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SCHOOL OF POSTGRADUATE STUDIES

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HYDROLOGY AND HYDRAULIC ENGINEERING CHAIR

MASTERS OF SCIENCE PROGRAM IN HYDRAULIC ENGINEERING

HYDRAULIC PERFORMANCE EVALUATION AND MODELING OF WATER SUPPLY DISTRIBUTION SYTEM: THE CASE OF KAREWO TOWN, DAWRO ZONE, SOUTHERN ETHIOPIA.

By:

Haile Dubale Bekalo

A thesis is Submitted to the School of Graduate Studies, Jimma university, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering in partial fulfilment of the requirements for the Degree of Master of Science in Hydraulic Engineering.

October, 2021
Jimma, Ethiopia

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Main Advisor: Dr. Dawd Temam (Ass.Prof)

Co-Advisor: Tilahun Haile (MSc)

October, 2021

Jimma, Ethiopia

DECLARATION

I hereby declare that this thesis entitled "Hydraulic Performance evaluation and modeling of water supply distribution system: The case of Karewo town, Dawuro Zone, SNNPR, Ethiopia" is my original work and has not been presented for a degree in any other University. All sources of materials used for the thesis has been duly acknowledged.

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APPROVAL PAGE

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ABSTRACT

Water distribution system(WDS) are critical infrastructure components that supply drinking water over area of the community. Water distribution system(WDS) are designed to provide consumers with a minimum acceptable level of supply in terms of pressure, velocity, availability and water quality at all times under a range of operating conditions. Hydraulic performance is the main criterion to evaluate the efficiency of the water distribution system. The general objective of this study focused on the hydraulic performance evaluation and modelling of water supply distribution system of Karewo town and the specific objectives are to evaluate the existing water supply capacity and demand, to simulate the hydraulic performance of WSDS, to identify the physico-chemical drinking water quality of the town and to evaluate the water supply coverage of karewo town. All relevant primary data collected from the project site and the secondary data has been collected from Dawro Zone water, mine and energy department, Zaba Gazo woreda water, mine and energy office and Karewo town municipal and water utility office. The collected data has been simulated on the combination of WaterGEMSV8i, ArcGIS, Google mapper and AutoCAD software's. The water supply and demand of the town was un balanced because the water supply of the town annually is 134,028m^3 and annual demand is 450,176.4m^3. The hydraulic performance of water supply distribution system was simulated by waterGEMSV8i and the result indicates 5.12% of junction pressures below normal minimum standard 15m and 34.61% is above exceptional maximum standard 70m and 60% is on the range allowable limit. The velocity distribution in the pipe lines result are larger portion pipes has low velocities below 0.6m/s and small portions of the pipe lines has high velocities above the permissible velocity of 2m/s. The laboratory test result of physico-chemical water quality parameters is under the acceptable WHO and Ethiopian standard and dissolved ammonia(NH_3) is above or greater the WHO and Ethiopian guidelines. The water supply coverage of the town in terms of per-capital consumption and level connection was 29.8% and 26.6% respectively.

Key words*: Hydraulic performance, Karewo town, supply and demand, WaterGEMSV8i and water quality.*

AKNOWLEDGEMENT

First of all, I would like to thank God Almighty for his mercy, guidance and protection. Secondly I would like to thank my main advisor Dr. Dawd Temam (Ass.Prof) for his good advising and timely commenting on this Thesis writing and I want to Express my appreciation to my co-advisor Mr. Tilahun Haile (MSc), who advised me how to write and what should I do during this Thesis work time. I have special thanks to SNNPR Water, Mine and Energy Bureau and the laboratory technician Mr. Zerihun Sebsibe for their admittance and helping me to conduct the laboratory tests. Finally, I would like to thank hydrology and hydraulic engineering chair for follow up and best guidance.

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ACRONMY

a.s.l	Above sea level
CAD	Computer aided design
CIWD	Commercial and institutional water demand
DEM	Digital elevation model
DWD	Domestic water demand
DWSN	Domestic water supply network
EC	Electrical conductivity
GIS	Geographical information system
GPS	Geographical positioning system
IWD	Industrial water demand
Mg/l	Milligram per liter
MoWE	Ministry of water and Energy
NTU	Nephelometric Turbidity Units
pH	Power of hydrogen
^{0}c	Degree centigrade
SDGs	Sustainable development goals
TDS	Total dissolved solid
USGS	United states geographical system
WDM	Water distribution model
WDS	Water distribution system
WDN	Water distribution network
WHO	World Health Organization
WSDS	Water supply distribution system
WSSs	Water supply systems
µS/cm	Micro Siemens per centimeter

1 INTRODUCTION

1.1 Background

Water is a natural resource in which all living things cannot exist without getting it. 70% of our earth is covered by water but the world population have a lot of scarcity to access water. Many developed and developing countries face significant shortage of water supply access and it takes time to overcome the problems. In developing countries, the population growth is fast, economic development capacity poor and as result there is a large problem of accessing drinking water(Kassa, 2017a).

Currently accessing safe drinking water to global community is the major problem and on the hand guaranteeing safe drinking water is more crucial for life continuation, prosperity and all human activities and water resources must be used effectively to meet the demand of growing population by considering the limited and decreasing water resource availability. This means consideration of limited and decreasing water resources due to the climatic changes of the world and the economy of the world(Itefa, 2020)

Modern societies rely on complex network of critical civil infrastructure systems such as road networks, water distribution systems(WDSs), sewage networks, oil and gas networks, and electric power systems, among others, which are extensive, often interdependent, and designed for long service life. WDS are among the most essential infrastructure systems necessary for the sustenance of societies(Mazumder *et al.*, 2018).

Water supply distribution network is responsible for delivering water from the source or treatment plant to its customers in the community at permissible pressures and the system consists different type of pipes, valves, storage and service tanks, pipe fittings and junctions(nodes). A water distribution network plays an important role in modern societies being its proper operation directly related to the well-being of population(Anore, 2020).

Water supply distribution system(WSDs) are designed to provide consumers with a minimum acceptable level of supply (in terms of pressure, velocity, availability and water quality) at all times under a range of operating conditions. The degree to which the system is able to achieve this, under both normal and abnormal conditions, is termed its Reliability.

The distribution network can be safely deliver the designed drinking water to the designed community with the expected quality and volume(Atkinson *et al.*, 2014).

Hydraulic performance or level of service provision in water distribution networks is the main criterion to evaluate the efficiency of the water distribution system. The knowledge about the actual network performance during different operating situations is the key tool to control and manage the existing water distribution systems or design new networks. This concept has been expressed as reliability or level of service in the literature. Reliability is the ability of the system to satisfy the required demand under sufficient pressure and velocity during normal and abnormal operating conditions. the abnormal conditions can occur due to pipe failure, outage of pumps, excess of demands, firefighting, leakage, outage of reservoirs(Zia, 2003).

Water distribution system(WDS) are critical infrastructure components that supply drinking water over area of the community. Water distribution system(WDS) should have sufficient capacity to ensure stable water supply in terms of system pressure and service flow. They are mainly designed carefully by using hydraulic models and algorithms to deliver efficient water and to serve for long life time. The different failures occur in the water distribution system are due to inadequate design of pressures and pipe dimensions(Jeong and Kang, 2020).

According to (Khobaragade and Khandeshwar, 2020), the main aim of water distribution system (WDS) is to convey wholesome water to the consumer at adequate residual pressure in sufficient quantity at convenient points. Requirement of good distribution system:

- ✓ Water quality should not get deteriorated in the distribution pipes.
- ✓ It should be capable of supplying water at all the intended places with sufficient pressure head.
- ✓ It should be capable of supplying the requisite amount of water during firefighting.
- ✓ The layout should be such that no consumer would be without water supply, during the repair of any section of the system.
- ✓ All the distribution pipes should be preferably laid one meter away or above the sewer lines.

- ✓ It should be fairly water-tight as to keep losses due to leakage to the minimum.

The expansions of urbanization, population growth, and others are the cause which puts increasing pressure on local water distribution system and water planners to satisfy the growing urban water and sanitation demands in developing countries. According to world health organization (WHO,2014) report, the global drinking water target was 91% in 2010 while central Asia, Northern America, Oceania, and sub-Saharan African countries did not achieve this land mark. The water problem is growing in Ethiopia and that has a great impact on countries economic development. Specially in developing towns of the country there is significant shortage of drinking water supply. Similarly karewo town in southern Ethiopia is a part of this shortage problem(Demeku, 2021).

Modern societies critically depend on infrastructure networks. A good example of these are the water distribution networks(WDNs) that are designed for distributing drinking water among consumers. In aged networks, the quality of this service is strongly affected by the growing demand for water in expanding cities and towns by leaks that occur as the result of the aging of the components the hydraulic system. Water quality control, leakage reduction and pressure management are difficult tasks due to the size of the water and the non-linear nature of the hydraulic system(Bianchotti *et al.*, 2021).

Designing effective water supply distribution network is acritical part of water supply system and which has an important contribution to proper and effective consumption of scarce water resource. Water flowing in WDN undergoes continuous variation in terms of its quality and hydraulic characteristics. Design of water supply system which is performed through technical experts and by the use different hydraulic modeling instruments are crucial for sustainability of water supply schemes(Sonaje and Joshi, 2015).

Nowadays, hydraulic simulation models are widely used for analyzing the behavior of water distribution systems(WDSs). Due to the high degree of uncertainty and to the lack of details of the system, the reliable management may be achieved only the calibration model. The calibration of water distribution models(WDMs) is the process that adjusts network parameters, such as pipe roughness and nodal demand, to minimize the differences between simulation results and real measurements(Zanfei *et al.*, 2020).

The drinking water quality deteriorates the water distribution systems(WDSs) because of problems associated with water age, chlorine residual and influx of contaminants across pipe walls through breaks and cross connections. Increase in water age can cause water quality problems such as multiplication of microbial organisms, chlorine residual decay, bad taste and odour of drinking water(Nono *et al.*, 2018).

Access to safe drinking water and sanitation is a global concern and in developing countries like Ethiopia, have suffered lack of safe drinking water from protected and improved sources. As a result, peoples are dependent on the un protected water sources such as rivers, ponds, streams and open springs and hand dug wells. Since they are open and exposed to atmosphere, they will be attacked by flood, human and wild animal contamination(Meride and Ayenew, 2016).

The human existence is mainly depending on fresh water supply and which is less than 1% of the water available on earth. Ground water or spring is representing an important source of drinking water and its quality is currently threatened by a combination of over-abstraction and microbiological and chemical contaminations. In addition to desertification and industrial development, pollution is also reducing the volume of safe drinking water. The drinking water is safe and pure enough to be consumed to reduce the harm. Compared developing countries developed countries can access pure drinking water which can fulfill WHO standards(Reda, 2015).

Water quality and the risk to the water borne diseases are serious public health diseases in Ethiopia. The world Health Organization (WHO) estimated that around 94% of the global diarrheal burden and 10% of the total disease burden are due to unsafe drinking water, in adequate sanitation and poor hygienic practices. Thus, the provision of safe and adequate water supply and sanitation contributes to better health and increased public productivity(Haylamicheal and Moges, 2012).

Karewo town has a networked water supply distribution system next to Dawuro zone capital Tarcha town. This study aims to evaluate the hydraulic performance of Karewo town water supply distribution system by using the hydraulic modelling tool (water GEMS software) and at the end giving scientific recommendation on the performance of the existing water supply distribution system of the town.

1.2 Statement of problem

The problems generally faced in water supply distribution system includes, losses and wastage of water, water quality reduction, inadequate carrying capacity of pipe lines and over distributed pressure at the ends of distribution system. According to(Hailu Gisha, 2016), people who are not accessed sustainable water with good quality and quantity are forced to use unsafe drinking water from unprotected wells, river and ponds.

Assessment of the performance of urban water supply system is critical to improve the water supply service provision level and the main activities is to determine the gap or to fill the gap between the demand and existing water supply system to analyze the distribution system is working as per the early design or not. Best performing systems should provide safe, sufficient and affordable water supply service, with low water loss and allowable pressure and velocities and good quality of water which fulfills national and international standards(Merga, 2019).

The karewo town water supply system has strongly faced different problems. The most known and critical problem of karewo town water supply system was: inadequate water supply, expanding of pipes in main pressure line, leakages in both pressure line and distribution lines, shortage of storage structure and water sources. This affects the balance between supply and demand. So, it requires the improvement on water supply distribution system to reduce water losses, to balance pressure and velocity and to provide additional reservoirs and sources and to enhance the quality of water. The quality reduction of drinking water was also an issue in the town which results to water borne diseases such as cholera, diarrhea, Pneumonia and giardia prevalence(dawuro zone Health, 2020).

Therefore, evaluating hydraulic performance, water supply and demand of karewo town water supply distribution system and determining the water quality of the town is very crucial to solve the problem. Hence, this study is the initial research in the study area because there is no past study in the study area about the water supply distribution system performance, drinking water quality and other water related scenarios.

1.3 Objective of the study

1.3.1 The general objective

The general objective of this study was performance evaluation and modeling of water supply distribution system of karewo town.

1.3.2 Specific Objectives

- ✓ To evaluate the existing water supply capacity and demand of the town.
- ✓ To simulate the hydraulic performance of the water supply distribution system by using Water GEMSV8i Model.
- ✓ To identify the drinking water quality level on the bases of physicochemical parameters and compare the results with corresponding national and international quality standards.
- ✓ To evaluate the existing water supply coverage of the town.

1.4 Research questions

- ✓ How is the existing water supply serves the demand of the karewo town?
- ✓ What is the hydraulic performance of water supply distribution system of karewo town?
- ✓ Are the physicochemical water quality parameters of karawo town meets the national and WHO water quality standard?
- ✓ What is the current water supply coverage of the town based on existing WSDS?

1.5 Significance of the study

This study mainly helps the Karewo town municipality and water utility office to understand the balance between the supply and demand, the design problems in the system, the water quality of the town and its water supply coverage. It also helps the town to develop an appropriate performance assessment system to evaluate in improving the efficiency of urban water distribution systems. Additionally, this study helps to assess the knowledge limitation and to determine future research areas and needs, to assess and analyze study findings. The findings or results help the town, woreda and zone administrative bodies and decision makers to plan future expansion works and to identify design problems of WSDS and to develop appropriate measures to improve the quality of water, enhance water coverage and efficient service reliability of the town water distribution system. As the initial research of the town, it is used as the basement to another further research.

1.6 Scope of the research

This study is limited to Dawuro Zone, karewo town administration areas and generally focuses on performance evaluation and modeling of the existing of water supply distribution systems by using Water GEMSV8i software. The water quality tests included in this study was physicochemical parameters, mainly (pH, Turbidity, water temperature, Total dissolved solids, Electrical conductivity, Free-Chlorine residual, Total hardness and Iron content) The existing water supply system is different gravity spring with all storage and distribution systems. In this study, on spot spring, hand dug well, bore hole and shallow wells will not be included.

1.7 Limitation of the study

The main challenges faced in this study was a shortage of written filed documents about the system, water consumption reports, previous water quality test reports and water coverage reports of the town. Additionally, also, shortage of skilled man power in the office to get the information clearly about the town water supply system performance and related issues.

1.8 Outline of thesis

Under this thesis work the five chapters are included. The chapter one explains about the general introduction of performances of water supply distribution systems, challenges, limitation and problems of water supply distribution systems. Chapter two about different literatures reviewed, chapter three talks about material and methods used to conduct this research, chapter four refers the result and discussions and finally, chapter deals with conclusions and recommendation of this thesis work.

2 LITERATURE REVIEW

2.1 The over view of water supply distribution system

According to(Berhane, 2020), to provide an adequate amount of potable water with sufficient pressure at the consumers, where the water demand is required namely, the residential, industrial, institutional, and commercial. Several scholars have been optimized the WDS through modified pipe diameters, energy consumptions of the pumps, and the locations reservoirs. As result of this, an optimized WDS should be implemented to minimize the total cost of the project and also satisfies required water flow velocities and pressure on the nodal.

An indication of system reliability can, in principle, can be calculated through the simulation multiple system states under array of different network conditions and configurations. However, this is likely computationally intensive and in feasible if optimal system solutions are being sought. To overcome this limitations, various indicators have been developed that aim to represent reliability. Assessing the key indicators with their advantages and disadvantages in terms of its reliability and vulnerability aspects is important(Atkinson *et al.*, 2014).

The high percentage of the water distribution networks that operate in cities and towns have leaks that cause significant water losses. The current management models of water distribution systems aim to control the main hydraulic variables and ensure that these infrastructures are used efficiently(Pérez-Padillo *et al.*, 2020).

According to(Demeku, 2021), intermittent water distribution is a key problems in developing countries, especially in Ethiopia. Due to this, evaluation of the hydraulic performance of water distribution system, the quality and quantity of water by using the hydraulic modeling is critical to identify the problems and Water GEMSV8i software was an interesting tool used to model the water distribution systems.

The water losses with in the domestic water supply network (DWSN) constitutes a huge problem around the world, in Ethiopia most the water is lost due to different reasons. The Huge investments and loss of domestic water, in water supply network, have brought drastic measures and investments in the water supply management system(Kiliç, 2021).

2.1.1 Water supply sources

In general, the water supply sources for different consumption are surface water and ground waters. Under surface water; rivers, lakes, oceans, surface reservoirs and rain waters are the main sources of water supply. Therefore, selection of appropriate sources of water for urban and rural areas was crucial and also the source is capable of supplying equitable water to the town is must be evaluated(Kondratyeva *et al.*, 2021).

2.1.1.1 Surface water

(Berhe, 2020), stated that rivers, perennial streams, seas and lakes that collects and stores water by forming impoundments. The formed surface water reservoirs are exposed to atmosphere and easily polluted. Making surface water for drinking water supply purposes is difficult and un economical due to treatment cost. But, the sources volume was high and effective to satisfy the demand of the town.

2.1.1.2 Ground water

Aground water is one of the most valuable natural resources supporting human health and economic development. Because of its continuous and improved natural water quality, ground water are the essential sources of water supply in urban and rural areas of the world. In Ethiopia also ground water is the major sources of drinking water supply. It is obtained from aquifers through wells, springs and infiltration galleries that the yields depends on depth, type of aquifer and gradient. Therefore, ground water is the most preferable water supply sources due to economical consideration and water quality(Berhanu and Hatiye, 2020).

2.1.2 Water distribution systems

The main goal of water distribution system is to convey the designed capacity of water from the sources to the intended end users by keeping the important requirements of water quality, water quantity, pressure and velocity. It is also an essential component in water supply system to transport adequate water from available sources to respective customers(Ramana *et al.*, 2015).

Water distribution system has three main components, namely, distribution storage, distribution pipelines and pumping stations. Therefore, water supply system is not thinkable without water distribution system. Drinking water distribution system is Trojan horse for some water borne diseases caused by opportunistic pathogens(Akbarkhiavi and Imteaz, 2020)

According to (Liu *et al.*, 2013) effective design and construction of water distribution is essential for system sustainability and durability. water distribution system quality is also an indispensable requirement for reliability and sustainability purpose. It is also the final and essential step to supply safe and high-quality drinking water to the customers.

2.1.2.1 Gravity water distribution system

According to(Debela, 2021) a gravity water distribution system is distribution of water from the source or from the service reservoirs to end points by gravity. It is distribution safe and potable water from reservoirs located or sources located at high elevation on the ground or above the ground and transmitting water by gravity, that means without use of pumps. It is an economical and sustainable water distribution system, by attaining pressure and velocity without consumption of pumps.

