ANALYSIS OF HYDRUALIC PERFOMANCE OF ALETA WONDO TOWN WATER SUPPLY DISTRIBUTION SYSTEM

MASTER OF SCIENCE THESIS

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ANALYSIS OF HYDRUALIC PERFOMANCE OF ALETA WONDO TOWN WATER SUPPLY DISTRIBUTION SYSTEM

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ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled "Analysis of Hydraulic Performance of Aleta Wondo Town Water Supply Distribution System" submitted in partial fulfillment of the requirements for the degree of Master‟s with specialization in Water Resource Engineering and Management, the Graduate Program of the Faculty of Bio-Systems and Water Resource Engineering, Department of Water Resource and Irrigation Engineering, and has been carried out by Teka Fetosa Jilo Id.No. WREMR/0015/11, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hence here by can submit the thesis to the department.

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We, the undersigned, members of the Board of Examiners of the final open defense by Teka Fetosa Jilo have read and evaluated his thesis entitled “Analysis of Hydraulic Performance of Aleta Wondo Town Water Supply Distribution System, Sidama Region, Ethiopia”, and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of master’s science.

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DECLARATION

I, Teka Fetosa Jilo, declare that this thesis is my own original work and has not been taken from any other sources except such works which have been cited and acknowledged within text, and that it has not been presented and will not be presented by me to any other university for similar or any other degree award.

Declared by

Name **Teka Fetosa Jilo**

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Date ……………………….

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ABSTRACT

In many of the developing countries, the hydraulic and physical performance of water distribution network is inadequate to meet consumers' demands that encounter significant losses in the system. Aleta-Wondo has been experiencing frequent and regular disruption of water supplies for days to a week. This study was conducted in Aleta-Wondo Town to analyze the existing water supply distribution system of the Town. Both primary and secondary data sources were used in this study. Primary data were collected though face-to-face interview with Aleta-Wondo Water Supply Office experts, field observation. For secondary data collection, document review was used to collect valuable information. To analyze the data which is collected from different sources, both qualitative and quantitative methods was used. Software applications tools called Origin8 WaterGEMSv8i and excel were used to analyze the data obtained from different source. The analysis shows that the current total domestic water demand in town was higher than supply, the water supply coverage was evaluated based level of connection per family and average per capita domestic water consumption was 14.11 l/c/day. Hence, this result indicates there is a gap between demand and supply in the year 2020. The average water loss in Town was 31%, showing that needs a matter of concern. None of the junctions had pressure bigger than 70 m. 65.21% of the junction water column recorded a pressure less than 15m water column due to high elevation. 34.79% of the Town has pressure within the optimum range of 15-70 m water column and the highest or lowest velocity recorded was zero during steady state analysis. Velocity in some pipe parts was below 0.6 m/s during steady period simulation. Generally the result of the analysis shows that the overall hydraulic performance of the water distribution system of the Town was poor, which is reflected by low water production rate, low water consumption, and high level of non-revenue water, low service coverage, not pressure in permissible range. Therefore, it is significant to rehabilitate and improve the water distribution system capacities, establishing pressure zone, increase pumping rate and drilling additional borehole. In addition provision of more attention to water losses reduction policies and strategies are vital for remedial measures.

Key words*:* Aleta Wondo, water demand, water coverage, simulation, distribution system water losses**.**

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ADP	Africa development fund
AWTADO	Aleta Wondo Town Agricultural development office
AWRDB	Amhara water resource development bureau
CIWD	Commercial and institutional water demand
DWD	Domestic water demand
EPA	Environmental protection agency
FCV	Flow control valve
GI	Galvanized Iron
GIS	Geographic information system
GPS	Geographic positioning system
GTP	Growth and transformation plan
HDPE	High Density Polyethylene
HTU	House tape user
HGL	High gradient level
IWA	International Water Association
JMP	Joint monitoring point
Km	Kilo Meter
L/C/D	Litter per capita per day
L/S	Liter per second
M^3/S	Meter cubic per second
MDF	Maximum Day factor
MDG	Millennium development goal
MOWR	Ministry of water resource
MOWE	Ministry of Water and Energy

