L/c/d	Liter per capita per day

MDG	Millennium Development Goal
MoWR	Ministry of Water Resource
NTU	Nephelometric Turbidity Unit
NRW	Non-Revenue Water
OD	Outside Diameter
PN	Pressure Nominal
PT	Public Tap
PVC	Polyvinyl Chloride
SCADA	Supervisory Control and Data Acquisition
SNNPR	South Nation Nationalities and Peoples Region
SPSS	Statistical Package for Social Science
UN	United Nation
UNCEF	United National Child’s Fund
UTM	Universal Transverse Mercator
UWSUAP	Urban Water Supply Universal Access Plan
WDS	Water Distribution System
WDWWMEO	Wera Dijo Woreda Water Mine and Energy Office
WHO	World Supply Health Organization
YCO	Yard Connection Own

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ABSTRACT

Drinking water is the most fundamental requirement for survival, every citizen of the country has the right to obtain it. The main objective of this study was to evaluate the technical analysis of water distribution system of Besheno rural town and assessment coverage of water supply. In this study, both secondary and primary data source were employed. Furthermore, to analyze the distribution system, a model was created using Water GEMS software. The analysis shows that the current total domestic water demand in town was 244.08 m^3*/day, the water supply coverage was 30 % and average per capital domestic water consumption was 12 l/c/day. Hence, this result indicates there is a gap between demand and supply. Using performance indicators including pressure, velocity, and head loss inside the water supply systems, the hydraulic efficiency of the supply system for water was assessed while the network of distribution was in operation. The result indicated that, 100% of the nodes are within acceptable range between (15m to 70m) for the existing distribution system of Besheno rural town. However, 64.74% of the nodes are within acceptable range between (15m to 70m), 25.81% of the nodes are above acceptable range (70m) and 6.45% of the nodes fall below acceptable range (15m) for the transmission mains and rural kebeles. According to the results of hydraulic performance analysis, 94% of the pipes in the research area have velocities below the recommended minimum velocity. 6% of the pipes within the current distribution system for water supply had velocities ranging from 0.6 m/s to 2 m/s. The head loss analysis shows that, 79% of the pipes are below the recommended minimum head loss range of 1m/km, and 15% are within the recommended head loss range (1 to 5m/km) and the rest of pipes, 5% head loss are above the recommend range. Generally, the result of the analysis showed that, the overall hydraulic performance of water distribution of the town was poor and, it is therefore significant to improve the water distribution system capacities, changing the diameter of the pipe to get the proper level of pressure and velocity. Drilling new boreholes sources and building additional service reservoir, to narrow the gap between supply and demand in water supply system. Water quality physicochemical test findings revealed that the fluoride concentration of boreholes exceeded than the Ethiopian standard and WHO recommendation. Thus, the community's water is treated before use.*

Key words*: Besheno town, water supply coverage, water demand, pressure, velocity, water distribution network, water GEMS, water quality.*

1. INTRODUCTION

1.1. Background

Water is a precious resource that is required for habitat survival and the continuance of human life (Temesgen et.al.,2018). Water supply that is sufficient, inexpensive, and of excellent quality, as well as enhanced sanitation services, are essential components of sustainable development. Water covers approximately 71% of the earth's surface. Only 3% of the water on the earth is fresh, with the rest being salt water. (WHO/UNICEF, 2017).

According to the Global water security by Macalister (2023) assessment, Africa has the lowest levels of safe water, sanitation, and hygiene services in the world, contributing to the region's poor levels of water security. Almost 31% (over 411 million) of people in African countries lack access to safe drinking water. Only 201 million (15%) people have access to safe drinking water. In terms of sanitation, 1.1 billion people (82%) still lack access to a well-managed sanitation service. However, most developing countries, like Ethiopia, are still unable to obtain adequate potable water and have restricted access to potable drinking water, resulting in a water crisis for residents (Mekuriaw, 2019).

A reliable and affordable water supply can boost a country's economic growth and significantly contribute to poverty reduction. A great number of children are dying in Ethiopia every day as a consequence of a lack of safe drinking water, proper sanitation, and hygiene (MoWIE., 2015).

According to the objectives and goals of Ethiopia, the second growth and transformation plan was given to the expansion of drinkable water supply with the goal of reaching 85%, 75%, and 83% drinkable water coverage, respectively, in rural areas, urban areas, and the country as a whole by the conclusion of GTP II (FDRoE., 2018). However, according to the GTP II mid-term review conducted by Birki (2019), potable water coverage has improved to 68.5% in rural regions, 54.7% in urban areas, and 65.7% overall. Today, water is under life-threatening threat from an increasing population, urbanization, increasing demand of agriculture and industry, and climate change has a significant impact on the availability and unpredictable of fresh water. This worsens the hydrological cycle and raises demand for water while diminishing the supply are the major issues facing us now a day (AW, et al., 2018).

Intermittent water supplies are found all over the developing world (Lee, 2005). Irregular water supply caused primarily by lack of sufficient water to serve all customers and keep the piped networks fully pressurized at all times. These causes' users forced to store large quantity of water in their home and may expose unhygienic water storage and handling (Mays, 2000).

The water supply distribution system (WSDS) is designed to meet the water needs of a combination of domestic, commercial, industrial and firefighting. The system should be meeting the demand placed on it all times and at satisfactory hydraulic performance (Warren Viessman, 1994). The WDS is difficult to analyze due to their many components, non-linear hydraulics and complex demand patterns. As a result, computer network models are required to calculate parameters such as flow rate, velocity and water pressures, at many points of for the described WDS. It is also important to measure flows and pressures in the network to monitor its behavior, and identify potential problems. The purpose of WSDS is to provide an adequate and reliable supply of safe water to its users (Vanzyl, 2014).

According to the Wera Dijo woreda water mine and energy Office, the most predominant complaint in the area community is that the water shift service system has insufficient and is unable to offer enough drinking water service to all consumers at once. As a result, the purpose of this study is to suggest remedies by analyzing the current water supply distribution system and evaluating water supply coverage using water GEMS vi8 software.

1.2. Statement of the Problem

A safe supply of drinkable water is a basic human need in a civilized society; thus, water distribution is the most important public utility. Water distribution system designs in general must satisfy a given set of demand points for each customer with a sufficient volume of water at a suitable pressure and deliver safe water that meets the customer's quality requirements. Unsuccessful, failing to meet customer demand for water, and an inadequate water shift service system, there are direct economic consequences on the degrading system. The main difficulties affecting rural town water works around Ethiopia are insufficient water supply and declining water quality in a water distribution system (SNNPRWIDB, 2023). The problem is especially significant in most regions, as well as Besheno rural town, Bubesa kebele, and Hantezo kebele; where rising urbanization, population growth, inadequate rural town design planning, and a lack of necessary resources all have a combined effect (CSA, 2007).

According to the Wera Dijo Woreda Water Mines and Energy Office in the study area water supply distribution system providing inadequate service level to its consumers, the common problems in the Besheno rural town, Bubesa, and Hantezo kebels water supply distribution were water shift system service supplies and users only have access to piped water three days interval, water pressure and velocity variation, valves damage by opening and closing look after shift services. Furthermore, as a result of limited infrastructure, local collection of finance practice and poor services are in the study areas. These worries are having an effect on the existing water delivery networks.

Previous research on water delivery systems was undertaken at both the world and national levels, with an emphasis on rural town and urban areas. However, no adequate research has yet been undertaken in the Besheno rural town, Bubesa kebele, and Hantezo kebele. As a result, this study attempted technical analysis of water distribution system and assessment of water supply coverage, then filling those mentioned gaps and recommending solutions for decision makers and further study.

1.3 Objectives of the Study

1.3.1. General Objective

The main objective of this research is to evaluate the technical analysis of water distribution system and assessment of water supply coverage in the case of Besheno rural town, Bubesa kebele and Hantezo kebele.

1.3.2. Specific Objectives

1. To assess existing status of water supply and forecasting future demand.
2. To evaluate technical performance of the current water distribution network system by using water GEMS v8i software.
3. To assess the water quality in the research area and compare it with the standards.

1.4. Research Questions

By seeking out the answers to the following questions, the study's goals would be met.

1. What are the current status of water supply and its future forecasting demand?
2. What is the current water supply distribution network's technical performance?
3. Does the research area's water quality meet the required standards?

1.5. Significance of the Study

The current study intends to conduct a technical investigation of the delivery system of water and coverage of water supply in Besheno rural town, Bubesa kebele, and Hantezo kebele, as well as identify some of the current concerns. The research findings can significantly aid policymakers and governments in their planning, scientific information provision, and other water resource development efforts. Furthermore, the research study can be utilized to fill gaps in other research work by including recommendations and launching another researcher into a similar area water system study.

1.6. Scope of the Study

This study primarily focused on the study area and was evaluated to identify technically existing distribution system of water and coverage of water supply, the factors for intermittent supply, and physico-chemical water quality and bacteriological water analysis.

1.7. Limitation of the Study

This research study was limited to analyzing the water distribution network from reservoir to the end users. The testing of water meters investigations was expensive; the essential data were gathered by reading various design documents available in the research region; and due to lack of sufficient kit, physicochemical water quality tests at boreholes and bacteriological analysis at selected points were performed.

1. LITERATURE REVIEW

2.1. Water Supply

The distribution system of water provides users with safe and ample water for both domestic and non-domestic needs. The most significant core constituents are the source of supply system, the treatment plant, the distribution system, and the point of use. The sources are either surface or ground water. The supplies can be obtained by the consumers in a variety of ways. Whatever methodological approach is chosen, the goal is to produce a sufficient amount of water that is fit for human consumption and is without difficulty accessible to everybody (S.K.Garg, 2010).

However, the vast majority of the world's inhabitants lacks obtainability of clean drinking water in both rural and urban regions. Only 16% of Sub-Saharan Africans had fit to drink access to via a household connection. Every water supply utility shares the same fundamental goal to provide consumers with a private connection to the water supply piping network (WHO, 2006)

2.1.1. Water Supply Coverage

Water supply coverage affords an image of a certain country's or town's water supply situation and allows comparisons across countries as well as inter and intra-town distribution within a definite country. The percentages of the population with or without a piped water connection are a useful indicator for comparing water supply coverage in urban regions (UN-Habitat, 2003). The key origins of the low coverage of water supply are oversupply compared to demand, inadequate management, climate change, low-priced water tariff, rapid population increase, and limited piped water coverage.

2.2. Water Demand

The water volume demanded by consumers to meet their demands is referred to as water demand. In a simplistic sense, it is sometimes equated with water consumption; nevertheless, the two phrases do not have the same conceptual meaning. In most developing countries, prospective water demand substantially exceeds actual consumptive water consumption (Zewdu, 2014).Water demand was computed by Maher Abu-Madi and Nemanja (2013) as the algebraic sum of the amount of water utilized by the user and water volume physically lost from the system. The sum of water consumed per person varies substantially. Due to differences in climatic conditions, standard of living, population growth, type of commercial and industrial activity, and water pricing. Because of population growth, water demand has risen over time. As a result, new water resources are being developed in order to fulfill the increasing water demand in the present and future.

2.2.1. Domestic Water Demand

Water requirements for domestic usage include drinking, cooking, and bathing, washing of clothes, utensils and house, as well as toilet flushing. Domestic water consumption varies widely, and as such, variation depends upon climatic condition, standards of living, distribution system pressure and system management (Fair, et al., 1981). Public fountains, house connections and garden connections are the most important water services for domestic water consumers. The average daily water consumption per person in Ethiopia is quite low throughout the country. If additional supplies are made available to the community, actual water demand is expected to exceed present usage (MoWE, 2011).

2.2.2. Non-Domestic Demand

Non-domestic demand includes industrial, commercial, and institutional demand, as well as firefighting and water system losses.

Industrial water demand: indicates the amount of water required by the area's industries and factories.

Commercial and institutional water demand: the amount of water required for consumers to use in places such as public offices, schools, hospitals, restaurants, and shops.

Animal demand: The amount of water utilized for animal consumption and allotted if there is no water source in the vicinity of the town or city that can meet the animal demand.

Firefighting demand: the amount of water allotted for a single fire occurrence and kept in a service reservoir.

Unaccounted water demand: Unaccounted water demand was defined as water loss on the distribution network, which could include illicit connections, overflow from service reservoirs and incorrect water meter readings.

2.3. Water Demand Predicting

Forecasting water demand has become a crucial component in planning and managing water resources, according to Zhai, et al.(2012), because it provides a simulated perspective of the future and aids in identifying an optimal water supply-demand balance. The primary goal of water demand forecast is to identify sufficient water supply to meet the combined demand curve. Setting up existing and projected future demands is an early and critical step, and an error can upset the entire planning process. Demands are used for a multitude of applications include as distribution system modeling, water supply planning, and determining treatment plant and transmission main capacities; as a result, it is critical that demands be consistent with accepted water use characteristics and existing data, and that they go through a review process.

2.4. Water Losses in Distribution System

Losses of water occur across all systems, according to EPA (2010). Only the volume changes and this shows a utility's capacity to manage its network. The actual amount of water misplaced from the water distribution network differed from one utility to another, based on local characteristics such as topography, length of mains, number of connections, and grade of service, as well as how well the system is handled and maintained (Lambert, 2002). Many factors contribute to water distribution system losses, according to Sharma (2008), including ageing infrastructure, high pressure, external and internal pipeline corrosion, service tank overflows, poorly designed and constructed WDS, metering errors, unauthorized usage, and insufficient operation and maintenance practices. A great level of actual losses decreases the quantity of valuable water delivered to customers, raises the utility's in-service costs, and reduces funds available for investment in new supply schemes. The usefulness of any water supply is concerned with reducing water losses.

Water loss is at all times existing in a water system. Water loss comprises of two separate constituents’ apparent losses and real losses. The physical loss is the real loss of water from the distribution system, including leakage through burst pipes, joints, fittings, connections and reservoir excesses flow. Apparent losses are losses result from meter imprecision, billing mistake, and dishonest use. Water loss results from numerous reasons. These factors consist of unidentified leaks in pipes, main breakdowns, fire hydrant flushing, tank drainage for repairs, unlawful use, unmetered facilities, mistaken and nonfunctioning meters, and located at the site water plant usage (Babić, 2011).

2.4.1. Revenue and non-revenue

Revenue water is water that is consumed and for which the utility is paid. It comprises metered and unmetered billed authorized use. Non-Revenue Water (NRW) is water that is not billed and for which no payment is made. It might be authorized, unauthorized, or caused by a water loss. Both metered and unmetered consumption that is not billed comprise authorized NRW.

2.5. Water Supply Distribution Network

The water delivery system should provide a sufficient volume of water at a passable pressure, and consumers should expect to receive all of the water they require. Failures of pipe in water delivery systems interrupt water supply to users and reduce system reliability. Particularly, developing countries face more challenges of satisfactory water distribution because of their larger population growth rate, poor infrastructure, lower income levels, and less developed policy and institutional capacity (Mays, 2000).

For that reason, hydraulic models for water supply networks have come to be essential apparatuses for understanding system behavior by simulating pressures and flows at dissimilar locations and times in the networks. The water distribution system's purpose is to provide users with adequate quantities and pressures of high-quality water (Paneria, 2017).A water distribution system is made up of a distribution of pipes, nodes that connect the pipes, reservoirs, pumps, and other accessories such as valves.

2.6. Evaluation of Water Distribution System

Water supply distribution networks are designed to provide the best level of service to customers and, first and foremost, to provide a sufficient flow of water at usable pressure levels to a given set of demand points. Water distribution system evaluation is critical for the water industry to provide appropriate levels of service. The ability of a water distribution network to deliver a required quantity of water under sufficient pressure and at an acceptable level of quality during various normal and abnormal operational situations, and any water utility's performance is measured by the efficiency of the existing water distribution networks; and the assessment of an undertaking's performance is used to measure the quality of service as well as the utility's effectiveness and efficiency (Makaya, 2014). A good distribution the system should be able to supply water at all times planned locations within the town with a reasonably appropriate pressure head and the necessary amount of water for various types of demand. The performance of the town water supply scheme was evaluated using four performance measures: hydraulic, structural, water quality, and customer perception (Jalal, 2008).

2.6.1. Water Distribution System Modeling

Water systems frequently include a hydraulic model to anticipate system performance and solve problems related to design, operation, and water quality. A hydraulic model may be anticipated, a model can monitor the flow of pressures and flow levels through the system and compare it to the design stages, and a system can represent water quality (Primer, 2018).

2.6.1.1. Comparison of Hydraulic Model

There are commercial and public domain software applications available for designing and modeling water distribution networks that differ in many ways, including capabilities and compatibility with different computer systems. The selection of a computer model for modeling a water distribution system is determined by the availability of data, the project's applicability, and the projects over preview (Josh, 2015). EPANET, Water CAD, and Water GEMS were some of the most commonly used computer models for water distribution network study (Tomas , 2003).

EPANET: is a free software package designed by the United States Environmental Protection Agency (EPA) to be used as an evaluation tool by any entity concerned with distribution system water quality. Epanet is a hydraulic model that can do a range of analyses such as extended-period simulation, water quality analysis, residual chlorine calculation for disinfection, and so on. In comparison to Water CAD, Epanet has the drawback of using a text editor for data input as well as a lack of graphical input possibilities. In general, Epanet is free software that can estimate head loss, pressure, and water quality in a distribution network (Bentley, 2014).

Water CAD: is the commercial software produced and marketed by Haested Method of Waterbury, standalone hydraulic simulation software containing its own graphical editor and strong modeling capabilities when compared to Epanet. Water CAD conducts hydraulic and water quality analysis, steady-state and extended period modeling, strong data arrangement, and Auto CAD and GIS integration. Water CAD, in comparison to Epanet, is a simplified model construction with geospatial model and tools such as Load Builder and Trex, fire flow analysis, optimization, and scenario management (Bentley, 2014).

Water GEMS: is a compact and simple to use water distribution system modeling Programme. It is a superset of Epanet and Water CAD water distribution system modeling; it includes everything in Water CAD and Epanet, as well as more in Water GEMS. It is the only hydraulic modeling software that can do automated design, calibration, pump scheduling, and pipe renewal planning. It distinguishes itself from other applications by having six components, including Skelebrator and pipe renewal planner (Bentley, 2014).

Pipe renewal planner: It is an asset management tool that ranks pipes based on performance to determine which pipes are crucial and should be repaired (Bentley, 2014). .

Darwin designer: With automated design, genetic algorithm approach will analyze many aspects of water distribution network design and rehabilitation based on cost reduction, benefit maximization, or multi-objective optimization. The automation design feature calibrator is only available with water GEMS; however, the model parameter is adjusted manually by guesswork and trial and error (Bentley, 2014). .

Darwin calibrator: determining the ideal values for model parameters such as pipe roughness, nodal demand, and link operating status to best reflect the real-life situation in your hydraulic system. It is useful for predicting the most likely location of hidden leakage. **Darwin Scheduler:** Find optimal pump operations for fixed or variable speed pumps, optimize your pumps to reduce energy used in the system, and/or reduce the cost of operations of the pumps in the system. This feature is only available in Water GEMS so if you are interested in optimized pump scheduling studies, Water GEMS would be the best choice (Bentley, 2014).

SCADA connect: Connecting SCADA data directly to the model allows you to easily calibrate an endless number of signals based on real-world conditions. SCADA link is the only functionality provided in Water GEMS because it is required for calibration studies (Bentley, 2014). .

Skelebrator: is a tool in Water GEMS (and more recent versions of hammer) that allows users to automate the process of simplifying a model and reducing the number of pipes in the system (Bentley, 2014).

2.7. Water Supply Method in Distribution System

The obtainable water sources from end to end the world are becoming no longer sufficient and this has brought into attention the imperative need for planned action to bring about water resources efficiently for sustainable development. Water network system is designed to supply the maximum hourly demand. In developing countries, the Water distribution systems are built to provide continuous water supply (CWS) with a peak flow rate factor, whereas in actual practice as a result of non-availability of adequate quantity of water at source and financial restrictions, it is not practically possible to operate drinking water systems for 24 h/day (Abu-Madi, 2013).

2.7.1. Continuous Water Supply

In the continuous system, water is available to the consumers for all the 24 hours of a day. This is the best system since water is available as and when it is needed, but this leads to losses will be more if there are leakage in the system. In this system less diameter of pipe are required, rusting of pipes will be less and on account of great volume of water continuously flow for long duration fresh water is always available. The water distribution network in the continuous supply systems should be designed to resist the range of pressures corresponding to the minimum and maximum supply conditions (Garg, 2010).

2.7.2. Intermittent Water Supply

Water supply to users is sporadic, with low and irregular pressure in the system. Intermittent water delivery is caused by insufficient water resources, inadequate infrastructure, and poor network condition, and is connected with delivering less water, less frequently, or a combination of these factors (Vairavamoorthy et al., 2007).

2.8. Types of Water Distribution Systems

A method for distributing water is a pipe network that transports water at a suitable quality and pressure from the source to consumers. Its designs should not only meet functional requirements, but should also be cost-effective. Water distribution networks are created with a variety of goals in mind, including functional, economic, reliability, water quality preservation, and future growth. Pumps, reservoirs, pipe fittings, pressure measurement instruments, and flow leak detectors are also part of the distribution system. According to Sharma (2008), water distribution networks can be classified as follows:

2.8.1. Branched System

This kind of network is commonly used in the water supply systems of most developing countries. There is only one possible route for the water from the source to the customer. The advantage of this system is that it is the most cost-effective, but it has some disadvantages, which are listed below;

- During any repair of pipes or valves, the entire downstream end is cut off from power.
- In low demand locations, branching systems create little chlorine residuals and may necessitate frequent cleansing of hydrants to draw chlorinated water into the system.
- There is stagnant water at dead ends of pipes, which causes contamination.
- During periods of high demand, velocity increases, head losses increase, and capacity decreases.

2.8.2. Looped System

As the name implies, a looped system minimizes service interruptions because key breakdowns can be kept apart due to multidirectional flow to demand points. Urban water networks are mostly looped, whereas rural water networks are branched. Because of the high reliability requirements of water service, loped configurations are preferred over branched configurations (Sarbu, 2002). The disadvantages of the systems are higher capital costs, as well as higher operational and maintenance costs.

2.9. Methods of Water Distribution System

Water must reach the end user at the required flow rate for well-organized distribution. As a result, some pressure in the pipeline is required to force water to spread every location. The supply system is classified into the following categories based on the methods of distribution.

2.9.1. Gravity Distribution

When the supply source of water is located at an elevation above the city, sufficient pressure can be sustained in the mains for domestic and fire services. The supply of water in pipeline flows due to gravity and pumping is not necessary es. This type of system is both dependable and cost-effective.

2.9.2. Pumping Distribution

Constant pressure in the system can be maintained in this method of distribution by straight pumping into mains. To meet demand, the pumping rate should be adequate. Power outages and pump breakdowns can have an influence on supply. A benefit of direct pumping is that a great fire service pump may be used which can run up any chosen amount of pressure amount allowable by the construction of mains. Such system works only in condition where there is continuous supply of power, reliable water source and where storage system intermediate cannot be installed.

2.9.3. Dual System of Distribution

This type of system is also called as a combined system of pumping and gravity. The pump is linked to both the mains and the elevated reservoir. When demand is low, water is kept in the raised reservoir; however, as demand rises, the degree of pumping increases, and the flow in the supply system comes from both the pumping station and the elevated reservoir. Because water comes from two sources in this system, one from the reservoir and the other from the pumping station, it is referred to as a dual system. This system is additional dependable and cost-effective because it requires a constant rate of pumping while meeting both low and high demand. The water put in storage in the raised-up reservoir meets demand during pump breakdowns and for firefighting.

2.10. Water Distribution System Components

2.10.1. Pipes

Pipes are an important component of a water distribution system because they transport potable water from the treatment plant to the distribution area based on the maximum capacity, and distribution mains transport water from the secondary mains to numerous consumers. They can be found in a variety of lengths, materials, and diameters as they are laid out in the network. The pipes are mainly come together into three such as, transmission line pipe, distribution line pipes and service pipes. The transmission line pipe connects the source and the storage element; it transports water from the source or pump station to the storage tank while having enough capacity to serve the consumers as well as transport additional water to the storage tank. The distribution line transports water to the pressure zone and then distributes it to the service nodes. Service pipes, the opposite hand, are the pipes that primarily deliver water to consumers.

2.10.2. Pumps

Pumping facilities are necessary whenever gravity cannot feed water to the distribution system at a sufficient pressure to meet all service needs and the water is also left at a higher elevation or under higher pressure. Pumps can be powered by electricity, diesel, or steam. They are useful in pumping water from the source, that is, from the intake to the treatment plant, and from the treatment plant to the distribution system or service reservoir. Various performance curves, such as power head and efficiency requirements developed for the friction rate, present the pump characteristics. To ensure reliability, efficiency, and flexibility, most pumping stations employ two or more pumps.

2.10.3. Reservoir and Storage Tanks

Reservoirs and storage tanks are primarily provided in water distribution systems to store excess water all through periods of low demand in order to meet variations in water demand, maintain stable pressure, and reserve water for disaster requirements. The most common reservoirs used in the water supply system are circular and rectangular in shape and made of concrete or steel.

2.10.4. Accessory Equipment

The water distribution system's ancillary equipment is categorized as valves, hydrants, fittings, drainage facilities, flow meters, and so on. When a failure happens, all of these accessories are installed in locations where they are necessary for network connectivity, system control and management, and maintenance (Bhadbhade, 2009).

2.11. Pipe Network Hydraulics

The fundamental physical laws of mass, momentum, and energy regulate the flow of a substance in a pressurized pipeline. Balance equations are used to express the conservation rules numerically. Interconnections of hydraulic elements, according to Sharma (2008), are characterized in terms of mass and energy conservation.

2.11.1. Conservation of Mass

The concept of conservation of mass states that, the fluid mass entering a pipe must be equal to the fluid mass leaving the pipe. In network modeling, all outflows are grouped at nodes or junctions (Walski, et al., 2003). The continuity equation at the node in the system is stated mathematically as follows:

$$\sum \mathrm{Qin}\ \Delta \mathrm{t} - \sum \mathrm{Qout}\ \Delta \mathrm{t} - \Delta \mathrm{vs} = 0 - - - - - - - - - - - -(2.1)$$

Where: -

$\sum Qin = total\ in\ flow\ (\frac{m^3}{s})$

$\sum Qout = total\ out\ flow\ (\frac{m^3}{s})$

ΔVS= change in storage volume

Δt= change in time

2.11.2. Low of Conservation of Energy

The principle of conservation of energy demands that the difference in energy between two points must be the same regardless of the path that is taken, according to Bernoulli's equation (Walski, et al., 2003). The energy equation between two portions of a water distribution network is represented in terms of head for a hydraulic study, such as:

$$Z1+\frac{P1}{\gamma}\ +\frac{V1^2}{2g}+\sum hp\ =Z2\ +\ \frac{P2}{\gamma}\ +\frac{V2^2}{2g}+\sum hl\ -------------(2.2)$$

Where,

Z = Elevation head

P= Pressure

γ = Unit weight of water

V=Flow velocity in pipe

g=Acceleration due to gravity

hp =Head added at pump

h_l =Head loss in a pipe

2.12. Head Losses

When water runs through pipes, it loses energy or head owing to wall friction, cross section change, or restriction in the flow. All of these losses are measured in terms of velocity head. The Hazen-William equation is the most often used method for calculating head loss in a pressure piping system. The most often used equation in water distribution network analysis and design, conduits flowing full, was established by the tryout and used only for water at temperatures generally observed in potable water systems.

$$.hL = 10.70\ L\left(\frac{Q^{1.852}}{C^{1.852}}\right)\ \frac{L}{D^{1.852}}\ \text{---------------------------}\ (2.3)$$

Where: -

h_L = Head loss in meter of water column

C = Hazen-Williams roughness coefficient (-)

L = Length of considered pipe section (m)

D = Diameter of pipe (m)

Q = discharge (Flow) through pipe (m^3/s)

The Darcy-Weisbach equation is theoretically based and is utilized in the analysis of pressure pipe systems. It can be employed to free-surface flow.

$$hL = \boldsymbol{\lambda} \frac{\boldsymbol{L}}{\mathbf{12.1}\,\boldsymbol{D^5}}\,\boldsymbol{Q^2}$$ -- (2.4)

Where: -

hL = Head loss in meter of water column

$\boldsymbol{\lambda}$ = Darcy -Weisbach Friction factor (-)

L = Pipe length (m)

D = Pipe diameter (m)

Q = Pipe flow (m^3/s)

2.13. Water Distribution Network Simulation

The process of emulating the behavior of one system through the function of another is referred to as simulation. In our case, simulation refers to the use of a mathematical representation or a real-world system. Simulation will be used without interfering with the actual system, and solutions will be examined before investing time, money, and resources in a real-world project.