2.1.2.2 Distribution by pumps

Specifically, water distribution system by using pump is the distribution of water from low ground level to the end customers and to service reservoirs by help of pump power. Typically, this is achieved by means of inter-connected elements which are intended with neighbors

that thus the entire water distribution system behavior depends on each of its elements. Therefore, this method used when there is an elevated reservoirs used to maintain the excess water pumped during periods of low consumption, and these stored quantities of water may use during the periods of high consumption(Paluszczyszyn, 2015).

2.1.2.3 Distribution by means pumps without storage

water can be pumped directly into the main distribution lines without transfer water to service reservoir. In this case, the pumping rate should be adequate to fulfill the demand. It is also distributing water from the source to end users without storing and directly delivering water to end consumers. An improvement of direct distribution by means of pumping without storage tank is that a large fire service pump may be used which can run up the pressure to any desired amount allowed by the client(Khatavkar and Mays, 2019)

2.2 The problems of water distribution system

According to study of (Andualem, 2020), the town has the problem of insufficient water supply in quality and quantity and the distribution system has the major challenges on consumptions of water supply. The findings of the study show that the existing water supply has multi-dimensional problems, such as lack of money and fund, the rapid growth rate of the town, loss of water by leakage and lack power to pump. As the result, the researcher recommended that redesign all components of water supply schemes starting from population forecasting up to distribution system.

The study of (Kassa, 2017a), has faced a problem of potable water supply, and also a large number of the did not have access to adequate amount of potable water supply and frequent water interruption is a common problem. The reasons stated for the problems are the WSDS covers only small area of the town, despite the large size of population, insufficient finance to upgrade the system, lack of skilled manpower to maintain the different components of system and low pressure distribution. Re- analysis and correcting of the pressure map of the water by changing the diameter of the pipe and relocating the tanker elevation improves the water supply to reach with adequate pressure to those low pressure areas.

Water supply is an important segment of development. However, in the city, the availability, adequacy and the quality of water are in danger, and the water demand of the city is unmet. The reasons behind are the city population is increasing alarmingly due to internal migration and high population growth rate and also the city is under rapid development and there are enormous construction activities along with rapid urbanization, and industrialization. The study found that prevention of future water shortages requires the implementation of water saving measures as well as the use of new water supplies(Alemu and Dioha, 2020).

The findings of (Anore, 2020), shows that water losses in the study area is as high as 40% of the produced water due to billing error, illegal connection, water theft, leakage during installation and pipe bursting. The population number of the town is increasing from time to time with increasing demand on the existing water supply system of the town. As the result, per capita water supply of the town gets lower and lower.

Natural disaster can cause widespread hydraulic damages and all water quality impacts to water distribution systems(WDSs) as well as a result in extensive service interruptions that can last for days or even months.in recognizing the vulnerability of WSDs under natural disasters, many researchers have started exploring how to minimize the impacts of these events to the WSDs to improve the system resilience when dealing with natural disasters(Zhang *et al.*, 2020).

The new challenges in water systems include different approaches from analysis of failures and risk assessment to system efficiency improvements and new innovative designs. In water distribution networks (WDNs), the risk function is a measure of its vulnerability level and security loss(Ramos *et al.*, 2020).

2.3 Factors affecting the performance of water distribution Network

Performance evaluation is crucial for water supply distribution network to assess the sustainability of the distribution network. The water distribution network must always meet the demands with adequate hydraulic performances mainly, pressure and velocity. But, water supply distribution networks performances in developing countries, mainly Africa was faced different hydraulic performance challenges like, pressure, velocity, water losses and water quality(Naamani and Sana, 2021).

2.3.1 Pressure of water

The WSDSs capacity is influenced by pressure because of the provision of minimum pressure requirement during water distribution system design is customer satisfaction. A low pressure head would not be acceptable and it causes limitation in water distribution to customers. It also results to operation and maintenance problems and additional costs when collapse in pipes, pumps, valves and other components occurred. The pressure in WDSs is at a minimum when the flows and subsequent head losses in the pipes are at the peak demand. On the other hand, the water pressure is a maximum when the flow is at a minimum condition which means at night time and institutions are shut down(mokonnen, 2017). Additionally, the study indicated that the house holds located on the higher elevation and near to the reservoir area have lower water pressure and low water pressure produces a low level of reliability of water beneficiaries on the water supply system.

The larger pressure on water supply systems(WSSs) and the increasing concern for the sustainability of the larger energy use for water supply, transportation, distribution, drainage and treatment are determining a new perspective in management of water systems(Carravetta *et al.*, 2020).

The water distribution network should be designed based on pressure criteria and in accordance with the existing criteria on minimum and maximum pressure in the network. The operating pressures in the distribution network according to ministry of water resources, urban water supply design criterion and the velocities in the distribution network should be also in between in the velocity design standard to avoid the stagnation and water quality problems(Dessalegn, 2021).

2.3.2 Velocity in pipes

The velocity of water in pipes has a standard and water supply distribution system designed to attain a minimum velocity. Low velocities in the distribution network has an importance in delivering water to the customers. Generally, the velocity in water distribution network is below **1m/s** to receive the reduced amount of water by customers. Based on minimum and maximum standard of flow velocity water distribution network of the pipes (0.3 and 2m/s).(Salehi *et al.*, 2018).

The velocity of pipe flow showed that there is the velocity range of <0.6m/s and 0.6-2m/s. that means there is tangible a velocity problem in different section of pipes which caused the stagnation of water in pipes, breakage of pipes at joints and at yard connections. In general, the water supply distribution systems need redesign to overcome pipe velocity and pressure problems(Genetie *et al*., 2019).

2.3.3 Rising of water demand

Rapidly growing urban regions are placing great demand on fresh water resources, and with a warming climate causing increased evaporative demand, urban and regional planning efforts becoming increasingly complex and challenging. Water utility planners have traditionally relied on models that forecast urban water demand as function of socio-economic and environmental factors(Sanchez *et al.,* 2020).

Forecasting the future urban growth and investigating the efficient water supply system to the town is critical to overcome the water supply problems. Urban infrastructures like, WSDS are an indispensable with urban growth. Forecasting urban population for the design of safe and sufficient water supply system is an important aspect and accurate prediction of future water consumption is necessary to create a satisfactory design for a water distribution system according to (Prerna Pandey, 2021).

2.4 Water supply and demand of urban areas

Supplying potable water to urban areas was challenging due to the rapid urbanization and population growth. Rapid urbanization resulting the imbalance of water supply and demand of the consumers. Based on that, developing countries has challenge to address the water supply and demand problems. The main challenges facing in the urban areas are shortage of water sources, lack of finance, man power, topography, population growth and different internal and external issues. But many of developing towns uses underground water sources to solve the water supply problems of the urban areas(Chen *et al.,* 2020).

Sustainable, low cost, environmentally conscious development is a major challenge for urban water supply systems. The urban water supply continues to be secure, robust and affordable as well as ensuring sustainable access to water with adequate quality. Urban Water supply systems are a closed loop hydrologic cycles. Most of the urban areas have a low access to water supply and getting challenge to satisfy the demand of water (Xu *et al*., 2020).

Urban water security is essential to get a resilient environment in smart cities, particularly under the stress of climate change and socio-economic factors. Moreover, cities located close to water resources are driven by all kinds of industries, hence lack of water lack is considered a classic problem for decision makers. Water supply and urbanization are indispensable to achieve the urban development strategies(Zubaidi *et al*., 2020).

A good water supply a town should fulfill two primary requirements, which are adequacy and reliability. Budget constraints, low revenues and shortfalls in operation and maintenance have resulted in insufficient expansion of the water supply system and gradual degradation of the services; at same time the water demand increased and scarcity worsened(Debela and Muhye, 2017).

The water demand of the town increased due to rapid urbanization and population growth, the existing water supply system of the town has a shortage to satisfy the customers demand. The existing system has shortage of storage, sources and pipe velocity and pressure problems faced. The system is also aged and it has frequent breaking in pipes, expanding of pipes and necessary losses are the some of the problems(Kassa, 2017b).

2.4.1 Average daily demand

The average daily demand is the total annual volume of water used is divided to the number of days in a year. The average day rate is used primarily as basis for estimating maximum day and hourly demands. The average rate is used to estimate the future revenues and operating costs(Mekuriaw, 2019a).

2.4.2 Maximum daily demand

The maximum daily demand is maximum quantity of water used in one day the year randomly. The maximum daily demand used to design the size of the reservoirs, treatment plants and pumping stations. A water supply structures deliver adequate drinking water at the maximum daily demand rate(Ketema *et al.*, 2015).

2.4.3 Average per capita consumption

The average per capita consumption has been obtained by summation of a towns yearly consumption which collected from the individual domestic water meters. The annual consumption data has been converted to average daily per capita consumption using the number of population and represented as l/person/day(Zewdu, 2014a).

2.4.4 Per capita water demand

The per capita water demand is the individual water demand in which it is determined based on the standard of the towns development, population size, the social and economic conditions and the water supply scheme type. The towns per capital water demand has been determined based on countries GTP standard for each towns/cities(Amsalu, 2020).

2.4.5 Population forecasting

Ethiopia's Central Statistical Authority (CSA) has been issuing population estimates annually by age and administrative divisions beginning in the 1960s when two national sample surveys were conducted both for urban and rural. Starting in the mid- 1980's CSA based its annual projections on the 1984 population and housing census. There are so many methods for population forecasting such as arithmetic increase method, geometric increase method, incremental increase method, decrease rate method, graphical method, master plan method, and logistic curve method. As a population of the country increases in the future, the present and past population data have to be taken from the census office to determine the amount of population by considering the different growth rates of the country(Adeba *et al*., 2020).

2.5 Hydraulic modelling analysis

Computer hydraulic modeling analysis is a method of predicting the hydraulic gradient pattern, Pressures, and flows across the water distribution network under a given set of conditions. The hydraulic gradient pattern depends upon the magnitude and location of system demands, the characteristics of the pipes in the distribution system, and the flows and gradients at network boundaries such as reservoirs and pumping stations. The head loss through each pipe is a function of flow rate, pipe diameter, length, and internal roughness, known as the "C" value. The available pressure, or head, at any point in the network is the difference between the hydraulic gradient and the ground surface elevation(Stetson Engineers, 2008).

Hydraulic models of WDSs consist of a large number of nodal mass balances and pressure difference–flow rate relationships, with the former being linear and the latter being nonlinear, due to the inherently nonlinear dependence of frictional pressure losses on flow and pump head curves. Hence, when calibrating a hydraulic model, one must cope with anon-linear algebraic equations(Wéber and Hős, 2020).

In the hydraulic modelling analysis, the pressure management is a powerful weapon to manage water pressure in the entire water distribution system. The hydraulic modeling analysis is conducted in different hydraulic modelling software's like, epanet, watercad, waterGEMS and others (Patelis *et al.*, 2020).

2.6 WaterGEMSV8i

WaterGEMSV8i is a hydraulic modeling application for water distribution systems with advanced interoperability, geospatial model building, optimization, and asset management tools. From fire flow and constituent concentration analyses, to energy consumption and capital cost management, WaterGEMSV8i provides an easy-to-use environment for engineers to analyze, design, and optimize water distribution systems. WaterGEMSV8i is a multi-platform hydraulic and water quality modeling solution for water distribution systems with advanced interoperability, geospatial model-building, optimization, and asset management tools. WaterGEMSV8i is useful for managing the water system data, time-series hydraulic result, current and future scenarios and other core infrastructure data all within the same GIS environment(Khobaragade and Khandeshwar, 2020).

WaterGEMSV8i which is used for modelling and simulation of hydraulic parameters in the distribution networks. The hydraulic parameters which is analyzed by waterGEMSV8i software are junction pressures, velocity of water in the networking systems and nodal demands. The software works with integration of AutoCAD and ArcGIS software. The water distribution systems will be analyzed for steady state and extended period simulation for the present population scenarios for intermittent water supply by using waterGEMSV8i(Dessalegn, 2021).

2.7 Drinking Water quality in water supply distribution systems

Drinking water quality refers to the level of water that meets the WHO and Ethiopian drinking water standards. In underdeveloped countries, poor water quality is one of the signs of poverty. However, distributing safe water to the public has been fraught with difficulties. Contamination of the urban water distribution system has a wide range of causes. The most common causes of water pollutants are wastes from faulty sanitation, agriculture, and other activities that find their way into water distribution systems. (Duressa *et al.*, 2019).

Provision of safe and adequate drinking water to the community was the preliminary issue to the government. Assessing qualified drinking water is an essential tool to be healthy community and to make healthy environment. Poor quality of drinking water could be associated with either source of water or inefficiency of the treatment method. Most drinking water in Ethiopia is from surface water and groundwater(Sitotaw and Geremew, 2021).

Drinking water quality deterioration is a big issue in many countries which could be a result many interconnected biological, physical, and chemical factors. The study was evaluated the quality of town drinking water using some bacteriological and physiochemical parameters from sources to house hold tap distribution systems. The results of the most parameters significantly based on sampling time and sampling point. Except the total dissolved solids(TDS) and turbidity, the physiochemical parameters tested for the town drinking satisfies the national quality standard(Garoma *et al.,* 2018)

The water quality deteriorates in water distribution systems (WDSs) because of problems associated with water age, chlorine residual and influx of contaminants of across pipe walls through breaks and cross connections. Increase water age can cause water quality problems such as multiplication of microbial organisms, chlorine residual decay, bad taste and odour of drinking water(Nono *et al.,* 2018).

According to (Nigus, 2021), delivering potable water to all citizens is among the top priorities the government in all nations. The sustainable development goals (SDGs) focuses on ensuring access to water and sanitation for all countries in world have promised to achieve SDGs of WHO. The drinking water will be checked the quality based on WHO and national standards before delivering to the communities.

Drinking water pollution has been a global challenge and poses a serious threat to human health. Drinking water can be polluted at the source, distribution line, and or at the household level, and such polluted water can be vehicles for several pathogens. This problem is severe in poor societies due to mainly lack of awareness about sanitary measures at the different levels(Sitotaw *et al.,* 2021).

2.7.1 Physicochemical drinking water quality

Physicochemical water quality test analyzes the different national and WHO water quality parameters. The parameters have been carried out in physicochemical tests are, pH, turbidity, electrical conductivity, temperature and other water quality standards. The majority of the population in poor nations lacks appropriate access to potable water, forcing them to rely on water from sources such as shallow wells, boreholes, springs, and streams, which are dangerous for residential and drinking uses due to significant contamination risks(Amanial, 2015)

Majority of Ethiopia's population does not have access to safe and reliable sanitation facilities besides insufficient hygienic practices related to food, water and personal hygiene. Accordingly, more than 75 % of the health problems in Ethiopia were due to infectious diseases attributed to unsafe and inadequate water supply, and unhygienic waste management, with human excreta being the major problem. To overcome such drinking water quality problems, physicochemical and bacteriological parameters of water should be tested based on Ethiopian and WHO standards(Bedassa and Desalegne, 2020).

It is very essential and important to test the water before it is used for drinking, domestic, commercial, agricultural and industrial consumption. The quality of water must be tested for different physicochemical parameters. The selection of different physicochemical parameters for testing of water is solely depends upon for what purpose going to use and for what extent need of its quality and purity. Some of the physical tests have been performed for testing of its physical appearance are temperature, turbidity, pH, TDS etc.(DEVANGEE *et al*., 2017).

2.7.1.1 Temperature

The drinking water temperature is an important factor to consider when assessing the water quality, as it is known to affect chemical and microbiological processes with in distribution system. The temperature in water increases as a result of natural volcanic activities and industrial waste discharges. Temperature is a significant element affecting several reactions, including disinfectant degradation and byproduct generation, in the study of the physico-chemical quality of pipe water samples(Zlatanović *et al.*, 2017).

The water temperature changes the solubility constants and can favor the precipitation of different substances and transforms the identities of corrosion products. The water temperature increases when there is the disinfectant increase in demand and by product formation. When assessing the water temperature, the minimum and maximum of Ethiopian and WHO standard have been achieved(Barakat *et al*., 2018).

2.7.1.2 Total dissolved solids(TDS)

Potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates, and other dissolved organic and inorganic mineral deposits or salts are present in drinking water. Water can dissolve a wide range of inorganic and organic mineral salts. There has been no agreement reached on the negative or positive effects of water that surpasses the WHO limit allowed level of 1,000 parts per million (ppm). TDS in drinking water can come from a variety of sources, including sewage and urban industrial waste water. As a result, a TDS test is usually used to monitor water quality(Ahmed *et al*., 2020).

2.7.1.3 Power of hydrogen(pH)

Power of hydrogen(pH) is known as the intensity of acidic or basic character of a solution at a given temperature. It is the logarithmic articulations of hydrogen fixation in water. It is also the acidity and alkalinity of water with respect to hydrogen ion and hydroxide ions. The numerical value range of pH is from 0 to 14. The water with pH value less than 7 is acidic water and greater than 7 is basic solution of water and equal to 7 is neutral water. The pH of most un polluted water lies between 6.5 to 8.5 and it is a significant operational parameter of water quality. Water with low pH value causes erosion in copper pipes and toxic while, high pH value of water has bitter taste which not recommendable for drinking. Therefore, pH value in drinking water has a standard according to WHO and Ethiopian guidelines(Palorkar *et al*., 2020).

2.7.1.4 Chlorine residual

Chlorine is mainly obtained from the dissolution of salts of hydrochloric acid as table salt. Surface Water bodies have low concentration of chlorides compared to ground water. It has also key importance for metabolism activity in human body and other main physiological processes. Treating water storage structures by chlorine is important for protecting and killing of water borne diseases. Therefore, chlorine residual is used as a disinfectant and it has less purchasing cost, easily available, effective and easily treated in field and laboratory. The water supply components like distribution system, reservoirs and tanks, house water storing components are also treated by chlorine residual(Duressa *et al.*, 2019).

2.7.1.5 Total hardness

The total hardness of water depends up on the amount of calcium and magnesium salts or both. The total hardness of drinking water having the magnesium, calcium and bicarbonates can be treated by boiling. It is also removed by the chemical precipitation using the lime and sodium carbonate. It is commonly measured as calcium carbonate (CaCO3) because it contains largely calcium and carbonates which are the most dissolved ions in hard water. Public suitability of the degree of hardness of water may be different considerably from one community to another. The degree of hardness of drinking water is important for aesthetic acceptability by consumers, for economic and operational consideration(Desye *et al.,* 2021).

2.7.1.6 Turbidity

Turbidity is an extremely important indicator that can yield valuable information quickly, relatively cheaply and on an ongoing basis. It is caused by suspended chemical and biological particles can have both water safety and aesthetic implication on drinking water supplies. Turbidity itself doesn't always represent a direct risk to public health; however, it can indicate the presence of pathogenic microorganisms and be an effective indicator of hazardous events throughout the water supply system up to point use. Turbidity can be easily, accurately and rapidly measured, and is commonly used for operational monitoring of control measures in included in water safety plans(WSPs) recommended by WHO guide lines of drinking water quality(WHO, 2017)

2.7.1.7 Electrical conductivity(EC)

The electrical conductivity is an estimation of the capacity of water to direct power. It is used to measure the ability of aqueous solution to carry the electric current. Some of the electric currents are concentration of ions, valence, temperature and mobility. Water with low salt levels, for example, refined water conducts power in adequately, while water with high salts levels, for example, sea and ocean water conducts power adequately(Fathi *et al.,* 2018). Saltiness in this way an estimation of the measure of TDS present in the water.