NRW	Non- Revenue Water
NTU	Neighbor tape user
OWWDSE	Oromia water work design & supervision enterprise
PBV	Pressure breaker valve
PHF	Peak Hour Factor
PRV	Pressure reducing valve
PSV	Pressure sustaining valve
PTU	Public tape user
PWS	Public water system
PVC	Polyvinyl Chloride Pipe
SNNPR	South nation national people region
WDN	Water Distribution Network
WDS	Water distribution system
WHO	World health organization
WSS	Water supply and sanitation
UFW	Unaccounted for water
UNICEF	United Nation Child Fund
YCU	Yard connection user
YSC	Yard share connection

1. INTRODUCTION

1.1. Background of the Study

Water is an essential resource for lives as 80% of the human body is made up of water it is considered a curial element of our food and materials and development. Water is unique to the necessities for the existence of living things in general and human beings in particular. For any municipal town, an efficient water supply distribution system is an essential service. Without meeting the water supply-demand of the town, the enhancement of developmental activities and improving the health condition of communities is impossible. The main role in entire provinces of human life and growth was led to a human civilization facing water insufficiency in many regions of the world. The earth hydrosphere has about 1.36 billion km^3 water and 75% of earth's surface is covered with, though, only 2.5 % of worldwide water is new water possibly existing for the drinking of living existences. The remaining 97.5% stays as salty water in the oceans (Abraham et al., 2018).

In Ethiopia, urbanization growth rate highly increasing time to time, 18% of the population is urbanizing according to data published by the country Central Statistical Agency (CSA, 2007). According to UNICEF joint monitoring programmer 2014 report, Ethiopia has improved water supply by 57% (97% in urban areas and 42% in rural areas). Despite the progress seen in Ethiopia, 43% of the population does not have access to an improved water sources.

The most common challenges in water distribution system include water quality degradation, capacity shortages, infrastructure aging and deterioration, demand increases, and their ever-increasing energy consumption coupled with the global energy crisis (CSA, 2007).

This is largely because most of the water utilities do not have enough attention and monitoring systems within water losses and its management, further, water theft, metering error and lack of effective data recording and handling system is the other problem of the water utilities in developing countries (EPA, 2010).

Because of rapid population growth and high water losses from the distribution network, the total water demand of the system in many developing countries exceeds available production capacity. To limit total demand and provide an equitable distribution of available water, intermittent water supplies with reduced system pressures are often introduce (Zdeneksvitak, 2006). The existing problems of inadequate service provision is exacerbated by the fact that population growth and mounting pressure of increasing urbanization have offset much of the gains in service coverage. Service coverage can be one of the indicators of accessibility of water supply that can have an effect on the performance of water utilities. Apart from serving coverage there are other problems that affect the performance of the public water utilities, for example, many public utilities in developing countries, experience high unaccounted

There are different problems that affect the performance of the public water utilities, for example, many public utilities in developing countries including Ethiopia, experience high (UfW) rate, which often average between 40 - 60%, meaning that about half of the potable water produced is lost somewhere in the supply process. Moreover, the public utilities often face financial challenges due to a combination of low tariffs, poor services, poor consumer records and inefficient billing and collection practice (Kimey et al, 2006).

Analysis of urban water supply system should provide to enough water supplies for human being and livestock consumption, for industrial and other uses in terms of coverage, quantity, reliability and acceptable quality taking the existing and future realities of the Town in to consideration. According to Aleta-Wondo Town water supply service office, the most common problems in the Town water supply system were shortage of water, interruption of water supply, break and burst of pipe, low coverage of water. Therefore, this research work was prepared to evaluate the performance of existing water supply distribution system in the Town using hydraulic model WaterGEMSv8i. Water GEMSv8i highly efficient and dynamic modeling software which provides the wide regime of analysis and solutions for fire-flow analysis, water quality modeling, and energy and capital cost management (Water CAD/GEMs, 2008).

1.2. Statement of the Problem

The primary goal of all water distribution system is the delivery of water to meet the demands on quantity and pressure. Unfortunately, as a water distribution system ages, its ability to transport water diminishes and the demands placed upon it typically increase. In addition to the unsatisfactory performance of a deteriorated network, there are direct economic impacts of a failing system (Utikarshnigam et al., 2015).