There are two basic types of simulation:

Steady-state simulation: estimates the system condition (flows, pressures, pumping characteristics, valve positions, etc.) with constant hydraulic requirements and boundary conditions. It is the most basic sort of simulation and gives the system's solution equality as a coordinating system; demand and tank height maintained this running, that is, the demand at each node is constant 24 hours a day.

Extended-period simulation: is used to manipulate the system's behavior over time. This type of study allows the user to simulate tanks filling and draining, regulating valves opening and closing, and pressures and flow rates changing throughout the system in response to varied demand conditions and automatic control strategies developed by the modeler. An extended-period simulation determines whether the system can deliver acceptable levels of service over a time span of minutes, hours, or days. Extended-period simulations can also be utilized for energy consumption and cost analyses, as well as water quality modeling. The user must identify water usage trends, provide more specific tank information, and enter operational rules for pumps and valves (Walski et al., 2003).

2.13.1. Hydraulic Design Parameters

The main hydraulic parameters in water distribution networks are the pressure and the flow rate, other related design factors are the pipe diameters, velocities, and the hydraulic gradients.

2.13.1.1. Pressure

The pressure at nodes is determined by the network's adopted minimum and maximum pressures, topographic conditions, and network size. To avoid water column separation and to ensure that consumers' demands are met at all times, the minimum pressure should be maintained. Maximum pressure constraints, which result from service performance requirements such as fire needs or pipe pressure bearing capacity, also limit leakage in the distribution system, especially since there is a direct relationship between high pressure and increasing leakage value in the system. According to MoWR (2006), the normal working pressure in a water delivery system range from 15m to 70m.

2.13.1.2. Flow Rate

It is the amount of water that flows through a particular portion in a given amount of time. The flow rate determines the velocity. The flow rate across a segment can be approximated for a given pipe diameter and velocity. Low velocities have an impact on proper supply and are unsanitary.

2.13.1.3. Velocity

According to MoWR (2006), the ideal velocity in a water distribution network was between 0.6 m/s and 2m/s to avoid sedimentation at low velocity and high head loss at high velocity. In a water distribution system, velocity is inversely proportional to pipe diameter. The suitable pipe diameter was necessary to accommodate demand during peak consumption periods while maintaining enough dynamic pressure in the water system (Jeffery , 2012).

2.14. Water Quality Parameters

Drinking water quality is determined by comparing water samples to drinking water quality recommendations. According to WHO (2017), the guidelines pose no considerable danger to health over a lifetime of consumption. Water quality is defined in terms of physical, chemical, and bacterial factors.

2.14.1. Physcio-Chemical Water Quality Parameters

PH

The potential hydrogen ion (H^+) accessible in water is determined by PH. The acidity of groundwater is caused by the presence of organic acids in the ground as well as those from the atmosphere that have penetrated into the water. According to WHO (2004), the optimum pH necessary is often between 6.5 and 8.5.

Temperature

Temperature influences chemical, physical and biological processes in water bodies; chemicals used in water treatment dissolve more easily in warm water than in cold water; particles settle out more quickly in warm water; high water temperature promotes the growth of microorganisms and may increase taste, odor, color, and corrosion problems, in general, cool water tastes better than warm water (EPA, 2010).

Total Dissolved Solid (TDS)

Water has the capacity to dissolve a wide variety of inorganic and organic minerals and salts. These minerals gave water an unpleasant flavor and a diluted color. There is no agreement on the detrimental or beneficial effects of water that surpasses the WHO standard limit of 1,000 ppm. In drinking water total dissolved solids (TDS) come from a variety of sources, including sewage and urban industrial wastes. As a result, the TDS test is regarded as a signal for determining the overall water quality (Mohsen et al., 2013).

Electrical Conductivity (EC)

It quantifies of water's capacity to pass electrical current; it is proportional to the quantity of salts dissolved in water. Total hardness (TH), pH value, alkalinity, temperature, calcium, total solids (TS), total dissolved solids (TDS), chemical oxygen demand, and chloride and iron concentrations of water all have a relationship with conductivity.

Turbidity

Water's clarity must be ensured in order for it to be aesthetically acceptable. Turbidity is defined as the light scattering and absorption quality that prohibits light from travelling in straight lines through the sample. Turbidity is significant because it influences both the acceptability of water to consumers and the selection and efficiency of treatment processes; particularly the efficiency of chlorine disinfection because it exerts a chlorine demand, protects microbes, and may also rouse bacterial growth. The World Health Organization considers appropriate water to be 5 NUT (WHO,2004).

Total Hardness

Both salts of calcium and magnesium are the main causes of hardness and is measured in terms of comparable amounts of calcium carbonate. Stream hardness may fluctuate seasonally due to variations in ground water and surface water runoff. Hard water comprises a high calcium (ca^{2+}) concentration and/or magnesium (mg^{2+}). According to MoWR (2007), water that is soft may contain sodium (Na^{+}) or other minerals. Total hardness is usually reported in one of four categories as follows:

Table 2.1: Classification of Water Based on Hardness

S. No	Total hardness mg/l as $CaCO_3$	Classification water
1	0-60 mg/l	Soft water
2	60-180 mg/l	Moderately hard water
3	180-300 mg/l	Hard water
4	Above 300 mg/l	Very hard water

(Source: MoWR and WHO, 2017)

Fluoride

Fluoride minerals are plentiful in some types of rocks. Fluoride concentrations high in immunoglobulin's can be released into groundwater through dissolution of fluoride minerals, especially after long contact periods inside aquifers. Fluoride levels in drinking water should not exceed 1.5mg/l, according to WHO and Ethiopian guideline.

Table 2.2: Essential Physico-Chemical Characteristics of Drinking Water

S. No	Substance or characteristics	Units	WHO guidelines	Ethiopian standards
1	PH		6.5 -8.5	6.5 -8.5
2	Turbidity	NUT	5	5
2	Total dissolved solids (TD)	Mg/l	1000	1000
3	Total hardness (Ca CO_3)	Mg/l	300	300
4	Electrical conductivity (EC)	µs/cm	400	1200
5	Fluoride (F^-)	Mg/l	1.5	1.5

(Source: - WHO, 2011 and ECS 58, 2013)

2.14.2. Bacteriological Parameters

Determining the level of disinfection and the presence of waterborne pathogens requires an understanding of the bacterial quality of the water. Specific microorganisms found in water are utilized as a quality index and potential contamination indicator (Barrell, 2000). Contamination of drinking water by human or animal excrement and the microorganisms found in faeces is the most frequent and extensive health concern connected to it. Screening for certain bacterial, viral, and protozoan diseases can be challenging, expensive, and time-consuming, and it's not always possible to identify them. Thus, the quick and simple tests for the presence of indicator organisms are employed to evaluate the quality of the microbiological material. According to WHO (2008), total coliforms (TC) and Escherichia coli (E. coli) are commonly used as microbiological markers.

Table 2.3: Bacteriological Parameters

S. No	Description	Unit	WHO Standard	Ethiopian Standard
1	Total Coliform	CFU/100ml	0	0
2	E. Coli (fecal coliform)	CFU/100ml	0	0

(Source: - WHO, 2011 and ECS 58, 2013)

2.15. Review of Scholarly Researches in the Context of Water Supply System

Previous studies conducted in various areas with the context of system for supplying water were researched and investigated in order to have a better understanding of the town's distribution network. Several of them are summarized below:

Yordanos (2021) did a study entitled "performance evaluation of Gudo Bahir water supply distribution system". The main goal of this research is to assess the water distribution system Gudo Bahir’s hydraulic performance by examining water losses, hydraulic efficiency of the water delivery modeling, and the water supply and demand gaps. The hydraulic network in the research area is imitation using Water GEMS V8i software. According to her findings, the water delivery system has poor hydraulic performance since 98% of pressures are below the permitted limit consumption at peak hour, and 90.3% of pressures are below the permissible range at minimum hour use, resulting in insufficient service coverage.

Cherinet (2015) Conduct a study titled "Evaluation of Water Supply System and Demand in Dore-Bafano Town". His goal was to examine supply coverage, anticipate current and future demand, pressure on the supply system, and evaluate water quality. In his findings, he discovered that some areas with high elevation and proximity to the reservoir site do not receive enough water due to low pressure head, while areas with lower elevation and proximity to the reservoir have high pressure, indicating problems with the current water supply system using EPANET-2. The researcher improved system performance by replacing the existing pipe with a new one that has a small diameter for low pressure and a bigger diameter for high pressure.

The laboratory analysis of the results of spring and borehole water quality tests revealed that average values for all selected physicochemical water quality parameters such as pH, EC, turbidity, TDS, total hardness, iron, fluoride; free chlorine residue, and total iron were found to be within the acceptable limits of WHO and Ethiopian water quality standards. However, the average temperature for the source, reservoir, pipeline, and domestic container exceeded the WHO recommended level.

The other study assessed was undertaken by Solomon Tadesse (2020) titled "Groundwater Quality Distribution of Addis Ababa Based on Chemical Content." The study's ultimate goal was to analyze the regional variance in ground water quality within the Addis Ababa city border and identify potential explanations. In his findings, the ground water samples taken from various parts of the Addis Ababa region indicated that three types of water exist in Addis Ababa city: ground waters with high iron and manganese region located in the city of northern part, containing high fluoride and total dissolved solid rich water confined in the central part which extends to the eastern part of the city, and the groundwater quality that comply with the WHO drinking.

3. MATERIALS AND METHODS

3.1. Description of the study area

Besheno rural town, Bubesa kebele, and Hantezo kebele are all located in Wera Dijo woreda, Halaba Zone, and the Central Ethiopia Region (CER), which was established in 2016. Besheno town serves as the capital for Wera dijo woreda. The rural town presently has public services such as a district hospital, education, water mining, and an energy office, while all other government offices are placed at the woreda level.

The study area is located between 7^{0}28' N latitude and 38^{0}12' E longitude and it has average elevation of 2092.69 meters above sea level. It is located approximately 317 kilometers from Addis Ababa and 66.3 kilometers from the regional capital of Hosanna. As a result of this, the area is bounded to the north and west by Silte Zone, to the east by Oromia Region, and to the south by Wera Wereda. Wera Dijo woreda is a new woreda that was established in 2011 EC. Wera Dijo woreda is made up of 13 rural kebeles and one settlement. Despite this, 14 kebeles were previously discovered under the control of the Halaba special woreda. Finally, those 14 rural kebeles band together to form Wera Dijo Woreda, and the Halaba zone chose Besheno as the Woreda’s principal town.

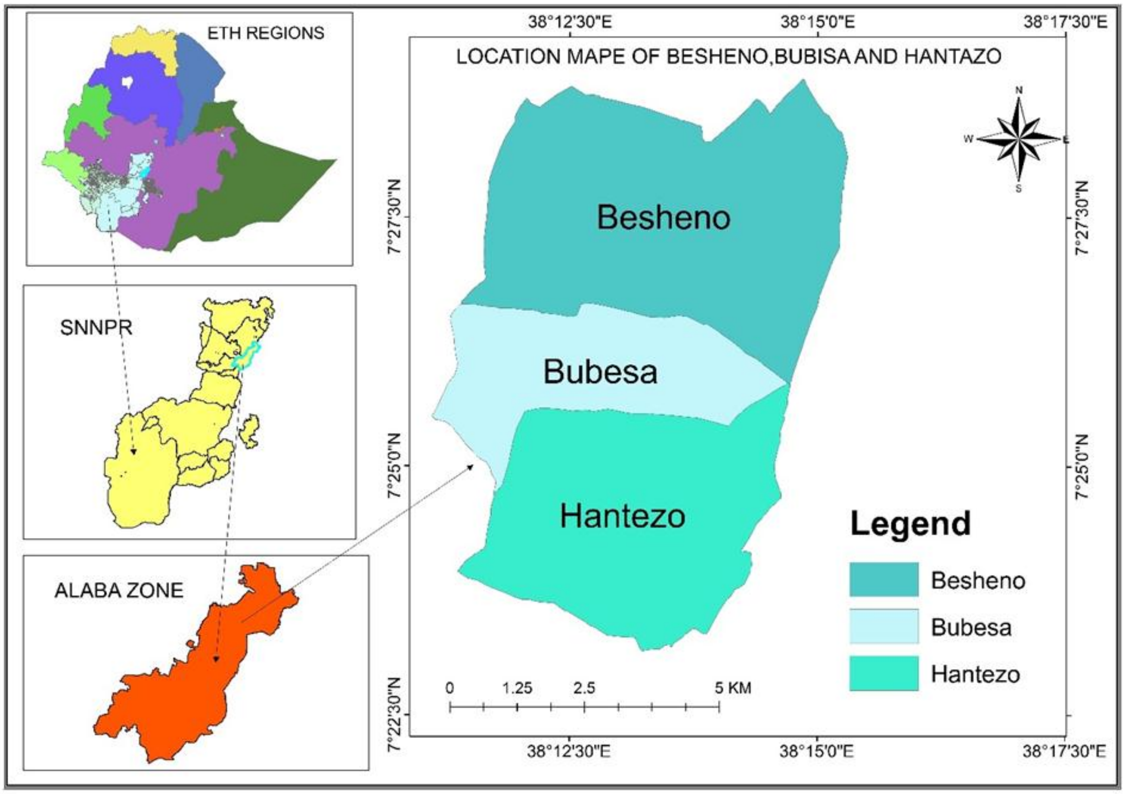

Figure 3.1: Map of study area

3.1.1. Population

During the second national census in 2007, the area's population increased to approximately 12,663. According to the woreda office of finance and economic development, the study area had a population of 18,677 in 2022. The geometric growth rate was used to construct population projections. The reason for selecting this population prediction approach was that it is applicable to growing towns and cities with a considerable expansion potential.

3.1.2. Climate and Rainfall Distribution

In terms of climate, Ethiopia's climate may have been a true tropical climate, but this is not the case due to the high altitude, which changes it. There is no adequate and trustworthy meteorological data for Besheno's climatic state. However, according to scattered statistics, the town has a kola climate with a mean annual rain fall of 601-1200 mm and a mean daily air temperature of 17^0 C - 20.8^0 C. This is further supported by the fact that, as with altitudes ranging from 1600 to 2000 meters above mean sea level.

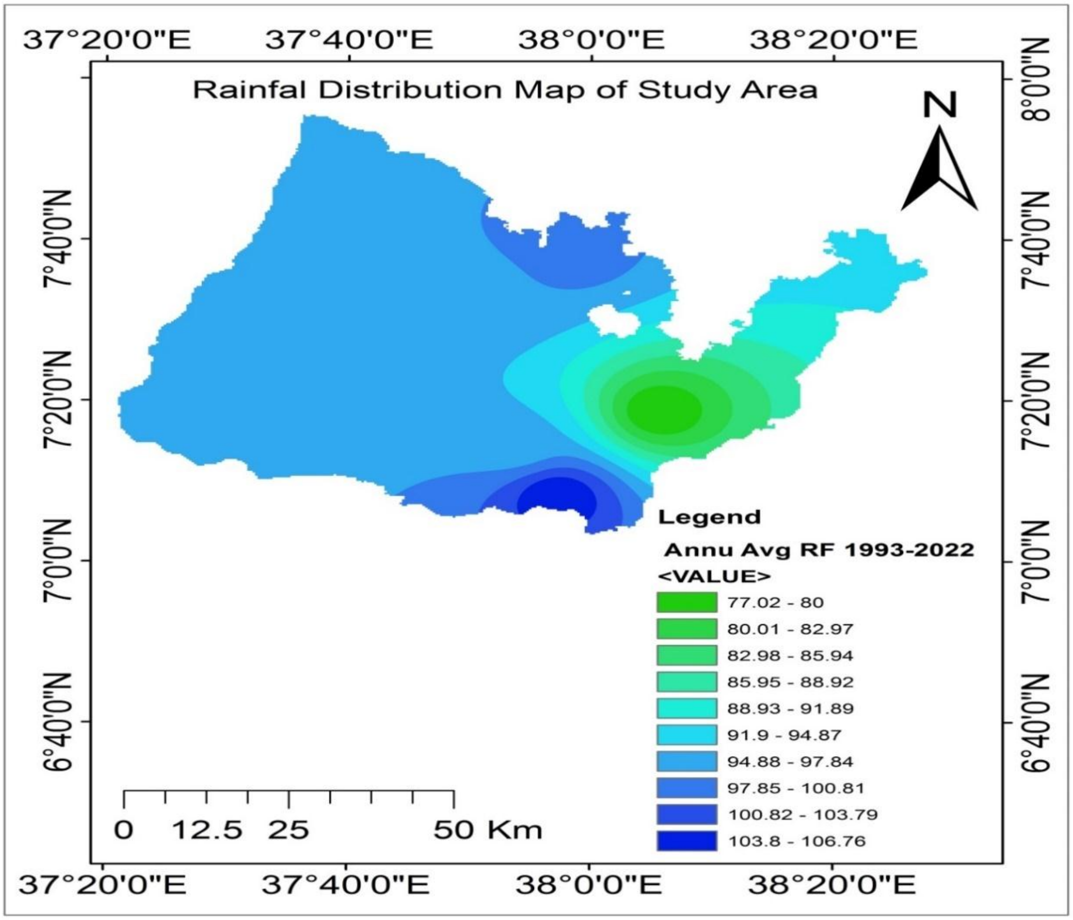

Figure 3.2: Map of Rainfall Distribution

3.1.3. Socio-economy

The socio-economy situations of the study area are both trading and agriculture. According to Wera Dijo Woreda Agriculture Office (2016) the major crops cultivated in the area are red pepper (Berbere), maize and wheat. Additionally, production of animal husbandry and chat.

3.1.4. Water Sources

The present water supply sources are drilled boreholes of developed groundwater at Bubesa kebele and Hantezo kebeles, with pump tests yielding 5.8 l/s and 5.5 l/s, respectively. Currently, the existing water supply from boreholes to the rural town, comprising two kebeles, is 11.3 l/s, or approximately 148,482 m^3 of water is delivered yearly.

3.2. Materials

To collect, process, and evaluate data for this study, the following tools and supplies were utilized.

- Water GEMS software, which determines velocity, nodal pressure, and water demand, is the primary material and equipment used for data gathering, processing, and analysis.
- Arc GIS 10.7 was used to mark out the study region and visualize the water distribution arrangement.
- GPS was utilized to collect the geographical position of the observed sample pressure point.
- Pressure gage was used to measure the pressure at the nodes.
- Google earth and Global Mapper were used to check the elevation network.
- Excel and SPSS software were also employed. For the household interviews, both structured and unstructured questioners were employed.

3.3. Data Collection

3.3.1. Primary Data collection

Primary data was collected via a field survey, field observations, GPS, a water meter, a laboratory, a key informant interview, a focus group discussion, and household survey questionnaires.

3.3.2. Secondary Data collection

Secondary data was acquired from the Wera Dijo woreda water mine and energy office, as well as other available data sources such as reports and project design document, Census and survey reports, books, different literature reviews, the internet, and other published and unpublished reports.

3.3.2.1. Existing Water Supply System

Water is supplied through pump from two boreholes to a reservoir located at a higher elevation than the distribution system and a concrete reservoir with a holding capacity of 200 m^3. Water is spread around the area by gravity from another 200 m^3 reservoir. Furthermore, the full water supply network of the study area facts such as pipe length, diameter and material type, pipe roughness coefficient, water pumps, and so on will be collected from Wera Dijo Wereda Water Mine and Energy Office, and as built drawings will be collected from South Design Construction Supervision Enterprise.

3.3.2.2. Water Pump Situations

A pump is a hydraulic mechanism that adds energy to the water flow by converting mechanical energy into potential energy to overcome friction loss and hydraulic grade differences within the system. There were two Submersible pumps in water sources.

Table 3.1: Pump Description

Source	Elevation (m)	Pump type	Pump power (KW)	Discharge (l/s)	Discharge (m^3/hr)	Head (m)
BH B-1	2003	Submersible	80	5.80	20.88	445
BH H-2	2041	Submersible	80	5.50	19.8	446
Total				11.30	40.68	

(Source: Wera Dijo woreda water mine and energy office)

3.3.2.3. Water Production

Water production has been calculated as the entire annual water provided to the water distribution system. Wera Dijo Wereda Water Mine and Energy Office (WDWWMEO) oversees water production. According to WDWWMEO, the design gross water production capacity of both boreholes is 406.8 m3/day, however currently roughly 244.08 m3/day output is produced from boreholes that work an average of 6 hours per day.

Table 3.2: Water source production

Source	Elevation (m)	Depth (m)	Casing diameter (mm)	Raiser pipe diameter (inch)	Yield (l/s)	Daily production (m^3)	Yearly production (m^3)
BH B-1	2003	383	8 $^{5/8}$	3”	5.8	208.8	76,212
BH H-2	2014	430	8 $^{5/8}$	3”	5.5	198	72,270
Total					11.3	406.8	148,482

(Source: Wera Dijo woreda water mine and energy office)

3.3.2.4. Transmission main line

The pressure main transports water simultaneously from the source to the service reservoir and distribution system. The system’s main pressure line of the system is 4.875 kilometers long. The lines of HDPE pipe with OD125mm PN25 were installed from the Bubesa borehole to the service reservoir, measuring 1.468 km in length, and from the Hantezo borehole to the service reservoir, measuring 3.407 km.

3.3.2.5. Service reservoir

A reservoir is a component of a water distribution system that is used to balance supply and demand across various consumption periods. The service reservoir is a circular reinforced concrete reservoir with a capacity of $200m^3$. It is situated at an elevation of 2090.27 meters above sea level in the Bubisa hilltop area, with UTM 415059.20E and 818331.00N. Water is provided to consumers via gravity from this reservoir.

3.3.2.6. Distribution pipe line

The existing distribution system is a network with a total length of 16.48 km with pipe diameters ranging from OD50mm to OD160mm.The pipe material was made up of UPVC, HDPE and GI. The data came from WDWWMEO and the as-built drawing.

3.3.2.7. Water consumption

Local way of recorded (not billed) water data is used to determine water loss in the distribution system. It was gathered from the WDWWME office on a monthly basis, and monthly water usage was converted to yearly for the purpose of analysis.

3.3.2.8. Length of water supply

The water distribution system for consumers was built to ensure a continuous supply. According to Wera Dijo Water Mine and Energy Office, due to pipe rupture open supply outlet one-third, frequent rise in fuel cost, piped water delivered to users after three days' interval.

3.4. Analysis of the existing water supply distribution system

3.4.1. Demand for water analysis

Before establishing a proper and adequate water supply for the area, the amount of water required daily must be determined. Water demand estimation is one of the fundamental inputs used to determine the source of water supply and the volume of water required to cover the system's supply and demand gap.

3.4.2. Forecasting the population

According to B.C.Punamia (1995) there are various methods for forecasting population; however, the results differ from one method to the next. The selection of appropriate for a certain place must take into account the entire condition of the chosen area. The geometric population growth model was used to project population over the next fifteen years. The existing water needs and future water demands of the rural town and kebeles were then projected using the current and projected population for the fifteenth year's population. This population projection method was chosen because it is applicable to growing towns and cities with a vast scope of expansion.

$$\mathrm{P_n} = \mathrm{P_o}(1 + \frac{\mathrm{r}}{100})^{\mathrm{n}} \quad ---------- (3.1)$$

Where: $P_{n=}$population projection

P_o=base population

r=annual growth rate in percent

n=number of years (annual rate of growth rate)

3.4.3. Water demand per capita by mode of service

Per capita water demand is the measure used to determine the overall water demand of the study area; it varies greatly depending on the size of the town, standard of living, socioeconomic factors, and climatic variables. Table (3.3) values were used to estimate per capita water demand for various modes of service.

Table 3.3: Water Use by Service Mode

Mode of service	Per capita water demand (l/c/day)
House connection (HC)	70
Yard connection (YC)	30
Yard shared connection (YSC)	40
Public fountains (PF)	25

(Source: MoWR, 2006)

3.4.4. Adjustment to climate

Water use is affected by the weather. Because the town is in a hot temperature, it requires more water than a cold climate. As a result, the adjustments owing to varied climate conditions are shown in Table 3.4 below.

Table 3.4: Climate factors

Mean annual temperature (^oC)	Description	Altitude	Factor
<10	Cool	>3300	0.8
10-15	Cool temperature	2300-3300	0.9
15-20	Temperature	1500-2300	1
20-25	Warm temperature	500-1500	1.3
Above 25	Hot	<500	1.5

(Source data compilation and analysis project, 1997)

As a result, Besheno rural town, encompassing Bubesa and Hantezo kebeles, was assessed to have temperature and with a factor of 1.

3.4.5. Socio economic adjustment condition

Water use in the home is directly related to socioeconomic level. Its residential water use per capita was adjusted using a fair factor. Table 3.5 shows the demand adjustments in socioeconomic characteristics.

Table 3.5: Socio Economic Adjustment Factors

Group	Description	Factor
A	Towns enjoying high living standards with very high potential development	1.1
B	Towns having a very high potential development but lower living standard at present	1.05
C	Towns under normal Ethiopian conditions	1
D	Advanced rural towns	0.9

(Source: MoWR, 2006)

As a result, Besheno rural town, including Bubesa and Hantezo kebeles, was determined to have advanced rural towns, and the case of the research area was classified as group D with a factor of 0.9.

3.4.6. Domestic water demand analysis

Domestic water demand refers to the amount of water required for various household activities. The amount of water utilized for home purposes varies according on the style of living and the mode of service provided by the climate. Data on residential water consumption in Besheno rural town, including Bubesa kebele and Hantezo kebele, were collected from Wera Dijo woreda water mine and energy office as yard connection own and public tap. The following formula was applied for determination of domestic water demand.

Domestic water demand = Population $*$ Per capita water demand ------------------------ (3.2)

3.4.7. Non domestic water demand

Institutional water demand: the amount of water required for various public utility functions, such as city hall, schools, hospitals, public offices, and so on. This figure was undoubtedly fluctuate depending on the nature of the city and the number of institutions there. It accounts for 5-10% of total domestic water demand on average.

Commercial Water Demand: Water demand for hotels, retail centers, service stations, movie theatres, and other similar establishments. It is determined by the type and quantity of commercial establishments. Commercial water use typically accounts for 10-20% of total domestic water demand.

Water demand for firefighting is the amount of water required to fight a fire that has broken out. Annual volumes required for firefighting purposes are generally small, but during times of need, the demand can be extremely high, controlling the design of distribution systems, storage, and pumping equipment. As a result, there is no reason to develop capacity to provide for firefighting in smaller communities. Water for combat purposes, on the other hand, is provided for in towns of moderate size as a reserve of 10% of the storage reservoir volume (MoWR, 2006).

Livestock water demand: is the amount of water required for livestock. In towns when there are no natural sources nearby such as rivers, streams, ponds, or springs. Water source to supplement animal water demand; the water demand estimates in Table 3.6 are used to estimate livestock water demand.

Table 3.6: Domestic Animal Water Demand

Type of livestock	Per capita per day
Cattles, donkeys, horses, etc.	50 l/head/day
Goats/sheep	10 l/head/day
Camels	15 l/head/day

(Source: MoWR, 2006)

Unaccounted for water (UFW): is often stated as a percentage of total water production for the system. It is caused by poor pipe joints, cracked and broken pipes, loose valves and fittings, illegal connections, unbilled usages, metering mistakes, and reservoir overflowing. According to the computation of the past record of water production and consumption, unaccounted for water on the water delivery system constantly declines (MoWR, 2006).

3.4.8. Variation of water demand

The level of water supply services varies from hour to hour, day to day, season to season, and year to year. As a result, in order to meet the required variation in demand, the average day demand was scaled up by the factor to meet the maximum day demand of the provided research region. It is used to calculate the size of the pump, transmission main line, distribution main line, and storage facilities.

Maximum day demand (MDD): The maximum water demand of any one 24-hour period in any given year. According to MoWR 2006, the highest day water demand factor in this study region is 1.25.

Peak hour demand (PHD): It represents the amount of water needed during a certain day's peak consumption hour. Peak hour factor is expressed as a multiple of yearly average daily demand and is used in conjunction with seasonal and peak day factors. The peak hour factor varies inversely with consumer population size (MoWR., 2006). The peak hour demands are shown in Table (3.7).