Electrical conductivity(EC) in drinking water causes an aggravation of salt and water balance in babies, heart patients, people with hypertension and renal sickness. Clean water is not a good electrode of electric current rather a good heat proofing and increase in ions concentration improves the electrical conductivity of water. Therefore, the WHO and Ethiopian guidelines about electric conductivity specified the standard and the drinking water of electric conductivity should not be greater than 50 to 1500µ mhos/cm(Yilma *et al.*, 2019).

2.7.1.8 Iron concentration(Fe)

Iron is the fourth most abundant element by mass in earth crust and in water, it mainly occurs in ferrous or ferric state. Iron in surface water generally occur in ferric state. It is an essential and non-conservative trace element found in significant concentration in drinking water because of its abundance in earth's crust. It also presents in ground water in the form of ferric hydroxides. Shortage of iron causes a disease called anemia and prolonged consumption of drinking water with higher iron content results in liver disease called hemorrhoids. Therefore, the drinking water should contain the recommendable amount of iron content according to WHO and Ethiopian guidelines(Mebrahtu and Zerabruk, 2011).

2.8 Water supply coverage

In evaluating the water supply coverage, the focus was on the volume of consumption and level of water connection as these are highly related to the issue of water loss. After evaluating the distribution of water supply coverage in the town, the water loss from the distribution system of the utility was analyzed(Zewdu, 2014b).

Water supply coverage provides a picture of the water supply condition or situation of one country, city, town and other rural and urban areas and it helps to compare one country with others, and the inter and intra city distribution with in specific countries. To identify the coverage, the percentage of population with or without piped water connections are an important indicator to evaluate the coverage in urban areas(BEYENE, 2020).

Water supply coverage of the town reflects a picture of the water supply system condition of the specific country or city and also rural areas and helps to compare one country with others. Water coverage is an important tool for decision makers to upgrade the water supply systems in the town/city. That means to identify the accessibility problems of piped water supply system the specific areas of towns/cities(Woldesenbet and Kebede, 2021).

The minimum quantity of 25 liters of potable water per person per day provided at a minimum flow rate of not less than 10 liters per minute with the source being available within 200 meters to form a household. In addition, the supply not interrupted for more than seven days per year (i.e. water should be available 98% of the time) is considered as a basic service for southern African cities' domestic water supply. In Ethiopia, the minimum quantity of urban water supply is 40 liters per capita/day within a distance up to 250m. However, the recommended quantity is different from each other depending on their activities and development(MOWIE, 2015).

3 MATERIALS AND METHODS

3.1 Description of the study area

Karewo town is the capital of Zaba Gazo woreda in Dawro zone and the town is located far from the country capital Addis Ababa 535km via Jimma chida road and 365km from southern capital Hawassa. Also it is located at 62km from Tarcha town, the capital of dawro zone. It has an elevation of 1749m a.s.l and latitude and longitude of 7°07’36’’N and 37°17’31’’E respectively. The average surface area of the town is above 1112 hectares and has total population of 15417 based on data of (Dawro Zone, 2019).

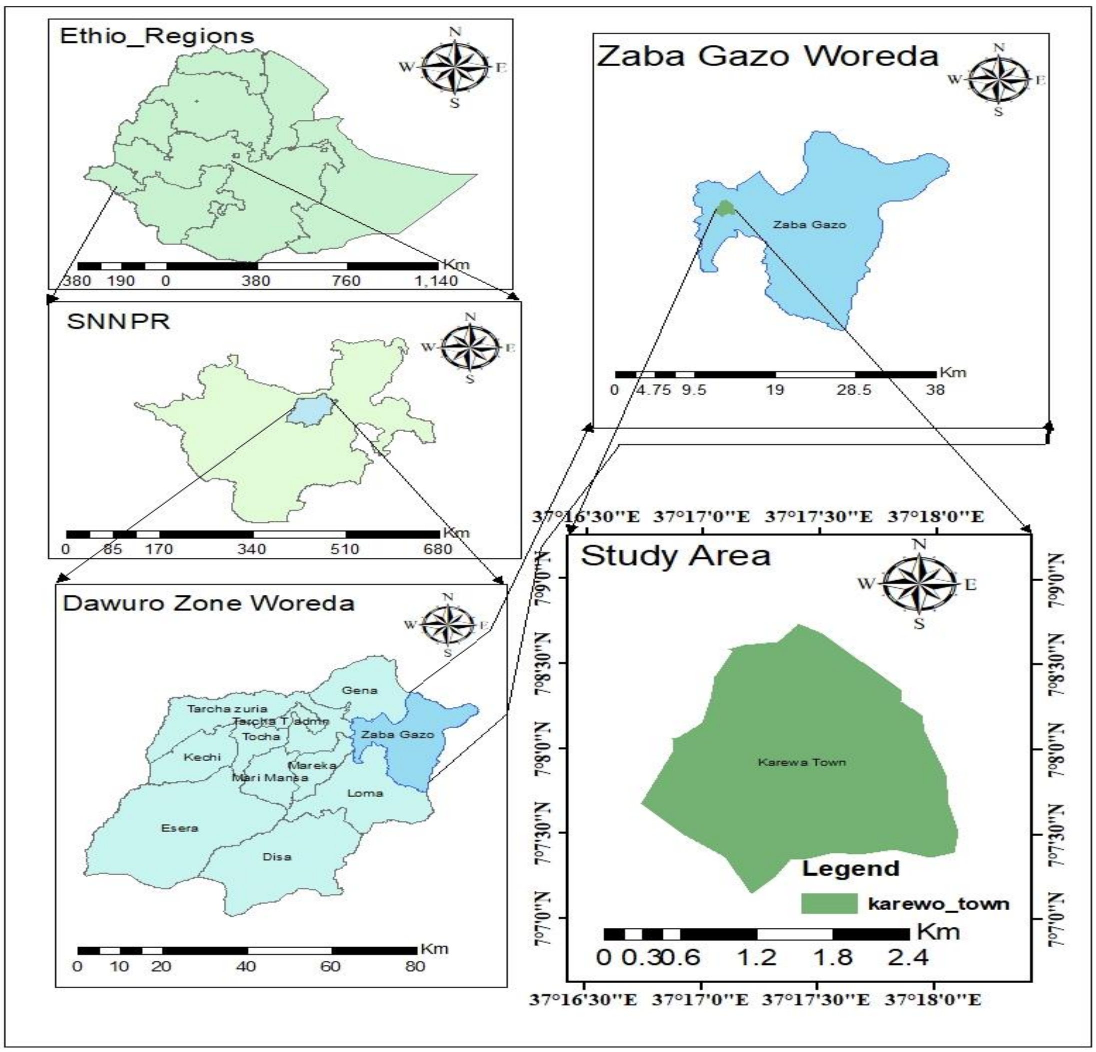

Figure 3.1 Study Area Map

3.1.1 Topography and climate condition of the area

Karewo town has one administrative and two plan area kebeles. The administrative kebele is karewo ediget and plan area kebeles are Gazo and Bara kebeles. The town consists of four local villages mainly, Action aid, Gebeya mender, Arenguade mender and Adebabay mender. Topographic feature of Karawo town was mainly manifested by somewhat rugged and gentler slope with some plain areas. Since the town is located at southern part of Gazo ridge & the area is highly exposed to surface erosion and it needs intensive water shed management. The average elevation of karawo town is 1749m above mean sea level and due to this the town is categorized as woiena dega agro- climatic condition.

3.1.2 Geological condition

The whole project area and its immediate vicinities are characterized by volcanic rocks of welded tuff, rhyolite and basaltic rocks. These types of rocks are part of the Cenozoic, particularly tertiary, volcanic rocks, which constitute the region. Outcrops of the rocks are observed near the project site, on the riverbanks and in the road cut. The rock unit is dark-to-dark grey in color, fine grained in size, and fractured. It is also affected by weathering and the rocks are discolored.

3.1.3 Hydrogeology

According to (Dawro Zone water, 2019), the hydrogeology of the area is determined by geologic, topographic and hydrologic condition of the area. The most important lithologic units in the area are the tertiary volcanic with jointed, fractured and weathered sections. They have in general a good productivity with fracture permeability as observed in the field visit. Open fractures in volcanic rocks are good potential ground water conduits of perennial gravity springs and wells.

Much infiltration is expected in the mountains portions of the catchments and recharged the fractured aquifer and then it gives its stored to topological low areas. The ground water is stored within weathered and fractured part of the rock horizon.

3.2 Tools and Materials

3.2.1 Tools

The tools that has been used in this study are listed and described in the table.

Table 3.1 Tools and their description

Tools/software	Description
Water GEMSV8i	Used for simulation of data's
Arc GIS	Used for overlapping the topographic map of the town and to delineate the study area from google earth.
Google mapper	Used for converting watergemsv8i drawn layout to open and show in google earth and also to find the elevation of each nodes.
Google earth	Used to display the water watergemsv8i drawing on the town map to identity the x,y,z coordinates.
Auto cad	Used for overlapping the map the town and to include the un included town area on the topographic map
Microsoft excel	Essential in the calculation of water demand on each nodes and to draw different graphs and charts
Microsoft word	Used for documentation

3.2.2 Materials

The different materials have been used in this research work are listed and described in detail below table.

Table 3.2 Materials and their descriptions

Materials	Description
GPS	Used to collect the geographic coordinate points of the distribution system
Pressure gauge	To measure pressures in each nodes
Plastic bottles	Used to collect samples of water for laboratory test
Conductivity meter	To determine pH value, TDS and EC values
Titration meter	To determine hardness
Spectrophotometer	For determination of iron content
Turbidity meter	To determine turbidity in the water
Chlorine test meter	For free chlorine residual determination

3.3 Methods

3.3.1 Data collection method

To conduct and analyze any type of researches, primary work has been collecting relevant and important information about the particular study area. Under this section the different type of data and sources of data which is used in the study was discussed below.

3.3.1.1 Primary data

Primary data is the data gained from the field of the study area and topographic surveying is used to identify the existing performance of the water supply distribution system. The data used in this study are:

- GPS coordinates of the distribution systems and they are:

- ✓ Springs data
- ✓ Reservoir data
- ✓ Valve chamber data
- ✓ Junctions
- ✓ Water points
- Measuring the dimensions and condition of retaining wall
- Measuring the pipe line length
- Taking samples from different points to test the water quality

3.3.1.2 Secondary data

Secondary data for this study will be gathered from the different stake holders and documents. The relevant data collected in this section are:

- ✓ Population data of the town and households which is gained from plan and development office
- ✓ Map of the town from zone urban development department
- ✓ House to house connection data from town water utility office
- ✓ Pipe data which is diameter, pipe age and type of pipe (from Dawuro zone water, mine and energy department).
- ✓ Reservoir capacity
- ✓ Springs data
- ✓ DEM data from USGS Earth Explorer

3.3.2 Water supply and demand analysis of karewo town

Water supply is the delivering water from the existing water supply system based on the capacity of the system and consumed by currently by the customers. But water demand is the need of water for different consumption purpose to satisfy its water demand. Water requirement capacity increases due to population growth and it is a problem of extending demand assessment and proper water supply scheme implementation efforts. Therefore, water demands are a huge challenge in urban areas of developing countries(Debela and Muhye, 2017) and in Ethiopia, especially in Dawuro zone karewo town is the victim.

The water supply and demand of karewo town were evaluated determined by the use of the data's collected by town water utility office. These collected data are annual water consumption of the town billed/measured and annual water demand of the town calculated based on the average per capital demand of category five towns/cities standard of Ethiopia. The annual billed data is the summation of individual water consumption of the customers having water meter and consumed of the year 2021 due to the measurement. Average per-capital water demand is the water demand of the individuals in a day in towns/cities and based GTP-II of MoWE (2016), karewo is category five town and Average daily water demand is 40l/c/day. The per-capital consumption determined based on population of the town, mode of services and socio-economic factors.

Per-capital consumption (l/c/day)= $\frac{annual\ water\ supplied}{total\ population}$ − − − − − − − − − − − − − −3.1

3.3.3 Population Forecasting

From different methods of population forecasting, geometric increase method was selected for the study area because it fulfills the criteria that are stated in this method. Hence, in this method the percentage increase is assumed to be the rate of growth of the town under considerations. It is mostly applicable for growing towns and cities having relatively high economic activity has observed and at the same time continuous expansion of town due to various reasons was experienced like opening of Karewo technic college, karewo primary Hospital and other plans to open small industry in the town.

According to the study of (Mekonnen, 2018), the percentage increase in growth rate of population from decade was constant and the base population has been obtained from previous census report. Based on the study of (Aryal, 2020) and (Mekuriaw, 2019b), they forecasted the annual population growth by using geometric methods. This method expressed by the formula,

$Pn= Po(1+k)^n$ ---3.2

Where: Pn is number of population at n^{th} year, Po is the initial population K is the population growth rate and n represents number of decades/years. Therefore, the Dawuro Zone Finance and Economic development department and Dawuro zone water and Energy department forecasted the current and future population based on the Census report of 2007.

3.3.4 Base water demand data collection

The base water demand data estimation was important to distribute the water delivered from the reservoirs via distribution network and to make equitable distribution to the customers in the town. Base water demand estimation in each node in the distribution network follows the following ways:

1. Determining the total population number of the town

Total population number determination of the town is important to evaluate and determine the water demand of the town and also to adjust the nodal demand in the water distribution network. The population of the town was determined by population forecasting of different methods. Determining the total population of karewo town in this study was important to calculate nodal water demand, average daily demand, maximum daily demand, average per-capital consumption and water coverage of the town. The total population of karewo town is determined by the population forecasting method of geometric increase and the initial population was taken from Zaba Gazo woreda plan and economic development office. The data was 2007 census report and forecasted to the year 2021 and the forecasted result of the karewo town population was 15,417. Therefore, starting from this result base water demand is adjusted/assigned to each node.

2. Determination of number of blocks and houses around each junctions/nodes

The determination of number of blocks and houses was obtained from karewo town topographic map which found in the Dawuro zone urban plan and construction department. The topographic map was drawn by AutoCAD and exported to waterGEMSv8i software and the topographic map is displayed in waterGEMSv8i software and shows all blocks and houses in the town. Additionally, to cross check the topographic map drawn by AutoCAD and exported to global mapper was essential to identify the ground information of blocks and houses in the town by displaying on google earth. Then drawing the distribution lines and simply counting the blocks and houses manually around each node/junctions.

3. Assigning and adjusting the number peoples in each junctions or nodes in distribution system

When determining of peoples in houses, the average number of persons in each house was found from the municipality of the karewo town and in each house have peoples assigned and taken was five (5) in number which means five peoples live averagely in home. The total number of houses in the town was identified by counting from the topographic map which was displayed on ArcMap. Therefore, in Microsoft Excel sheet, all the nodal junctions in the system and the number of peoples of node were calculated by using the following formula.

Number of people for individual node=average people per house*number of houses around the node---3.3

4. Adjusting average day demand of karewo town

The Average daily water demand of karewo town was calculated as average per-capital consumption based on annual water supplied and consumed by the customers and total population of the town. Therefore, by the formula stated in equation 3.1 average per-capital water consumption was calculated. After calculating the average per-capital water consumption, the average water supplied and consumed was founded by multiplying the per-capital consumption by total population of the town.

Average water demand (Qav)= per-capital consumption*total population of the town---3.4

Where, Qav is the total volume in liter(l)

5. Assigning base demand on each junction/node

Using the value determined for per-capital consumption and total population on each water supply nodes/junctions, the base water demand of each was calculated.

Base water demand at each node=per-capital consumption* population at each nodes---3.5

3.3.5 Data processing

The collected data will be processed by the help of WaterGEMSV8i software and ArcGIS software. In the processing of data to conduct the study, the procedures will be followed are:

- ✓ Preliminary data collection
- ✓ Building of model in the WaterGEMSV8i
- ✓ Assigning of water demands to each node
- ✓ Hydraulic modelling by using WaterGEMSV8i

3.3.5.1 Modeling a water distribution system by using WaterGEMSV8i

WaterGEMSV8i is a hydraulic simulation software, distributed by Bentley systems. Once the spatial model is built, the parameters which is defined for each model components include:

- ✓ Pipes: Pipe lengths, diameters and the friction coefficient factors. By default, WaterGEMSV8i considers the pipe material as ductile iron having a Hazen William friction coefficient factor of 130
- ✓ Nodes: base demands and elevations
- ✓ Tanks: Base Elevation, the minimum and maximum levels, diameter of the tank
- ✓ Pumps: The most important parameter defining the pump operation is the pump curve. Other input needed is the elevation of the pump
- ✓ Reservoir: Elevation

The all discussed parameters required to run the simulation are interned in to model, the successfully simulated results provides the following solutions:

- ✓ Velocities in the pipes
- ✓ Flows at every point of time in the system
- ✓ Pressure at every single point in the system
- ✓ The tanks level
- ✓ Pump cycles
- ✓ Water age and constituent concentrations

Additionally, it has the capability of performing the analysis of the system for the steady state scenarios and for an extended period of any length. The other capabilities of the software are as follows:

- ✓ Evaluate the hydraulics for different demands at a single node with varying time patterns
- ✓ Solve for different frictional head losses using Hazen-William, Darcy Weisbach or the Chezy- Manning equations
- ✓ "Can determine immediate inefficiencies in the system" (Haestad Methods 2003)
- ✓ Determine fire flow capacities for hydrants
- ✓ Model tanks, including those which are not circular
- ✓ Model various valve operations
- ✓ Provides control based operations
- ✓ Perform energy cost calculations
- ✓ Model fire sprinklers, irrigation systems, leakages and pressure dependent.

According to (Tomas *et al*., 2003), the networks of different interrelated hydraulic elements is affected by each of its vicinity elements; the overall system is interrelated by such way that a condition of one element must be dependent on the condition of other of elements. Therefore, these way of condition are specifically solved by the Law of conservation of mass and law of conservation of energy.

A. Law of conservation of Mass

The law of conservation mass, states that the fluid particle or mass entering to the any type of pipe will be proportional to the fluid leaving the pipe. It is also known as a fluid in a hydraulic system neither created nor destroyed. In the case of distribution network modeling, the all outflows are the collected sum at the nodes/junctions. Which is also known as inflow is proportional or equal to outflow(Tomas *et al*., 2003). It is stated mathematically below.

ΣInflow - ΣOutflow=0--3.6

Which means

ΣQi-ΣQo=0, Where, Qi is the inflow water in pipes/junctions(V/T)

Qo is the outflow of water in pipes/nodes/junctions(V/T)

(V/T) is the volume of water per time consumed.

B. Law of conservation of energy

The law of conservation of states that the energy difference or head loss between two points of pipes are constant or the summation of energy between two points is zero. It also known as Bernoulli's equation(Tomas *et al*., 2003). The formula of Bernoulli's equation is stated below.