Mostly problems that occurred in developing countries are intermittent, erratic pressure is not acceptable, inequalities in service provision between the rich and the poor, high rate of water losses from the distribution systems, Population growth and urbanization, Growing urban water demand, Infrastructure is aging and deteriorating (Jalal, 2008). A serious problem arising from intermittent supplies, which generally ignored, is the associated high levels of contamination. This occurs in networks where there are prolonged periods of interruption of supply due to negligible or zero pressures in the system (Zyoud, 2003).

The level of service provided by water supply and distribution systems is one of the key issues facing the water industry today (Tamminen et al., 2008). Regarding coverage and water availability the capacity of the water supply system which encompass sources, transmission, storage facilities and distribution system satisfy current and future demands.

In case of Aleta-Wondo Town the supply system does not satisfy the demand of present population and the distribution system does not cover the whole part of the Town. The common problems in the town water supply system was frequent and regular disruption of water supplies for days to a week, high rate of water losses from the distribution systems, frequent pipe bursting in the water distribution network, water pressure and velocity variation, very old and outdated structures and intermittent water flow.

In addition to insufficient water supply coverage, high water loss issues due to aged pipe and villages in the town which are out of water supply area of distribution network and even if, villages with distribution network unavailability of water most of the time. Therefore, there is a need to perform analysis of the present status of water supply performance of the existing water distribution system of the Town.

1.3. Objectives

1.3.1. General objective

The General objective of the research was to analyze the performance of water supply distribution system in Aleta Wondo Town by different modeling tools.

1.3.2. Specific objectives

The specific objectives of this research include:

- To evaluate the existing water supply coverage of the Town;
- To evaluate the deficit of existing water supply and demand of the Town;
- To asses water loss from water supply distribution system ;
- To study hydraulic performance of existing distribution network velocity and pressure.

1.4. Research Question

1. How much water is consumed by domestic consumer and what is the level of water connection?
2. Is the existing water supply satisfied current demand and future demand for the next decade?
3. How much water losses are in the water distribution network?
4. How to simulate hydraulic parameters of the existing distribution system using water GEMSV8i of the Town?

1.5. Significance of the Study

For developing countries like Ethiopia, different problems have been identified which are responsible for inadequacies of water distribution system. The current study aims to assess the performance of existing water distribution system in Aleta-Wondo Town. The research findings can strongly help, decision makers in planning, urban water and other development activities to achieve good hydraulic performance of water distribution system. In addition, the study can be used to provide scientific information on the future water resource development and fill the gaps of the works by incorporating the recommendation in other research works. Moreover, the study will help to create awareness in societies about water demand consumption, water losses.

1.6. Scope of the Study

In this study, the water that delivers to consumer was assumed quality water and all population use water from town existing water supply distribution system. The demand of livestock assumes river or other sources. Finance analysis of water supply system is not a part of this study. The performance of the existing water supply distribution system was observed under peak hour consumption and minimum consumption time and its performance were evaluated based on hydraulic conditions not including water quality.

1.7. Limitation of the Study

The problem faced in the course of this study was associated with getting sufficient updated secondary data. For example, there was shortage of well-documented data sources and adequate report especially in the study area from Aleta-Wondo Town water office and due to resource constraints in terms of the research experiment materials coupled with cost to be incurred on the research to study water quality.

2. LITERATURE REVIEW

2.1. Water Supply in Ethiopia

The water supply coverage in Ethiopia has been one of the lowest in Sub-Saharan Africa (ADF, 2005). The country's water supply sub-sector has been characterized by poor performance with a number of problems including unsustainability and unreliability of water supply services (MoWRD, 2006). To tackle these problems, the Government of Ethiopia issued the National Water Resources Management Policy in 1999 (MoWRD, 1999) and the Water Sector Strategy in 2001 (MoWRD, 2001) so as to increase and sustain the water supply services in both rural and urban areas and ultimately to ensure that every Ethiopian citizen has access to water of acceptable quality and sufficient quantity. According to ADF (2005) the Millennium Development Goals (MDG) of Ethiopia is expected to increase the improved water supply coverage from 2004 levels of 25% water supply and 8% sanitation to 62% for water supply and 54% sanitation by 2015. In 2010 the government presented the equally ambitious Growth and Transformation Plan (GTP, 2011) that aims at increasing drinking water coverage in rural area from 65.8% (baseline at 2010) to 98% at 15 litter per person per day within the radius of 1.5km and to increase Urban Water Supply coverage from 91.5% to 100% at 20 liters per person per day within the radius of 0.5km and thereby increase national water supply from 68.5% to 98.5% in the year 2015 (MoWR,2010).