Table 3.7: Peak Hour Factors

Total population	Peak hour factor (PHF)
0 - 20,000	2
20,001- 50,000	1.9
50,001 - 100,000	1.8
> 100,000	1.6

(Source: MoWR, 2006)

The population of Besheno advanced rural, which includes Bubesa kebele and Hantezo kebele, is less than 20,000, and a peak hour factor of 2 is employed for the purpose of analysis.

3.5. Water supply coverage

The study area's water supply coverage was assessed using the average per capita usage. The annual usage obtained from water meters were used to calculate the average per capita consumption. The number of domestic and the average daily per capita water usage are utilized in the research section of the analysis to analyze the water supply coverage for the complete water distribution system.

3.5.1. Domestic water consumption

The volume of water consumed for domestic purposes has been combined across all system users in order to analyze the distribution of water supply coverage across the study region. Using the population size, total annual consumption data was translated to average daily per capita consumption (Welday, 2005). The following formula was used to calculate water usage per capita.

$$\text{Per capita consumption (L/C/day)} = \frac{\text{Annual consumption} * (\text{m}^3) 1000 \text{ l/m}^3}{\text{Population number} * 365 \text{ days}} \text{ ----- (3.3)}$$

3.6. Analysis of water loss

Water loss occurred in the distribution system as a result of leakage caused by poor pipe joins, valves, and fittings. There are two distinct approaches for calculating water loss. These are based on a minimum night flow analysis and an annual water balance from the top down. The top-down water balancing approach is commonly used in developing countries to follow the guidelines proposed by IWA, (2000), and it is applied in this study to assess water loss in the system. The entire annual water produced and distributed to the distribution system, as well as the water billed from individual customer meter readings, are used to calculate the overall water loss in the supply system (EPA., 2010).

$$\text{NRW}(\%) = \frac{(\text{Water produced} - \text{Billed water}) * 100}{\text{Water produced}} \text{ ---------------------------------- (3.4)}$$

3.7. Hydraulic performance of water distribution system

The primary goal of modeling is to evaluate the current system, determine pressure levels at crucial places within the system, and construct a simplified model. Input data gathering, model development in Water GEMS, data entry, model testing and hydraulic modeling, and problem analysis are the modeling steps. Node data, pipelines data, tank data, pumps data, and reservoir data are all examples of input data for distribution system studies.

Data entry procedure: all previously gathered and generated data have been entered into the Water GEMS software. The system was then simulated for both steady state and long-term simulation.

Calibration was accomplished by a trial-and-error technique similar to that used for Water GEMS calibration or manual approach. This is typically accomplished by simply estimating pipe diameter, length, roughness, as well as nodal demands and elevation, analyzing simulation results, and comparing expected performance to actual performance. If the analysis results are unacceptable, the reason of the problem must be hypothesized, and changes to the same parameter must be made before repeating the process until an acceptable output is obtained.

3.8. Sample location

Sampling locations are chosen at random, and restriction factors such as age are usually used (Walski et al.,2003). Sampling points should be in the network's apex, a significant distance from the network's boundary nodes (reservoirs and tanks), and have relatively high discharges and pressures. The real values of the minimum distance from border nodes, minimum discharge, and minimum pressure are pertinent to and specific to a certain style.

3.8.1. Sample size

Beneficiaries of the research region were the key primary data sources for this study, according to Cochran (1977). To guarantee that the findings were generalizable to a larger population, the study considered an adequate sample respondent for selection using proper methodologies. This formula is used to calculate the number of samples HHs for interviews:

$$n_o = \frac{\mathrm{Z}^2 \mathrm{p\ q}}{e^2} \text{ --------------------------------- } (3.5)$$

$$\mathrm{n} = \frac{n_o}{1+\frac{n_{o-1}}{N}} \text{ ---------------------------------- } (3.6)$$

Where, $\mathrm{n_o}$= desired sample size when the population > 5,000

n= No of samples size when the population < 5,000

Z= 95 % confidence level corresponding z-value is 1.96

P= 0.05 (proportion of the population to be included in the sample i.e. 5 %)

q = 1 - 0.05 i.e. (0.95)

N= total number of HHs (1694)

e= margin of error or degree of accuracy (0.05).

Table 3.8: Total Number of Sampling HHS from Besheno Town, Bubesa and Hantezo Kebele

No	Study area	Population in number			Total HHS	Sampling HHS
		Male	Female	Total		
1	Besheno rural town	5255	4103	9358	900	38
2	Bubisa kebele	2028	2249	4277	344	14
3	Hantazo kebele	2443	2599	5042	450	19
	Total	9726	8,951	18,677	1,694	71

Source :(SNNPRBoFED, 2015)

Out of 1694 HHs in the study area of only the current water supply distribution system, 71 HHs were chosen for interviews using the previously indicated formula in order to produce primary data.

3.9. Method of data analysis and presentation

3.9.1. Existing water supply coverage and forecasting future water demand analysis

The quantitative data which shows the population, water use, water production and water loss in percentage as well as the numerical data were analyzed interpreted in tabular and graphical forms. Qualitative data that shows the existing situation, major problem of the study area water supply and demand scenario was aggregated, interpreted and explained with the support of the quantitative data analysis. Excel was used to analyze the data generated from different offices and field survey data. The fifteen years populations forecasting were done by using geometric population growth method. Then the future water demands of the study area were projected. The analysis of future water demand scenario is based on the water supply design criteria guideline (MoWR., 2006).

3.9.2. Distribution system analysis

The information was gathered from primary and secondary sources, as well as a field survey, key informants, and chosen households. The distribution system field survey data, such as x and y coordinates, elevation, pipe length, pipe diameter, pipe material type, pump data, reservoir data, and node data, were analyzed using engineering software such as water GEMS, Arc GIS, and Global Mapper. The pressure and velocity parameters were used in the analysis. The data collected from sampled households was analyzed using statistical techniques. To evaluate the water distribution system, each question in the questionnaires and respondents' replies were entered into the SPSS computer Programme, and descriptive statistics based on percentages and frequencies were utilized to analyses the results. The outcome was given in tabular, percentage and graphical formats. For data analysis and interpretation, both qualitative and quantitative analysis techniques were applied.

3.9.3. Physico-chemical analysis

The sampling bottles that were used to determine PH, temperature, turbidity, total dissolved solids, and electrical conductivity were thoroughly cleaned and rinsed. A turbidity meter was used to measure the turbidity, while a Sens ION portable PH/ISE Meter was used to measure the PH, temperature, electrical conductivity (EC), and total dissolved solids (TDS). Titrations were used to assess total chlorine (Cl2), total hardness, calcium hardness, and magnesium hardness. Using standard protocols, the DR/5000 UV-V spectrophotometer (using HACH reagent) was used to measure nitrate, manganese, calcium, phosphate, and fluoride. Finally, the outcomes of the analysis were compared to WHO guidelines and Ethiopia guidelines. Physico-chemical sample was chosen from two boreholes such as Bubesa and Hantezo (BH B1 and BH H2).

3.9.4. Bacteriological Parameters

To prevent the growth or death of microorganisms in the sample, the bacteriological tests were conducted within 6 hours of sample collection (WHO, 2006). 0.45μm membrane filters were used to filter water samples immediately after they were collected in plastic bottles that had been presterilized. In a Wagtech Potatest incubator, the filters were incubated at 37°C and 44°C for total coliforms and E. coli/fecal coliforms, respectively, in a sterilized aluminum Petri dish containing bacterial medium made of Membrane Lauryl Sulphate Broth. To evaluate bacterial growth, the filters were inspected for eighteen hours. The highest allowable limit value specified by the WHO was compared to the results.

3.10. Demand allocation

In this study, Water GEMS and ArcGIS were used to allocate demand to the consumption nodes. Thus, to allocate demand properly, the service area was created using the Thiessen polygon for each demand node, and the spatial population density of the town was used as shown in figures below. Using the service area created by the Thiessen polygon, the boundary flow data, and spatial population density data; the lump sum demand was allocated to each demand node using the population density method of load builder in Water GEMS. The boundary flow and spatial population density shape files were created within ArcGIS. There are four villages in the town and each village has its density as shown in Figure 3.3 below.

$$\text{Population density } = \frac{\text{Village population}}{\text{Area (ha)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..3.7$$

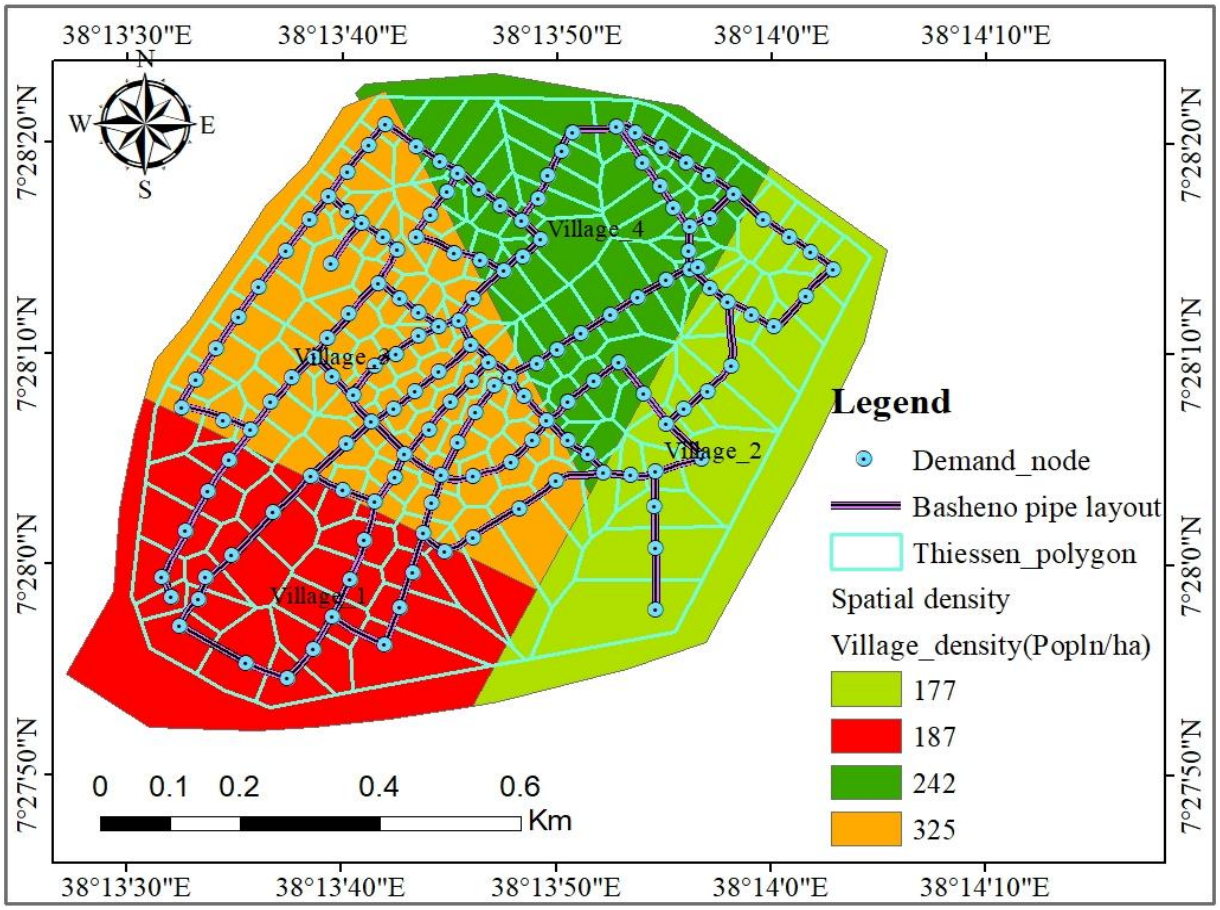

Figure 3.3: Spatial population density of Besheno town

Therefore, based on above spatial population data and service area polygon, the demand was allocated to each node using the following equation;

$$N_d = \frac{Pd_{sa}}{Pd_v} * Q_v \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..3.8$$

Where Pd_{sa} is the population density of the service area (pop/ha), pd_v is the population density of the village (pop/ha), Qv is the village discharge (L/s) and N_d is nodal demand (l/s).

The village demand (Qv) is determined by multiplying per capita demand by the total population of the specific village. Figure below shows the nodal demand allocation of Besheno town.

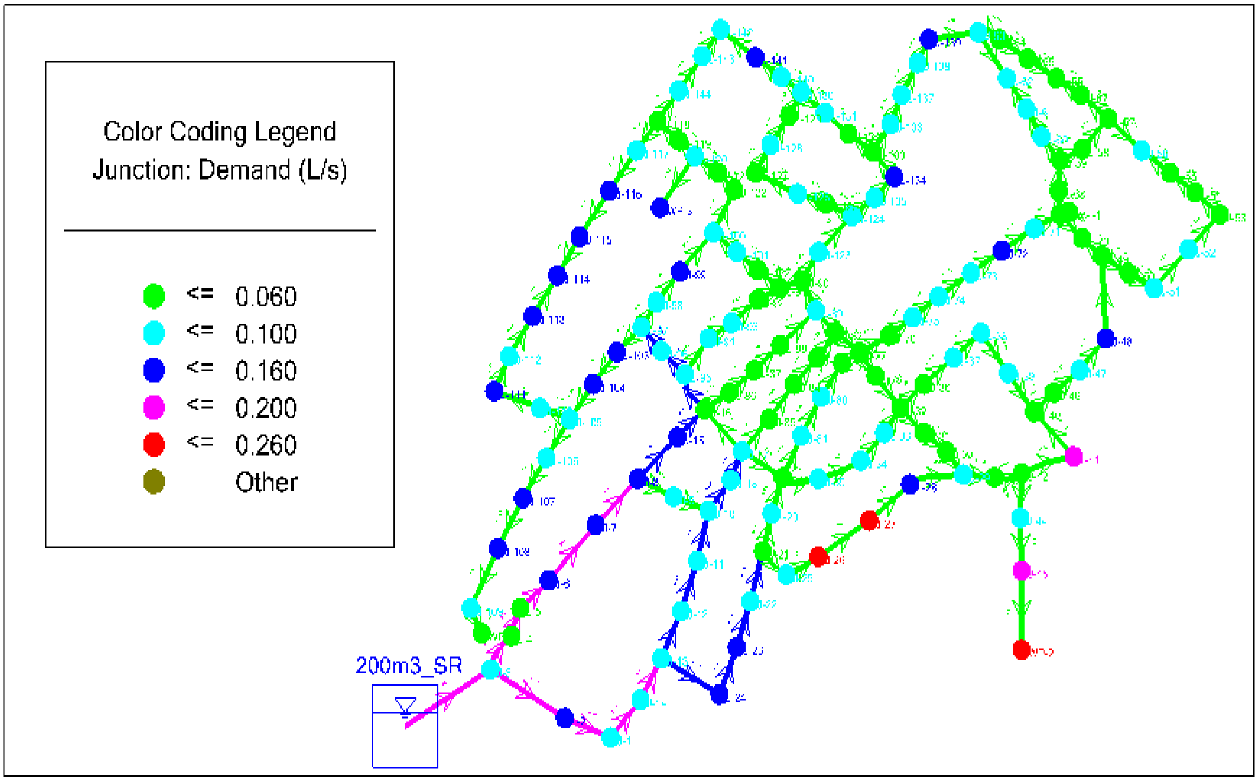

Figure 3.4:Spatial demand allocation of Besheno town

4. RESULTS AND DISCUSSION

4.1. Evaluating Existing Water Supply Coverage

4.1.1. Water Production and Demand

It is commonly recognized that as the population grows, so does the demand for water, as does the area's economic status. The population of Besheno rural town, Bubesa kebele and Hantezo kebele is rapidly growing. During the 2007 G.C, the population was 12,663. The population growth rate is expected to be 2.58 percent between 2007 and 2020 G.C. According to projections from the CSA and Wera Dijo water mine and energy office, the population has been increased by 17,630 by 2020. The total water production and consumption in the study region have increased in parallel with the study area's population expansion. Based on data acquired from WDWMEO, the table below depicts the four-year trend in water production and consumption. As shown in Table 4.1 below, water production and consumption increased from 68,527 m^3 and 60,276 m^3 in base year 2020 to 87,565 m^3 and 83,134 m^3 in 2023, respectively, assuming a decrease 18.54% average water loss. During the last four years, the average water output increased by 6,346 m^3 each year, and 8.52% increases. Similarly, average water use increased by 7,619m^3 per year, a 11.33% increase during the same period

Table 4.1: Water Production, Use, and Loss Trends in 2020-2022 G.C in M3

Month	2020			2021			2022			2023		
	Production	**Consumption**	**Loss**	**Production**	**Consumption**	**Loss**	**Production**	**Consumption**	**Loss**	**Production**	**Consumption**	**Loss**
January	6898	5629	1269	7884	7678	206	8012	7420	592	9450	9201	249
February	6737	5469	1268	7820	6584	1236	8120	8011	109	9239	9011	228
March	6604	5310	1294	7625	7109	516	8140	7693	447	8840	8459	381
April	6349	5022	1327	6479	5978	501	7650	7101	549	7412	7110	302
May	4986	4690	296	5879	5241	638	7200	6897	303	7350	7010	340
Jun	5244	4892	352	5740	5298	442	5689	4970	719	6894	6243	651
July	4781	4312	469	5398	5089	309	5901	5646	255	6325	5987	338
August	5375	4989	386	5380	5096	284	5967	5510	457	6711	6123	588
September	4694	4336	358	5360	5058	302	5894	5532	362	5897	5500	397
October	5503	5020	483	5879	5162	717	5766	5612	154	6250	5789	461
November	5698	5336	362	5698	5266	432	6674	6233	441	6325	6201	124
December	5658	5271	387	6103	5255	848	5824	5230	594	6872	6500	372
Total	**68,527**	**60,276**	**8,251**	**75,245**	**68,814**	**6,431**	**80,837**	**75,855**	**4.982**	**87,565**	**83,134**	**4,431**

(Source: Wera Dijo Woreda Water Mine and Energy Office, 2015)

WDWWMEO states that present boreholes have a gross water production capacity of 406.8 m3/day; however, with an average of 6 hours of work/pumping per day, water output is currently 244.08 m3/day.

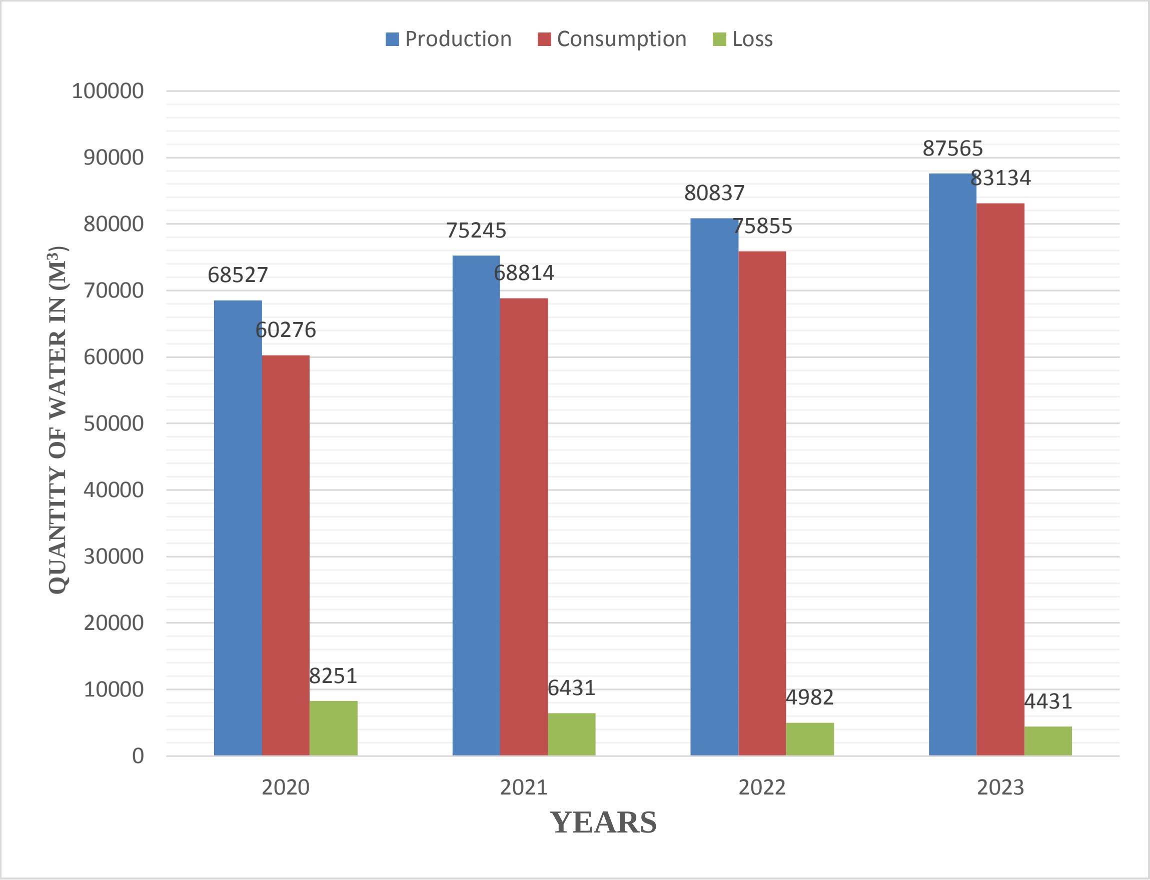

Figure 4.1: Production, Consumption and Loss in m3

Source: Wera Dijo water mine and energy office

4.1.2. Analysis of Water Supply Coverage

4.1.2.1. Average Daily Per-Capital Water Consumption

Water supply coverage in the study area was calculated using average per-capita use. The average water consumption per capita was calculated by aggregating the annual consumption of the area from the public fountain water meter and individual water meter. As a result, annual consumption data was translated to average daily per-capita consumption using the research area's population numbers as follows:

$$\text{Per-capita consumption (L/C/day)} = \frac{75855\,(\mathrm{m}^3) * 1000\,\mathrm{l/m}^3}{18{,}677 * 365\ \text{days}} = 11\ \text{L/c/day}$$

$$\text{Per-capita consumption (L/C/day)} = \frac{83{,}134\ (\mathrm{m}^3) * 1000\ \mathrm{l/m}^3}{19{,}219 * 365\ \text{days}} = 12\ \text{L/c/day}$$

Therefore, the study area's total per-capita water consumption for the years 2022 G.c and 2023 G.c were calculated. The population was 18,677 in 2022 G.c. and 19,219 in 2023 G.c.

The summed average per-capita water consumption of the research region was 11 l/c/day in 2022G.c and 12 l/c/day in 2023 G.c by using equation (3.3). According to the country standard the minimum quantity of water necessary for household usage is 40 l/c/day, while non-domestic consumption is 30% of domestic consumption (MoWE, 2011).

Thus, the above-mentioned result indicates that the aggregated per-capita water consumption of Besheno rural town, Bubesa kebele, and Hantezo kebele is below the standard.

4.1.2.2. Coverage of Water Supply

The study area's water supply coverage computes both the UWSUAP of the country standard (MoWR, 2011) and the GTP-2 target for urban minimum service level of water supply access. According to the results of the analysis, UWSUAP of the country standard, (MoWR, 2011); water supply coverage in year 2022 were 67.6% and 68.52 % coverage in year 2023 G.C as country level. According to the findings, the research area's water supply coverage is inadequate and does not meet national standards. In comparison, the GTP-2 aim of delivering public tap water supply is 40 l/c/day. However, the present water supply distribution infrastructure has not met the MoWR and GTP-2 standards. The study area's water supply coverage in 2022 and 2023 was 27.5% and 30%, respectively. As a result, the research revealed a significant gap in water supply coverage between in the study area and the GTP-2 goal of safe water supply availability. This number suggests that the use of water supplies is occasionally on the rise. The growth in supply from 2022 to 2023 is the primary cause of the rise in per capita water usage. However, because of pump failure, seasonal variations in the source, and population growth, the town's water demand is not met. The town's population is growing annually, and this is putting more strain on the available water supply of the town. Therefore, in order to balance supply and demand in the town, it makes sense to improve the source and pumping system and expand the water supply system.

4.2. Response of House Holds

Structured and unstructured interviews were employed for household surveys in Besheno rural town, Bubisa, and Hantazo kebeles to observe the existing water supply status. The information on sampled HHs, gender, age, marital status, and survey results are shown below. A total of 71 households were interviewed for this study in order to gather their perspectives on the current water supply situation in the study region. Appendix C-1 shows that 40.8% of the HHs surveyed was male and 59.2% were female.

The age distribution of sampled respondents in appendix C-2 shows that 19.7% were 18 to 29 years old, 22.5% were 30 to 39 years old, 46.5% were 40 to 49 years old, and 11.3% were 50 years or above. The education level of respondent household as appendix 3 indicate; 11.3% of respondent were uneducated, 29.6% of respondent were study elementary school, 42.3% of respondent were study Secondary School, 7% of respondent were at diploma level and 9.9% respondent were at degree level.

The marital status of sampled respondents is shown in appendix C-4, 14.1% of respondents were single, 77.5% were married, 5.6% were divorced, and 2.8% were widowed. According to the information analysis obtained from the response on frequency of water supply revealed in appendix C-9, 4.2% of respondents answered that water is obtainable once every two days, 76.1% of respondents answered that water is obtainable once every three days, and 19.7% of respondents answered that water is obtainable once every week. This clearly demonstrates that the frequency of water for customers is available for a limited time and does not match their needs.

To examine user perceptions of the reasons for the lack of water, appendix C-11 shows that those who responded fuel problem were 5.6%, those who responded water is not available from the distribution system were 14.1%, those who responded water is unavailable from source were 1.4%, and the remaining 78.9% of respondents responded fuel problem and distribution system. The main reasons were a water distribution system pipe burst issue and an increase in fuel costs. The respondents responded on the pressure of the water supply distribution system as shown in appendix C-8, with 1.4% responding very good pressure, 12.7% responding good, and the remainder responding 85.9% bad pressure. The water pressure is low because the output gate valve was opened one-third to lessen the possibility of a pipe rupture in the distribution system.

4.3. Population Projection

Population projection provides information on the future size and composition of a certain area's population. Knowledge of this information is critical for development plans whose goal is to meet the population's future needs in areas such as water demand, health, education, and housing, among others. The goal of the population projection in this study is to forecast the demand for domestic water supply over the planned period. In order to estimate future demand of water supply, the population size has to be projected. According to CSA reports, the population size of the area during the 2007 census was about 12,663. Based on the population size of the area in 2007 and 2020, the rate at which the population was growing between the two periods has been estimated to be 2.58 percent. According to CSA records and the Wera Dijo water mine and energy office, the population in 2022 was approximately 18,677. The present growth rate for tiny rural communities like Besheno rural town, Hantezo, and Bubisa kebeles is roughly 2.9 percent, according to the Geometrical Increment Method. This rate of increase is expected to continue over the next planned horizon. As a result, the population of the study area is predicted to increase to around 33,518 by the end of design year 2043. Table 4.2 shows population projections from 2007 to 2043.

Table 4.2: Population Projection of Besheno Town, Bubesa and Hantezo Kebele

Year	2007	2021	2023	2027	2032	2037	2043
Growth rate (%)		2.9	2.9	2.9	2.8	2.8	2.8
Population	12,663	18,151	19,219	21,547	24,737	28,400	33,518

Source: CSA reports, SNNPR, Wera Dijo water mine and energy office

4.4. Water Demand Estimation

4.4.1. Classification of Water Demand

Potable water demand can be classed as domestic or non-domestic based on the kind of user and the purpose of water consumption. The following approaches can be used to calculate the water demand projection for these demand categories.

4.4.1.1. Domestic Water Demand

Domestic water is required for a variety of household functions, primarily drinking, cooking, washing, cleaning, and other associated duties, and the factors influencing domestic demand vary depending on the manner of supply, socioeconomic conditions, and climate.

4.4.1.1.1. Mode of service

In a water supply system, there are four sorts of connections based on living standards. House connection, yard owned connection, yard shared connection and public tap are examples of these Users of house and yard connections rise annually, whereas those of public fountains fall, as the design criteria make evident.

In general, the models and levels for the piped system under consideration can be divided into two categories: yard connection and public tap (PT). From the WDWWMO 85% of consumers utilize public taps, 15% of customers possess yard connections (YCO), and the present service modes. Based on the population served in 2023 and the current modes of service, Table 4.3 shows the percentage mode of service.