$Z_{1+}p/\gamma+v_1^2/2g+\Sigma hl_1=z_2+p/\gamma+v_2^2/2g+\Sigma hl_2$---3.7

Where,

Z1 is elevation difference(m) at section 1

P is pressure($m/l/t^2$)

γ is fluid specific weight($m/l/t^2$)

g is gravity constant(m/s^2)

v velocity in (m/s)

hl is head loss(m)

3.3.5.2 Capability of watergemsv8i model

According to(Darshan and Mehta, 2017) WaterGEMSV8i is the hydraulic modeling application for water distribution system with advanced interoperability, geospatial model building, optimization, and asset management tools. From fire flow and constituent concentration analysis, to energy consumption and capital cost management. Thus, it provides an easy-to-use environment for engineers to analyze, design and optimize water distribution system which is a multi-platform hydraulic and water quality modeling solution for distribution systems with advancements.

Watergemsv8i software provides a friendly interface for engineers to analyze, design and water distribution systems. The software also manages water system data, time series-hydraulic results, current and future scenarios and other core infrastructure data all with in the same GIS environment. In addition, the software easily communicable with other software like global mapper, AutoCAD 2007 and google earth to operate different works to conduct the study(EKWULE and UTSEV, 2019).

The main reason for the selection of watergemsv8i software for this study was its versatility, easy to operation and simulation, superior capability for adaption of GIS environment and model building capacity. Utilities and consultants can share a single dataset using different interfaces, and modeling teams can leverage the skills of engineers from different departments. Engineers can flatten learning curves by choosing the environment they already know and provide results that can be visualized on multiple platforms Water GEMS' ArcGIS interface allows GIS professionals to leverage ESRI's geodatabases architecture to guarantee a single dataset for modeling and GIS(Wadekar *et al*., 2021).

Table 3.3 Comparisons of different Hydraulic Models

S.NO	Scenarios	WaterGEMSV8i	WaterCAD	Epanet
1	Ease of use	Yes	Yes	No
2	Hydraulic elements	Yes	Yes	Yes
3	CAD and GIS interoperability	Yes	No	No
4	Advanced hydraulic features	Available	Not available	Not available
5	Demand allocation based population	Available	Available	Not available
6	Works inside of ArcGIS and includes Darwin calibrator	Available	Not available	Not available

(Source: Bentley, 2015)

3.3.5.3 Data simulation method

The term simulation specifically refers to the process of imitating the behavior of one system through the functions of another. It can be used to predict system responses to events under a wide range of conditions without disrupting the actual system. Using simulations, problems can be anticipated in proposed or existing systems, and can be evaluated before time, money, and materials are invested in a real-world project(Dessalegn, 2021). As their study the basic type of model simulation method in water distribution networks are:

- **Steady-state simulation**: represent a particular view of point in time and are used to determine the operating behavior of a system under static conditions. It computes the hydraulic parameters such as flows, pressures, pump operating characteristics, and others by assuming that demands and boundary conditions were not change with respect to time.
- **Extended-period simulation**: are determine the dynamic behavior of a system over a period of time, and it analyze the system on assumption that the hydraulic demands and boundary conditions were change with respect to time. For conducting this study, the extended- period simulation type will be used.

Creating of the model in waterGEMSv8i

It is the building of a hydraulic model in waterGEMSV8i. This will be done by opening the software and adding the town land use map which exported from AutoCAD and finally drawing the network components by clicking on the required elements and drawing up to the known points. It includes the following processes: Sketching all the components of distribution networks on WaterGEMS software, assigning base water demands to each node: to assign base demand to each supply node, it is necessary to know the houses around each supply node. It is a multi-step procedure, includes: Identification of houses around each supply node: This will be done counting the number of house from the land use map of the karewo town.

Hydraulic modeling in waterGEMSV8i

It includes the setting of elevation for ground water well and spring sources, setting pump data, assigning the base demand to each node, assigning roughness coefficients to the pipe lines and assigning demand patterns and finally computing the results.

For the calculation of head losses Hazen-William equation will be used.

$$HL=10.68L\frac{(Q^{1.852})}{C^{1.85}D^{4.87}} \quad \text{--} 3.8$$

Where: -

HL: Frictional head loss through the pipe

L: length of the pipes

Q: Flow rate through the pipe

C: Hazen Williams roughness coefficient

D: Diameter of the pipe

C values depends on the type of pipe material. The value for GI pipe 120 and for HDPE pipe 150 will be used in the calculation.

WaterGEMS has an engineering library where different factors of friction used for different pipe. Hazen-Williams equation for determination of head loss will be used why it is the most widely used equation to determine friction loss in pipe especially when the liquid is water.

Assigning demand patterns

The components tab has an option called ‘Patterns’ which opens the pattern manager window and it helps to create water usage patterns based on daily, weekly and monthly use. For maximum hourly demand, a multiplier of 5 have been used.

3.3.6 Physico-chemical Water Quality Assessment

Water quality assessment is the evaluation of the chemical, physical and bacteriological characteristics of water. It is most frequently used by reference to a set of standards against which compliance can be assessed. Drinking water starts its journey with in its catchments, and is subsequently purified at treatment plants and delivered through the distribution systems. Before delivering to distribution system, the water quality must met the highest quality standards in terms of supporting beneficial uses or meeting its environmental standards in order to get potable water, which is the suitable for drinking purpose and purposes(Sitotaw *et al*., 2021).

The safe drinking water quality should fulfill the WHO and Ethiopian standard of drinking water. The quality evaluation will be performed by taking samples from different points of the water supply distribution system which is exposed to quality problems. Therefore, this study mainly focused on physico-chemical water quality assessment and covered the physico-chemical parameters. The samples for this study was taken from:

- ✓ Sources
- ✓ Reservoirs or tanks
- ✓ Public water points
- ✓ House to house connection

After collecting all the samples, testing the quality of water in the laboratory with respect to its WHO and national standards and the result was discussed in detail.

Table 3.4 WHO and Ethiopian guidelines of water quality

WHO and Ethiopian guide lines values of drinking water	Parameters	WHO standard	Ethiopian standard
1	pH	6.5-8.5	6.5-8.5
2	Turbidity	<5 NTU at disinfection point	<5
3	Free chlorine residual(mg/l)	0.2-0.5 at distribution	0.1-0.5
4	Hardness	300mg/l	300mg/l
5	Electrical conductivity	2000µS/cm	2000µS/cm
6	Temperature	25^{o}c	25^{o}c
7	TDS	1000mg/l	1000mg/l
8	Iron	>0.3mg/l	0.3mg/l

(Source: http://www.lenntech,2012)

3.3.6.1 Sampling and testing of physico-chemical parameters

Sampling for physico-chemical water quality parameters was conducted by collecting the samples of water from different sources. The samples were taken from two reservoirs, public water point and houses to house connection. Therefore, these were tested in the water quality laboratory of southern Ethiopia water, mine and energy bureau, Hawassa and finally the laboratory results are evaluated based on Ethiopian and WHO guidelines.

The physico-chemical parameters were tested by different instruments and some of the instruments used for testing the parameters are pH-meter, conductivity meter, turbidity meter, titration method, spectrophotometer, residual chlorine test method and other supportive materials were used.

3.3.7 Water supply coverage

The water supply coverage of the town will be determined based on the average per capita consumption of water and mode of service delivery. The average per capita consumption will be derived from the yearly consumption and that will be aggregated from the individual domestic water meters. Besides to average per capita water consumption, the distribution of number of domestic mode of service will be also evaluated. The statistical analysis was used to evaluate the supply coverage for the entire town(Nigus, 2021). As his study the water supply coverage of the town will be calculated as:

$$\text{Water supply coverage}=\left(\frac{annual\ production}{annual\ demand}\right)*100 \text{ ---3.9}$$

Water supply coverage also evaluated based on level of connection to the customer's house or connection per individual family. Therefore, identifying the connection level of water meter per family helps to determining the water supply coverage of towns/cities. Accordingly, karewo town water supply coverage determined additionally by level of connection per family method. In this method, the individual water meter connected house, institution and other public service center data collected from karewo town water utility office. Mathematically, the method represented as:

$$\text{Level of connection(\%)}= \left(\frac{number\ of\ connection\ in\ the\ town}{total\ number\ houses\ in\ town}\right)*100 \text{ ------------------------3.10}$$

Finally, based on the two methods represented above helps to determine water supply coverage of the town and also karewo town water supply coverage determined and evaluated by this method.

3.4 Flow chart

In this flow chart the necessary methods used to conduct the study.

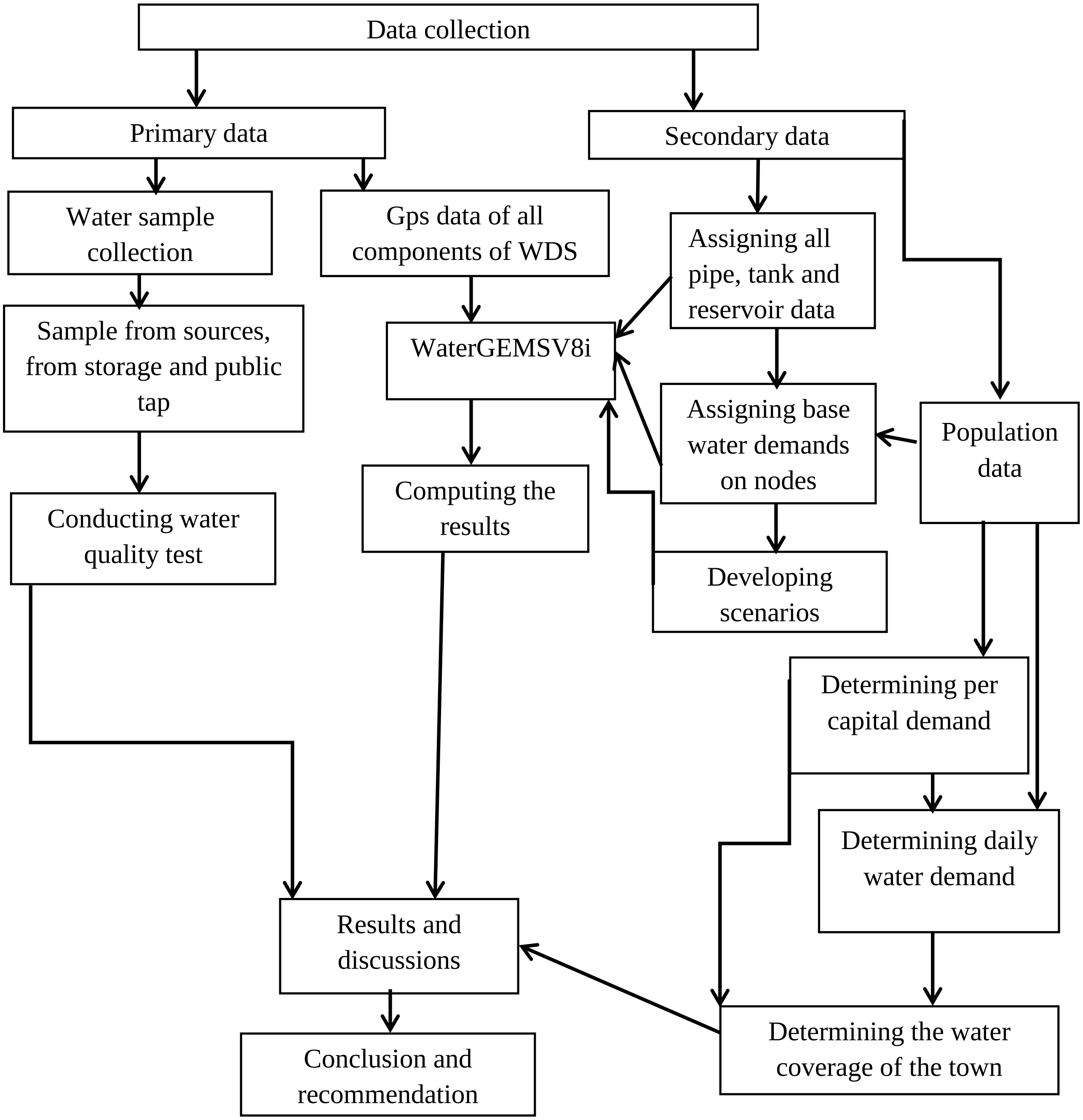

Figure 3.2 Flow chart

4 RESULT AND DISCUSSION

4.1 Karewo town water supply systems

The karewo town water supply system is composed of different gravity spring sources, reservoirs, tanks and pipes. The sources of water supply are three gravity springs located in the highest portion of the surrounding kebele and supply the water to the town by the gravity. The distribution network type is branched system and mostly used in developing countries, especially in Africa. The water supply system of the town is constructed and commissioned by the collaboration of action aid Ethiopia and SNNPR water resource bureau since 2017 G.c.

Figure 4.1 Karewo town topographic map and water supply network

4.1.1 The source of water for the town

The source of water for karewo town is an underground water, which is gravity springs. The three gravity springs are located at near the town. The springs found in Gazo kebele of Zaba Gazo woreda at the mountainous area of karewo town. Mountainous area of the town has numerous perennial gravity springs but only three springs are capped and supplied to the town by the gravity flow system. The three springs has collected discharge of 5l/s and the perennial gravity springs are flowing 24 hours and the total daily discharge is 432m^3/day. But due to shortage of storage structures 15percent of the discharge from the source is removed as wastage by the help of overflow pipe from reservoirs.

4.1.2 The storage structures of the town

The karewo town water supply distribution system has three sandwiched masonry reservoirs. Three of them located different places of the town. The geometry of the reservoirs was circular and the places where the reservoirs located are at the high school, on the compound of action aid Ethiopia office and at the orthodox church of karewo town. All the three reservoirs have water storing capacity of 100m^3.

Table 4.1 Table 4. 1 The existing reservoirs information

No	Site name	Capacity in m^3	(GPS) Coordinates points		
			Northing	Easting	elevation
1	high school	50	311753	789027	1820
2	Dinku garden	25	311496	788970	1807
3	Orthodox church	25	310159	788229	1797

Figure 4.2 Sample figure of service reservoirs

4.1.3 The pipelines of the town

Pipes the essential component water supply distribution system which is used to deliver water from the source to the end users. In karewo town, there are different type and diameter of pipes are used in the water supply distribution network. The types of pipes used are GI pipes and plastic Hdpe pipes with different diameters in different places. The GI pipes are used at highest pressure areas from the source to the reservoirs and from one reservoir to another reservoir. The total installed length of pipelines in the karewo town are 11.73km including GI and Hdpe pipes. The length and diameter of distribution pipelines are shown briefly in the below table.

Table 4.2 Existing Pipe line information

No	Diameter (mm)	Length (m)	Type of pipes used	
			GI	Hdpe
1	90	428	-	428
2	75	959	894	65

3	63	790	-	790
4	50	2601	-	2601
5	32	3669	264	3405
6	25	3283		3283
Total	-	**11730**	**1158**	**10572**

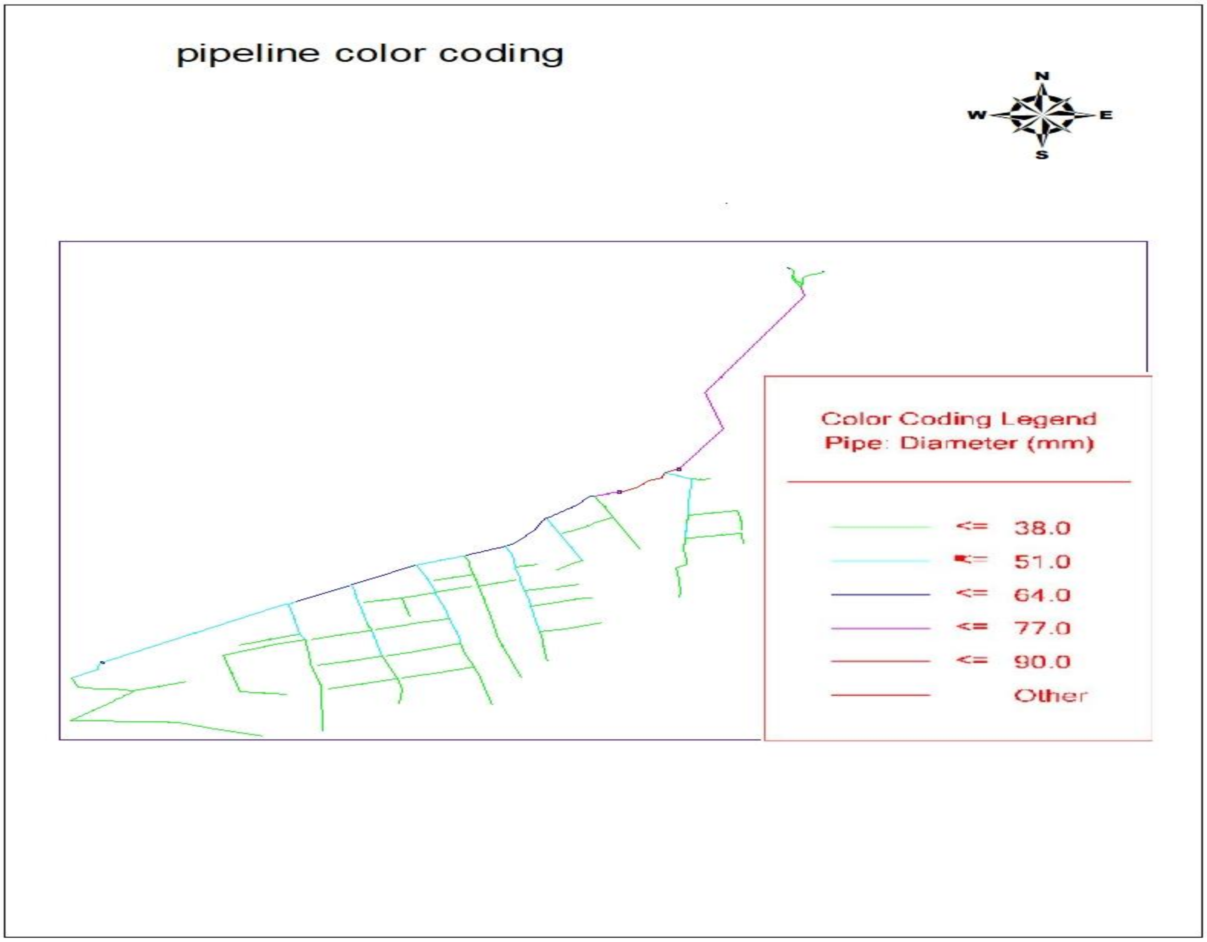

Figure 4.3 Color coding of pipe line simulated from software

4.2 Water supply and demand of the town

4.2.1 Population forecasting of the town

Population forecasting is an important way to estimating present and future population size for different design purposes. In this specific work, population forecasting helps to determine water supply and demand of the town. The methods of population forecasting are arithmetic mean method, geometric mean method and exponential methods and others. Fore rapidly growing population, geometric increase method is preferable. Karewo town is fast growing town and its population size also increasing rapidly. So, geometric increase method is selected for prediction of karewo town population forecasting. The total population of karewo town in 2007 was 7890 according the repot of census (Dawro zone finance department, 2012). The regionally allocated annual growth rate of karewo town obtained from Dawuro zone finance report for 2021 was 4.9% and the projected population is 15,417.

In geometric increase method

$$Pn=Po(1+k)^n$$

Where,

Pn is number of population at the n^{th} year

Po is current population in the initial year

K is the geometric growth rate, and n is number of years.

Table 4.3 Population Projection of Karewo town

Year (Gc)	2007	2017	2021	2027
Population	7890	12730	15417	20,540

4.2.2 Domestic water demand of the town

The domestic water demand is the daily water requirement of an individual for different domestic consumptions, like drinking, bathing, cooking, sanitary services and others. The domestic water demand required by human being can be supplied or obtained through different modes of services depending on the economic level and facilities owned by the individual.