Safe drinking water is the birthright of all human kind as much a birthright as clean air while access to clean water can be considered as one of the basic needs and rights of a human being. Health of people and dignified life is based on access to clean water (Korkeakosk, 2006).

Water is important in a number of ways; these include domestic and productive uses. Domestic water use takes the form of drinking, washing, cooking and sanitation, while productive water uses includes those for agriculture, Beer brewing, brick making, etc. Safe drinking water matched with improved sanitation contributes to the overall well-being of people; it has significant bearing on infant mortality rate, longevity and productivity. However, the majority of the world's population in both rural and urban settlements does not have access to safe drinking water (Alehegn., 2009). According to WHO (2006), only 16% of people in sub-Saharan Africa had access to drinking water through a household connection (an indoor tap or a tap in the yard).

Provision of safe and sufficient water supply and adequate sanitation services are Indispensable components in the sustainable development of Ethiopia's urban and rural socioeconomic wellbeing. At present, most of the population does not have adequate and safe access to water supply and sanitation (WSS) facilities. As a result, over 70% of the contagious diseases in the country are water borne/based diseases. Source of most of these diseases could be traced back to inadequate WSS facilities (MOWE, 2011).

2.2. Urban Water Supply Coverage

Water supply coverage provides a picture of the water supply situation of one specific country or city and helps to compare one country with others and the inter and intra city distribution with in specific country. The percentages of population with or without piped water connection are a relevant indicator to compare the coverage of water supply in urban areas. Although the water supply coverage is better in urban areas while compared with the rural, the actual water supply coverage in cities of developing countries in general and African cities in particular is very low while compared to the demand. According to the Global Water Supply and Sanitation Assessment 2000 Report, the African capital cities are having 43% house connection or yard tap, 21% served by public tap while 31% of the population are un-served (WHO, 2000).

A household is considered to have access to improved drinking water if it has sufficient amount of water (20 liters/person/day) for family use, at an affordable price (less than 10% of the total household income), available to household members without being subject to extreme effort (less than one hour) a day for the minimum sufficient quantity), especially to women and children) (UN-Habitat, 2003).

In a simplified way it is often considered equal to water consumption, although conceptually the two terms do not have the same meaning (Wallingford, 2003). In most developing countries, the theoretical water demand considerably exceeds the actual consumptive water use. Water demand management refers to any socially beneficial action that reduces average or peak water withdrawals or consumption form either surface or ground water, consistent with the protection or enhancement of water quality.

2.2.1. Potable water coverage

The WHO/UNICEF JMP report of 2015 indicated that the improved water coverage in Ethiopia was found to be 93% and 49% in urban and rural areas, respectively. The country coverage of improved water source usage reached 57%. On the other hand, 30% of the total Ethiopian citizens rely on unimproved drinking water sources. Even though improved water sources are available, they are often far away from the beneficiary households and are located at inconvenient locations. The management system of stakeholders coupled with water quality problems and inaccessible water sources are some of the basic problems. The topography of Ethiopia is characterized by rugged landscapes on which women and children travel long distances by carrying large containers up and down steep slopes. In addition to that, the lack of safe water supply has other series negative consequences such as the Workload in fetching unsafe water from mostly distant unimproved or traditional water points make them vulnerable to health problems. As a result, most of the children miss the opportunity of attending school, while women spend 10-50% of their daytime fetching water from polluted water points, losing time on productive activities (Ethiopian Water Resources Management Policy, 1999; Crow, 2001).WHO, basic access can be defined as the availability of drinking water at least 20 liters per day per person, a distance of not more than 1 km from the source to the house and a maximum time taken to collect round trip of 30 minutes. The UNDP (2008) says the minimum absolute daily water need per person per day is 50 liters.