Table 4.3: Population Percentage in Each Mode of Service

Mode of service type	Unit	Number of Population Served	Percentage (%)
Yard connection own (YCO)	No	2883	15
Public tap (PT)	No	16,336	85
Total	No	19,219	100

4.4.1.1.2. Mode of Service Projection

Using the existing mode of service as a guide, the mode of service projection is based on the project's goal design year 2043, when the town water coverage will stay at 100% and the communities will receive enough water to meet their needs. Due to the town's continued development and the willingness of its citizens to pay more for the water they use, it is anticipated that by the target year of 2043, 19.8% of users will be using HC mode of service, compared to 46.6% YCO, 16.6% who YCS and 17% who use public taps. According to the data gathered, the number of people using house, yard connections and share yard connection rises annually, while the number of people using public fountains falls.

These methods of service projection are based on average annual connection increases of 56.3% for houses, 31.99% for yard connections, and 31.59% for Ford yard connections, respectively. These increases were adopted while accounting for the socioeconomic situation, the community's standard of living, and the possibility of receiving assistance from the government and non-governmental organizations.

Table 4.4: Projected Percentage of Mode of Service

Connection type	Unit	Years				
		2023	2027	2032	2037	2043
House connection	%	0	5.2	8.6	12.8	19.8
Yard connection own	%	15	18.8	23.4	29.4	46.6
Yard connection share	%	0	8	10.2	12.6	16.6
Public tap	%	85	68	57.8	45.2	17
Total	%	100	100	100	100	100

Table 4.5: Population Distribution by Mode of Service

Connection type	Unit	Years				
		2023	2027	2032	2037	2043
House connection	No	0	1120	2127	3635	6637
Yard connection own	No	2883	4051	5789	8350	15,619
Yard connection share	No	0	1724	2523	3578	5564
Public tap	No	16336	14,652	14,298	12,837	5698
Total	No	19,219	21,547	24,737	28,400	33,518

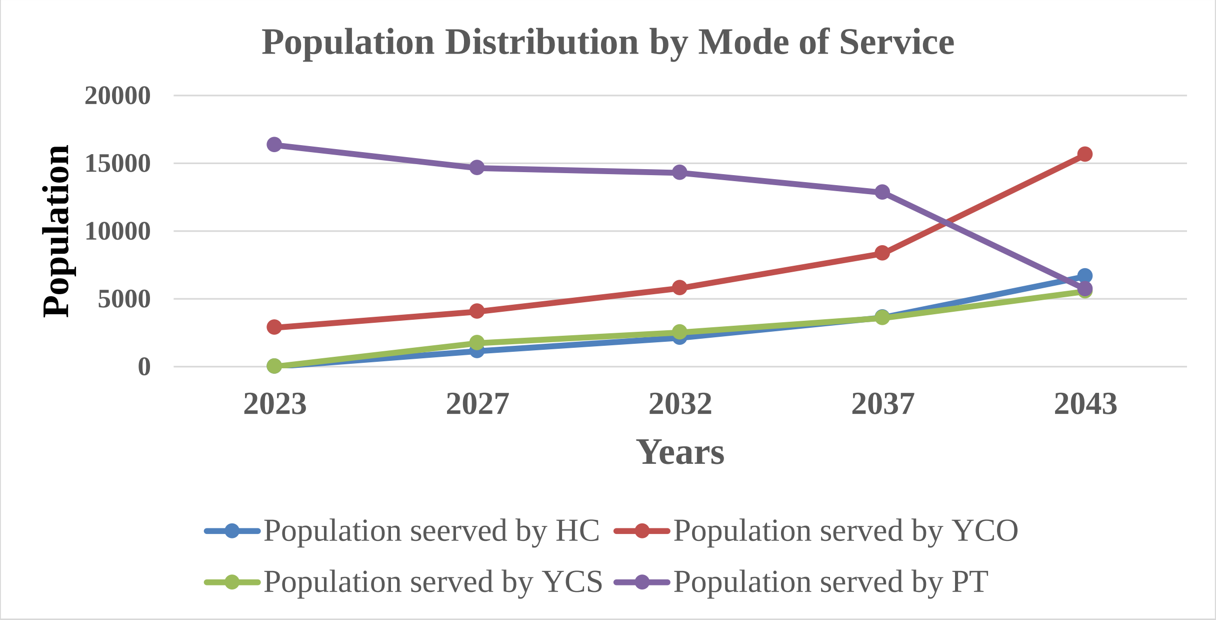

Figure 4.2: Population Distribution by Mode of Service for the Years of 2023-2043

4.4.1.1.3. Per Capita Demand

The per-capita water demand for several demand groups differs depending on the size of the area and the level of development, the type of the water supply scheme, the socio-economic conditions and the climatic condition. The per-capita water demand is the sum of the water requirement for different uses, which are connected to specific, conditions of the town, living standard of customer or end users and availability of water supply facilities, etc. Water requirements for various home uses may also fluctuate depending on the mode of service employed and the suitability and proximity to water supply infrastructure. Thus, Table 4.6 shows the predicted per capita water demand in the research region based on the MoWR(2006) guide line and Growth and Transformation Plan II.

But, As per GTP-II indicated in appendix C-19, water supply service level standard, required for providing safe water for urban community; this means the towns/cities were classified with category based on the population.

For this study for both phases the projected population ranges up to category-5 towns/cities (with a population less than 20,000) and so in the study area population falls under category- 5. Therefore; the minimum/average service level was 40 l/c/day.

Table 4.6: Projected Per Capita Water Demand by Mode of Service

Per capita demand by mode service	Unit	2023	2027	2032	2037	2043
HC	l/c/d	0	40	55	70	85
YCO	l/c/d	40	42	45	48	50
YCS	l/c/d	0	40	43	50	55
PT	l/c/d	25	27	29	31	33

Table 4.7: Domestic Water Demand by Mode of Services (m3/day)

Domestic water demand by mode of service	Unit	Years				
		2023	2027	2032	2037	2043
HC	m3/day	0	44.8	117	254.5	563.8
YCO	m3/day	115.3	170	260.5	400.8	781
YCS	m3/day	0	68.96	108.49	178.9	306
PT	m3/day	523.7	395.6	414.6	397.9	188
Total domestic demand	**m3/day**	**639**	**679.36**	**900.59**	**1232.1**	**1838.8**
	l/s	**7.4**	**7.86**	**10.42**	**14.26**	**21.28**

According to Table 4.7, overall domestic water demand in 2023 was 639m3/day and 1838.8 m3/day in 2043.

The above-mentioned per-capita consumption will be changed in accordance with the socioeconomic development and climatic characteristics of the research area.

Climatic and socio-economic adjustment factors: A person's water consumption may vary depending on the area's climatic and socioeconomic factors. This indicates that in hot areas, more water is used than in cold areas.

Adjustment of climatic factor: Climatic factors should be included in order to account for changes in climate that effect water consumption trends. The research area's average yearly temperature and altitude fall inside the temperate zone. As a result, the study area climatic factor 1 has been accepted based on the Design Criteria Guide line of MoWR (2006). **Adjustment of socioeconomic factor** Domestic water consumption is heavily influenced by socioeconomic factors. According to the MoWR (2006) Design Criteria Guideline, the area's socioeconomic category is group D advanced rural towns. As a result, a socioeconomic adjustment factor of 0.9 was used.

4.4.1.1.4. Estimation of Domestic Water Demand

After calculating the percentage split for yard connection own and public tap modes of service, as well as the related per-capita demands, the adjusted domestic water demand for the study region is shown in Table 4.8 below. The average domestic water demand at the end of the design period 2043 is found to be 1,564.8m3/day, respectively, and considering this socio-economic and climatic adjustment factors, the average day per-capita consumption for the study area in the beginning and at the end of the coming design period become 6.7 and 19.15 l/s.

Table 4.8: Adjusted Domestic Water Demand

Description	**unit**	**Years**				
		2023	**2027**	**2032**	**2037**	**2043**
Total Population	No	19.219	21,547	24,737	28,400	33,581
House connection	%	0	5.2	8.6	12.8	19.8
Yard connection own	%	15	18.8	23.4	29.4	46.6
Yard connection share	%	0	8	10.2	12.6	16.6
Public tap	%	85	68	57.8	45.2	17
Population by Mode of Service						
House connection	No	0	1120	2127	3635	6637
Yard connection own	No	2883	4051	5789	8350	15619
Yard connection share	No	0	1724	2523	3578	5564
Public tap	No	16336	14652	14298	12837	5698

Demand by Level of Service standard						
House connection	m3/day	0	44.8	117	254.5	563.8
Yard connection own	m3/day	115.3	170	260.5	400.8	781
Yard connection share	m3/day	0	68.96	108.49	178.9	306
Public tap	m3/day	523.7	395.6	414.6	397.9	188
Total Domestic Demand	m3/day	**639**	**679.36**	**900.59**	**1232.1**	**1838.8**
Socio- Economic Factor	Unit less	0.9	0.9	0.9	0.9	0.9
Climatic Factor	Unit less	1	1	1	1	1
Adjusted Domestic Water Demand (ADD)	m^3/day	**575.1**	**611.42**	**810.53**	**1108.89**	**1654.92**
Average day per-capita demand	l/s	**6.7**	**7.1**	**9.4**	**12.8**	**19.15**

4.4.1.2. Non-Domestic Water Demand

Non domestic water demand classified as institutional and commercial water demand, industrial water demand, livestock water demand, firefighting water demand and non-revenue water demand.

4.4.1.2.1. Institutional and Commercial Demand

Water demands for institutions and commercial areas will be influenced by the type and quality of services offered. Institutional and commercial demands are combined into public water demand, which is typically stated as a percentage of home water demand. The water consumption for both activities is estimated to equal 10.13% of adjusted domestic demand.

Educational water demand: The number of pupils attending school is typically projected to increase in tandem with the overall population growth. Day schools have a need of 5 l/pupil (MoWR 2006). The current number of students in the study area is as follows, according to the Wera Dijo Wereda Education Office.

Table 4.9: Per Capita Consumption of School

School	Daily demand	No. of students and teachers	Demand (l/day)	Demand (m^3/day)
Hantezo primary school (1-8)	5	1256	6280	6.28
Besheno primary school (1-8)	5	2320	11,600	11.6
Besheno secondary school (9-12)	5	2586	12930	12.93
Average demand (l/d)			**30,810**	
Average demand (m^3/day)				**30.81**

Source: Wera Dijo Wereda Education Office for Year 2023G

Healthy center water demand: Currently, there is one health extension in Hantazo and one hospital in Besheno rural town. The hospital need was 65 l/d per bed, and the health extension demand will be 50 l/d per bed, according to MoWR (2006). According to the Wera Dijo woreda well-being office, there are 32 hospital beds and three health extension beds

Table 4.10: Per Capita Consumption of Health Canter

Consumer category	Qty	Demand l/ Beds	No of Beds/visitors	Demand (l/day)	Demand (m3/day)
Hospital	1	65	32	2080	2.08
Health extension	1	50	3	150	0.15
Average demand (l/d)				**2,230**	
Average demand (m^3/day)					**2.23**

Source: Wera Dijo Wereda Health Office for Year 2022 G.c

Government office water demand: According to the socioeconomic survey report for the study region, there are currently 28 sectors of government offices. There are other workers in these offices. According to MoWR (2006), the daily consumption requirement of public offices is 5 l/employee per capita, and each organization's water demand was determined as follows:

Table 4.11: Per Capita Water Consumption of Governmental Office

Consumer category	Qty	Demand l/employee	No of employee	Demand (l/day)	Demand (m3/day)
Governmental offices	28	5	2879	14,395	14.4
Total Average demand (l/day)				**14,395**	
Total Average demand (m^3/day)					**14.4**

Source: Wera Dijo Wereda Human Resource Administration Office.

Religious water demand: also, was 5 l/Worshippers adopted based on MoWR (2006).

Table 4.12: Water Religious for Religious

Religion	Demand l/worshippers	No. of worshippers	Demand (l/day)	Demand of worshipper 4 days per month in liter	Demand (m3/day)
Muslim	5	14,074	70,370	9,383	9.4
Total Average demand (l/day)				**9,383**	
Total Average demand (m^3/day)					**9.4**

Commercial water demand: Water requirements for hotels, restaurants, cinema houses, bus stations, retail centers, abattoirs, workshops, and local drink establishments (Teji, Areke, Tella bet) are all considered commercial water demand. Commercial water demand in the research area was assessed using the MoWR (2006) Design Criteria Guideline.

Table 4.13: Commercial Water Demand

Consumer category	Qty	No. of employee	Daily demand (l/day)	Demand (l/day)	Demand (m3/day)
Bars	3	5	10	150	
Trading businesses	112	2	5	1120	
Barbary	10	2	5	100	
Local drinks	4	2	5	40	
Beauty salon	3	2	5	30	
Total Average demand (l/day)				**1440**	
Total Average demand (m^3/day)					**1.44**

Source: Wera Dijo Woreda Water Mine and Energy Office

Table 4.14: Summary of Commercial and Institutional Water Demand for Year 2023 G.C

Description	Demand (m^3/day)	Demand (l/c/day)
Commercial	1.44	0.02
Religious institution	9.4	0.11
Organization	45.21	0.52
Health institution	2.23	0.03
Total	57.52	0.69

Table 4.15: Percentage of Commercial and Institutional Water Demand for Year 2023 G.C

Description	Unit	Amount
Commercial water demand	m^3/day	1.44
Institutional water demand	m^3/day	56.84
Institutional and commercial water demand	m^3/day	**58.28**
Adjusted domestic demand	m^3/day	**575.1**
Percentage increment for commercial and institutional water demand in relative to ADD	%	**10.13**

4.4.1.2.2. Livestock Water Demand

The amount of water required to meet the needs of livestock watering, which can be allocated based on the individual demand of each livestock established by MoWR in 2006, in liters per head per day. However, the use of improved home water sources for cattle is discouraged. The community indicated that they only use communal ponds and have no other option if there are no rain during the rainy season. The livestock watering demand was adjusted by 5.81% of domestic water demand.

Table 4.16: Livestock Water Demand

Consumer category	**Qty. in Number**	**Daily Demand (l/day)**	**Deman(l/day)**	**Demand (m3/day)**
Cattle	235	50	11750	11.75
Donkey &Horse	340	50	17000	17
Sheep and Goat	435	10	4350	4.35
Poultry	1020	0.3	306	0.306
Average demand (l/d)			**23,386**	
Average demand (m^3/day)				**33.406**

Table 4.17: Percentage of Livestock Water Demand

Description	Unit	Amount
Livestock Water Demand	m^3/day	33.406
Adjusted Domestic Demand	m^3/day	575.1
Percentage increment for Livestock water demand in relative to ADD	%	5.81

4.4.1.2.3. Unaccounted for Water

Water loss in the distribution pipe cannot be avoided entirely. It can arise in a variety of ways, including cracks, unlawful connections, poor valve and fitting connections, and so on. Unaccounted for water is often reported as a percentage of total water production for the system. Assuming appropriate management, the predicted water loss over the scheme's service life is 15%. For projections, a loss of 15% water in the system from the first to the final design year was used.

4.5. Average Water Demand

Average daily demand for water supply is the combined total of domestic demand, water loss by the system, livestock demand and industrial water demands. It is shown in Table 4.18 below

Table 4.18: Average Day Water Demand (m3/day)

Description	Unit	2023	2027	2032	2037	2043
Adjusted water demand (ADD)	**m^3/day**	**575.1**	**611.42**	**810.53**	**1108.89**	**1654.92**
Non-Domestic Water Demand						
Commercial & Institutional Water Demand (10.13 % ADD)	m^3/day	58.26	61.94	82.11	112.31	167.43
Livestock water demand (5.81% of ADD)	m^3/day	33.41	35.52	47.09	64.43	96.15
Total water demands (TWD)	**m^3/day**	**666.77**	**708.88**	**939.73**	**1285.63**	**1918.50**
Unaccounted-for water (15%)	m^3/day	100.02	106.33	140.96	192.85	287.78
Average Day Demand	**m^3/day**	**766.79**	**815.21**	**1080.69**	**1478.48**	**2206.28**

4.6. Maximum Day Demand

The maximum day demand is the highest demand for any single 24-hour period in any given year. The rate of water demand varies seasonally, daily, and hourly. In the hot season, more water is consumed than in the rainy season. Weekends and holidays have higher water consumption than usual days, and more water is required in the morning and evening than early afternoon and late at night. To account for these variable water demands, the average day demand must be adjusted by a particular amount to determine the maximum day demand. It is shown in Table 4.19.

Table 4.19 : Maximum Day Factor

Population	Maximum day factor
0-20,000	1.3
20,001-50,000	1.25
50,001 and above	1.2

Source: Design Criteria Guide line of MoWR (2006)

For the study area the population was 18,677 in the year 2022.Therefore the value was taken to calculate maximum day water demand factor is recommended to be 1.30 to 1.25.

4.7. Peak Hour Water Demand

Peak hour demand is the highest demand in any given hour throughout the year. It represents the daily change in water demand caused by the local population's behavioral habits. Furthermore, studies on the hourly variation of demand suggest that the peak hour factor is greater in smaller populations than in larger ones. The peak hour demand is calculated by multiplying the daily average demand by the peak hour factor, which is typically determined by population size. For this study, the peak hour factor was 2.0 until 2022 since the population range of the study region was between 0 and 20,000, and 1.9 from 2027 to 2037 because the population of the study area was greater than 20,001, according to MoWR (2006). It is shown in Table 4.20.

Table 4.20: Peak Hour Factor

Population rang	Peak hour factor
0-20,000	2
20,001-50,000	1.9
50,001-100,000	1.8
>100,000	1.6

Source: Design Criteria Guide line of MoWR (2006)

4.8. Summary of Water Demand Assessment

Based on the above different type water demand and demand variations are forecasted for fifteen years was done by adjusting with different factors for each demand categories and is indicated the Table 4.21 below.

Table 4.21: Summary of Maximum Day and Peak Hour Demand

Description	Unit	2023	2027	2032	2037	2043
Average day demand	**m^3/day**	**766.79**	**815.21**	**1080.69**	**1478.48**	**2206.28**
	l/s	8.87	9.40	12.51	17.11	25.54
Maximum day factor	Unit less	1.3	1.25	1.25	1.25	1.25
Maximum day demand	**m^3/day**	**996.83**	**1019.01**	**1350.86**	**1848.10**	**2757.85**
	l/s	11.54	11.79	15.64	21.39	31.92
Peak hour factor	Unit less	2	1.9	1.9	1.9	1.9
Peak hour demand	m^3/day	1533.58	1548.90	2053.31	2809.11	4191.93
	l/s	17.75	17.93	23.77	23.51	48.52

According to the above Table 4.21, the rural town's and kebeles highest daily demand was 766.79 m3/day in 2023 and 2206.28 m3/day in 2043 or at the end. The design production capacity of the water supply source was 406.8m3/day; however, the average water output was 244.08 m3/day, suggesting a variation of 162.72m3/day and 59,392.8 m3/year. This fluctuation occurs for a variety of causes, including fuel shortages, shorter working hours; pump breakdowns, and a lack of timely maintenance. As a result, the current water supply-demand mismatch is 522.71 m3/day. Based on this result the gap can be increased to 1962.2m3/day for the coming twenty years. This indicates the need for new water supply system planning for the study area to meet the gap between water supply and water demand.

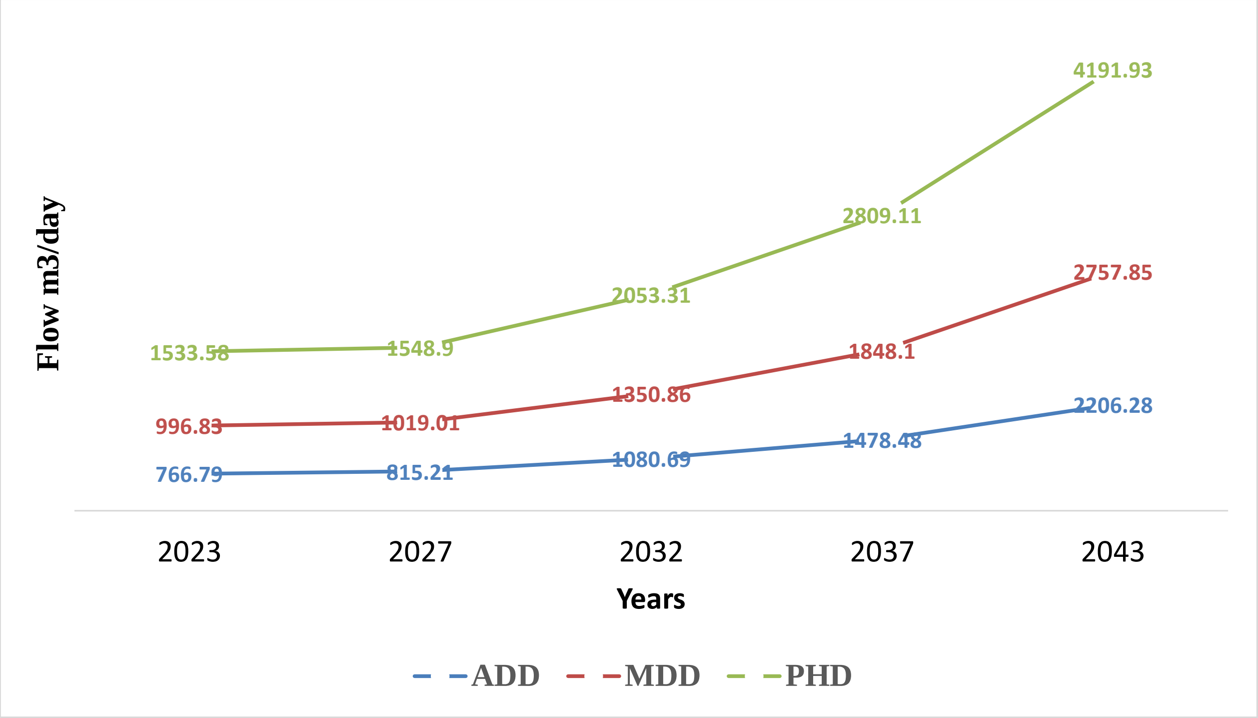

Figure 4.3: Summary of Water Demand

4.9. Pipe Network of Distribution System

The existing water distribution network covers several system elements such as the transmission and distribution mains. Thus, the water distribution network of Besheno town, Bubisa and Hantazo kebeles water supply system compromises the water network system of main and distribution pipes with a total length of 16.479 km having pipe material HDPE with diameters ranging from OD 50mm to OD 160mm, UPVC OD 90mm and GI 80mm. Table 4.22 below shows the pipe material type with corresponding length and coverage.

Table 4.22: Pipe Materials with their corresponding length and coverage

Pipe material	Length (m)	Percentage
HDPE	11,017	66.85%
UPVC	5,422	32.90%
GI	40	0.24%
Total	16,479	100%

As shown on Table 4.22 above, HDPE and PVC are the most dominant types of pipe used in the existing system. Figure below shows the pipe size with corresponding length and coverage of the Besheno town distribution network.

Table 4.23: pipe size with corresponding length and coverage of the Besheno town

Diameter (mm)	**Length (m)**	**Percentage**
50	1,669	21%
63	3,40	4%
75	387	5%
80	40	1%
90	5343	68%
110	127	2%
Total	**7906**	**100%**

Depending on the above Table 4.23 the 90mm diameter PVC pipe material covers the major part of the of the pipe network of the water supply system indicating about 68% while 80 mm diameter GI pipe network were in smallest quantity used in the network of the study area water distribution system.

Figure 4.4:Besheno town existing pipes diameter

In the case of transmission pipes and rural kebeles, the 160mm diameter HDPE pipe material covers the major part covering 48% as shown on table below.

Table 4.24: pipe size with corresponding length and coverage of the Transmission pipes and rural kebeles

Diameter (mm)	Length (m)	Percentage
110	2239	26%
140	2183	25%
160	4151	48%
Total	**8573**	**100%**

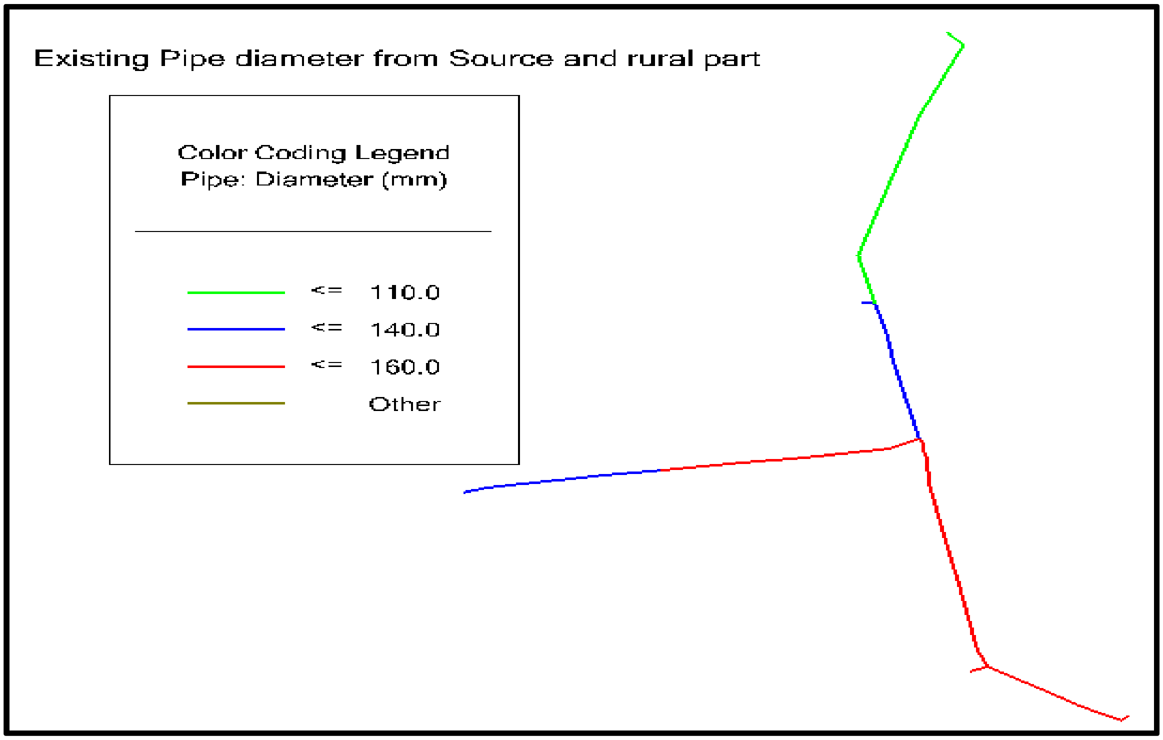

Figure 4.5: Existing Pipe size of transmission pipes and rural kebeles

4.9.1. The Existing Reservoir Capacity

The reservoir in the water delivery system balances fluctuating water demand during peak hours. The capacities of reservoirs in the water delivery system were determined using several approaches. Using 24-hour supply demand simulation mass curves is the most cost-effective way to determine reservoir storage volume. Developing such curves requires good historical data on the area's hourly water demand. However, in the absence of such data, the reservoir volume was sized as one-third of the maximum daily demand, as is common in many water supply systems, and based on the ministry of water resources' rural water supply design criteria. According to the MoWR's design standards, the maximum day factor typically ranges from 1.0 to 1.3. As a result, a maximum day factor of 1.3 was used at the start of the design period in 2022 and 1.25 at the end of the design period in 2037 to assess the maximum day water demand and reservoir capacity for the study area's water delivery system.

Maximum day demand = 1.3*574.29 m3/day = 746.58 m3/day in year of 2022

Maximum day demand = 1.25*1661.96 m3/day = 2077.45 m3/day in year of 2037

According to MoWR (2006) of our country set design criteria, the capacity of reservoir is 1/3 of maximum day demand.

Reservoir capacity = maximum day demand *1/3 in year of 2022

= 746.58*1/3=248.86 m^3

Reservoir capacity = maximum day demand *1/3 in year of 2037

= 2077.45*1/3= 692.48m^3

By considering other emergencies demand, while the existing reservoir capacity was 200m3 indicating the requirement for additional service reservoir to balance the demand and water supply from the water network system.