According to (MoWE, 2016), The Federal Democratic Republic of Ethiopia government GTP-II planned to provide urban water supply access of minimum service level of 100 l/c/day for category–1 towns/cities (greater than 1,000,000), 80 l/c/day for category-2 towns/cities (100,000 -1,000,000), 60 l/c/day for category-3 towns/cities (50,000 - 100,000), 50 l/c/day for category-4 towns/cities (20,000 - 50,000), up to the premises and 40 l/c/day for category–5 towns/cities (less than 20,000) of the urban population will provide safe and potable water. Therefore, the current population of karewo town is less than 20,000 and found in category-5 towns/cities and the domestic water demand of 40l/sec.

4.2.2.1 Average Per-capital water demand

The per-capita water demand to ensure sustainability of adequate supply level has to be determined based on the basic human water requirements for various activities of demand category. Therefore, per capital demand varies for different town/cities categories and population size. It also depends on the type of water supply scheme, climatic condition of the area, socio-economic condition, the size and level of development of the town/cities. In case of karewo town the average per-capital water demand is 40l/sec based on the standard of Ethiopian towns/cities(MoWE, 2016). The per- capital demand of the town is 1233.36m^3/day which is obtained from peak hourly demand and the annual demand is 450,176.4m^3/year.

Table 4.4 Per-capital water demand and Adjustment factor

Year	Unit	2021
Population	-	15417
Per-capita demand	l/c/day	40
Domestic demand	l/day	616680
Climatic adjustment Factor	-	1
Climatically adjusted domestic demand	l/day	616680
Socio-economic adjustment factor	-	1
Socio-economically adjusted domestic demand	l/day	616680

4.2.3 The water supply of the town

The average water supplied from the three perennial gravity spring sources was **432m^3/day** and due the shortage of storage structures, operational problems and wastage, only **367.2m^3** /day delivered and consumed by the customers (karewo town water utility office,2020). The gap between the water supplied from the source and delivered to end users was very high that is **64.8m^3/day**. Which indicates that large amount of water is wasted and not reach to the beneficiary because of highly shortage of reservoirs, pipe line design problems, pressure balancing equipment problems and others. The daily water demand of the town which is calculated by using mode of service, population growth rate and other important parameters is **1233.36m^3/day** but the daily water supplied is **367.2m^3/day.** The difference between the towns water demand and supply is 866.16m^3/day. This result indicates that the town high water shortage problems and there is strong concern was given to the town water supply system to solve all the problems of reservoirs, source identification and addition to the system, design of the pipelines and all revision of the system to meet the GTP-II standard the country.

4.2.3.1 Average per capital consumption

The amount of water that consumed for domestic purpose was aggregated from all water meters of each individual customer which helped to analysis the distribution of water coverage of the town. Therefore, the annual consumption data was converted to average daily per capital consumption using the number of population. As the data of karewo town water utility office, the water supplied annually was 134,028m^3 and annual demand calculated above is 450,176.4m^3. From this, we determine the per-capital water consumption and demand of the town.

Per-capital consumption (l/c/day)= $\frac{annual\ water\ supplied}{total\ population} = \frac{134028m^3*1000l/m^3}{15417*365} = \frac{23.82l}{c}/day$

Per-capital demand (l/c/day)= $\frac{annual\ water\ demand}{total\ population} = \frac{450176.4m^3*1000l/m^3}{15417*365} = \frac{80l}{c}/day$

According to (MoWIE, 2016) in the GTP-II plan of the Federal Democratic Republic of Ethiopia, it is impracticable and non-recommendable because, the GTP-II minimum standard is 40l/c/day. So that, further reviewing detail work of the water supply system of the town and trying to provide safe and potable based on national and regional standard. On the other hand, the demand of the town was 80l/p/day and the water supply from the distribution system was only 23.82l/p/day. This result also indicates that there was high deficit of water supply and the gap between water demand and water supply was 56.18l/c/day. Therefore, daily per capita consumption of the town was very low and needs more attention to minimize the gap. The gaps are shown in table briefly.

Table 4.5 Water supply and demand of the town

Year	Total population	Annual Water demand (m^3)	Annual water supplied (m^3)	ADD (l/c/day)	ADC (l/c/day)	The difference in supply and demand (m^3)
2021	15417	450,176.4	134,028	80	23.82	316148.4

As indicated above in the table, the annual water supply of karewo town is 134,028$m^3$and the annual water demand of the town is 450,176.4m^3. This result shows that the water supply demand and supply of the town is far apart. The different in water supply and demand is greater that of the annual water supply of the town. The town needs a large amount of water to satisfy its demand. Therefore, the water supply system has insufficiency to meet the demand of the town and the needs the attention of the responsible bodies to overcome the problem.

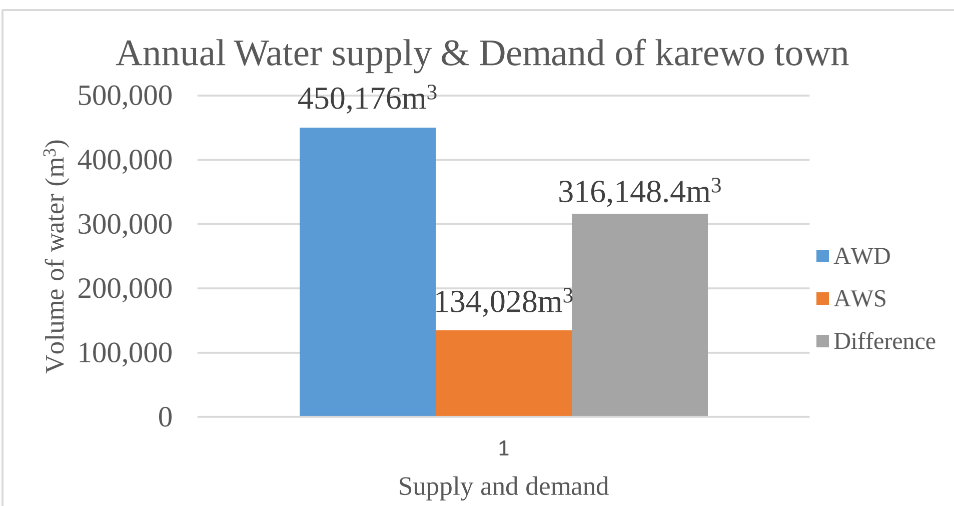

Figure 4.4 Annual water supply, Demand and difference graph

4.3 Hydraulic performance evaluation of water supply distribution system

In evaluating hydraulic performance, different water supply distribution components data are required to analyze hydraulic parameters like, pressure, velocity and demand analysis. The data of water supply distribution components that used for analysis are source data, reservoir data, pipe data and junction(node) data used. Therefore, checking and evaluating hydraulic performance of water supply system is important to monitor the sustainability and efficiency of water supply distribution components.

4.3.1 Extended period simulation

Steady state simulation is used for evaluation of average daily water demand in which at every node(junction) the demand doesn't change with time. Therefore, in this study steady simulation of hydraulic parameters are not considered. In extended period simulation, it determines the dynamic behavior of the system over a period of time and evaluates the water distribution system by assuming hydraulic demands and boundary conditions with change of time(Dessalegn, 2021).

4.3.2 Evaluation of pressure and velocity in water supply distribution system

In evaluating karewo town water supply distribution system, the hydraulic performance of water supply distribution systems was assessed. The main hydraulic parameters of water supply distribution systems are water pressure in junctions(nodes), velocity of water in pipelines and head losses in pipes lines. Therefore, pressure and velocity are an important parameter in designing and construction of water supply system and its sustainability.

4.3.2.1 Pressure of water in junctions(nodes)

Water pressure in pipelines and junctions or nodes of water supply distribution system may fulfill the allowable standards to maintain and protect the water supply distribution system from pipe breakage, losses, stagnation of water and uneven distribution of water customers. Low pressure in distribution system causes stagnation of water in pipes and results in quality problems and consumes more time to deliver water to end users. High water pressure in water distribution system causes pipe line breakage, uneven distribution between customers, water losses in joints and connections, scouring of pipe lines and results in system demolition, wastage of water, public disturbances due to distribution of water and economic wastage due to operation and maintenances. Therefore, water pressure has limit and standard in pipelines according to ministry of water and energy of Ethiopia. The allowable operating pressures in water supply system of towns/cities are below in the table.

Table 4.6 MoWE water pressure standard of the junction

NO	Conditions	Normal	Exceptional conditions
1	Minimum	15m H_2O head	10m H_20 head
2	Maximum	60m H_2O head	70m H_2O head

Source: MoWE, Towns water supply feasibility study and engineering design report, 2011

Based on hydraulic simulation in waterGemsV8i software, the result of water pressure in junctions or nodes of 5.12% pressure in junction was under low pressure which is below normal minimum head and under exceptional minimum head and 34.61% of junction pressures are above exceptional maximum allowable head and 60% of junction pressures are on the range of allowable normal and exceptional maximum head. The high and low junction pressures shown in the table.

Table 4.7 Summary of high and water pressures in the junctions

Junction NO	low pressure <15m H2O	high pressure >70m H2O
J-6	4	
J-65	8	
J-12	11	
J-85	14	
J-29		75
J-30		83
J-31		86
J-32		90
J-36		72
J-42		80
J-43		90
J-44		104
J-50		81

J-51		80
J-52		95
J-53		122
J-56		91
J-57		118
J-58		98
J-59		79
J-60		104
J-69		72
J-74		93
J-76		79
J-79		77
J-80		72
J-81		130
J-82		78
J-87		101
J-93		71
J-94		120

According to the simulation result, the junction pressure of karewo town water supply distribution system has 40% pressure problem which needs correction to be safe and sustainable because more high pressures and slightly low pressures attack the performance of the system. The simulated pressure of junctions was in detail shown in appendix 1.

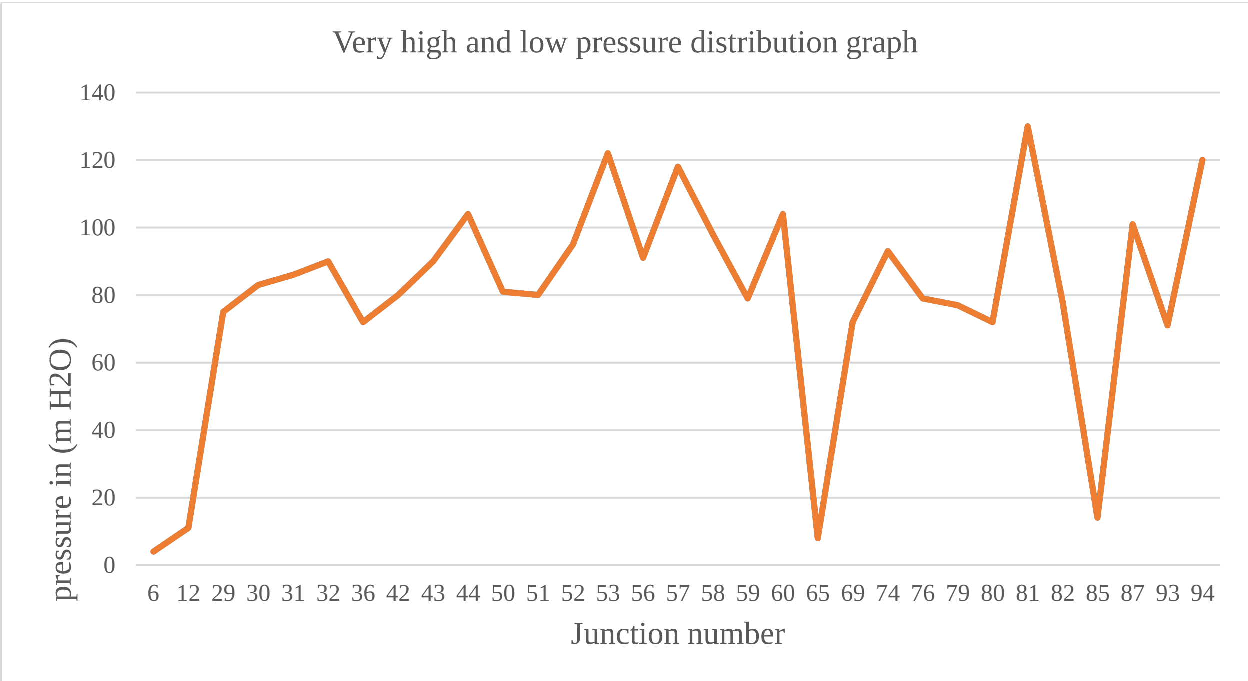

Figure 4.5 High and low pressure distribution graph

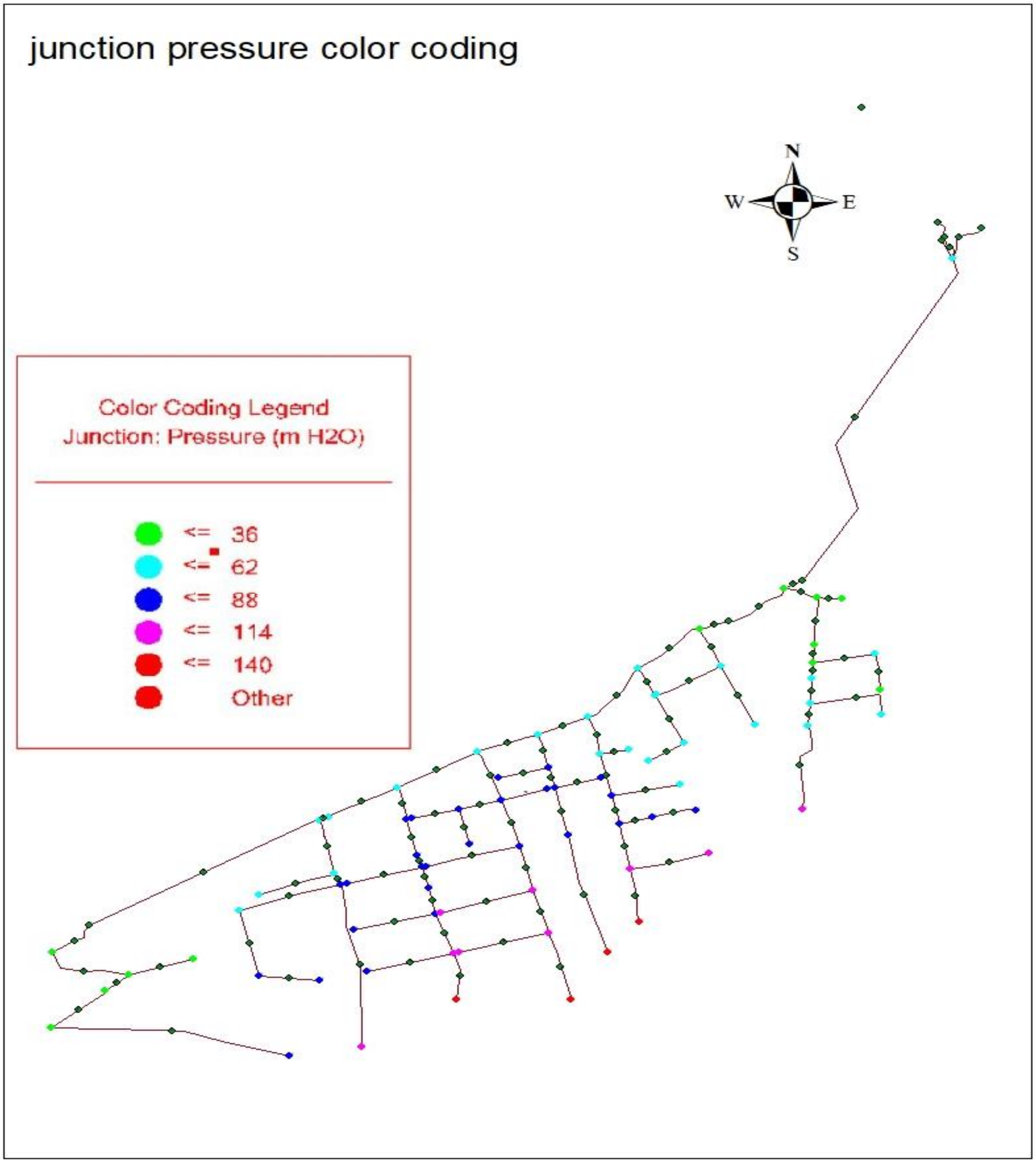

Figure 4.6 Color coding of pressure distribution in junctions

4.3.2.2 Water pressure contour

The pressure distribution in karewo town water distribution network has pressure head difference in junctions of different sections. High pressure head at up to 130m H_2O at market village(mender) and slightly low pressure at action aid Ethiopia mender. the simulation result of pressure contour shows the pressure difference in the town water distribution network by different colors. Basically high pressures in the node bursts and breaks pipes, connections and joints. Junctions with always high pressure above the allowable head were damaged and exposed to subsequent maintenance and change of equipment's. therefore, high pressures and approach to high pressures shown by red colors in the pressure contour diagram.

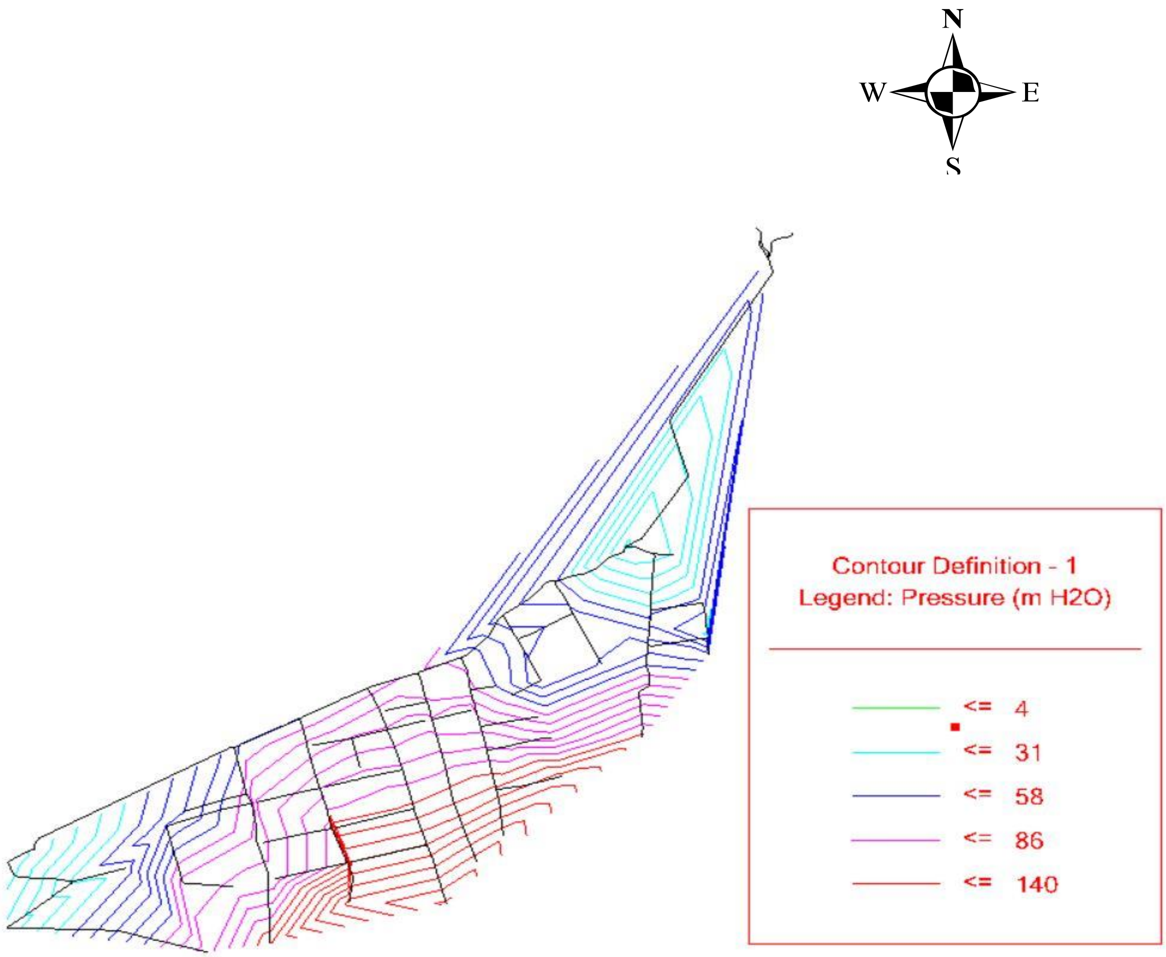

Figure 4.7 Pressure distribution contour in the water distribution system

4.3.2.3 Velocity distribution

Evaluating the velocity distribution in water distribution pipe line is important concept to assess the functionality and sustainable water flow in pipe lines. Velocity is an essential parameter in hydraulic modeling performance evaluation of the efficiency and sustainability and water distribution and transmission lines. In the design of water supply distribution system, velocity has a permissible range criterion in which high velocity causes head loss and damage in pipes while low velocity causes hygienic problem and water quality cases occur.