Problems in provision of adequate water supply to the rapidly growing urban population are increasing dramatically. Financial constraint is one of the major factors for the low water coverage of the water supply but poor management of the existing water supply system also has a great impact for the low coverage. Beside to the overall low supply coverage, supply disparity exists among different localities.

2.3. Urban Water Demand

Water demand is the volume of water requested by users to satisfy their needs. In a simplified way, it is often considered equal to water consumption, although the two terms conceptually do not have the same meaning (Wallingford, 2003). In most developing countries, the theoretical water demand considerably exceeds the actual consumptive water use (Berhe, 2005). (Maher and Trifunovic, 2013) noted that, water demand is the algebraic sum of the quantity of water utilized by consumer (consumption) and the amount of water physically lost from the system leakage. It usually expressed as per capita demand. Per capita water usage varies widely due to the differences in climatic conditions, standard of living, population growth, type of commercial and industrial activity and water pricing. Water demand increases with time due mainly to population growth. Therefore, new water resources ought to be developed in order to meet the increasing water demand at present and in future (Abdo, 2009). It is usual to classify water demand in various sorts depending on the characteristics of the consumers.' The most common types are domestic, commercial, industrial, firefighting and unaccounted water demand.

According to (Rothert, 2000) water demand management is the adaptation and implementation of a strategy by institution to influence the water demand and usage in order to meet any of the following objectives: economic efficiency, social development, social equity.

2.3.1. Domestic water demand

Domestic demand includes the water required in private building for drinking, cooking, bathing, flushing and washing clothes (Garg, 2010) indicated that the domestic consumption varies according to the living conditions of the consumers, economic status of the community, climatic condition, mode of service and affordability and accessibility of the service. Daily per capita water consumption in Ethiopia is generally very low throughout the country. DWD is suppressed in almost all towns in the country because of supply shortages. Actual demand is expected to be greater than present consumption if greater supplies were available to the community (MOWE, 2011) .

2.3.2. Non-domestic demand

Non-domestic demand comprises Industrial, Commercial, and Institutional, Firefighting demands, Unaccounted Water Demand (UWD).

Industrial water demand: represents the amounts of water demand required by industries and factories in the cities. According to (Garg, 2010), the ordinary per capita consumption of industries is 50l/c/d. but due to the modernization of technology in reusing waste water the amount of water require for industry getting reduced.

Commercial and institutional water demand (CIWD): In addition to those of household consumers, the water requirements of towns include the needs of such commercial and institutional consumers as public schools, clinics, hospitals, offices, shops, bars, restaurants, and hotels. CIWD is usually linked directly to population size. For medium town, the CIWD estimate is taken as 10 per cent of DWD (MoWE, 2011).

Unaccounted water demand: is the amount of water physically lost from the system and theft (Motiee et al, 2007). Losses from water supply systems vary considerably according to diverse factors. According to (MoWE, 2011) water losses are a function of the quality of construction, The type and age of the pipes in the distribution network and pressure within the system. Losses can also originate in treatment plants. Loss for urban scheme is taken as 25 per cent of the total domestic, commercial and institutional, and industrial water demand. It can be obtained as the difference between the supplied volume and the metered volume.

2.3.3. Urban water demand forecasting

Water demand should forecast in time. Many water resource projects have a relatively long useful life. Therefore, in studies of water demand forecasting the plan should extended to about 50 years for long term. In medium scale development plans, a lead-time of 15 to 25 years may apply (Karamouz, 2003). As per GTP-II water supply service level standard, required to provide safe water in minimum 100 l/c/day for category 1 towns/cities(towns/cities with a population more than 1 million), 80 l/c/day for category 2 towns/cities (towns/cities with a population in the range of 100,000-1million), 60 l/c/day for category 3 towns/cities (towns/cities with a population in the range of 50,000 -100,000), 50 l/c/day for category 4 towns/cities (towns/cities with a population in the range of 20,000-50,000) up to the premises, and 40 l/c/day for category-5 towns/cities (towns/cities with a population less than 20,000) within a distance of 250m (GTP-II,2014).