4.9.2. Pressure Analysis

The water supply distribution system network is designed to operate within specific pressure limits. According to the Ministry of Water Resources MoWR (2006), the minimum operating pressure is set at 15m, while the maximum operating pressure is set at 70m. These pressure limits are determined based on various factors such as the network's size, topographic conditions, and the desired level of service. Maintaining a minimum pressure of 15m is crucial to prevent water column separation within the distribution system. Water column separation can cause issues such as air pockets and cavitation, which can disrupt the flow and affect the system's performance. By ensuring a minimum pressure, the water supply network can reliably meet consumer demands and maintain a reliable water supply to customers. However, the maximum pressure constraints are imposed to meet specific service performance requirements. For example, firefighting needs may require higher pressures to ensure an adequate water supply for firefighting operations. Additionally, the maximum pressure is also limited by the structural capacity of the pipes in the system. Excessive pressure can lead to pipe failures or increased leakage rates within the distribution network. It is significant to note that there is a direct relationship between high pressure and increased leakage in the system. Higher pressures can cause stress on the pipes, joints, and fittings, leading to potential leaks. By maintaining the pressure within the specified maximum limits, the distribution system can minimize leakage and improve overall efficiency.

Table 4.25: Pressure Distribution in Besheno Town existing network

Pressure (m of H_2O)	Number of nodes	Percentage
P <= 15	0	0%
15 < P <= 25	11	8%
25 < P <= 35	73	49%
35 < P <= 45	59	40%
45 < P <= 70	5	3%
Total	148	100%

During peak hour usage, as indicated in Table 4.25, every node within the distribution network-maintained pressure levels that fell within the desirable range. Specifically, not a single node recorded a pressure below the minimum acceptable threshold of 15 meters, nor did any node exceed the maximum desirable pressure of 70 meters of water column. This observation underscores a commendable achievement: 100% of the nodes operated within the recommended pressure range of 15 to 70 meters. The ability of all nodes to sustain pressure levels within these limits is crucial for ensuring a reliable and satisfactory water supply to customers. This consistent performance indicates that the entire distribution network effectively managed to maintain appropriate pressure stages, thereby meeting the operational requirements and enhancing service quality.

To visually represent the spatial distribution of pressure within the distribution network, different colors were assigned to the distribution junctions, as shown in Figure 4.6. The color-coded junctions provide an indication of the pressure range at each location. The junctions coded with green color represent areas where the pressure is below 15m of water column. The blue color-coded junctions indicate areas where the pressure ranges between 15m and 25m of water column. These junctions represent locations within the distribution network that maintain pressures within this specific range. Additionally, the red color-coded junctions represent areas where the pressure ranges between 25m and 35m of water column. These junctions depict locations within the network with pressures falling within this range. Furthermore, there are junctions coded with yellow color, which carries a pressure between

35m and 45m of water column. There are few junctions coded with Magenta color, which carries a pressure between 45m and 70m of water column. This specific junction represents a location within the distribution network where the pressure falls within this specific range.

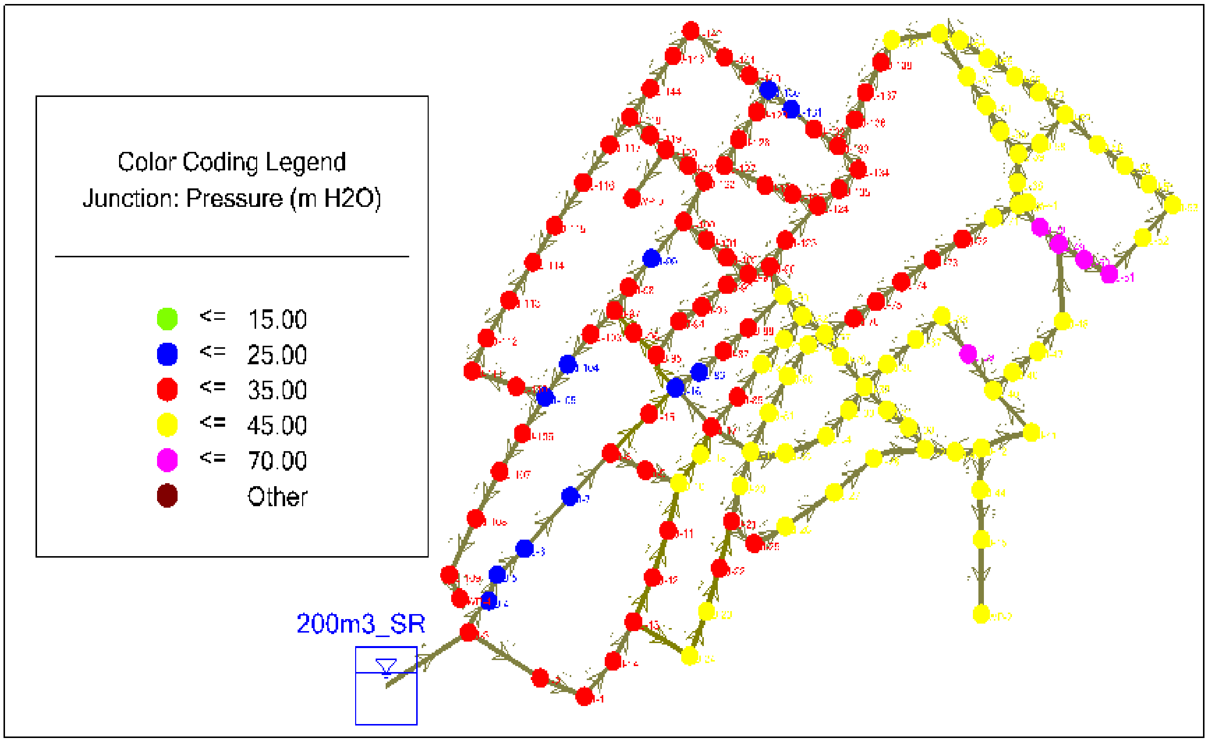

Figure 4.6: Besheno Spatial distribution of pressure in distribution network

Table 4.26: Pressure Distribution in Transmission mains and rural kebeles

Pressure (m of H_2O)	Number of nodes	Percentage
<= 15	2	6.45%
<= 25	1	3.23%
<= 45	4	12.90%
<= 70	16	51.61%
<= 100	8	25.81%
Total	31	100%

Based on Table 4.26, during peak hour usage, 6.45% of the nodes in the transmission main and rural kebeles system fell below the desirable minimum pressure of 15m. This indicates that a small portion of the network experienced pressures lower than the recommended minimum, which can potentially lead to inadequate water supply and service disruptions in those areas. Additionally, 25.81% of the junctions in the system were above the recommended maximum pressure of 70m water column. This suggests that a significant portion of the network had pressures exceeding the desired upper limit. High pressures can contribute to increased leakage and potential stress on the infrastructure. However, the majority of the nodes, 67.74%, were within the recommended pressure range of 15m to 70m. These nodes experienced pressures that fell within the desired operating range, indicating that most parts of the transmission main and rural kebeles system maintained appropriate pressure levels. To visually represent the spatial distribution of pressure within the network, different colors were assigned to the junctions, as shown in Figure 4.7. The color-coded junctions provide an indication of the pressure range at each location. The junctions coded with purple color represent areas where the pressure is below 15m of water column. These purple-colored junctions highlight the locations within the network that experience pressures below the desirable minimum. The green color-coded junctions indicate areas where the pressure ranges between 15m and 25m of water column. These junctions represent locations within the network that maintain pressures within this specific range.

Furthermore, the yellow color-coded junctions represent areas where the pressure ranges between 25m and 45m of water column. These junctions depict locations within the network with pressures falling within this range. The blue color-coded junctions carry the pressure between 45m and 70m of water column. These junctions represent areas where the pressure falls within this specific range. The junctions coded with red color carry a pressure between 70m and 100m of water column. These red-colored junctions indicate locations within the network where the pressure exceeds the recommended upper limit.

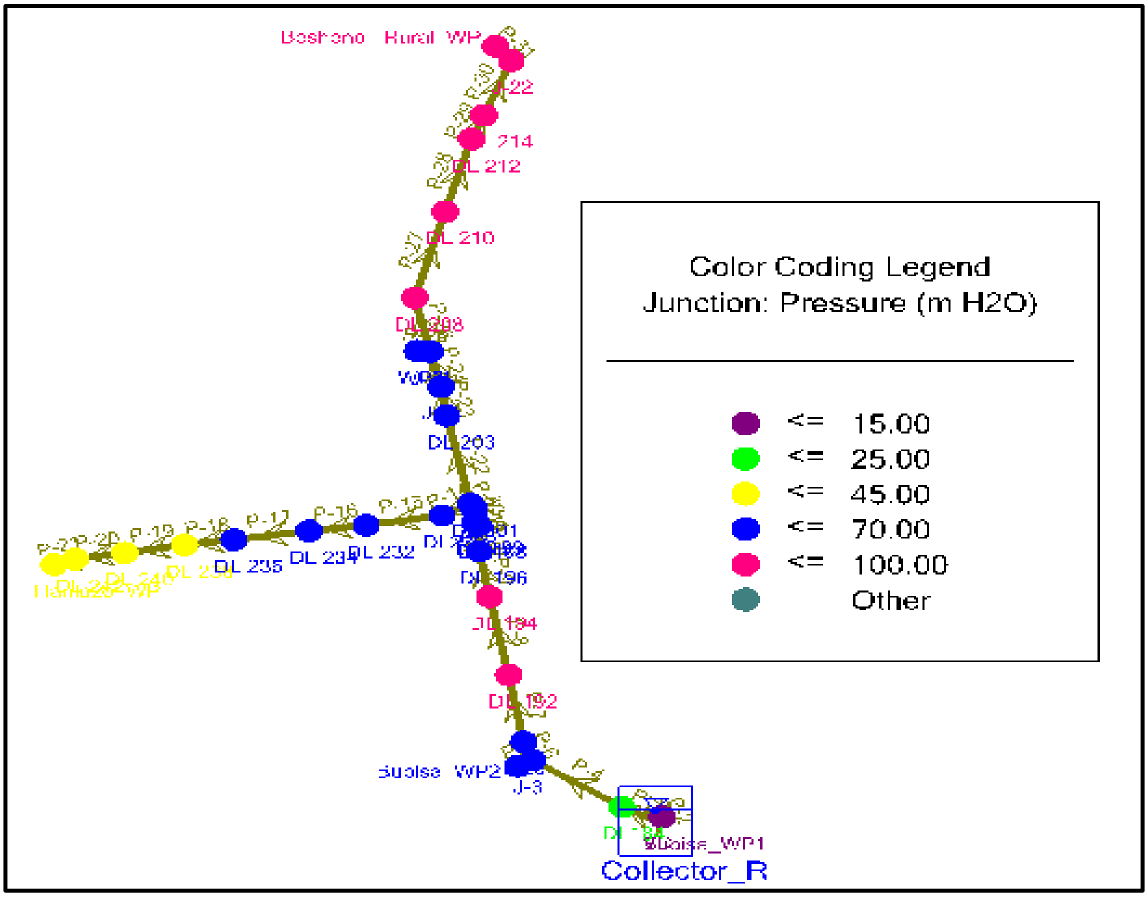

Figure 4.7: Transmission mains and rural kebeles spatial distribution of pressure

4.9.3. Velocity analysis

The velocity of water flow in a pipe is an important parameter when analyzing the hydraulic performance of a water distribution system. It refers to the speed at which water travels through the pipe and is directly related to the flow rate, which is the amount of water passing through a section of the pipe in a given amount of time. The Ministry of Water Resources (MoWR, 2006) provides guidelines regarding the acceptable velocity range in water distribution systems. According to these guidelines, water velocity in a pipe should be maintained within specific limits to avoid certain issues. When the water velocity in a pipe is less than 0.6m/s, it can lead to water stagnation. Stagnant water is undesirable as it can promote the growth of bacteria and other microorganisms. Stagnation can occur when the water flow is too slow, and the water remains in the pipe for extended periods, increasing the risk of water quality deterioration. On the other hand, water velocities greater than 2m/s can result in water hammer problems. Water hammer refers to the sudden increase in pressure caused by the rapid change in water velocity within a pipe. This can lead to hydraulic shocks and potentially damage the pipe or associated equipment. Water hammer can occur when the flow velocity is too high, causing abrupt changes in flow direction or sudden valve closures.

Table 4.27: Besheno Town Pipe Velocity

Velocity (m/s)	Number of pipe	Percentage
V <= 0.3	141	85%
0.3 < V <= 0.6	14	9%
0.6 < V <= 2	10	6%
Total	165	100%

According to Table 4.27, the analysis shows that 94% of the pipes in the research area have velocities below the recommended minimum velocity. This indicates that a significant portion of the pipe network does not meet the specified velocity range of 0.6 m/s to 2 m/s. It suggests that additional development or improvements are necessary to achieve the minimum suggested velocity and ensure the desired hydraulic performance. On the other hand, 6% of the pipes in the research area meet the specified velocity range of 0.6 m/s to 2 m/s. These pipes maintain velocities within the desired range, indicating that a portion of the network is operating within the recommended hydraulic conditions. To visually represent the spatial distribution of velocity within the pipe network, different colors were assigned to the pipes, as shown in Figure 4.8. The color-coded pipes provide a clear indication of the velocity range at each location. The pipes coded with green color represent areas where the velocity is below 0.3 m/s. These green-colored pipes highlight the locations within the network that have velocities below the specified minimum. These areas require attention and further development to improve the flow velocities. The blue color-coded pipes indicate areas where the velocity ranges between 0.3 m/s and 0.6 m/s. These pipes represent locations within the network that maintain velocities within this specific range. Furthermore, the magenta color-coded pipes represent areas where the velocity ranges between 0.6 m/s and 2 m/s. These pipes describe locations within the network with velocities falling within this range, meeting the specified velocity criteria. By using different colors to code the pipes based on velocity ranges, Figure 4.8 provides a visual representation of the spatial distribution of velocity within the pipe network. This information can help identify areas with specific velocity conditions and guide decision-making for targeted improvements or adjustments to achieve the desired minimum velocity.

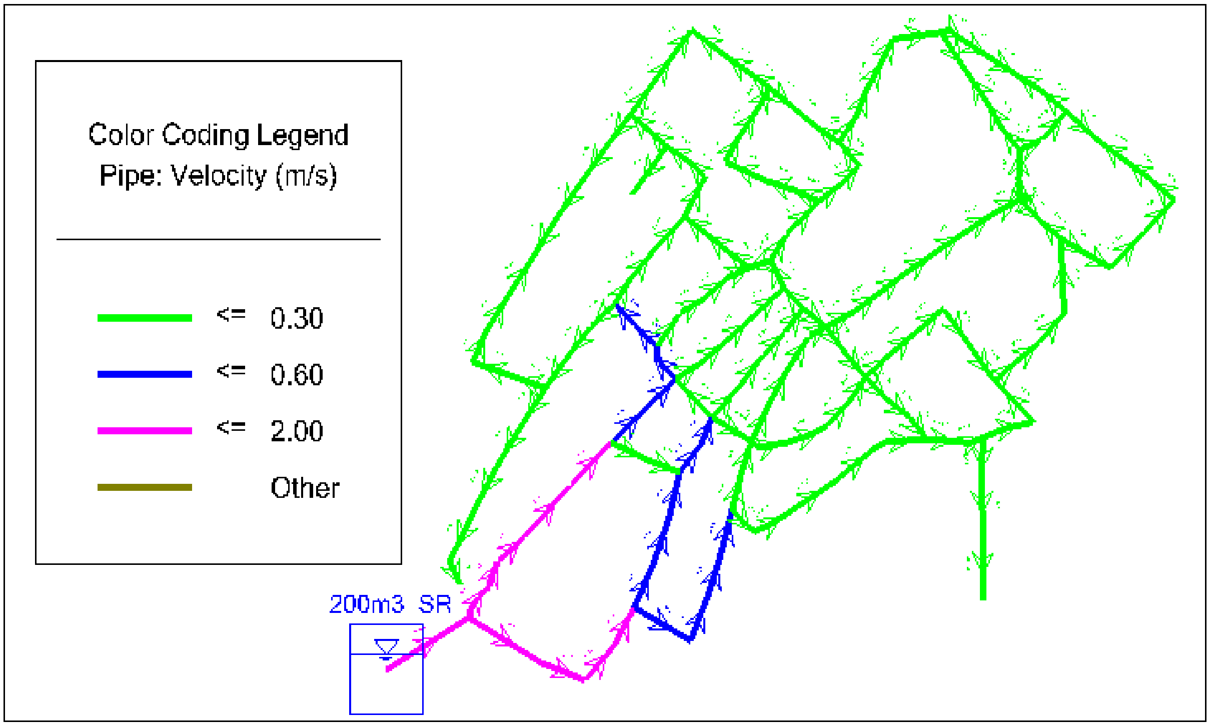

Figure 4.8: Besheno town Spatial Distribution of velocity

Table 4.28: Transmission mains and rural kebeles Pipe Velocity

Velocity (m/s)	Number of pipe	Percentage
V<=0.3	21	68%
0.3 < V<=0.6	10	32%
Total	31	100%

Based on Table 4.28, it is evident that 100% of the pipes in the research area have velocities below the recommended minimum velocity. This indicates that the entire pipe network falls short of meeting the specified velocity range. Consequently, additional development and improvements are necessary to achieve the minimum suggested velocity and enhance the hydraulic performance of the system. In Figure 4.9, the spatial distributions of velocity through the pipe network are depicted using different colors to clearly illustrate the variations in velocity within the mains and rural kebeles distribution network. The pipes coded with violet color represent areas where the velocity is below 0.3 m/s. These violet-colored pipes highlight locations within the network where the velocities are significantly lower than the desirable minimum. These areas require particular attention and further development to improve the flow velocities. The pipes coded with green color indicate areas where the velocity ranges between 0.3 m/s and 0.6 m/s. These green-colored pipes represent locations within the network that maintain velocities within this specific range. While these areas exhibit better velocities compared to the violet-coded pipes, they still fall below the recommended minimum velocity.

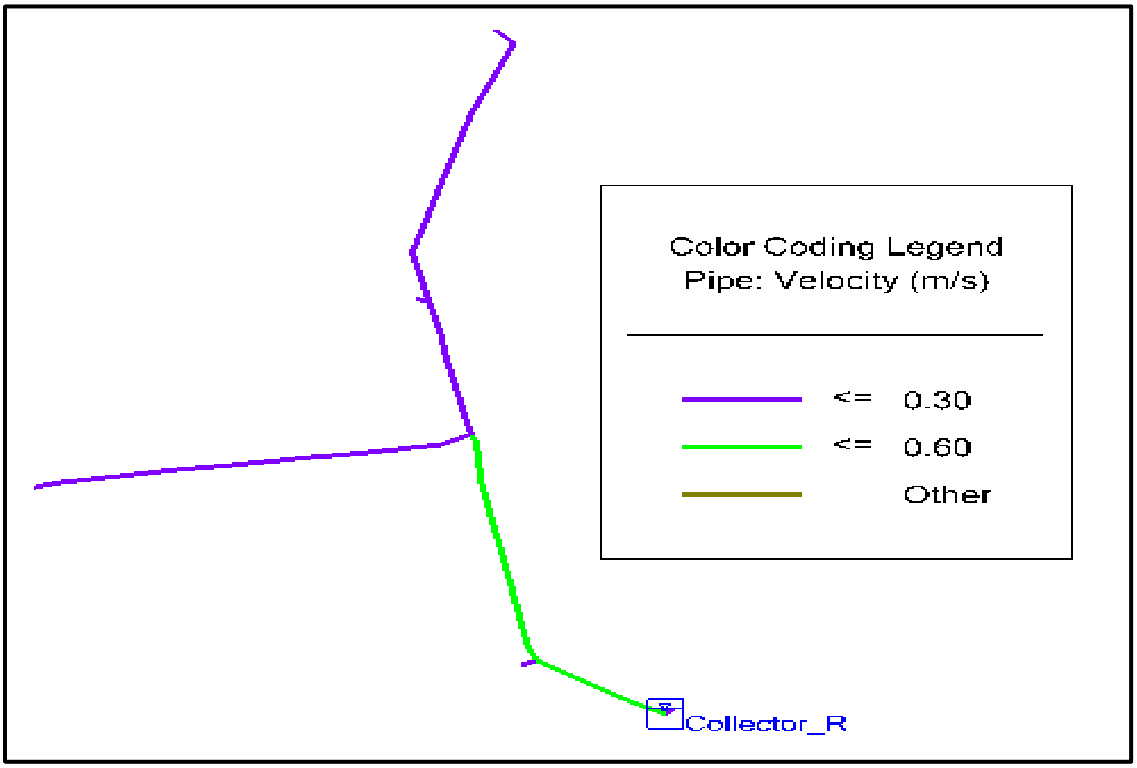

Figure 4.9: Transmission mains and rural kebeles Spatial Distribution of velocity

4.9.4. Head loss Gradient analysis

Head loss refers to the pressure drop that occurs in a pipe due to friction. It is influenced by factors such as pipe size, length, number of fittings, valves, and other obstructions within the system. Properly sizing pipes is crucial to balance the trade-off between excessive head losses and the cost of oversizing. Undersized pipes tend to have increased head losses because of the higher friction resulting from the restricted flow area. On the other hand, oversizing pipes beyond reasonable limits can lead to unnecessary costs associated with larger pipe diameters. In the study area, Table 4.29 provides information about the distribution of head losses within the pipe network based on the recommended ranges according to the Ethiopia urban water supply design guideline criteria. As shown on the table, 79% of the pipes fall below the recommended minimum head loss range of 1m/km. This suggests that these pipes have significantly lower head losses than what is considered optimal. Such pipes may be oversized or have relatively smooth internal surfaces, resulting in lower friction losses. 15% of the pipes fall within the recommended head loss range of 1 to 5m/km. These pipes maintain head losses within the desired range and indicate a reasonably balanced frictional behaviour. It suggests that a significant portion of the pipe network is operating within acceptable head loss limits. The remaining 6% of the pipes exhibit head losses above the recommended range. This indicates that there are the pipes in the network which have higher friction losses, potentially due to factors such as undersized pipes, longer pipe lengths, an increased number of fittings, or other obstructions. These higher head losses may result in reduced pressure at the endpoint and affect the overall hydraulic performance of the system.

Table 4.29: Besheno town Head loss gradient analysis

Head loss gradient (m/Km)	Number of pipes	Percentage
HL <= 1	131	79%
1 < HL <= 5	24	15%
HL > 5	10	6%
Total	165	100%

Figure 4.10 below shows the spatial distributions of Head loss gradient through pipe network which was coded with different color. As shown on figure below, the pipe coded with cyan color falls below the Head loss gradient of 1Km/m. The pipe coded with green color carries the Head loss gradient between 1 Km/m and 5 Km/m. The pipe coded with red color carries the head loss gradient above 5 Km/m.

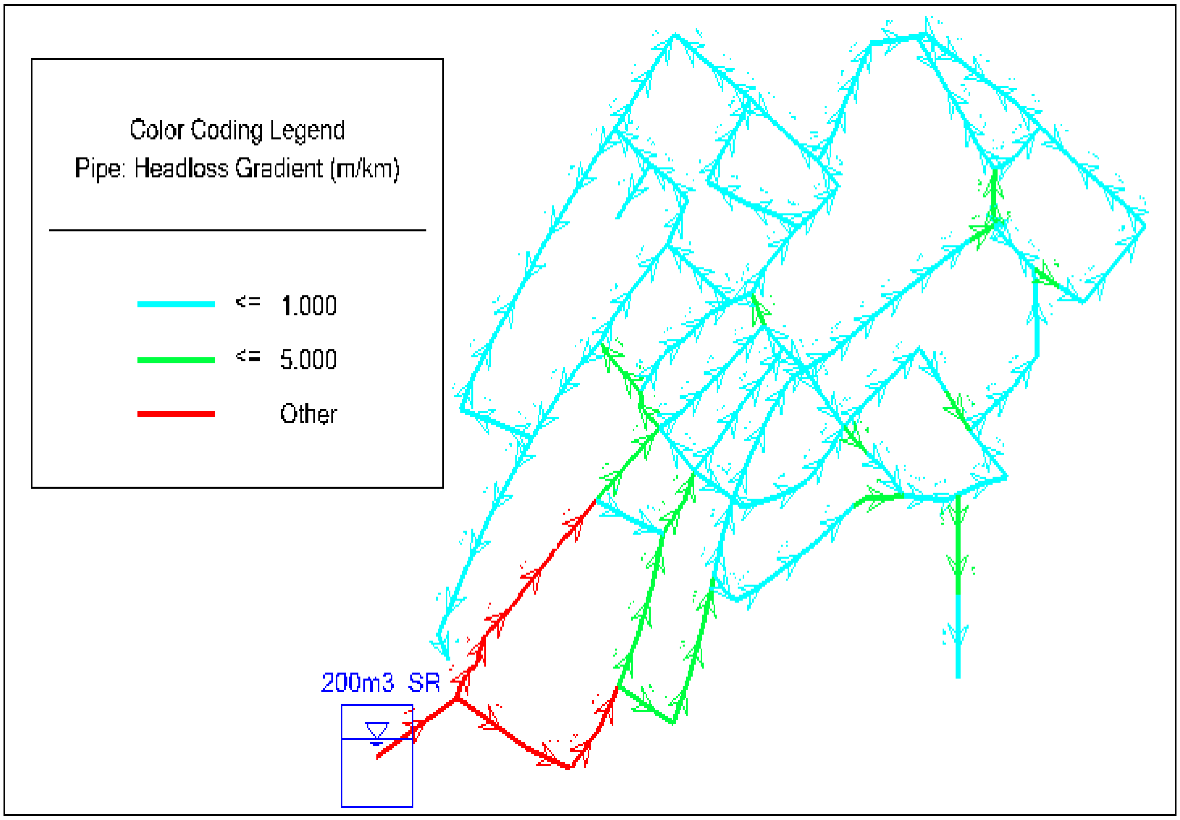

Figure 4.10: Besheno town Spatial Distribution of Head loss gradient

The transmission mains and the rural kebeles head loss gradient as indicated in Table 4.30 below, 67.74% of the pipes are below the recommended minimum head loss range of 1m/km, 32.26% are within the recommended head loss range (1 to 5m/km) based on Ethiopia urban water supply design guideline criteria.

Table 4.30 :Transmission mains and rural kebeles Head loss gradient analysis

Head loss gradient (m/Km)	Number of pipes	Percentage
HL< 1	21	67.74%
1< HL< 2	7	22.58%
2 < HL< 5	3	9.68%
Total	31	100%

Figure 4.11 below shows the spatial distributions of head loss gradient through pipe network for transmission mains and rural kebeles. As shown on figure below, the pipe coded with cyan color falls below the head loss gradient of 1Km/m. The pipe coded with blue color carries the head loss gradient between 1 Km/m and 2 Km/m. The pipe coded with magenta color carries the head loss gradient between 2 Km/m and 5 Km/m.

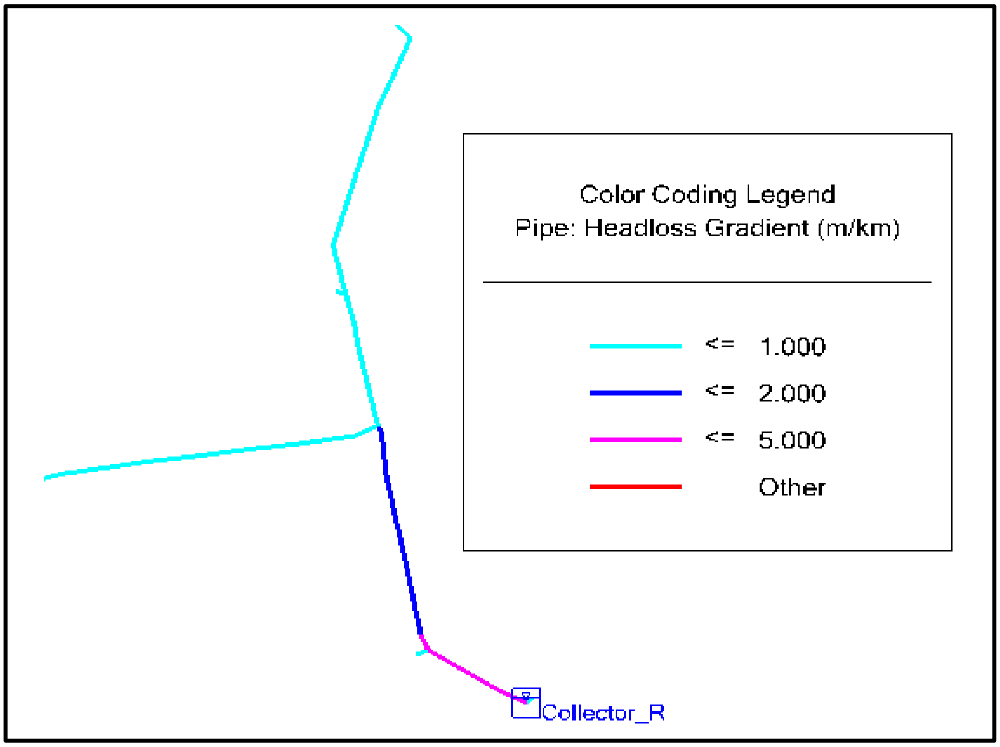

Figure 4.11: Transmission mains and rural kebeles Spatial Distribution of Head loss gradient

4.9.5. Pressure zone and elevation of an area

Figure 4.12 displays the contour map of pressure of the Besheno town distribution system, which consists of three distinct pressure zones: the low-pressure zone, the medium-pressure zone, and the high-pressure zone. Each zone is represented by specific colors on the pressure contour map, along with corresponding-colored junctions that indicate the pressure range within each zone. The low-pressure zone, represented by a yellow pressure contour, is characterized by can-colored junctions. This zone encompasses areas where the pressure is between 15mH2O and 25mH2O. The medium-pressure zone, were represented by a blue pressure contour. This zone includes areas where the pressure ranges between 25mH2O and 45mH2O. Lastly, the high-pressure zone is depicted by a red pressure contour. This zone comprises areas with pressures exceeding 45mH2O but remaining below 70mH2O.