According to MoWE (2011), the allowable water velocity in pipes may sustain 2m/s in the short distributions. In small diameter pipes the velocity will be low to reduce head loss and pipe damage. Therefore, the minimum permissible velocity in water distribution system may attain 0.6m/s.

Table 4.8 Allowable velocity ranges in with water distribution pipelines

S.NO	Distribution system type	Allowable velocity range in m/s
1	Maximum velocity in main pipe	2
2	Maximum velocity distribution pipe	2
3	Minimum velocity in distribution pipe	0.6

Source: MoWE, Towns water supply feasibility study and engineering design report, 2011

According to the simulation result, karewo town water distribution pipe line velocity was 75% low velocity which is than the minimum velocity and 15% are on the range of maximum velocity in distribution pipe and 10% are at high velocity range greater than maximum velocity in main pipe line. High velocity occurred in the area on the main line from the source to the reservoir and area in the high school mender. low velocity occurred in the distribution line of areguade mender and adebabay mender. Therefore, the velocity distribution in karewo town water distribution line needs high inspection and correction to have safe and stable main and distribution pipe line. Avery high pressures occurred pipelines are shown in the table below.

Table 4.9 Summary of very high velocities in the pipe lines

Label	Distribution system type	>Allowable velocities
P-7	Main line	7.04
P-8	Main line	3.58
P-9	Main line	8
P-11	Main line	4.57
P-12	Distribution line	2.94
P-19	Distribution line	2.71

Therefore, this a very high velocities indicate that there is high steepness in the pipelines which causes head loss and pipeline breaking up. Based on the simulation, the pipe line installation routs for this high pressure areas must be changed to reduce and balance the pipe velocities. Karewo town water distribution system based velocity distribution should be renewed or redesigned to maintain allowable and stable water distribution in each main and transmission lines of the network. The velocity distribution in different areas of karewo town water distribution network was represented by different colors. The color coding was done the in the simulation software watergemsv8i and helps to easily identify the high and low velocity pipes in the network. In the diagram shown below, the largest portion of the pipe lines below minimum permissible velocity of 0.6m/s and small parts of the pipelines are above permissible velocity of 2m/s. therefore, the velocity distribution in the pipelines are represented in color coding diagram below. The detail simulation results of velocity in pipe lines are included in the appendix 2 at the end.

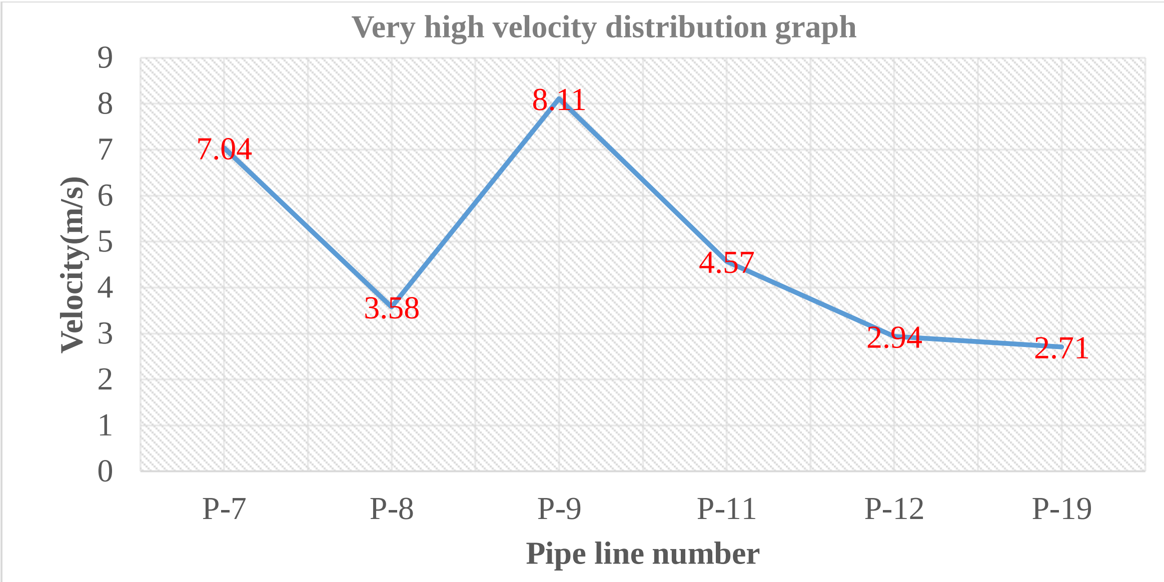

Figure 4.8 High velocity distribution graph in pipes

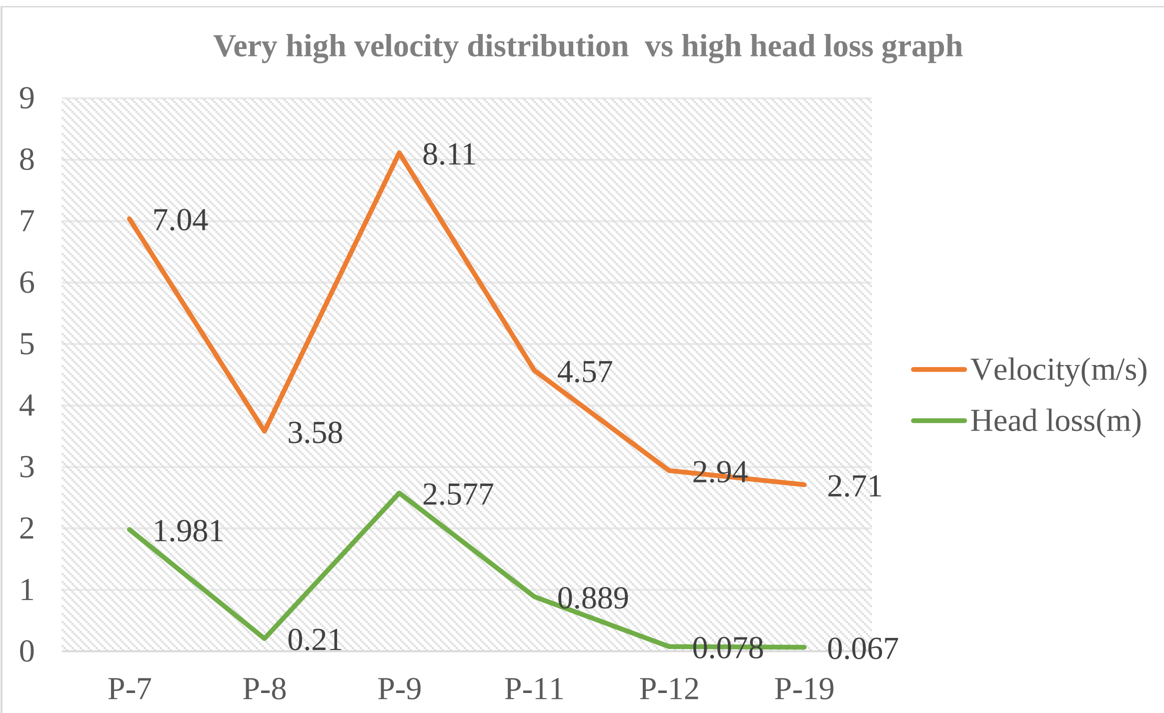

Figure 4.9 High velocity vs high head loss graph

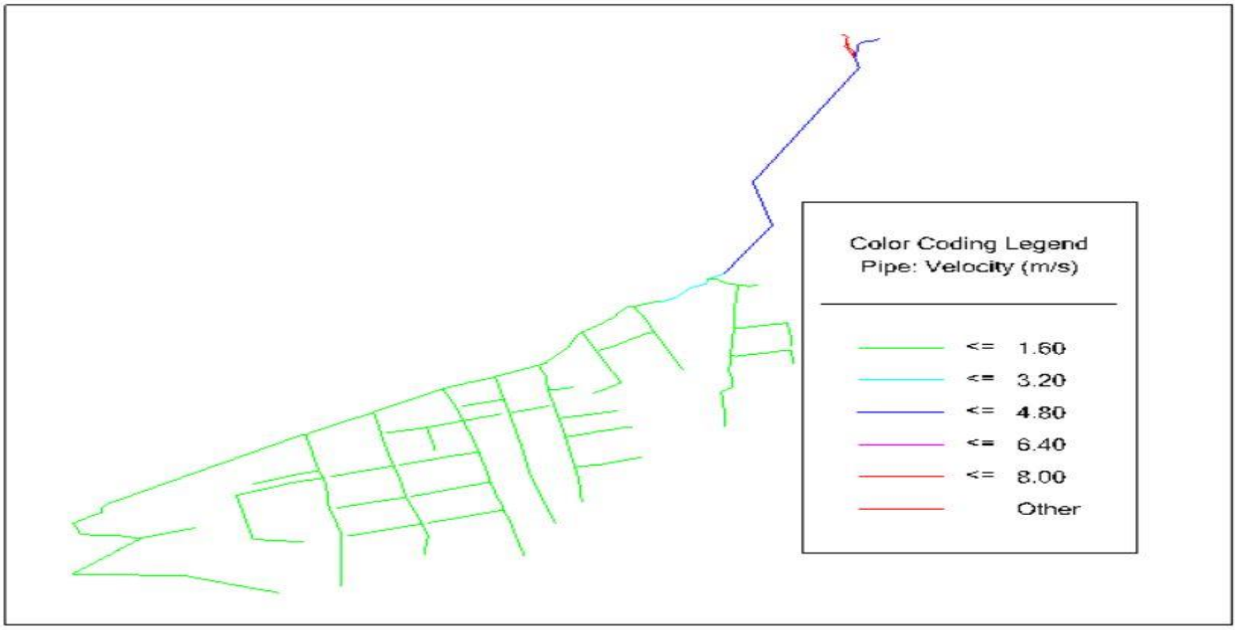

Figure 4.10 Color coding of velocity distribution in pipes

4.4 Physico-chemical water quality tests

The physico-chemical water quality test is essential to identify the drinking water quality of physico-chemical parameters. The different parameters are checked in the laboratory to determine the physico-chemical water quality. The water samples collected from different sources to check to drinking water quality are: from two reservoirs, public water point and house to house connection. The physico-chemical parameters tested under the water quality laboratory are: power of hydrogen(pH), temperature, conductivity, Total dissolved solids(TDS), Turbidity, residual chlorine, total alkalinity, dissolved ammonia(NH_3) and Iron and chemical parameters. The different laboratory testing chemicals and equipment's used to test the parameters are: pH-meter, conductivity meter, chlorine test meter, titration meter, Spectrophotometer and turbidity meter. Based on the laboratory test results, each result of the physico-chemical parameters is discussed.

4.4.1 Power of hydrogen(pH)

pH is an important parameter in evaluating the acid-base balance of water. It is also an indicator of acidic or alkaline condition of drinking water status. The Ethiopian and WHO standard limit of pH recommended is 6.5 to 8.5. The pH meter which results obtained from the laboratory to different samples tested (7.1-7.7). as the standard the pH value from 7.1

to 14 is basic solution and from 0 to 6.9 is acidic solution. pH is the result of natural geological condition of the site and the type of minerals found in the local rock. The pH meter measures the hydrogen ion concentration in the sample and the results of market area water point is 7.7, market area house connection is 7.4, high school $50m^3$ reservoir is 7.1 and dinku $25m^3$reservoir is 7.1. All the four samples results are under the range of Ethiopian and WHO standard. The results which indicates the quality of water is safe and desirable for drinking purposes. Sometimes pH value greater than 7 indicates alkalinity and slightly tends to affect the taste of water. But due to the standard the pH value of all samples are on the range and recommended as safe.

4.4.2 Temperature

The temperature of water has an effect on both chemical and biological condition of water quality. If the water temperature rises 25^0C is not recommended for drinking purpose and which enhances the development of microorganisms. 0The water temperature is measured by conductivity meter and all samples of water are measured in laboratory by conductivity meter. The samples were taken for physico chemical test results indicates that water temperature was in the range of the standard. The water temperatures of all samples were 21.3^0c,19^0c,19.3^0c and 21^0c according to the water quality report. That means, the average water temperature of all samples were 20.15^0c. Therefore, the karewo town water quality temperature is under recommendable range and that contributed to poor growth microorganisms.

4.4.3 Electrical conductivity(EC)

Pure water is not a good conductor of electric current and rather a good insulator. An increase in ion concentration enhances the electrical conductivity of water. The amount of dissolved solids in water also determines the electrical conductivity of water. Conductivity meter actually measures the ionic of a solution that enables water to transmit current. According to WHO and Ethiopian water quality standard the electrical conductivity value should not exceed 400µs/cm. the investigation result of all samples are under the recommended range of marker area water point sample 290µs/cm, market area house to house 282µs/cm, high school reservoir 238µs/cm and orthodox church reservoir 294µs/cm.

This results shows that water in the study area of karewo town is not considerably ionized and has lower level of ionic concentration activity due to slightly small dissolved solids.

4.4.4 Total dissolved solids(TDS)

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as calcium, potassium, sodium, bicarbonates, chlorides, magnesium and others. This organic and inorganic minerals produce unwanted taste and color change in water. Water with high TDS value indicates that water has a high mineral content. Based on WHO standard the desirable maximum limit of TDS is 1000mg/l which is recommended for drinking purpose. High concentration of dissolved solids may affect kidneys and heart disease patients and high value of TDS in ground water is not harmful for human beings(Meride and Ayenew, 2016). The results of the samples fall on the range of the WHO and Ethiopian standard limit and the average of the samples result value is 138mg/l. Therefore, the total dissolved minerals in the karewo town water supply is safe and advisable for drinking purposes.

4.4.5 Turbidity

The turbidity of water depends on the quantity of solid particles which in the form of suspended state. It is also a measure of light emitting properties of water and the test is used to indicate the quality waste materials discharge with respect to colloidal matter. Hence, turbid water is not safe and advisable for drinking purposes due to the presence of different harmful suspended particles. Testing and checking the turbidity of water is important to determine the madness and purity of water. It also helps to know and decide the safety water is recommendable for drinking purposes. The turbidity result of the samples is: market area water point 4NTU, market area house to house connection 3NTU, orthodox church 25m^3 reservoir 2NTU and high school 50m^3 reservoir is 1NTU. The mean turbidity values of the samples are 2.5NTU. Therefore, the results show that the value of turbidity is under range of WHO and Ethiopian standard limit and safe for drinking uses.

4.4.6 Total Chlorine residual (cl_2)

The main source of chlorine is dissolution of salts of hydrochloric acid as table salts(NaCl), NaCo2 and additionally industrial waste, sewage, sea water and others. It has key importance for metabolism activity in the human body. High chlorine concentration damages metallic pipes and metal structures and also harms growing of plants. The recommended chlorine residual in the water supply distribution system prevents the contamination and formation of biofilms in the system. According to WHO and Ethiopian standard the concentration of chlorine residual doesn't exceed 5mg/l. the average results of chlorine for the samples is 0.02mg/l and which is normal and recommendable for drinking purposes.

4.4.7 Total alkalinity

Total alkalinity of water is defined as the ionic concentration which neutralizes the hydrogen ion. It is a measure of waters ability to neutralize acids. Alkaline compounds that are present in water, like hydroxides and carbonates eliminate hydrogen ion from water, which lowers the acidity of water and results higher pH. The results of the samples are market area water point 180, market area house to house connection 200, orthodox church 25m^3 reservoir is 180 and high school 50m^3 reservoir is 160mg/l as $caco_3$ respectively. The WHO and Ethiopian standard is 500mg/l as $caco_3$ and the results are the recommended range of the WHO and Ethiopian standard.

4.4.8 Dissolved ammonia(NH_3)

Ammonia occurs naturally and is produced by human activities. It is a colorless gas with a very distinct odor. It is also dissolved in water and said to be liquid ammonia or aqueous ammonia. Ammonia levels excess of limit it sometimes creates an unpleasant taste and smell. High concentration of ammonia by long time ingestion, it may affect and damage internal organ of human beings. According to WHO and Ethiopian guidelines of water quality, the dissolved ammonia concentration not be greater than 1.5mg/l. Based on the laboratory test the results of the samples are market area water point 0.48mg/l, market area house to house connection 0.26mg/l, orthodox church 25m^3 reservoir 0.29mg/l and high school 50m^3 reservoir 1.71mg/l. three samples are safe and under the range but high school 50m^3 reservoir is not safe and over the standard limit. Therefore, treating the 50m^3 reservoir is important to be safe and to get protected water.

4.4.9 Total hardness

Hardness of drinking water is due to the existence of calcium and magnesium carbonates and which can be removed by boiling. Calcium and magnesium sulfate and chloride which can be also removed by chemical precipitation using lime and sodium carbonate. Titration meter was used to determine the total hardness of the collected sample. The laboratory test result refers that the values range fall between 140 to 160mg/L. The total hardness of market area water point was 140mg/L, the total hardness of market area house to house connection was 150mg/L, the total hardness of orthodox church 25m^3 reservoir was 140mg/L and the total hardness of high school 50m^3 reservoir was 160mg/L. The drinking water of Karewo town was under the category of moderately soft and the degree of hardness was not exceeded the standard set by both WHO and Ethiopia. Based on the result the total hardness in the drinking water of karewo town was safe and advisable for drinking purposes.

4.4.10 Iron content(Fe)

Iron imparts a disagreeable metallic taste to water. Iron in water does not usually present a health risk. Our body needs iron to transport oxygen in the blood. But low level of iron content, contains bacteria and high level of iron content in drinking water leads to an overload which can causes diabetes, hemochromatosis and other heart and liver damages. According to WHO and Ethiopian standard the iron content in drinking water doesn’t exceed 0.3mg/L. The results of the samples in the laboratory test are market area water point 0.08mg/L, market area house to house connection 0.12mg/L, orthodox church 25m^3 reservoir was 0.05mg/L and high school 50m^3 reservoir was 0.07mg/L. The results indicate that the iron content in karewo town water supply system was under normal and acceptable range due to laboratory test results. Therefore, it was safe for drinking purposes.