2.3.4. Spatial allocation of demands

Consumption or water demand is that part of the water leaving the system at customers' faucet, leaky mains or open hydrants. This demand is the driving force behind the hydraulic dynamics in the distribution system (Amedework, 2012). It is possible to evenly distribute the overall demand data to each node starting from the bottom/from the customers' billing records/ or from the top/the treatment plant production data/. Although water utilities make a large number of flow measurements, such as those at customer meters for billing and at treatment plants and wells for production monitoring, data are usually not compiled on the node-by-node basis needed for modeling. The modeler is thus faced with the task of spatially aggregating data in a useful way and assigning the appropriate usage to model nodes. The most common method of allocating baseline demands is a simple unit loading method. This method involves counting the number of customers [or acres (hectares) of a given land use, number of fixture units, or number of equivalent dwelling units] that contribute to the demand at a certain node, and then multiplying that number by the unit demand for instance, number of gallons (liters) per capita per day for the applicable load classification. Two basic approaches exist for filling in the data gaps between water production and computed customer usage: top-down and bottom-up. Both of these methods are based on general mass-balance concepts. Top-down demand determination involves starting from the water sources (at the “top”) and working down to the nodal demand (Amedework, 2012).

2.3.5. Challenges for water supply demand

Vairavamoorthy *et.al*, (2008) indicated that water demand is increasing throughout the world for different activities such as for agricultural, recreational and domestic consumptions.

Bartram and Howard (2003) underlined that the role of potable water supply has a vital contribution upon development activities and health of the society, for that reason availability of drinkable water is important components in poverty mitigation.

Adequate and reliable water supply is critical for coping with every day urban life. Poor access to potable water has negative impact on development. As demand for water is increasing at higher rate than supply, water resource developments and management is given a great attention.

new dams construction, harvesting rain water, desalination plants or water recycling are the most common methods of water supply management techniques. Soil and water conservation engineering is the solution of soil and water management problem. International City Managers Association (1957) in (Bihon, 2009) states that water conservation steps include coating reservoirs to protect leakage, covering reservoirs to reduce evaporation, industrial and agricultural reuse of water.

2.3.5.1. Lack of capacity

According to Wallace F et al.,(2008) capacity is a flexible concept and encompasses the public sector, academia; community based organizations and the private sectors, and ranges from the individual to institutions to society as a whole. Capacity can be described in terms of the human, technological, infrastructural, institutional and managerial resources required at all levels from the individual through to national governance. Not only does capacity have to be built within each of these levels, but it has to be institutionalized and local communities need to be empowered to use it effectively.

2.3.5.2. Technological capacity

Innovative technologies are essential to overcome barriers to water and sanitation service provision**.** Technological capacity includes the development and application of new technologies, the technical skills needed to effectively construct, operate and manage a technical solution; the translation of information regarding technologies to promote informed decision-making when implementing a technical solution; the availability and accessibility of spare parts (Sijbesma, 1989). However, technology providers need a better understanding of local conditions and policies.

2.3.5.3. Inadequate financing

Historically, water and sanitation has suffered from severe under financing. This results from inadequate internal financial capacity in the poor countries to achieve water and sanitation goals; poor political decisions for allocation of development aid; an overall reduction over time in development aid; and the limited cost recovery potential in poverty stricken regions (Wallace et al, 2008). In addition, poor targeting of aid and a multiplicity of actors and structures compound the financial shortfall. Prioritization of spending plays a key role, with many developing countries investing only a small fraction of money into water compared with military spending. For instance, military spending in Ethiopia is 10 times greater than that spent on water and sanitation and in Pakistan the discrepancy is even greater 47 times (UNDP, 2006).

Wallace et al (2008) also stated that, to ensure that resources for safe water and sanitation are used effectively at the local level, the local capacities to design, finance and manage improved service delivery must be greatly enhanced. To this end, the Camdessus Panel and others have urged that corruption, managerial capacity, sustainable cost recovery and legal and contractual aspects of safe water and sanitation management within developing countries be addressed.

2.3.5.4. Increasing global water scarcity

(UN-HABITAT, 2006) Stated that, not only is the numbers of those requiring better water supplies very large, water itself is becoming scarcer. The number of people living in water stressed and water scarce over the world is estimated to increase approximately six fold from 1995 to 2025 to reach 2.8 billion.