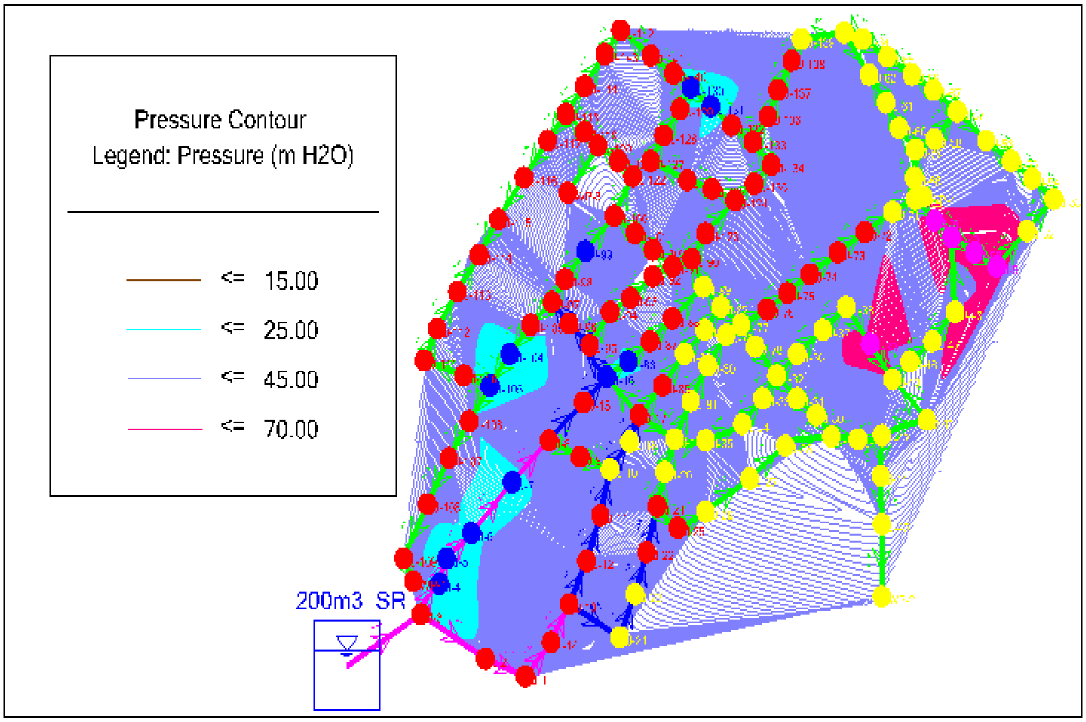

Figure 4.12: Pressure Zone contour of the Besheno Town

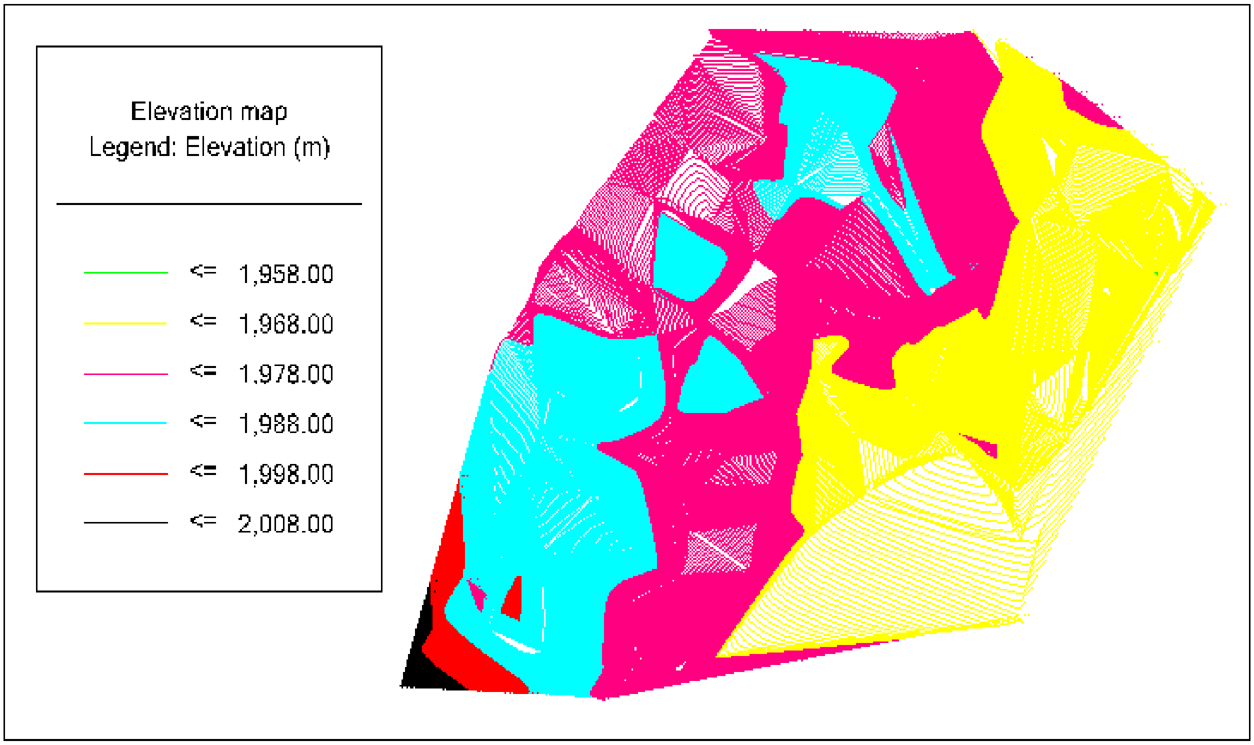

Figure 4.13: Elevation map of Besheno Town

In the same manner, the pressure contour for transmission mains and rural kebeles were developed as indicated on the figure 4.14 below, the pressure contour with green colour is the area of low-pressure zone. The pressure contour represented with Cyan, blue, and magenta, colour is the area of medium pressure zone. The pressure contour represented with deep green colour is the area of high-pressure zone.

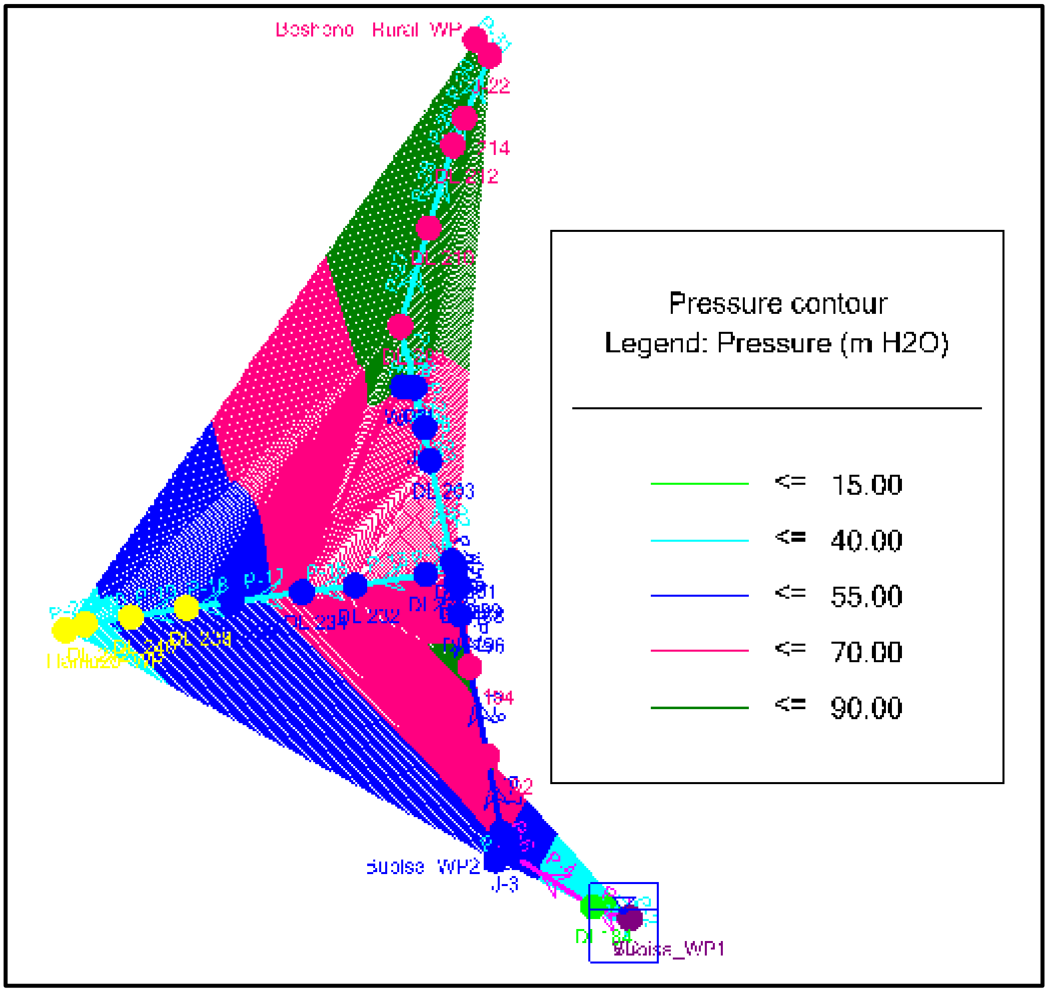

Figure 4.14: Pressure Zone contour of the Transmission mains and rural kebeles

4.9.6. Model Calibration and Validation

For the calibration process, pressures were measured at five points within the water distribution system using pressure gauges. According to a study by Walski et al. (2003), the sampling locations were selected randomly. It is significant that the selected points are situated at the extremities of the network and at a considerable distance from boundary nodes such as reservoirs and tanks. Additionally, these points should have relatively high discharges and pressures to provide a comprehensive representation of the system. According to the American Water Works Association (AWWA, 2005), for a medium to highly detailed network model, it is suggested to test pressure readings at 3% of the nodes in the network and flow readings at 5% of the pipes. In the circumstance of the Besheno town distribution network, which has a total of 148 junctions, 3% of the total junctions were used for calibration. This translates to a sample size of 3% * 148 = 4.44, which means that 5 representative samples were used for calibration. To ensure the validity of the calibration, 3 additional samples, different from those used in calibration, were reserved for validation. The calibration process involved adjusting the simulated pressure values until an acceptable level of agreement was achieved with the observed pressure values at the selected measurement locations. Additionally, during the process of calibration, the simulated pressure values during peak demand were adjusted to better match the measured pressure values. Table 4.31 shows that the computed pressure values had an average error of -1.208 m when compared to the observed values. This level of accuracy indicates that the model is acceptable and satisfies the criteria for pressure calibration. Typically, the average error is expected to be within ±1.5 m, and the maximum error within ±5 m. Therefore, the model's performance meets the required criteria for pressure calibration, demonstrating its reliability in representing the hydraulic behavior of the Besheno town distribution network.

Table 4.31: Sampled points for model calibration

Time (hrs.)	Node	Observed pressure	Simulated pressure	Differences in pressure error (m H2O)	**x**	**y**	**z**
7:00AM	WP-1	42.5	44.71	-2.21	415,303.09	825,845.16	1,962.00
	WP-2	40.62	41.55	-0.93	415,242.30	825,345.36	1,965.00
	WP-3	32.1	29.73	2.37	414,778.75	825,850.19	1,977.00
	WP-4	34.15	31.7	2.45	414,550.14	825,364.41	1,975.00
	J-123	32.39	34.81	-2.42	414,981.95	825,799.39	1,972.00
8:30AM	WP-1	43.66	44.71	-1.05	415,303.09	825,845.16	1,962.00
	WP-2	42.47	41.55	0.92	415,242.30	825,345.36	1,965.00
	WP-3	30.53	29.73	0.8	414,778.75	825,850.19	1,977.00
	WP-4	35.04	31.7	3.34	414,550.14	825,364.41	1,975.00
	J-123	33.41	34.81	-1.4	414,981.95	825,799.39	1,972.00
10:00AM	WP-1	41.66	44.71	-3.05	415,303.09	825,845.16	1,962.00
	WP-2	37.18	41.55	-4.37	415,242.30	825,345.36	1,965.00
	WP-3	28.39	29.73	-1.34	414,778.75	825,850.19	1,977.00
	WP-4	32.41	31.7	0.71	414,550.14	825,364.41	1,975.00
	J-123	35.44	34.81	0.63	414,981.95	825,799.39	1,972.00
11:30AM	WP-1	40.59	44.71	-4.12	415,303.09	825,845.16	1,962.00

	WP-2	38.17	41.55	-3.38	415,242.30	825,345.36	1,965.00
	WP-3	25.68	29.73	-4.05	414,778.75	825,850.19	1,977.00
	WP-4	29.31	31.7	-2.39	414,550.14	825,364.41	1,975.00
	J-123	30.14	34.81	-4.67	414,981.95	825,799.39	1,972.00
			Average	-1.208			

As shown in table 4.31 above, the compared values of observed and simulated pressure within an average error of -1.208 m. The statistical correlations plot of observed versus computed pressure during calibration process. The results show that value of R^2 is 82.28%. This implies that the computed pressures were within the acceptable limit recommended by 0 to 1.

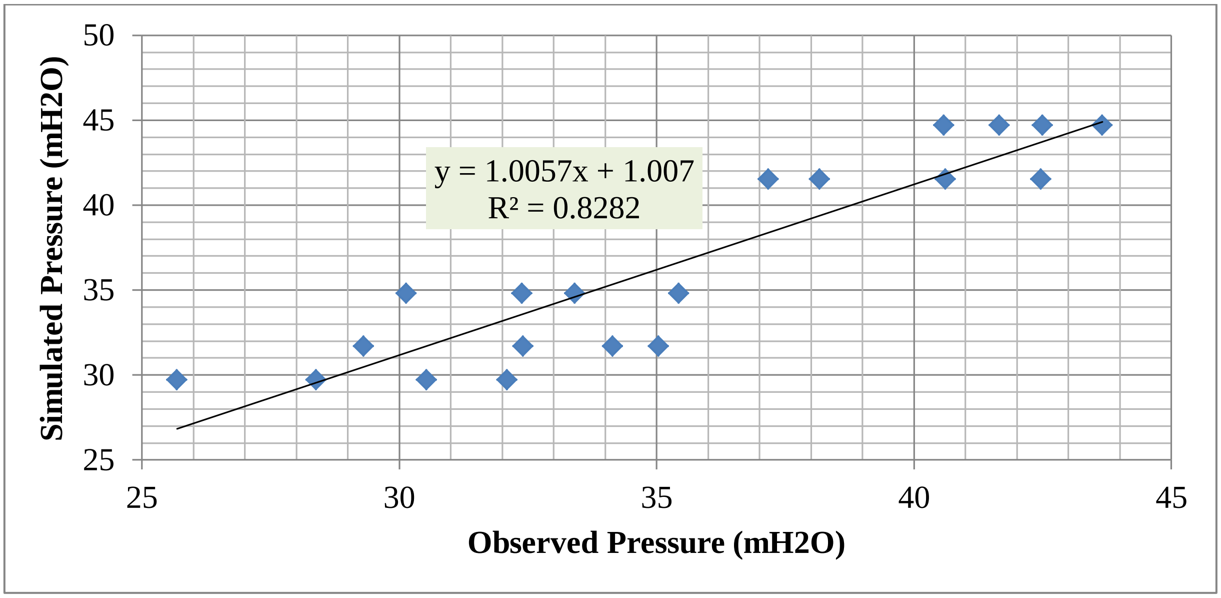

Figure 4.15: Correlated plot during pressure calibration

The process of model validation involved evaluating the simulated pressure against field-measured pressure at three specific junctions: J-38, J-62, and J-138. The determination coefficient, denoted as R^2, was calculated as part of this validation process. R^2 provides an indication of the variance proportion in the measured pressure that can be clarified by the simulated pressure. In this case, the coefficient of determination’s high value (R^2), which accounts for 83.82% of the variance, suggests a strong correlation between the field-measured pressure and the simulated pressure obtained from the validated model. This means that the validated model is able to accurately capture and explain 83.82% of the variability in the measured pressure data.

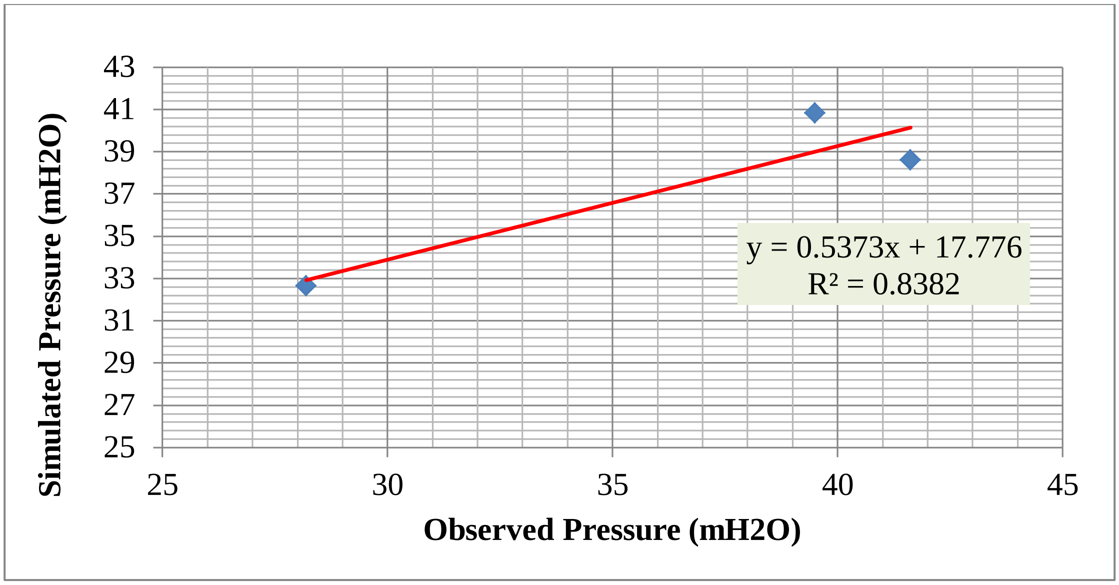

Figure 4.16: Correlated plot during pressure validation

4.10. Water Quality Analysis

4.10.1. Physico-chemical analysis of the existing water supply

Physicochemical characteristics are closely related to the safety of drinking water for human consumption. The physicochemical water quality metrics provide valuable information about a water body's health. These metrics are used to assess the quality of water for drinking purposes. During the field survey, the following physicochemical parameters were studied through laboratory experiments. The physical and chemical water quality indicators analyzed in the laboratory were PH, turbidity, temperature (degree), electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), and fluoride (WHO, 2017).

4.10.1.1. Turbidity

The turbidity in Table 4.32 shows that the study area is range from 2-5 NTU, which fit the WHO maximum Permissible limit which are 2NTU and 5NTU (BHH2 and BHB1) respectively. In research conducted in Bona district, Sidama Zone, southern Ethiopia, out of 6 rehabilitated well, one recorded 11 NTU, while the others reported <5 NTU (Berhanu & Hailu, 2015)

4.10.1.2. Temperature (^{0}C)

Temperature measurements are extremely valuable in determining the trend of physical, chemical, and biological activities that are promoted or slowed by temperature changes. In the current investigation, the average water temperature measured from samples was 20.7 0C. The temperature in the Rift Valley area exceeds WHO's suggested unit of <15^{0}C (2004), perhaps leading to bacterial development and increased water testing. It has no national guideline value (since it is not a health-related problem, it is non-objectionable, according to ES (2001).

4.10.1.3. PH

The PH value of water measures its acidity or alkalinity. Substances having a PH greater than 7.0 (7.1-14.0) are termed alkaline or basic, whereas those with a PH less than 7.0 (0-6.9) are classified as acidic. The WHO defines the minimum and maximum permissible PH values for drinkable water as 6.5 and 8.5, respectively. The research region has PH values of 7.50 and 7.70. A similar study conducted in the Wondogenet district of southern Ethiopia found that the PH ranged from 6.6 to 7.8 (Moges, 2012). Overall, the results reveal that the water supply schemes at Besheno rural tow, Bubesa kebele, and Hantezo kebele are slightly more basic and have a better taste.

4.10.1.4. Electrical Conductivity

The electrical conductivity of water is determined by the concentration of ions and its nutritional status. The EC value in study regions should not exceed 400-1,200 µS/cm, as per WHO regulations. The EC values for all samples were 695µS/cm and 704µS/cm. The conductivity rises with increasing ion concentration because ions in solution carry the electrical current. As a result, it is one of the primary factors used to assess whether water is suitable for irrigation and drinking. As shown in Table 4.32, the results showed that every sample fell within the WHO drinking water values range.

4.10.1.5. Total Dissolved solid

Total dissolved solids in drinking water are mostly composed of organic salts, with minor amounts of organic debris, natural interaction with rocks and soil accounts for the majority of total dissolved solids in water. The total dissolved solid in the sample study area ranged between 348 mg/l and 352 mg/l. Thus, the TDS values were within the acceptable limits of WHO standards and ESA (2013)

4.10.1.6. Total Hardness

Calcium carbonate ($CaCO_3$) is commonly used to test hard water since it contains the majority of dissolved calcium and carbonates. According to WHO guidelines, the hardness of water is 500 mg/l, although Ethiopia's standard is 300 mg/l. The hardness of the study area ranges between 160 and 280 mg/l, which are classified as moderately hard water and hard water, according to Table 2.1 in the literature review. The increased overall hardness score could be attributed to the presence of a high concentration of calcium and magnesium in the water. In addition, sodium, chlorides, sulphates, and nitrates may contribute to the total hardness value in relative terms. Therefore, the values were not exceeded the standard limit of both WHO guide line and Ethiopian standard.

4.10.1.7. Fluoride

The fluoride in groundwater is primarily geogenic. Fluoride enrichment in groundwater occurs primarily through the leaching and weathering of fluoride-bearing minerals found in rocks and sediments, which is determined by a variety of factors such as the origin of the water, the composition of the water-bearing medium, the length of time the water has been in contact with the medium, the temperature and pressure conditions, ion exchange, rate of recharge and discharge, and so on. Fluoride-bearing minerals include fluorite (fluorspar), fluorapatite, cryolite, biotite, muscovite, lepidolite, tourmaline, and hornblende series minerals, among others. The human body requires low levels of fluoride because it aids in the prevention of tooth caries, however high levels of fluoride can cause major health issues. According to the World Health Organization's (WHO, 2011) Drinking Water Quality Guideline Values, prolonged exposure to and use of water containing more than 1.5 mg/l of fluoride causes dental, skeletal, and non-skeletal fluorosis.

Dental fluorosis is defined as the loss of luster and shine in the dental enamel. The deterioration progresses from white, yellow, and brown to black. It affects both the interior and outside surfaces of the teeth. Skeletal fluorosis occurs when an excessive amount of fluoride is deposited in the skeleton. Fluoride poisoning causes significant discomfort, rigidity, and restricted movement of the cervical and lumber spines, knee and pelvic joints, and shoulder joints. Kyphosis, scoliosis, flexion deformity of knee joints, paraplegia, and quadriplegia are examples of crippling deformities related with joint rigidity. Skeletal fluorosis affects both adults and young children. Fluorosis is permanent, and there is no cure.

The laboratory results showed that the fluoride concentrations in the study areas were BHB1 2.19 mg/l and BHH2 1.97 mg/l. Both boreholes have fluoride levels that surpass the WHO Guide value and the Ethiopian norm for drinking water. Therefore, treatment was required at the Woreda water mine and energy office. The Rift Valley region of Ethiopia has greater levels of groundwater fluoride. For example, Solomon (2020) reported that 34.26% of the 108 wells tested for fluoride levels in Ethiopia's Rift Valley region had values greater than 1.5 mg/l.

Table 4.32: Physico-Chemical Analysis of Laboratory Results from the Sources

Parameter	Unit	Source		Guideline	
		BHB-1	BHH-2	WHO	ES
Temperature	℃	20.7	2007	15	15
PH		7.7	7.5	6.5 - 8.5	6.5 - 8.5
Turbidity	NTU	5	2	5	5
EC	µS/cm	695	704	400	1200
TDS	Mg/l	348	352	500	1000
Total hardness	Mg/l as $CaCO_3$	160	280	300	300
Fluoride	Mg/l	2.19	1.97	1.5	1.5

4.10.2. Bacteriological analysis of the existing water supply

The results of the test for the presence of bacteria in water samples from reservoirs, water points (Bono), and boreholes are shown in Table 4.33, where there are zero CFU of faecal coliform and zero CFU of total coliform per 100ml. The World Health Organization (2017) and the Ministry of Water and Resources (2002) have established bacteriological guidelines that recommend zero total coliform and zero E. coliform per 100ml of water at the point of use and at the source. As a result, the water is bacteriologically safe to consume.

Table 4.33: Bacteriological analysis results

Source	Unit	Result		Guide line	
		E. Coliform	Total Coliform	WHO	ES
Bubisa WP	CFU/100ml	0	0	0	0
Reservoir-1	CFU/100ml	0	0	0	0
Bubisa BH	CFU/100ml	0	0	0	0
Reservoir-2	CFU/100ml	0	0	0	0
Besheno town WP	CFU/100ml	0	0	0	0
Hantazo BH	CFU/100ml	0	0	0	0

5. CONCLUTION AND RECOMANDATIONS

5.1. CONCLUTION

Based on the results of the investigation, the study area's average daily water supply consumption is 12 liters/ c/day. The value falls low of the GTP-II criterion, which is 40 l/day per capita consumption for category-5 town like Besheno rural with a 250-meter travel distance. However, the research area's total water consumption per person falls below of the recommended level. Based on the GTP-2 aim for urban minimum service level of water supply access, the water supply coverage was calculated. thus, that the research area's water supply coverage was determined to be 30%.

During the hydraulic modeling of the rural town's water pressure, 165 pipes and 148 nodes were found. The model is calibrated to an acceptable level, meeting the pressure calibration criterion at average levels (average ±1.5m to maximum ±5m). Field measured pressure and simulated pressure have a strong correlation because the scenario's R^2 value is close to 1.

During peak hour usage, every node within the distribution network maintained pressure levels that fell within the desirable range. Specifically, not a single node recorded a pressure below the minimum acceptable threshold of 15 meters, nor did any node exceed the maximum desirable pressure of 70 meters of water column. This observation underscores a commendable achievement: 100% of the nodes operated within the recommended pressure range of 15 to 70 meters.

According to the results of hydraulic performance analysis, 94% of the pipes in the research area have velocities below the recommended minimum velocity. This indicates that a significant portion of the pipe network does not meet the specified velocity range of 0.6 m/s to 2 m/s. It suggests that additional development or improvements are necessary to achieve the minimum suggested velocity and ensure the desired hydraulic performance. On the other hand, 6% of the pipes in the research area meet the specified velocity range of 0.6 m/s to 2 m/s.