Table 4.10 Summary of the physico-chemical laboratory test results

No	Parameters	Unit	Samples and site name			
			Water point of market area	HH connection of market area	Orthodox church 25m^3 reservoir	High school 50m^3 reservoir
1	pH	-	7.7	7.4	7.1	7.1
2	Temperature	^0C	21.3	21	19	19.3
3	Electrical conductivity(EC)	µs/cm	290	282	294	238
4	Total dissolved solids(TDS)	Mg/L	145	141	147	119
5	Turbidity	FTU	4	3	2	1
6	Total chlorine residual(Cl_2)	Mg/L	0.03	0.02	>0.02	>0.02
7	Total alkalinity	Mg/l as $CaCo_3$	180	200	180	160
8	Dissolved ammonia(NH_3)	Mg/L	0.48	0.26	0.29	1.71
9	Total hardness	Mg/l as $CaCo_3$	140	150	160	140
10	Iron content(Fe)	Mg/L	0.08	0.12	0.05	0.07

Table 4.11 The average physico-chemical result summary of the laboratory report.

NO	Parameters	Unit	Average values of the sample results
1	pH	-	7.3
2	Temperature	^0C	20.15
3	Electrical conductivity(EC)	µs/cm	276
4	Total dissolved solids(TDS)	Mg/L	138
5	Turbidity	FTU	2.5
6	Total chlorine residual(Cl_2)	Mg/L	0.02
7	Total alkalinity	Mg/l as $CaCo_3$	180
8	Dissolved ammonia(NH_3)	Mg/L	0.685
9	Total hardness	Mg/l as $CaCo_3$	147.5
10	Iron content(Fe)	Mg/L	0.08

Finally, based the physico-chemical test results the karewo town water supply system was safe under physico-chemical test result according to WHO and Ethiopian guidelines except high school $50m^3$ reservoir. In high school $50m^3$ reservoir, the dissolved ammonia concentration was high and exceeds the WHO and Ethiopian standard. From high school $50m^3$ reservoir, the students, teachers and other administrative staffs and also high school villages in the town uses water. Therefore, treating and balancing dissolved ammonia concentration in $50m^3$ reservoir was important to deliver safe and protected drinking water. Detail physico-chemical parameters laboratory test results are attached under appendix 3.

4.5 Water coverage of karewo town

The water supply coverage of the town was determined based on the average per capita consumption and level of connection per family. The average domestic water supply coverage of karewo town is found to be 23.82 l/capital/day. The identified average per capita consumption is very low when we compare with the country standard of GTP-II set for design purpose (30 to 50l/c/day) and to the regional standard set by SNNPR water mines and energy bureau which is 40l/c/day to the town/cities. This result shows that, the water supply distribution system of karewo needs evaluation of all the town water supply system components and identify the problems the system. In this result, special consideration to reservoir shortage is very crucial because large amount of water is not stored in the reservoir because of immediate filling of the reservoir and removed as wastage through overflow pipes.

The water supply coverage of the town/cities was done by considering two scenarios. They are; the number of domestic water connection per family and the average daily per capita water consumption. The average per capita water consumption was identified by cumulating annual consumption of each customer from the individual domestic water meters. The current population of the town was used to evaluate the average per capital consumption. The total number of domestic connection which is the water meter installed within the town was about **820** from the obtained from karewo town water utility office. Identification of the total number of connection in the town is an essential component to determine the water supply coverage of the town. Starting from the result determined above, water supply coverage of karewo town is very low instead of national and the regional standard of Ethiopia.

Table 4.12 Water supply coverage in terms of level of connection

Year	Population	Average people per HH	NO of connections	Population with water meter connection	Level of connection
2021	15417	5	820	4100	26.6%

4.5.1 Water demand analysis

Water demand analysis is the evaluation safe and potable water is allocated for different domestic and non-domestic purposes. Both non-domestic and domestic water demand analysis of karewo town is briefly discussed below.

4.5.1.1 Domestic water demand analysis

Domestic water demand analysis is including the evaluation of water used for domestic purposes like, drinking, bathing, washing and other different domestic consumptions. In domestic water demand analysis of karewo town maximum daily water demand(MDWD), peak hourly water demand(PHWD) is discussed below.

4.5.1.2 Maximum daily water demand(MDWD)

Daily water consumption varies according to time of day, season and climatic conditions. Thus, people draw out more water on weekend and festival days. So that, it makes increasing demand at this day and it was taken into account by the use of peak day factor.

MDWD= 1.25*DWD

MDWD=1.25*616680= 770850l/day

4.5.1.3 Peak hourly water demand(PHWD)

As it have a wide ranges, peak hourly water demand was very important to consider during active domestic water demand or household working hours. Thus, it was from six to ten in the morning and four to eight at the evening time huge amount of water is consumed. Hence, if a fire breaks out, a huge quantity of water was required to be supplied in short duration by necessitating the needs for a maximum rate of hourly supply. The water that was supplied by pumping directly and the pumps and distribution system is designed to meet the peak demand.

PHWD= 2*DWD, Karewo town PHWD is

PHWD= 2*616680= 1233360l/day.

4.5.2 Non domestic water demand analysis

Non domestic water demand is a water demand used for out of domestic purposes and was also determined systematically. It can be classified as the following major categories: like commercial and institutional water demand (CIWD), industrial water demand (IWD), livestock water demand (LD), firefighting water demand (FWD) and non-revenue water demand (NRWD).

4.5.2.1 Commercial and institutional water demand(CIWD)

The commercial and institution water demand is also known public water demand and includes the quantity of water used for numerous public activities. The public water demands include the water requirement of commercial and institutional water consumptions. Commercial and institutions like, different public schools, hospitals, college and universities, health posts and health centers, different offices, bar and restaurants, shops and hotels(AWDSE, 2016).

CIWD = 5% of DWD, then the current commercial and institutional demand of karewo town is:

CIWD= 0.05*616680= **30834l/day.**

4.5.2.2 Industrial water demand(IWD)

However, water demand for larger industries was considered separately as point supplies from the system. Therefore, for planning purpose a reliable industrial water demand indicator was assumed to be 30% of domestic water demand for large towns and 10% for small towns.

IWD= 10% of DWD, hence industrial water demand of karewo town is

IWD= 0.1*616680= 61668l/day.

4.5.2.3 Non-revenue water demand(NRWD)

Non-revenue water demand is the system loss water in water supply system, over flow from reservoirs, illegal connections, improper metering and water losses due to operational requirements like washout. In case of karewo town water supply system, as per data obtained from karewo Town Water utility office, it is adopted and taken as 15% of total water demand of the town.

NRWD= 15% of DWD

NRWD= 0.15*616680= 92,502/day

4.5.2.4 Firefighting water demand

The annual volume required for firefighting purpose was quite small; however, during periods of need, the demands may be exceedingly large and in many cases govern the design of distribution, storage and pumping requirement is considered to meet by stopping supply to consumers and directing it to this purpose. Therefore, the firefighting demand is 10% of service reservoir capacity.

Table 4.13 Non-domestic water demand table

Non- domestic Water demand	Unit(l/day)	Year
DWD	616680	2021
CIWD	30834	2021
IWD	61668	2021
NRWD	92,502	2021
FFWD	10000	2021

Table 4.14 Summary of water demand analysis of the town

Water demand	Unit	Year
		2021
ADWD	l/day	616680
TNDWD	l/day	102502
TDD	l/day	776400
NRWD	l/day	92,502
ADD	l/day	930570
MDDF	-	1.25
MDWD	l/day	770850
PHDF	-	2
PHWD	l/day	1233360
Annual water demand	m^3/year	450,176.4
Annual water supply	m^3/year	134,028
Town water coverage	-	29.8%

As it was indicated on the above table, the total water supply coverage of the karewo town for the year 2021 based on average per capita consumption **29.8%**. The result indicates which indicates that there is very poor water supply in the town to satisfy the demand of the town. This coverage also indicates that the water supply coverage of the is very low compared to country's plan of GTP-II urban water supply coverage of (75%-100%). The local government and other stakeholders has strong work on their hand to go with country's standard and to satisfy the water demand of the town.

The water supply coverage based on level of connection of karewo town is 26.6% and this also indicates that there is a big gap between house to house connection with water meter and total population in the town. Large amount of the town population is accessing water from public taps and this also leads the customers to get water in difficulties of long queue. So, the water utility office remains strong concern to solve the problems of level of connection.

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusions

In this study, the main component addressed are the existing water supply and demand analysis, hydraulic performance of the existing water supply system, phsico-chemical water quality assessment and water supply coverage of the town. Therefore, the result of water supply and demand analysis of existing water supply distribution system of karewo town was evaluated and there is high gap between water supply and demand of the town. The annual calculated water supplied to the is 134,028$m^3$and the annual calculated water demand of the town is 450,176.4m^3 and the average per-capital consumption of the town is 23.82l/c/day and the average per-capital demand of the town is 80l/c/day. Since, figure indicates a huge variation in water supply and demand of the town.

The hydraulic performance evaluation the existing water supply distribution system is simulate and modeled through Bentley WaterGEMSV8i. The simulation result in junction/nodes pressure and pipe velocities were evaluated based on MoWE guidelines. Therefore, 2.56% of junction pressures are below normal allowable minimum head, 2.56% of junction pressures also below exceptional allowable head, 34.61% of junction pressure are above maximum allowable head which is greater than 70m and 60% of junction pressures are under the allowable limit which is from 10m-70m. The pipe velocities of the existing water supply distribution system resulted are the largest portion pipe velocities are below the permissible pipeline velocities which is 0.6m/s and small portion of the pipelines in the distribution are above the allowable velocities of 2m/s. Hence, based on the result of pressure and velocities, the karewo town water supply distribution system has high hydraulic performance problem.

The physico-chemical water quality assessment addressed the different phsico-chemical water quality parameters and the result of the parameters except dissolved ammonia(NH_3) are under the recommended WHO and Ethiopian standard. But dissolved ammonia concentration exceeds the standard and needs treatment. The water supply coverage of the town was evaluated in terms of per-capital consumption and level of connections. Therefore, the resulted water supply coverage based on per-capital consumption is 29.8%

and 26.6% based on level of connection. This result also indicates there is a significant water supply problem in karewo town.

5.2 Recommendations

This study has found out very critical findings, which are the most essential for the overall performance of karewo town water supply distribution system. Therefore, the researcher has a serious duty to recommend some critical points to improve the performance of water supply distribution system of the town.

- ✓ The water supply of the town does not satisfy the demand of the town, therefore, to balance the water supply and demand additional water sources, additional reservoirs and public taps must be provided.
- ✓ The water distribution system has faced high pressures at nodes, therefore, provision of pressure reducing valve and air release valve was important to prevent pipe breakage and un wanted water loss. Reducing or balancing high pressures at the junction has a value in pipe velocities because reducing nodal pressures which increase the pipe line velocities. Hence, adjusting junction pressure overcome low and pipe lines velocities.
- ✓ The physico-chemical water quality parameters except dissolve ammonia(NH_3), was good based on the result of laboratory test. But, continual inspection and following is important for proactive protection of the system from infection. In the case of dissolve ammonia(NH_3), the concentration is high compared to WHO and national standard. Therefore, treating the system is important to prevent dissolve ammonia related problems.
- ✓ The water supply coverage is very low in terms of per-capital consumption and level of connections because of the shortage of water supply problem in the town. So, the respective administrative bodies must work to solve the problems.

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APPENDICES

Appendix 1: Junction pressure table

Label	Elevation (m)	Zone	DEMAND(L/S)	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-6	1,809.00	Zone - 1	<Collection: 1 item>	0	1,817.29	8
J-12	1,805.00	Zone - 1	<Collection: 2 items>	1	1,816.48	11
J-14	1,792.00	Zone - 1	<Collection: 2 items>	0	1,816.41	24
J-15	1,784.00	Zone - 1	<Collection: 2 items>	0	1,816.39	32
J-16	1,778.00	Zone - 1	<Collection: 2 items>	0	1,816.29	38
J-17	1,762.00	Zone - 1	<Collection: 2 items>	0	1,816.24	54
J-18	1,772.00	Zone - 2	<Collection: 2 items>	0	1,807.50	35
J-19	1,763.00	Zone - 2	<Collection: 2 items>	0	1,807.46	44
J-20	1,765.00	Zone - 2	<Collection: 2 items>	0	1,805.85	41
J-21	1,760.00	Zone - 2	<Collection: 2 items>	0	1,805.84	46
J-22	1,766.00	Zone - 1	<Collection: 2 items>	0	1,805.84	40
J-23	1,743.00	Zone - 2	<Collection: 2 items>	0	1,803.49	60
J-24	1,746.00	Zone - 2	<Collection: 2 items>	0	1,800.76	55
J-27	1,746.00	Zone - 2	<Collection: 2 items>	0	1,800.96	55
J-28	1,735.00	Zone - 2	<Collection: 2 items>	0	1,800.91	66
J-29	1,726.00	Zone - 2	<Collection: 2 items>	0	1,800.87	75
J-30	1,718.00	Zone - 2	<Collection: 2 items>	0	1,800.75	83
J-31	1,715.00	Zone - 2	<Collection: 2 items>	0	1,800.74	86
J-32	1,711.00	Zone - 2	<Collection: 2 items>	0	1,800.69	90
J-33	1,746.00	Zone - 2	<Collection: 2 items>	0	1,804.36	58

J-35	1,744.00	Zone - 2	<Collection: 2 items>	0	1,804.32	60
J-36	1,750.00	Zone - 2	<Collection: 2 items>	0	1,804.31	54
J-37	1,732.00	Zone - 2	<Collection: 2 items>	0	1,804.29	72
J-38	1,743.00	Zone - 2	<Collection: 2 items>	0	1,804.29	61
J-39	1,745.00	Zone - 2	<Collection: 2 items>	0	1,801.56	56
J-40	1,732.00	Zone - 2	<Collection: 2 items>	0	1,801.48	69
J-41	1,732.00	Zone - 2	<Collection: 2 items>	0	1,801.44	69
J-42	1,721.00	Zone - 2	<Collection: 2 items>	0	1,801.45	80
J-43	1,711.00	Zone - 2	<Collection: 2 items>	0	1,801.43	90
J-44	1,697.00	Zone - 2	<Collection: 2 items>	0	1,801.38	104
J-45	1,738.00	Zone - 2	<Collection: 2 items>	0	1,800.60	62
J-46	1,756.00	Zone - 2	<Collection: 2 items>	0	1,800.34	44
J-47	1,734.00	Zone - 3	<Collection: 2 items>	0	1,800.13	66
J-48	1,730.00	Zone - 2	<Collection: 2 items>	0	1,800.07	70
J-49	1,738.00	Zone - 2	<Collection: 2 items>	0	1,802.59	64
J-50	1,721.00	Zone - 2	<Collection: 2 items>	0	1,802.50	81
J-51	1,724.00	Zone - 2	<Collection: 2 items>	0	1,804.28	80
J-52	1,709.00	Zone - 2	<Collection: 2 items>	0	1,804.28	95
J-53	1,680.00	Zone - 2	<Collection: 2 items>	0	1,802.42	122
J-54	1,767.00	Zone - 2	<Collection: 2 items>	0	1,807.47	40
J-55	1,760.00	Zone - 2	<Collection: 2 items>	0	1,807.46	47
J-56	1,725.00	Zone - 1	<Collection: 2 items>	0	1,816.18	91
J-57	1,686.00	Zone - 2	<Collection: 2 items>	0	1,804.27	118

J-58	1,703.00	Zone - 2	<Collection: 2 items>	0	1,801.41	98
J-59	1,722.00	Zone - 2	<Collection: 2 items>	0	1,801.39	79
J-60	1,697.00	Zone - 2	<Collection: 2 items>	0	1,801.31	104
J-61	1,749.00	Zone - 2	<Collection: 2 items>	0	1,800.67	52
J-62	1,740.00	Zone - 2	<Collection: 2 items>	0	1,800.61	60
J-63	1,757.00	Zone - 2	<Collection: 2 items>	0	1,800.52	43
J-65	1,795.00	Zone - 3	<Collection: 2 items>	0	1,799.45	4
J-66	1,767.00	Zone - 3	<Collection: 2 items>	0	1,796.84	30
J-67	1,772.00	Zone - 3	<Collection: 2 items>	0	1,796.26	24
J-68	1,780.00	Zone - 3	<Collection: 2 items>	0	1,795.45	15
J-69	1,718.00	Zone - 3	<Collection: 2 items>	0	1,790.25	72
J-70	1,771.00	Zone - 1	<Collection: 2 items>	0	1,816.27	45
J-71	1,770.00	Zone - 1	<Collection: 2 items>	0	1,816.26	46
J-72	1,780.00	Zone - 1	<Collection: 2 items>	0	1,816.36	36
J-73	1,788.00	Zone - 1	<Collection: 2 items>	0	1,816.35	28
J-74	1,707.00	Zone - 2	<Collection: 2 items>	0	1,800.41	93
J-76	1,722.00	Zone - 2	<Collection: 2 items>	0	1,800.77	79
J-77	1,731.00	Zone - 2	<Collection: 2 items>	0	1,800.75	70
J-78	1,733.00	Zone - 2	<Collection: 2 items>	0	1,800.69	68
J-79	1,727.00	Zone - 2	<Collection: 2 items>	0	1,804.26	77
J-80	1,732.00	Zone - 2	<Collection: 2 items>	0	1,804.25	72
J-81	1,671.00	Zone - 2	<Collection: 2 items>	0	1,801.35	130
J-82	1,723.00	Zone - 2	<Collection: 2 items>	0	1,801.42	78

J-83	1,730.00	Zone - 2	<Collection: 2 items>	0	1,800.63	70
J-84	1,751.00	Zone - 1	<Collection: 2 items>	0	1,805.83	55
J-85	1,802.00	Zone - 1	<Collection: 2 items>	0	1,816.47	14
J-86	1,736.00	Zone - 2	<Collection: 2 items>	0	1,802.37	66
J-87	1,703.00	Zone - 2	<Collection: 2 items>	0	1,804.27	101
J-88	1,735.00	Zone - 2	<Collection: 2 items>	0	1,801.41	66
J-89	1,970.00	Zone - 2	<Collection: 2 items>	0	2,008.40	38
J-90	1,732.84	Zone - 2	<Collection: 2 items>	0	1,802.54	70
J-91	1,730.00	Zone - 2	<Collection: 2 items>	0	1,802.53	72
J-93	1,730.00	Zone - 2	<Collection: 0 items>	0	1,801.48	71
J-94	1,680.00	Zone - 2	<Collection: 2 items>	0	1,800.69	120
J-95	1,765.00	Zone - 3	<Collection: 2 items>	0	1,796.82	32