The result of Head loss analysis, 79% of the pipes fall below the recommended minimum head loss range of 1m/km. This suggests that these pipes have significantly lower head losses than what is considered optimal. Such pipes may be oversized or have relatively smooth internal surfaces, resulting in lower friction losses. 15% of the pipes fall within the recommended head loss range of 1 to 5m/km and the remaining 6% of the pipes exhibit head losses above the recommended range for Besheno town and 67.74% of the pipes are below the recommended minimum head loss range of 1m/km, 32.26% are within the recommended head loss range (1 to 5m/km) for transmission mains and rural kebeles based on Ethiopia urban water supply design guideline criteria. Based on the current study, the entire distribution system of the Besheno town has three pressure zones (low-pressure zone, medium pressure zone and the high-pressure zone) which is indicated by pressure contour developed for an area.

The laboratory results of borehole water quality tests revealed that the fluoride content of the analyzed water sample exceeds WHO and Ethiopian recommended levels for user safety and acceptability. Variations in climate and geology are linked to elevated concentrations of geogenic fluoride in groundwater. Arid climates, alkaline volcanic rocks, and granite basement aquifers are examples of environments that are strongly linked to fluoride. Excessive fluoride in drinking water can have detrimental effects on human health, such as dental fluorosis and skeletal fluorosis. In order to set corrective measures and treatments, the woreda water mine and energy office required involvement.

In general, the results of the analysis showed that the overall technical performance of the existing water distribution of the area was poor, as reflected by low water production rate, low water consumption, low service coverage, not velocity and pressure in permissible range and fluoride is treated before supply to the community.

5.2. Recommendations

Based on findings, the following recommendations are made:

- The hydraulic performance of the water distribution system should be improved after a pressure lowering valve is installed at high pressure and the velocity outside of the design range is adjusted by resizing the pipe diameter.

- To narrow the gap between the current demand for water supply and the supply, the appropriate steps should be made, such as raising the pump hour and designing a new water distribution system.
- In order to solve present and future water demand and supply shortages for customers, additional borehole exploration and reservoir building is needed.
- The local method of collecting water fees from users should be replaced by a bill.
- The fluoride concentration exceeds WHO guidelines and Ethiopian drinking water standards. Because of this, the water is unsafe to drink, and the woreda water mine and energy office should be included in any remedial measurement and treatment done before the water is given to the community. Bone charcoal, calcium phosphates, and aluminum phosphate are some ways to lower the fluoride water content.

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7. APPENDICES

Appendix A: Existing Pressure (Junction) Result

Besheno town junctions report						
Label	x(m)	y(m)	z(m)	Demand (L/s)	Hydraulic grade(m)	Pressure (m H2o)
J-1	414,715.25	825,245.35	1,976.00	0.069	2008.54	32.48
J-10	414,840.66	825,504.11	1,971.00	0.064	2007.4	36.32
J-100	414,847.01	825,821.61	1,976.00	0.073	2006.83	30.77
J-101	414,877.17	825,799.39	1,975.00	0.07	2006.85	31.79
J-102	414,904.16	825,778.75	1,976.00	0.053	2006.88	30.82
J-103	414,723.18	825,685.09	1,977.00	0.105	2006.83	29.77
J-104	414,693.02	825,648.57	1,987.00	0.125	2006.81	19.77
J-105	414,662.86	825,608.89	1,982.00	0.088	2006.79	24.74
J-106	414,632.69	825,564.44	1,981.00	0.067	2006.79	25.74
J-107	414,602.53	825,518.40	1,980.00	0.107	2006.79	26.73
J-108	414,570.78	825,461.25	1,979.00	0.101	2006.77	27.71
J-109	414,535.86	825,392.99	1,978.55	0.062	2006.77	28.16
J-11	414,826.37	825,446.96	1,978.00	0.075	2007.48	29.42
J-110	414,624.76	825,621.59	1,980.00	0.082	2006.79	26.74
J-111	414,566.02	825,640.64	1,978.00	0.108	2006.78	28.73
J-112	414,585.07	825,680.32	1,978.00	0.086	2006.78	28.73
J-113	414,615.23	825,726.36	1,976.00	0.114	2006.78	30.72
J-114	414,646.98	825,772.40	1,978.00	0.119	2006.78	28.72
J-115	414,675.56	825,816.85	1,975.00	0.128	2006.78	31.72
J-116	414,713.66	825,869.24	1,975.00	0.101	2006.78	31.72
J-117	414,748.58	825,915.27	1,974.00	0.077	2006.78	32.72
J-118	414,775.57	825,948.61	1,976.00	0.053	2006.79	30.72
J-119	414,802.56	825,926.39	1,976.00	0.049	2006.79	30.73
J-12	414,805.73	825,389.81	1,976.00	0.092	2007.57	31.51
J-120	414,823.20	825,908.92	1,977.00	0.067	2006.79	29.73
J-121	414,853.36	825,889.87	1,976.00	0.058	2006.8	30.74
J-122	414,874.00	825,870.82	1,977.00	0.052	2006.81	29.75
J-123	414,981.95	825,799.39	1,972.00	0.091	2006.89	34.81
J-124	415,024.81	825,840.66	1,979.00	0.066	2006.84	27.78
J-125	414,991.47	825,854.95	1,979.00	0.048	2006.83	27.77
J-126	414,954.96	825,866.06	1,980.00	0.09	2006.82	26.77
J-127	414,900.98	825,889.87	1,974.00	0.052	2006.81	32.74

J-128	414,920.03	825,921.62	1,975.00	0.084	2006.8	31.73
J-129	414,943.85	825,954.96	1,980.00	0.044	2006.79	26.74
J-13	414,780.33	825,335.84	1,973.00	0.094	2007.67	34.6
J-130	414,959.72	825,981.95	1,986.00	0.074	2006.79	20.74
J-131	414,989.88	825,958.14	1,983.00	0.066	2006.79	23.74
J-132	415,020.05	825,934.32	1,981.00	0.053	2006.79	25.73
J-133	415,051.80	825,913.69	1,978.00	0.034	2006.79	28.73
J-134	415,078.78	825,885.11	1,977.00	0.133	2006.8	29.74
J-135	415,053.38	825,861.30	1,979.00	0.066	2006.83	27.77
J-136	415,074.02	825,945.44	1,978.00	0.063	2006.75	28.7
J-137	415,088.31	825,978.77	1,978.00	0.097	2006.73	28.67
J-138	415,108.95	826,015.29	1,974.00	0.099	2006.71	32.64
J-139	415,123.23	826,042.27	1,969.00	0.11	2006.7	37.62
J-14	414,753.35	825,288.21	1,975.00	0.099	2008.09	33.02
J-140	414,934.32	825,999.41	1,975.00	0.092	2006.78	31.72
J-141	414,900.98	826,021.64	1,973.00	0.12	2006.78	33.72
J-142	414,856.53	826,053.39	1,974.00	0.085	2006.78	32.72
J-143	414,832.72	826,023.22	1,973.00	0.081	2006.78	33.72
J-144	414,802.56	825,983.54	1,974.00	0.088	2006.78	32.72
J-15	414,800.97	825,588.25	1,977.00	0.117	2007.23	30.17
J-16	414,835.90	825,620.00	1,983.00	0.056	2007.06	24.02
J-17	414,883.52	825,572.37	1,975.00	0.064	2007.08	32.02
J-18	414,869.23	825,539.04	1,972.00	0.067	2007.22	35.15
J-19	414,935.91	825,542.21	1,970.00	0.059	2007.04	36.97
J-2	414,656.51	825,267.57	1,982.00	0.129	2009.05	27
J-20	414,921.62	825,500.94	1,970.00	0.074	2007.06	36.99
J-21	414,910.51	825,458.07	1,976.00	0.057	2007.09	31.02
J-22	414,894.63	825,400.92	1,978.00	0.063	2007.2	29.14
J-23	414,877.17	825,348.54	1,971.00	0.154	2007.32	36.24
J-24	414,854.95	825,294.56	1,968.00	0.15	2007.45	39.37
J-25	414,940.67	825,431.09	1,972.00	0.095	2007.06	34.99
J-26	414,981.95	825,451.72	1,966.00	0.253	2007.04	40.96
J-27	415,047.03	825,493.00	1,964.00	0.248	2007.02	42.93
J-28	415,099.42	825,534.27	1,963.00	0.131	2007.01	43.92
J-29	415,167.68	825,545.39	1,965.00	0.063	2006.86	41.78
J-3	414,561.26	825,323.14	1,984.00	0.084	2009.99	25.94
J-30	415,145.46	825,572.37	1,965.00	0.058	2006.88	41.8
J-31	415,116.88	825,593.01	1,967.00	0.045	2006.91	39.83

J-32	415,086.72	825,621.59	1,968.00	0.037	2006.96	38.88
J-33	415,066.08	825,593.01	1,966.00	0.062	2006.97	40.89
J-34	415,035.92	825,561.26	1,964.00	0.084	2006.99	42.9
J-35	414,981.95	825,540.62	1,967.00	0.085	2007.02	39.94
J-36	415,116.88	825,648.57	1,964.00	0.054	2006.94	42.86
J-37	415,154.98	825,678.74	1,964.00	0.063	2006.93	42.84
J-38	415,189.91	825,707.31	1,966.00	0.083	2006.91	40.83
J-39	415,224.83	825,661.27	1,959.00	0.084	2006.9	47.8
J-4	414,588.24	825,361.24	1,990.00	0.052	2009.51	19.47
J-40	415,258.17	825,616.82	1,962.00	0.047	2006.83	44.74
J-41	415,308.97	825,566.02	1,963.00	0.161	2006.83	43.74
J-42	415,242.30	825,546.97	1,965.00	0.042	2006.85	41.76
J-43	415,207.37	825,542.21	1,969.00	0.04	2006.85	37.78
J-44	415,240.71	825,496.17	1,963.00	0.083	2006.75	43.66
J-45	415,242.30	825,435.85	1,964.00	0.179	2006.67	42.59
J-46	415,283.57	825,639.05	1,965.00	0.038	2006.82	41.74
J-47	415,316.91	825,664.45	1,963.00	0.086	2006.82	43.73
J-48	415,350.25	825,700.96	1,965.00	0.129	2006.81	41.72
J-49	415,345.48	825,794.62	1,960.00	0.055	2006.8	46.71
J-5	414,599.36	825,392.99	1,988.00	0.044	2009.21	21.17
J-50	415,378.82	825,775.57	1,960.00	0.045	2006.76	46.66
J-51	415,412.16	825,758.11	1,958.00	0.092	2006.72	48.62
J-52	415,456.61	825,802.56	1,963.00	0.076	2006.69	43.6
J-53	415,496.30	825,842.25	1,962.00	0.054	2006.67	44.58
J-54	415,464.55	825,867.65	1,964.00	0.042	2006.67	42.58
J-55	415,432.80	825,889.87	1,964.00	0.057	2006.67	42.58
J-56	415,396.28	825,915.27	1,966.00	0.065	2006.67	40.58
J-57	415,353.42	825,951.79	1,970.00	0.06	2006.67	36.59
J-58	415,320.08	825,916.86	1,964.00	0.052	2006.68	42.59
J-59	415,291.51	825,904.16	1,962.00	0.028	2006.69	44.6
J-6	414,635.87	825,424.74	1,985.00	0.114	2008.8	23.75
J-60	415,267.70	825,931.15	1,962.00	0.078	2006.68	44.59
J-61	415,248.65	825,962.90	1,962.00	0.077	2006.67	44.58
J-62	415,223.25	825,997.82	1,968.00	0.079	2006.67	38.6
J-63	415,186.73	826,050.21	1,968.00	0.068	2006.67	38.6
J-64	415,213.72	826,042.27	1,968.00	0.045	2006.67	38.59
J-65	415,250.23	826,020.05	1,966.00	0.046	2006.67	40.58
J-66	415,286.75	825,997.82	1,967.00	0.049	2006.67	39.59

J-67	415,318.50	825,978.77	1,971.00	0.055	2006.67	35.59
J-68	415,289.92	825,869.24	1,962.00	0.039	2006.75	44.66
J-69	415,291.51	825,842.25	1,963.00	0.017	2006.8	43.71
J-7	414,696.20	825,488.24	1,985.00	0.125	2008.08	23.03
J-70	415,320.08	825,815.26	1,961.00	0.049	2006.8	45.71
J-71	415,258.17	825,826.37	1,963.00	0.083	2006.89	43.8
J-72	415,216.90	825,800.97	1,973.00	0.131	2006.9	33.83
J-73	415,177.21	825,775.57	1,981.00	0.093	2006.91	25.86
J-74	415,135.93	825,748.59	1,980.00	0.081	2006.92	26.87
J-75	415,102.60	825,724.77	1,976.00	0.069	2006.93	30.87
J-76	415,072.43	825,704.14	1,973.00	0.057	2006.95	33.88
J-77	415,034.33	825,685.09	1,969.00	0.031	2006.97	37.89
J-78	415,054.97	825,658.10	1,971.00	0.056	2006.96	35.89
J-79	415,012.11	825,672.39	1,967.00	0.032	2006.97	39.89
J-8	414,750.17	825,540.62	1,976.00	0.114	2007.48	31.42
J-80	414,985.12	825,634.29	1,967.00	0.066	2006.99	39.91
J-81	414,959.72	825,589.84	1,968.00	0.064	2007.02	38.94
J-82	415,004.17	825,707.31	1,970.00	0.054	2006.97	36.89
J-83	414,980.36	825,678.74	1,968.00	0.037	2006.99	38.91
J-84	414,950.20	825,648.57	1,971.00	0.045	2007.01	35.94
J-85	414,918.45	825,608.89	1,978.00	0.059	2007.05	28.99
J-86	414,867.65	825,639.05	1,984.00	0.055	2007.04	22.99
J-87	414,899.40	825,664.45	1,974.00	0.055	2007.02	32.95
J-88	414,932.73	825,693.02	1,974.00	0.058	2006.99	32.93
J-89	414,978.77	825,732.71	1,969.00	0.062	2006.96	37.89
J-9	414,796.21	825,519.99	1,974.00	0.077	2007.44	33.37
J-90	414,961.31	825,767.64	1,972.00	0.041	2006.92	34.85
J-91	414,932.73	825,758.11	1,976.00	0.036	2006.92	30.86
J-92	414,904.16	825,745.41	1,976.00	0.043	2006.92	30.86
J-93	414,870.82	825,718.42	1,976.00	0.065	2006.93	30.87
J-94	414,840.66	825,700.96	1,976.00	0.069	2006.93	30.87
J-95	414,810.50	825,659.69	1,975.00	0.068	2006.94	31.88
J-96	414,780.33	825,686.67	1,978.00	0.066	2006.89	28.83
J-97	414,754.93	825,713.66	1,976.00	0.062	2006.85	30.79
J-98	414,773.98	825,742.24	1,978.00	0.094	2006.84	28.78
J-99	414,804.15	825,777.16	1,982.00	0.103	2006.84	24.79
WP-1	415,303.09	825,845.16	1,962.00	0.029	2006.8	44.71
WP-2	415,242.30	825,345.36	1,965.00	0.229	2006.63	41.55

WP-3	414,778.75	825,850.19	1,977.00	0.125	2006.79	29.73
WP-4	414,550.14	825,364.41	1,975.00	0.034	2006.77	31.7

Transmission mains and Rural kebeles junctions report					
Label	x(m)	y(m)	z(m)	Hydraulic grade(m)	Pressure (m H2o)
Besheno_ Rural WP	414,149.12	823,664.19	1,997.83	2,087.65	89.63
Bubisa_WP1	415,098.50	818,356.95	2,089.65	2,093.80	4.14
Bubisa_WP2	414,274.53	818,709.16	2,039.21	2,091.98	52.66
DL 192	414,224.48	819,336.55	2,016.52	2,090.76	74.09
DL 194	414,115.16	819,876.13	2,016.19	2,089.85	73.51
DL 196	414,056.35	820,187.32	2,028.15	2,089.40	61.13
DL 198	414,050.86	820,369.52	2,030.18	2,089.16	58.86
DL 199	414,035.53	820,395.04	2,030.58	2,089.12	58.42
DL 201	414,008.28	820,513.52	2,031.20	2,088.96	57.65
DL 203	413,871.78	821,120.64	2,024.91	2,088.49	63.46
DL 208	413,691.28	821,931.58	2,012.81	2,087.94	74.98
DL 210	413,862.86	822,524.96	2,007.05	2,087.71	80.49
DL 212	414,012.06	823,023.21	2,005.63	2,087.65	81.86
DL 214	414,083.26	823,188.05	2,004.44	2,087.65	83.04
DL 232	413,414.70	820,367.11	2,027.06	2,088.81	61.63
DL 234	413,089.43	820,328.54	2,029.96	2,088.76	58.68
DL 236	412,663.18	820,267.17	2,037.85	2,088.72	50.76
DL 238	412,383.37	820,232.02	2,043.82	2,088.70	44.79
DL 240	412,042.54	820,177.69	2,048.20	2,088.69	40.41
DL 242	411,761.49	820,133.24	2,051.94	2,088.69	36.68
DL184	414,868.50	818,428.73	2,070.35	2,093.30	22.9
DL230	413,846.66	820,433.68	2,030.34	2,088.92	58.46
Hantazo_0WP	411,641.24	820,097.32	2,052.71	2,088.69	35.91
J-20	414,310.38	818,875.47	2,032.19	2,091.69	59.38
J-21	413,778.15	821,561.92	2,019.08	2,088.26	69.04
J-22	414,238.83	823,565.48	1,998.08	2,087.65	89.39
J-23	414,030.58	820,475.32	2,030.87	2,089.02	58.03
J-3	414,363.03	818,748.67	2,040.22	2,091.98	51.65
J-4	413,840.79	821,319.89	2,023.11	2,088.38	65.14
VC	415,095.80	818,363.54	2,089.22	2,093.80	4.57
WP3	413,707.08	821,566.68	2,018.22	2,088.26	69.9

Appendix B: Existing Besheno Pipe Result

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Velocity (m/s)	Headloss Gradient (m/km)
P-1	48	J-3	J-4	90	HDPE	140	0.91	10.023
P-2	34	J-4	J-5	90	PVC	150	0.9	8.675
P-3	48	J-5	J-6	90	PVC	150	0.89	8.551
P-4	88	J-6	J-7	90	PVC	150	0.87	8.236
P-5	75	J-7	J-8	90	PVC	150	0.85	7.897
P-6	70	J-8	J-15	90	PVC	150	0.57	3.68
P-7	47	J-15	J-16	90	PVC	150	0.55	3.462
P-8	67	J-16	J-17	90	PVC	150	0.13	0.232
P-9	36	J-17	J-18	90	PVC	150	0.58	3.808
P-10	45	J-18	J-10	90	PVC	150	0.59	3.938
P-11	59	J-10	J-11	90	PVC	150	0.34	1.417
P-12	61	J-11	J-12	90	PVC	150	0.35	1.511
P-13	60	J-12	J-13	90	PVC	150	0.36	1.627
P-14	55	J-13	J-14	90	PVC	150	0.84	7.675
P-15	57	J-14	J-1	90	PVC	150	0.86	7.936
P-16	63	J-1	J-2	90	PVC	150	0.87	8.126
P-17	110	J-2	J-3	90	PVC	150	0.89	8.479
P-18	47	J-10	J-9	90	PVC	150	0.26	0.864
P-19	50	J-9	J-8	90	PVC	150	0.27	0.941
P-20	85	J-13	J-24	90	PVC	150	0.46	2.529
P-21	58	J-24	J-23	90	PVC	150	0.44	2.297
P-22	55	J-23	J-22	90	PVC	150	0.41	2.07
P-23	59	J-22	J-21	90	PVC	150	0.4	1.977
P-24	44	J-21	J-20	90	PVC	150	0.2	0.521
P-25	44	J-20	J-19	90	PVC	150	0.19	0.47
P-26	60	J-19	J-17	90	PVC	150	0.21	0.608
P-27	37	J-16	J-86	90	PVC	150	0.22	0.631
P-28	41	J-86	J-87	90	PVC	150	0.21	0.586
P-29	44	J-87	J-88	90	PVC	150	0.2	0.542
P-30	61	J-88	J-89	90	PVC	150	0.19	0.499
P-31	36	J-89	J-82	90	PVC	150	0.11	0.182
P-32	37	J-82	J-83	90	PVC	150	0.2	0.552
P-33	43	J-83	J-84	90	PVC	150	0.21	0.579
P-34	51	J-84	J-85	90	PVC	150	0.22	0.618

P-35	51	J-85	J-17	90	PVC	150	0.23	0.669
P-36	37	J-82	J-77	90	PVC	150	0.08	0.107
P-37	26	J-77	J-79	90	PVC	150	0.17	0.378
P-38	47	J-79	J-80	90	PVC	150	0.17	0.402
P-39	51	J-80	J-81	90	PVC	150	0.18	0.448
P-40	53	J-81	J-19	90	PVC	150	0.19	0.495
P-41	49	J-19	J-35	90	PVC	150	0.2	0.531
P-42	58	J-35	J-34	90	PVC	150	0.19	0.467
P-43	44	J-34	J-33	90	PVC	150	0.17	0.404
P-44	35	J-33	J-32	90	PVC	150	0.16	0.367
P-45	48	J-32	J-78	90	PVC	150	0.07	0.068
P-46	34	J-78	J-77	90	PVC	150	0.07	0.083
P-47	50	J-16	J-95	90	PVC	150	0.45	2.38
P-48	40	J-95	J-96	90	PVC	150	0.32	1.276
P-49	37	J-96	J-97	90	PVC	150	0.31	1.201
P-50	43	J-97	J-103	90	PVC	150	0.19	0.474
P-51	47	J-103	J-104	90	PVC	150	0.17	0.402
P-52	50	J-104	J-105	90	PVC	150	0.15	0.322
P-53	54	J-105	J-106	90	PVC	150	0.06	0.055
P-54	55	J-106	J-107	90	PVC	150	0.05	0.038
P-55	77	J-108	J-109	90	PVC	150	0.02	0.004
P-56	32	J-109	WP-4	90	PVC	150	0.01	0
P-57	34	J-97	J-98	90	PVC	150	0.11	0.182
P-58	46	J-98	J-99	90	PVC	150	0.1	0.139
P-59	56	J-100	J-122	90	PVC	150	0.15	0.321
P-60	28	J-122	J-121	90	PVC	150	0.14	0.291
P-61	36	J-121	J-120	90	PVC	150	0.13	0.259
P-62	74	J-120	WP-3	90	PVC	150	0.02	0.008
P-63	27	J-120	J-119	90	PVC	150	0.1	0.16
P-64	35	J-119	J-118	90	PVC	150	0.1	0.14
P-65	43	J-118	J-117	90	PVC	150	0.05	0.038
P-66	58	J-117	J-116	90	PVC	150	0.04	0.023
P-67	65	J-116	J-115	90	PVC	150	0.02	0.009
P-68	53	J-115	J-114	90	PVC	150	0	0
P-69	56	J-114	J-113	90	PVC	150	0.02	0.008
P-70	55	J-113	J-112	90	PVC	150	0.04	0.022
P-71	44	J-112	J-111	90	PVC	150	0.05	0.041
P-72	62	J-111	J-110	90	PVC	150	0.07	0.07

P-73	40	J-110	J-105	90	PVC	150	0.08	0.096
P-74	44	J-118	J-144	90	PVC	150	0.04	0.027
P-75	50	J-144	J-143	90	PVC	150	0.03	0.012
P-76	38	J-143	J-142	90	PVC	150	0.01	0
P-77	55	J-142	J-141	90	PVC	150	0	0
P-78	40	J-141	J-140	80	Galvanized iron	120	0.02	0.019
P-79	31	J-140	J-130	75	HDPE	140	0.05	0.053
P-80	31	J-130	J-129	75	HDPE	140	0.08	0.143
P-81	41	J-129	J-128	75	HDPE	140	0.09	0.174
P-82	37	J-128	J-127	75	HDPE	140	0.11	0.245
P-83	59	J-127	J-126	75	HDPE	140	0.12	0.3
P-84	38	J-126	J-125	90	PVC	150	0.1	0.144
P-85	36	J-125	J-124	90	PVC	150	0.11	0.164
P-86	35	J-124	J-135	90	PVC	150	0.14	0.266
P-87	35	J-135	J-134	75	HDPE	140	0.18	0.645
P-88	39	J-134	J-133	75	HDPE	140	0.15	0.458
P-89	38	J-133	J-132	75	HDPE	140	0.01	0.004
P-90	38	J-132	J-131	75	HDPE	140	0	0
P-91	38	J-131	J-130	75	HDPE	140	0.01	0.004
P-92	51	J-95	J-94	90	PVC	150	0.12	0.198
P-93	35	J-94	J-93	90	PVC	150	0.11	0.167
P-94	43	J-93	J-92	90	PVC	150	0.1	0.139
P-95	31	J-92	J-91	90	PVC	150	0.09	0.119
P-96	35	J-91	J-102	63	HDPE	140	0.21	0.996
P-97	34	J-102	J-101	63	HDPE	140	0.19	0.854
P-98	37	J-101	J-100	63	HDPE	140	0.17	0.671
P-99	39	J-89	J-90	90	PVC	150	0.29	1.09
P-100	38	J-90	J-123	90	PVC	150	0.27	0.924
P-101	60	J-123	J-124	90	PVC	150	0.25	0.835
P-102	30	J-91	J-90	63	HDPE	140	0.04	0.04
P-103	39	J-133	J-136	63	HDPE	140	0.19	0.837
P-104	36	J-136	J-137	63	HDPE	140	0.17	0.677
P-105	42	J-137	J-138	63	HDPE	140	0.14	0.465
P-106	31	J-138	J-139	63	HDPE	140	0.11	0.283
P-107	64	J-139	J-63	50	HDPE	140	0.11	0.419
P-108	64	J-63	J-62	50	HDPE	140	0.01	0.009
P-109	43	J-62	J-61	50	HDPE	140	0.03	0.031
P-110	37	J-61	J-60	50	HDPE	140	0.07	0.157

P-111	36	J-60	J-59	50	HDPE	140	0.11	0.372
P-112	31	J-59	J-58	50	HDPE	140	0.11	0.433
P-113	48	J-58	J-57	50	HDPE	140	0.09	0.262
P-114	44	J-57	J-67	50	HDPE	140	0.03	0.044
P-115	37	J-67	J-66	50	HDPE	140	0.01	0.004
P-116	43	J-66	J-65	50	HDPE	140	0.02	0.014
P-117	43	J-65	J-64	50	HDPE	140	0.04	0.07
P-118	31	J-64	J-63	50	HDPE	140	0.07	0.152
P-119	43	J-77	J-76	90	PVC	150	0.17	0.402
P-120	37	J-76	J-75	90	PVC	150	0.16	0.362
P-121	41	J-75	J-74	90	PVC	150	0.15	0.316
P-122	49	J-74	J-73	90	PVC	150	0.14	0.272
P-123	47	J-73	J-72	90	PVC	150	0.12	0.218
P-124	48	J-72	J-71	90	PVC	150	0.1	0.157
P-125	37	J-71	J-69	50	HDPE	140	0.29	2.426
P-126	12	J-69	WP-1	50	HDPE	140	0.01	0.012
P-127	27	J-69	J-68	50	HDPE	140	0.25	1.883
P-128	35	J-68	J-59	50	HDPE	140	0.23	1.618
P-129	39	J-69	J-70	50	HDPE	140	0.01	0.008
P-130	33	J-70	J-49	50	HDPE	140	0.01	0.005
P-131	94	J-49	J-48	90	PVC	150	0.07	0.083
P-132	49	J-48	J-47	90	PVC	150	0.09	0.129
P-133	42	J-47	J-46	90	PVC	150	0.11	0.163
P-134	34	J-46	J-40	90	PVC	150	0.11	0.185
P-135	56	J-40	J-39	63	HDPE	140	0.24	1.304
P-136	58	J-39	J-38	90	PVC	150	0.13	0.247
P-137	45	J-38	J-37	90	PVC	150	0.14	0.294
P-138	49	J-37	J-36	90	PVC	150	0.15	0.331
P-139	40	J-36	J-32	90	PVC	150	0.16	0.368
P-140	42	J-32	J-31	50	HDPE	140	0.19	1.114
P-141	35	J-31	J-30	50	HDPE	140	0.17	0.878
P-142	35	J-30	J-29	50	HDPE	140	0.14	0.613
P-143	40	J-29	J-43	90	PVC	150	0.12	0.198
P-144	36	J-43	J-42	90	PVC	150	0.11	0.18
P-145	70	J-42	J-41	50	HDPE	140	0.09	0.257
P-146	72	J-41	J-40	50	HDPE	140	0	0
P-147	51	J-42	J-44	50	HDPE	140	0.25	1.839
P-148	60	J-44	J-45	50	HDPE	140	0.21	1.305