Appendix 2: velocity distribution table in pipes

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)	HL (m/m)
P-7	98	R-1	J-89	32	GI	120	6	7.04	1.981
P-8	903	J-89	T-1	75	GI	120	16	3.58	0.21
P-9	59	R-4	J-89	32	GI	120	7	8.11	2.577
P-11	109	R-2	J-89	32	GI	120	4	4.57	0.889
P-12	44	T-1	J-6	90	Hdpe	150	19	2.94	0.078
P-19	146	J-6	T-2	90	Hdpe	150	17	2.71	0.067
P-20	75	J-6	J-12	50	Hdpe	150	1	0.69	0.011
P-23	117	J-12	J-14	50	Hdpe	150	0	0.15	0.001
P-24	43	J-14	J-15	50	Hdpe	150	0	0.14	0.001
P-25	41	J-15	J-16	32	Hdpe	150	0	0.23	0.002
P-28	65	T-2	J-18	75	Hdpe	150	3	0.57	0.005
P-31	164	J-18	J-20	63	Hdpe	150	2	0.78	0.01
P-32	76	J-20	J-21	50	Hdpe	150	0	0.04	0
P-33	130	J-21	J-22	50	Hdpe	150	0	0.03	0
P-40	160	J-27	J-24	63	Hdpe	150	1	0.26	0.001
P-41	82	J-27	J-28	50	Hdpe	150	0	0.15	0.001
P-42	91	J-28	J-29	50	Hdpe	150	0	0.13	0
P-44	65	J-30	J-31	50	Hdpe	150	0	0.07	0
P-45	105	J-31	J-32	32	Hdpe	150	0	0.1	0.001
P-47	161	J-20	J-33	63	Hdpe	150	2	0.74	0.009
P-48	115	J-33	J-23	63	Hdpe	150	2	0.65	0.007
P-50	95	J-33	J-35	50	Hdpe	150	0	0.12	0
P-51	62	J-35	J-36	32	Hdpe	150	0	0.04	0
P-52	106	J-35	J-37	50	Hdpe	150	0	0.09	0
P-53	146	J-37	J-38	32	Hdpe	150	0	0.01	0
P-54	133	J-23	J-39	50	Hdpe	150	2	0.81	0.014
P-55	190	J-39	J-27	63	Hdpe	150	1	0.41	0.003
P-56	127	J-39	J-40	50	Hdpe	150	0	0.15	0.001
P-57	91	J-40	J-41	32	Hdpe	150	0	0.09	0
P-59	119	J-40	J-42	50	Hdpe	150	0	0.09	0
P-60	113	J-42	J-43	50	Hdpe	150	0	0.06	0
P-61	107	J-43	J-44	32	Hdpe	150	0	0.1	0.001
P-64	220	J-45	J-46	32	Hdpe	130	0	0.14	0.001
P-65	165	J-46	J-47	25	Hdpe	150	0	0.14	0.001
P-66	126	J-47	J-48	25	Hdpe	150	0	0.08	0
P-68	83	J-23	J-49	32	Hdpe	150	0	0.53	0.011
P-71	70	J-37	J-51	50	Hdpe	150	0	0.07	0
P-73	112	J-51	J-52	50	Hdpe	150	0	0.03	0

P-76	298	J-50	J-53	25	Hdpe	150	0	0.06	0
P-78	159	J-54	J-19	32	Hdpe	150	0	0.03	0
P-79	153	J-54	J-55	32	Hdpe	150	0	0.02	0
P-80	219	J-17	J-56	32	Hdpe	150	0	0.08	0
P-81	132	J-52	J-57	32	Hdpe	150	0	0.02	0
P-82	201	J-43	J-58	25	Hdpe	150	0	0.04	0
P-83	202	J-42	J-59	25	Hdpe	150	0	0.06	0
P-84	192	J-44	J-60	25	Hdpe	150	0	0.07	0
P-85	22	J-24	J-61	50	Hdpe	150	1	0.39	0.004
P-86	544	J-61	T-3	50	Hdpe	150	0	0.25	0.002
P-87	135	J-61	J-62	50	Hdpe	150	0	0.13	0
P-88	167	J-62	J-63	25	Hdpe	150	0	0.09	0.001
P-90	109	T-3	J-65	50	Hdpe	150	1	0.36	0.003
P-91	186	J-65	J-66	32	Hdpe	150	0	0.61	0.014
P-92	63	J-66	J-67	32	Hdpe	150	0	0.47	0.009
P-93	145	J-67	J-68	32	Hdpe	150	0	0.37	0.006
P-94	506	J-68	J-69	25	Hdpe	150	0	0.44	0.01
P-95	59	J-16	J-70	50	Hdpe	150	0	0.08	0
P-96	56	J-70	J-17	32	Hdpe	150	0	0.11	0.001
P-97	198	J-70	J-71	32	Hdpe	150	0	0.04	0
P-98	131	J-15	J-72	32	Hdpe	150	0	0.06	0
P-99	90	J-72	J-73	25	Hdpe	150	0	0.04	0
P-100	30	J-62	J-45	50	Hdpe	150	0	0.09	0
P-101	402	J-45	J-74	25	Hdpe	150	0	0.08	0
P-102	29	J-29	J-76	32	Hdpe	150	0	0.28	0.003
P-103	53	J-76	J-30	50	Hdpe	150	0	0.09	0
P-104	160	J-76	J-77	25	Hdpe	150	0	0.04	0
P-105	174	J-31	J-78	25	Hdpe	150	0	0.06	0
P-106	70	J-51	J-79	32	Hdpe	150	0	0.06	0
P-107	95	J-79	J-80	25	Hdpe	150	0	0.04	0
P-108	174	J-44	J-81	25	Hdpe	150	0	0.05	0
P-109	86	J-41	J-82	25	Hdpe	150	0	0.05	0
P-110	187	J-32	J-83	25	Hdpe	150	0	0.07	0
P-111	84	J-22	J-84	32	Hdpe	150	0	0.04	0
P-112	103	J-18	J-54	32	Hdpe	150	0	0.08	0
P-113	50	J-12	J-85	25	Hdpe	150	0	0.06	0
P-114	108	J-49	J-86	25	Hdpe	150	0	0.18	0.002
P-115	167	J-52	J-87	32	Hdpe	150	0	0.02	0
P-116	103	J-41	J-88	25	Hdpe	150	0	0.06	0
P-118	52	J-49	J-90	32	Hdpe	150	0	0.14	0.001
P-119	119	J-90	J-50	32	Hdpe	150	0	0.07	0
P-120	102	J-90	J-91	32	Hdpe	150	0	0.04	0
P-122	99	J-40	J-93	32	Hdpe	150	0	0	0

P-123	114	J-32	J-94	32	Hdpe	150	0	0.02	0
P-124	141	J-66	J-95	32	Hdpe	150	0	0.05	0

Appendix 3: sample of all physico-chemical water quality laboratory results

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

Physico-Chemical Analysis Report

(Drinking Water Quality)

Client	Dawro zone water ,mines &energy department	Zone	Dawuro
Contact person	Dawro zone water ,mines &energy department	Woreda	zaba Gazo
Sample Number	7926c	Kebele	karawo municipality
Date of Sampling	29/10/2013 (Ethiopian, EC)	Village	karawo
Date of Testing	09/11/2013 (Ethiopian, EC)	Site Name	market area
(dd mm yyyy)	06/07/2021 (International)	GPS Northing	788422
Nature of Sample	Untreated	(UTM) Easting	311259
Source	sp(water point)	Altitude [m]	1711
Depth [m]		Sample taken by	Mitiku Mekonnen

Analysis results

Item	Unit	Result	Standard
pH	-	7.7	6.5 - 8.5
Temperature	[°C]	21.3	-
Conductivity	[µS/cm]	290	-
TDS	[mg/L]	145	1000
Turbidity	[FTU]	4	5
Total Chlorine [Cl_2]	[mg/L]	0.03	5
Total Hardness	[mg/L as $CaCO_3$]	140	300
Calcium Hardness	[mg/L as $CaCO_3$]	100	-
Magnesium Hardness	[mg/L as $CaCO_3$]	40	-
Total Alkalinity	[mg/L as $CaCO_3$]	180	500
Bicarbonate Alkalinity	[mg/L as $CaCO_3$]	180	-
Carbonate Alkalinity	[mg/L as $CaCO_3$]	0	-
Hydroxide Alkalinity	[mg/L as $CaCO_3$]	0	-
Dissolved NH_3	[mg/L]	0.48	1.5
NH_4 Ammonium	[mg/L]	0.61	-
Na^+ Sodium	[mg/L]	25.2	-

Item		Unit	Result	Standard
K^+	Potassium	[mg/L]	0.9	-
Ca^+	Calcium	[mg/L]	40.0	100
Mg^+	Magnesium	[mg/L]	9.7	30
Fe	Iron	[mg/L]	0.08	0.3
Cu^{2+}	Copper	[mg/L]	0.04	2
Mn^{2+}	Manganese	[mg/L]	0.40	0.5
Cr^{6+}	Chromium	[mg/L]	0.02	0.05
Cl^-	Chloride	[mg/L]	<10	250
F^-	Fluoride	[mg/L]	0.28	1.5
Br_2	Bromine	[mg/L]	0.07	-
NO_2^-	Nitrite	[mg/L]	0.02	3
NO_3^-	Nitrate	[mg/L]	0.2	50
SO_4^{2-}	Sulfate	[mg/L]	14	250
PO_4^{3-}	Phosphate	[mg/L]	0.39	-
HCO_3^-	Bicarbonate	[mg/L]	220	-
CO_3^{2-}	Carbonate	[mg/L]	0	-

Note:
Values that exceed WHO gudline are underlined.

Remark:
The test result indicates that all the parameters measured meet the WHO guideline and Ethiopian standard set for drinking water. Therefore, the water is suitable for drinking purpose.Note that the water sample was taken by the client.

Analyzed on 09/11/2013 *by* ***Zerihun sebsibe*** *Signature*

Approved on 15/11/2013 *by* *WRSMD* *Signature*

S/N/N/P/R/S/Water Gov't Bureau

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

Physico-Chemical Analysis Report

(Drinking Water Quality)

Client	Dawro zone water ,mines &energy department	Zone	Dawuro
Contact person	Dawro zone water ,mines &energy department	Woreda	zaba Gazo
Sample Number	7927c	Kebele	karawo municipality
Date of Sampling	29/10/2013 (Ethiopian, EC)	Village	karawo
Date of Testing (dd/mm/yyyy)	09/11/2013 (Ethiopian, EC) 06/07/2021 (International)	Site Name	market area
		GPS (UTM) Northing	788400
Nature of Sample	Untreated	GPS (UTM) Easting	311280
Source	from yohannes dagoye yard connect	Alttitude [m]	1707
Depth [m]		Sample taken by	Mitiku Mekonnen

Analysis results

Item	Unit	Result	Standard
pH	-	7.4	6.5 - 8.5
Temperature	[°C]	21	-
Conductivity	[µS/cm]	282	-
TDS	[mg/L]	141	1000
Turbidity	[FTU]	3	5
Total Chlorine [Cl_2]	[mg/L]	0.02	5
Total Hardness	[mg/L as $CaCO_3$]	150	300
Calcium Hardness	[mg/L as $CaCO_3$]	120	-
Magnesium Hardness	[mg/L as $CaCO_3$]	30	-
Total Alkalinity	[mg/L as $CaCO_3$]	200	500
Bicarbonate Alkalinity	[mg/L as $CaCO_3$]	200	-
Carbonate Alkalinity	[mg/L as $CaCO_3$]	0	-
Hydroxide Alkalinity	[mg/L as $CaCO_3$]	0	-
Dissolved NH_3	[mg/L]	0.26	1.5
NH_4^+ Ammonium	[mg/L]	0.33	-
Na^+ Sodium	[mg/L]	31.8	-

Item		Unit	Result	Standard
K^+	Potassium	[mg/L]	1.7	-
Ca^+	Calcium	[mg/L]	48.0	100
Mg^+	Magnesium	[mg/L]	7.3	30
Fe	Iron	[mg/L]	0.12	0.3
Cu^{2+}	Copper	[mg/L]	0.16	2
Mn^{2+}	Manganese	[mg/L]	0.60	0.5
Cr^{6+}	Chromium	[mg/L]	0.02	0.05
Cl^-	Chloride	[mg/L]	<10	250
F^-	Fluoride	[mg/L]	0.28	1.5
Br_2	Bromine	[mg/L]	0.05	-
NO_2^-	Nitrite	[mg/L]	0.15	3
NO_3^-	Nitrate	[mg/L]	1.3	50
SO_4^{2-}	Sulfate	[mg/L]	10	250
PO_4^{3-}	Phosphate	[mg/L]	3.82	-
HCO_3^-	Bicarbonate	[mg/L]	244	-
CO_3^{2-}	Carbonate	[mg/L]	0	-

Note:

Values that exceed WHO guidline are underlined.

Remark:

The test result indicates that all the parameters measured meet the WHO guideline and Ethiopian standard set for drinking water. Therefore, the water is suitable for drinking purpose.Note that the water sample was taken by the client.

Analyzed on 09/11/2013 *by* ***Zerihun sebsibe*** *Signature*

Approved on 15/11/2013 *by* *W.R.S.M.D* *Signature*

S/N/N/P/R/S/ Water ... Bureau

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

Physico-Chemical Analysis Report

(Drinking Water Quality)

Client	Dawro zone water ,mines &energy department	Zone	Dawuro
Contact person	Dawro zone water ,mines &energy department	Woreda	zaba Gazo
Sample Number	7928c	Kebele	karawo municipality
Date of Sampling	29/10/2013 (Ethiopian, EC)	Village	karawo
Date of Testing (dd mm yyyy)	09/11/2013 (Ethiopian, EC) 06/07/2021 (International)	Site Name	st, marry church
		GPS (UTM) Northing	788434
Nature of Sample	Untreated	GPS (UTM) Easting	310250
Source	sp(25m reservoir)	Alttitude [m]	1798
Depth [m]		Sample taken by	Mitiku Mekonnen

Analysis results

Item	Unit	Result	Standard
pH	-	7.1	6.5 - 8.5
Temperature	[°C]	19	-
Conductivity	[µS/cm]	294	-
TDS	[mg/L]	147	1000
Turbidity	[FTU]	2	5
Total Chlorine [Cl_2]	[mg/L]	<0.02	5
Total Hardness	[mg/L as $CaCO_3$]	160	300
Calcium Hardness	[mg/L as $CaCO_3$]	110	-
Magnesium Hardness	[mg/L as $CaCO_3$]	50	-
Total Alkalinity	[mg/L as $CaCO_3$]	180	500
Bicarbonate Alkalinity	[mg/L as $CaCO_3$]	180	-
Carbonate Alkalinity	[mg/L as $CaCO_3$]	0	-
Hydroxide Alkalinity	[mg/L as $CaCO_3$]	0	-
Dissolved NH_3	[mg/L]	0.29	1.5
NH_4^+ Ammonium	[mg/L]	0.38	-
Na^+ Sodium	[mg/L]	22.9	-

Item		Unit	Result	Standard
K^+	Potassium	[mg/L]	0.6	-
Ca^+	Calcium	[mg/L]	44.0	100
Mg^+	Magnesium	[mg/L]	12.2	30
Fe	Iron	[mg/L]	0.05	0.3
Cu^{2+}	Copper	[mg/L]	0.27	2
Mn^{2+}	Manganese	[mg/L]	<0.1	0.5
Cr^{6+}	Chromium	[mg/L]	0.01	0.05
Cl^-	Chloride	[mg/L]	<10	250
F^-	Fluoride	[mg/L]	0.20	1.5
Br_2	Bromine	[mg/L]	<0.05	-
NO_2^-	Nitrite	[mg/L]	0.07	3
NO_3^-	Nitrate	[mg/L]	3.5	50
SO_4^{2-}	Sulfate	[mg/L]	15	250
PO_4^{3-}	Phosphate	[mg/L]	1.00	-
HCO_3^-	Bicarbonate	[mg/L]	220	-
CO_3^{2-}	Carbonate	[mg/L]	0	-

Note:
Values that exceed WHO guidline are underiined.

Remark:
The test result indicates that all the parameters measured meet the WHO guideline and Ethiopian standard set for drinking water. Therefore, the water is suitable for drinking purpose.Note that the water sample was taken by the client.

Analyzed on 09/11/2013 *by* ***Zerihun sebsibe*** *Signature*

Approved on 15/11/2013 *by* *W.R.S.M.D* *Signature*

S/N/N/P/R/S/Water Mine ... Bureau

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

Physico-Chemical Analysis Report

(Drinking Water Quality)

Client	Dawro zone water ,mines &energy department	Zone	Dawuro
Contact person	Dawro zone water ,mines &energy department	Woreda	zaba Gazo
Sample Number	7929c	Kebele	karawo municipality
Date of Sampling	29/10/2013 (Ethiopian, EC)	Village	karawo
Date of Testing (dd/mm/yyyy)	09/11/2013 (Ethiopian, EC) 06/07/2021 (International)	Site Name	high school area
		GPS (UTM) Northing	789236
Nature of Sample	Untreated	GPS (UTM) Easting	311846
Source	sp(50m reservoir)	Alttitude [m]	1816
Depth [m]		Sample taken by	Mitiku Mekonnen

Analysis results

Item	Unit	Result	Standard
pH	-	7.1	6.5 - 8.5
Temperature	[°C]	19.3	-
Conductivity	[μS/cm]	238	-
TDS	[mg/L]	119	1000
Turbidity	[FTU]	1	5
Total Chlorine [Cl_2]	[mg/L]	<0.02	5
Total Hardness	[mg/L as $CaCO_3$]	140	300
Calcium Hardness	[mg/L as $CaCO_3$]	90	-
Magnesium Hardness	[mg/L as $CaCO_3$]	50	-
Total Alkalinity	[mg/L as $CaCO_3$]	160	500
Bicarbonate Alkalinity	[mg/L as $CaCO_3$]	160	-
Carbonate Alkalinity	[mg/L as $CaCO_3$]	0	-
Hydroxide Alkalinity	[mg/L as $CaCO_3$]	0	-
Dissolved NH_3	[mg/L]	<u>1.71</u>	1.5
NH_4^+ Ammonium	[mg/L]	2.20	-
Na^+ Sodium	[mg/L]	14.9	-

Item		Unit	Result	Standard
K^+	Potassium	[mg/L]	1.4	-
Ca^+	Calcium	[mg/L]	36.0	100
Mg^+	Magnesium	[mg/L]	12.2	30
Fe	Iron	[mg/L]	0.07	0.3
Cu^{2+}	Copper	[mg/L]	0.14	2
Mn^{2+}	Manganese	[mg/L]	<0.1	0.5
Cr^{6+}	Chromium	[mg/L]	0.02	0.05
Cl^-	Chloride	[mg/L]	<10	250
F^-	Fluoride	[mg/L]	0.26	1.5
Br_2	Bromine	[mg/L]	<0.05	-
NO_2^-	Nitrite	[mg/L]	0.06	3
NO_3^-	Nitrate	[mg/L]	1.5	50
SO_4^{2-}	Sulfate	[mg/L]	11	250
PO_4^{3-}	Phosphate	[mg/L]	0.84	-
HCO_3^-	Bicarbonate	[mg/L]	195	-
CO_3^{2-}	Carbonate	[mg/L]	0	-

Note:

Values that exceed WHO guidline are underlined.

Remark:

The test result indicates that all the parameters measured meet the WHO guideline and Ethiopian standard set for drinking water. Therefore, the water is suitable for drinking purpose.Note that the water sample was taken by the client.

Analyzed on 09/11/2013 *by* ***Zerihun sebsibe*** *Signature*

Approved on 15/11/2013 *by* *W/R/S/M/D* *Signature*

S/N/N/P/R/S/Water Mine & Energy Dev't Bureau