P-149	90	J-45	WP-2	50	HDPE	140	0.12	0.446
P-150	41	J-21	J-25	90	PVC	150	0.2	0.527
P-151	46	J-25	J-26	90	PVC	150	0.18	0.453
P-152	77	J-26	J-27	90	PVC	150	0.14	0.292
P-153	67	J-27	J-28	90	PVC	150	0.1	0.161
P-154	70	J-28	J-29	50	HDPE	140	0.27	2.136
P-155	38	J-49	J-50	50	HDPE	140	0.2	1.167
P-156	38	J-50	J-51	50	HDPE	140	0.17	0.925
P-157	63	J-51	J-52	50	HDPE	140	0.13	0.516
P-158	56	J-52	J-53	50	HDPE	140	0.09	0.263
P-159	41	J-53	J-54	50	HDPE	140	0.06	0.132
P-160	39	J-54	J-55	50	HDPE	140	0.04	0.061
P-161	44	J-55	J-56	50	HDPE	140	0.01	0.003
P-162	56	J-56	J-57	50	HDPE	140	0.02	0.021
P-163	62	J-100	J-99	90	PVC	150	0.08	0.099
P-164	127	200m3_SR	J-3	110	PVC	150	1.21	11.909
P-165	65	J-108	J-107	50	HDPE	140	0.1	0.337

Transmission mains and rural kebeles pipe report

Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)	Head loss Gradient(m/Km)
P-3	214	160	HDPE	140	12	0.59	2.329
P-4	598	160	HDPE	140	12	0.58	2.21
P-6	137	160	HDPE	140	11	0.56	2.101
P-7	469	160	HDPE	140	11	0.54	1.985
P-8	551	160	HDPE	140	10	0.49	1.646
P-9	317	160	HDPE	140	9	0.45	1.422
P-10	182	160	HDPE	140	9	0.44	1.344
P-11	30	160	HDPE	140	9	0.43	1.285
P-12	80	160	HDPE	140	9	0.43	1.282
P-13	44	160	HDPE	140	8	0.42	1.225
P-22	622	140	HDPE	140	5	0.3	0.752
P-26	380	110	HDPE	140	3	0.27	0.839
P-23	202	140	HDPE	140	4	0.25	0.567
P-24	250	140	HDPE	140	4	0.23	0.473
P-14	180	160	HDPE	140	4	0.18	0.256

P-27	618	110	HDPE	140	2	0.18	0.381
P-15	437	160	HDPE	140	3	0.17	0.232
P-16	328	160	HDPE	140	3	0.15	0.173
P-17	431	160	HDPE	140	2	0.11	0.095
P-28	520	110	HDPE	140	1	0.09	0.1
P-18	282	140	HDPE	140	1	0.08	0.069
P-29	180	110	HDPE	140	0	0.05	0.031
P-25	71	140	HDPE	140	1	0.04	0.021
P-19	345	140	HDPE	140	1	0.04	0.02
P-30	408	110	HDPE	140	0	0.02	0.008
P-20	285	140	HDPE	140	0	0.01	0.003
P-31	133	110	HDPE	140	0	0.01	0.002
P-5	97	160	HDPE	140	0	0.01	0.002
P-1	49	160	HDPE	140	0	0.01	0
P-21	126	140	HDPE	140	0	0	0
P-2	7	160	HDPE	140	0	0	0

Appendix C-1: Gender of the Respondent

Sex	Frequency	Percent (%)
Male	29	40.8
Female	42	59.2
Total	71	100

Source: Household own survey

Appendix C-2: Age Distribution of the Respondent

Age distribution of the respondent	Frequency	Percent (%)
18-29 years	14	19.7
30-39 years	16	22.5
40-49 years	33	46.5
50 and above years	8	11.3
Total	71	100.0

Source: Household own survey

Appendix C-3: education level of respondent

education level of respondent	Frequency	Percent (%)
Uneducated	8	11.3
Elementary school	21	29.6
Secondary school	30	42.3
Diploma level	5	7.0
Degree level	7	9.9
Total	71	100.0

Appendix C- 4: Marital Status of the Respondent

Marital Status of Respondent	Frequency	Percent (%)
Single	10	14.1
Married	55	77.5
Divorce	4	5.6
Widow	2	2.8
Total	71	100.0

Source: Household own survey

Appendix C.5: Response on Color of Water

Response on Color of Water	Frequency	Percent (%)
Very good	4	5.6
Good	62	87.3
Poor	5	7.0
Total	71	100.0

Source: Household own survey

Appendix C-6: Response on Pipe Water Test

Response on pipe water test	Frequency	Percent (%)
Very good	2	2.8
Good	58	81.7
Poor	11	15.5
Total	71	100.0

Source: Household own survey

Appendix C-7: Response on Pipe Water Quality Satisfaction

Response on pipe water quality satisfaction	Frequency	Percent (%)
Very good	1	1.4
Good	43	60.6
Poor	27	38.0
Total	71	100.0

Source: Household own survey

Appendix C-8: Response on Pressure of the Water

Response on pressure of the water	Frequency	Percent (%)
Very good	1	1.4
Good	9	12.7
Poor	61	85.9
Total	71	100.0

Source: Household own survey

Appendix C-9: Response on Frequency of Water Supply

Response on frequency of water supply	Frequency	Percent (%)
Once in two days	3	4.2
Once in three days	54	76.1
Once in a week	14	19.7
Total	71	100.0

Source: Household own survey

Appendix C-10: Response on Frequency Water Sufficient for Your Need

Response on frequency water sufficient for your need	Frequency	Percent (%)
Yes	6	8.5
No	65	91.5
Total	71	100.0

Appendix C-11: Response on Unavailability of Water

Response on unavailability of water	Frequency	Percent (%)
Fuel problem	4	5.6
Distribution system problem	10	14.1
water is not available source	1	1.4
Fuel problem and Distribution system problem	56	78.9
Total	71	100.0

Source: Household own survey

Appendix C-12: Response on Water Tariff is Fair

Response on water tariff is fair	Frequency	Percent (%)
Yes	4	5.6
No	67	94.4
Total	71	100.0

Source: Household own survey

Appendix C-13: Response on Judgment on the Tariff

Response on judgment on the tariff	Frequency	Percent (%)
Very expansive	5	7
Expansive	63	88.7
Fair	2	2.8
Cheap	1	1.4
Total	71	100.0

Source: Household own survey

Appendix C-14: Response on Reading Frequency of Water Meter

Response on reading frequency of water meter	Frequency	Percent (%)
Once in month	49	69.0
once in two month	22	31.0
Total	71	100.0

Source: Household own survey

Appendix C-15: Response on the Water Supply Scheme Management

Response on the water supply scheme management	Frequency	Percent (%)
Woreda water mine and energy office	52	73.2
Water committee	15	21.1
Community	4	5.6
Total	71	100.0

Source: Household own survey

Appendix C-16: Response on Time Queuing to Fetch Water

Response on time queuing to fetch water	Frequency	Percent (%)
Yes	67	94.4
No	4	5.6
Total	71	100.0

Source: Household own survey

Appendix C-17: Response on Length of Time to Fetch Water

Response on length of time to fetch water	Frequency	Percent (%)
30min-1hr	1	1.4
1:30hr-2hr	7	9.9
2:00-2:30hr	63	88.7
Total	71	100.0

Source: Household own survey

Appendix C-18: Response on Suggestion for Improvement of the Water Supply System

Response on suggestion for improvement of the water supply system	Frequency	Percent (%)
Quality	4	5.6
Pressure	58	81.7
Service quality	6	8.5
Maintenance	3	4.2
Total	71	100.0

Appendix C-19: Minimum water supply service level standard

No	Category of towns/cities	Population in towns/cities	Minimum safe water supply l/c/day	Remark
1.	Category -1	More than 1 million	100	
2.	Category -2	100,000 to 1 million	80	
3.	Category -3	50,000 to 100,000	60	
4.	Category -4	20,000 to 50,000	50	
5.	Category -5	Less than 20,000	40	

Appendix D-1 Images of Hantezo Borehole Source Used for Testing

Appendix D-2 Images of Bubesa Borehole Source Used for Testing

Appendix D-3 Images of Water Point (Bono) Source Used for Testing

Appendix D-4 Group Discussions

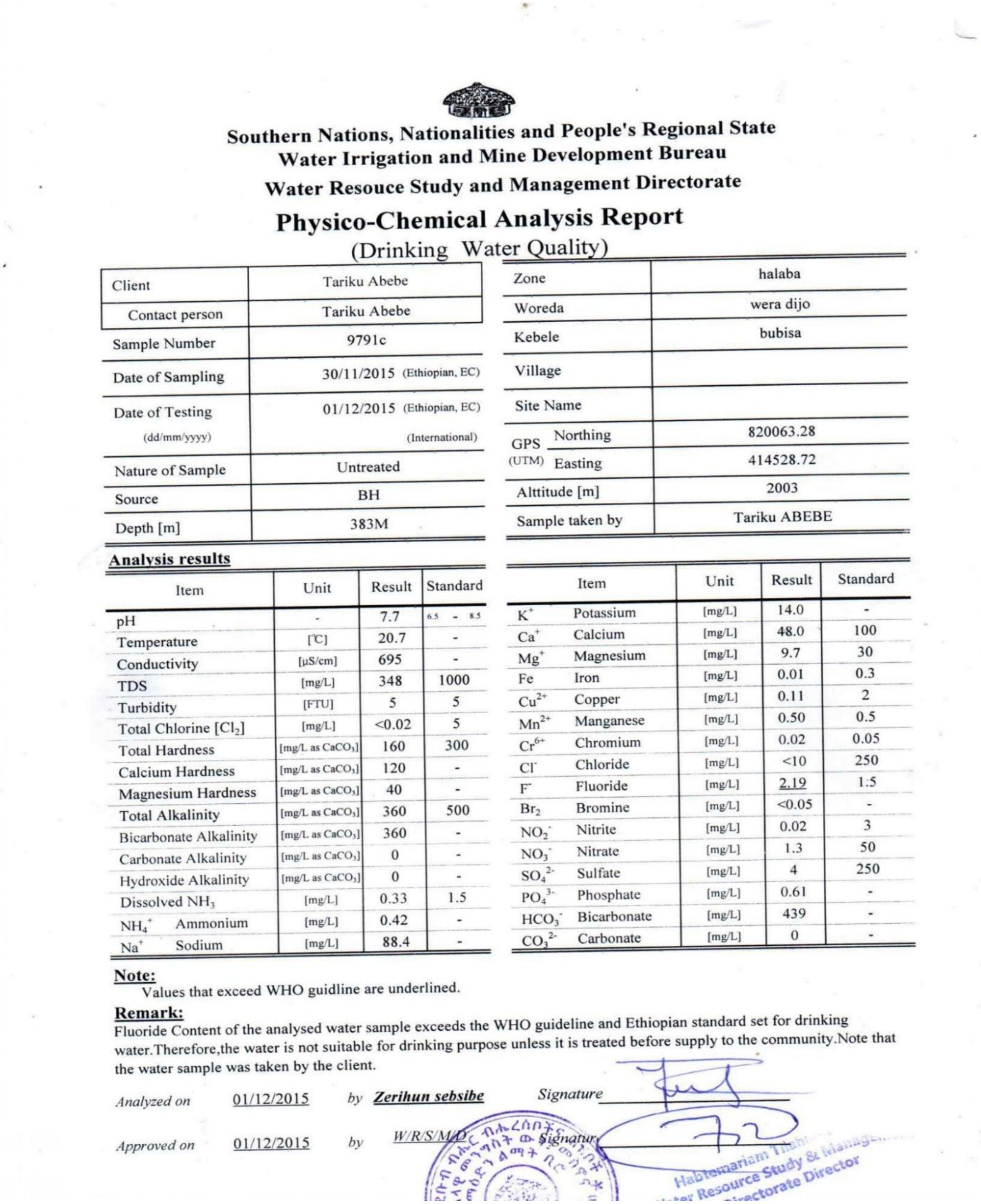
Appendix D-5 Existing 200m3 Reservoir

Appendix D-6 Tuesday Water Market at Beshen

Appendix D-7 Bacteriologica Sample Analysis

Appendix D-8 Bacteriologica Sample in Wagtech Potatest incubator

Appendix E-1 Bubisa BH Physico-Chemical Analysis Result



Southern Nations, Nationalities and People's Regional State
Water Irrigation and Mine Development Bureau
Water Resouce Study and Management Directorate

Physico-Chemical Analysis Report

(Drinking Water Quality)

Client	Tariku Abebe
Contact person	Tariku Abebe
Sample Number	9791c
Date of Sampling	30/11/2015 (Ethiopian, EC)
Date of Testing (dd/mm/yyyy)	01/12/2015 (Ethiopian, EC) (International)
Nature of Sample	Untreated
Source	BH
Depth [m]	383M

Zone	halaba
Woreda	wera dijo
Kebele	bubisa
Village	
Site Name	
GPS (UTM) Northing	820063.28
GPS (UTM) Easting	414528.72
Alttitude [m]	2003
Sample taken by	Tariku ABEBE

Analysis results

Item	Unit	Result	Standard
pH	-	7.7	6.5 - 8.5
Temperature	[°C]	20.7	-
Conductivity	[μS/cm]	695	-
TDS	[mg/L]	348	1000
Turbidity	[FTU]	5	5
Total Chlorine [Cl_2]	[mg/L]	<0.02	5
Total Hardness	[mg/L as $CaCO_3$]	160	300
Calcium Hardness	[mg/L as $CaCO_3$]	120	-
Magnesium Hardness	[mg/L as $CaCO_3$]	40	-
Total Alkalinity	[mg/L as $CaCO_3$]	360	500
Bicarbonate Alkalinity	[mg/L as $CaCO_3$]	360	-
Carbonate Alkalinity	[mg/L as $CaCO_3$]	0	-
Hydroxide Alkalinity	[mg/L as $CaCO_3$]	0	-
Dissolved NH_3	[mg/L]	0.33	1.5
NH_4^+ Ammonium	[mg/L]	0.42	-
Na^+ Sodium	[mg/L]	88.4	-

Item	Unit	Result	Standard
K^+ Potassium	[mg/L]	14.0	-
Ca^+ Calcium	[mg/L]	48.0	100
Mg^+ Magnesium	[mg/L]	9.7	30
Fe Iron	[mg/L]	0.01	0.3
Cu^{2+} Copper	[mg/L]	0.11	2
Mn^{2+} Manganese	[mg/L]	0.50	0.5
Cr^{6+} Chromium	[mg/L]	0.02	0.05
Cl^- Chloride	[mg/L]	<10	250
F^- Fluoride	[mg/L]	2.19	1:5
Br_2 Bromine	[mg/L]	<0.05	-
NO_2^- Nitrite	[mg/L]	0.02	3
NO_3^- Nitrate	[mg/L]	1.3	50
SO_4^{2-} Sulfate	[mg/L]	4	250
PO_4^{3-} Phosphate	[mg/L]	0.61	-
HCO_3^- Bicarbonate	[mg/L]	439	-
CO_3^{2-} Carbonate	[mg/L]	0	-

Note:
Values that exceed WHO guidline are underlined.

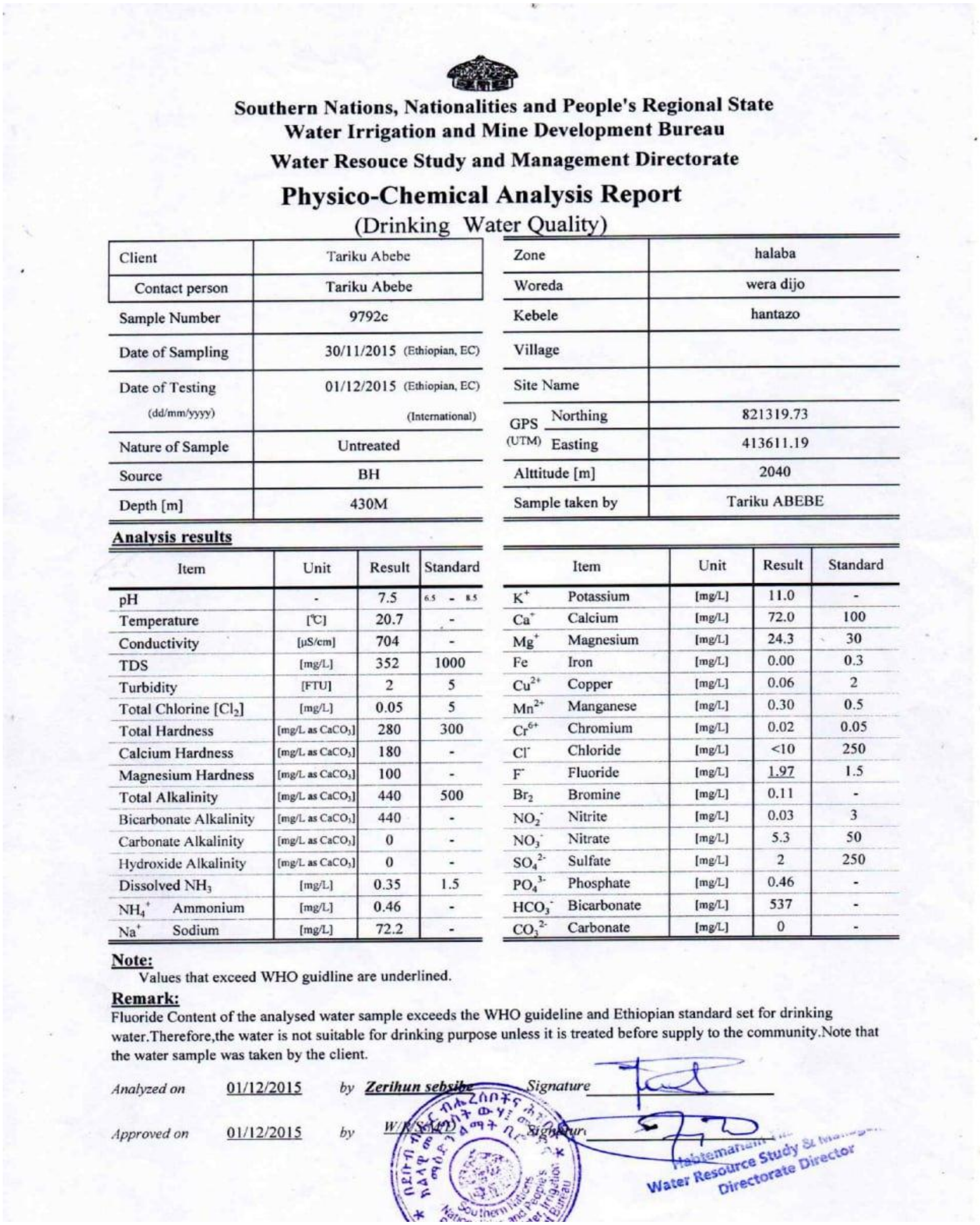
Remark:
Fluoride Content of the analysed water sample exceeds the WHO guideline and Ethiopian standard set for drinking water.Therefore,the water is not suitable for drinking purpose unless it is treated before supply to the community.Note that the water sample was taken by the client.

Analyzed on 01/12/2015 *by* ***Zerihun sebsibe*** *Signature*

Approved on 01/12/2015 *by* *W/R/S/M/D* *Signatur*

Habtemariam

Appendix E-2 Hantazo BH Physico-Chemical Analysis Result



Southern Nations, Nationalities and People's Regional State
Water Irrigation and Mine Development Bureau
Water Resouce Study and Management Directorate

Physico-Chemical Analysis Report

(Drinking Water Quality)

Client	Tariku Abebe
Contact person	Tariku Abebe
Sample Number	9792c
Date of Sampling	30/11/2015 (Ethiopian, EC)
Date of Testing (dd/mm/yyyy)	01/12/2015 (Ethiopian, EC) (International)
Nature of Sample	Untreated
Source	BH
Depth [m]	430M

Zone		halaba
Woreda		wera dijo
Kebele		hantazo
Village		
Site Name		
GPS (UTM)	Northing	821319.73
	Easting	413611.19
Alttitude [m]		2040
Sample taken by		Tariku ABEBE

Analysis results

Item	Unit	Result	Standard
pH	-	7.5	6.5 - 8.5
Temperature	[°C]	20.7	-
Conductivity	[µS/cm]	704	-
TDS	[mg/L]	352	1000
Turbidity	[FTU]	2	5
Total Chlorine [Cl_2]	[mg/L]	0.05	5
Total Hardness	[mg/L as $CaCO_3$]	280	300
Calcium Hardness	[mg/L as $CaCO_3$]	180	-
Magnesium Hardness	[mg/L as $CaCO_3$]	100	-
Total Alkalinity	[mg/L as $CaCO_3$]	440	500
Bicarbonate Alkalinity	[mg/L as $CaCO_3$]	440	-
Carbonate Alkalinity	[mg/L as $CaCO_3$]	0	-
Hydroxide Alkalinity	[mg/L as $CaCO_3$]	0	-
Dissolved NH_3	[mg/L]	0.35	1.5
NH_4^+ Ammonium	[mg/L]	0.46	-
Na^+ Sodium	[mg/L]	72.2	-

Item		Unit	Result	Standard
K^+	Potassium	[mg/L]	11.0	-
Ca^+	Calcium	[mg/L]	72.0	100
Mg^+	Magnesium	[mg/L]	24.3	30
Fe	Iron	[mg/L]	0.00	0.3
Cu^{2+}	Copper	[mg/L]	0.06	2
Mn^{2+}	Manganese	[mg/L]	0.30	0.5
Cr^{6+}	Chromium	[mg/L]	0.02	0.05
Cl^-	Chloride	[mg/L]	<10	250
F^-	Fluoride	[mg/L]	<u>1.97</u>	1.5
Br_2	Bromine	[mg/L]	0.11	-
NO_2^-	Nitrite	[mg/L]	0.03	3
NO_3^-	Nitrate	[mg/L]	5.3	50
SO_4^{2-}	Sulfate	[mg/L]	2	250
PO_4^{3-}	Phosphate	[mg/L]	0.46	-
HCO_3^-	Bicarbonate	[mg/L]	537	-
CO_3^{2-}	Carbonate	[mg/L]	0	-

Note:

Values that exceed WHO guidline are underlined.

Remark:

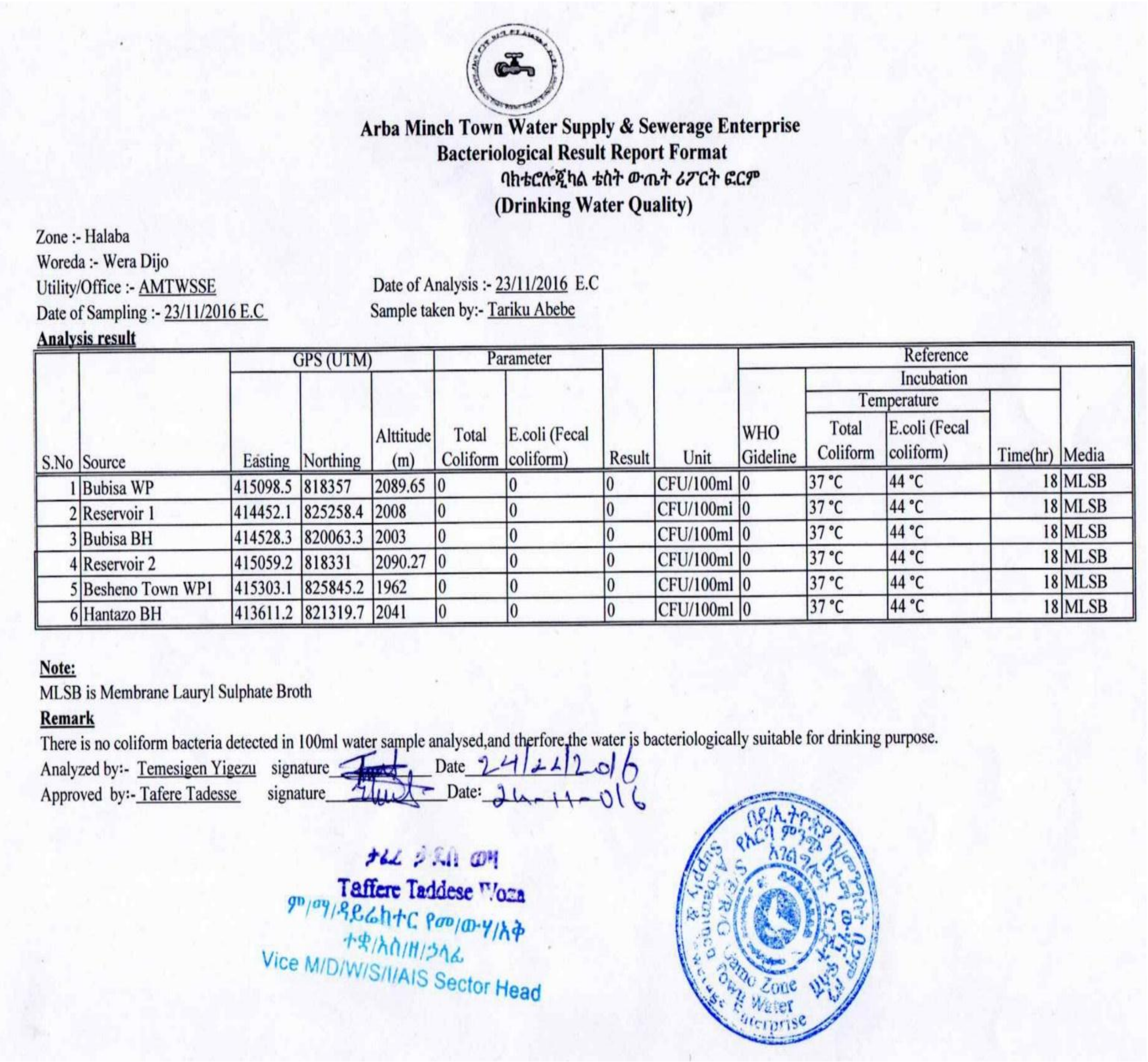
Fluoride Content of the analysed water sample exceeds the WHO guideline and Ethiopian standard set for drinking water.Therefore,the water is not suitable for drinking purpose unless it is treated before supply to the community.Note that the water sample was taken by the client.

Analyzed on 01/12/2015 *by* ***Zerihun sebsibe*** *Signature*

Approved on 01/12/2015 *by* W/R/S&M/D *Signature*

Water Resource Study & Management
Directorate Director

Appendix E-3 Bacteriological Analysis Result



Arba Minch Town Water Supply & Sewerage Enterprise
Bacteriological Result Report Format
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(Drinking Water Quality)

Zone :- Halaba
Woreda :- Wera Dijo
Utility/Office :- AMTWSSE
Date of Sampling :- 23/11/2016 E.C
Date of Analysis :- 23/11/2016 E.C
Sample taken by:- Tariku Abebe

Analysis result

		GPS (UTM)			Parameter				Reference				
										Incubation			
										Temperature			
S.No	Source	Easting	Northing	Alttitude (m)	Total Coliform	E.coli (Fecal coliform)	Result	Unit	WHO Gideline	Total Coliform	E.coli (Fecal coliform)	Time(hr)	Media
1	Bubisa WP	415098.5	818357	2089.65	0	0	0	CFU/100ml	0	37 °C	44 °C	18	MLSB
2	Reservoir 1	414452.1	825258.4	2008	0	0	0	CFU/100mi	0	37 °C	44 °C	18	MLSB
3	Bubisa BH	414528.3	820063.3	2003	0	0	0	CFU/100ml	0	37 °C	44 °C	18	MLSB
4	Reservoir 2	415059.2	818331	2090.27	0	0	0	CFU/100ml	0	37 °C	44 °C	18	MLSB
5	Besheno Town WP1	415303.1	825845.2	1962	0	0	0	CFU/100ml	0	37 °C	44 °C	18	MLSB
6	Hantazo BH	413611.2	821319.7	2041	0	0	0	CFU/100ml	0	37 °C	44 °C	18	MLSB

Note:
MLSB is Membrane Lauryl Sulphate Broth

Remark
There is no coliform bacteria detected in 100ml water sample analysed,and therfore,the water is bacteriologically suitable for drinking purpose.

Analyzed by:- Temesigen Yigezu signature____ Date 24/11/2016
Approved by:- Tafere Tadesse signature____ Date: 24-11-016

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Taffere Taddese Woza
ም/ዋ/ዳይሬክተር የመ/ው-ሃ/አቅ
ተቋ/አስ/ዘ/ኃላፊ
Vice M/D/W/S/I/AIS Sector Head