2.4. Evaluation of Urban Water Distribution System Performance

Performance of a water distribution network can be defined as its ability to deliver a required quantity of water under sufficient pressure and an acceptable level of quality during different normal and abnormal operational situations (Dolatkhahi, Tabesh , 2006). Evaluating the performance of water supply systems is an important for water industry to deliver competent levels of service. A good distribution system should be a capable of supplying water at all intended place within the town with reasonably sufficient pressure head and the requisite amount of water for various types of demand (Garg, 2010)). The performance of urban water supply scheme can be evaluated based on four performance measures: Hydraulic, Structural, Water quality and Customers perception.

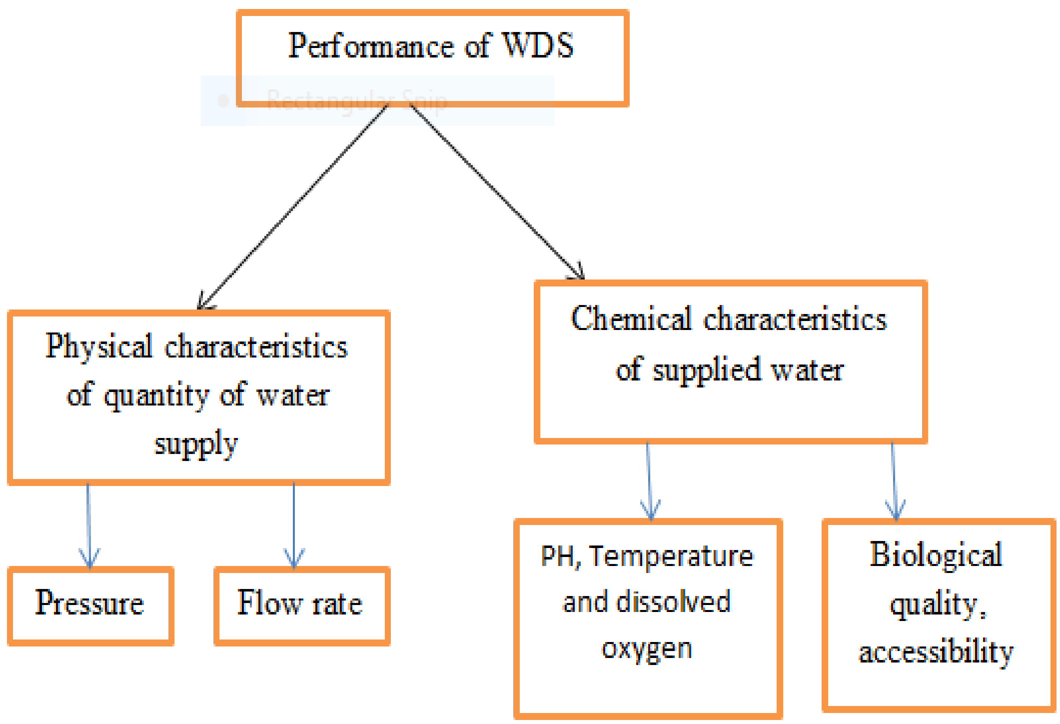

Figure 2. 1:   Performance Classification of WDS (Jalal, 2008)

2.4.1. Physical performance

Water mains generally comprise a variety of pipe work and fittings, and which over time are subject to various episodes of augmentation, refurbishment, renewal, replacement, repair and extension. Physical performance of water supply system is the ability of the distribution system to act as a physical barrier that prevents external contamination from affecting the quality of the internal, drinking water supply (Dolatkhahi, Tabesh , 2006). The most obvious indication of the physical deterioration and failure of the pipe network is leakage. Analysis of a pipe network is essential to evaluate a physical system of water supply systems. The annual volume of water lost is an important indicator of water distribution efficiency, both in individual years, and as a trend over a period of years. High and increasing water losses are an indicator of ineffective planning and construction, and of low operational maintenance activities (Mckenzi et al., 2006). The other indicator is the volumetric efficiency which is the ratio of the registered volume and the total supplied volume during a certain reference period of time a value above 75% is considered to be acceptable. Figure below show water distribution problems within utility.

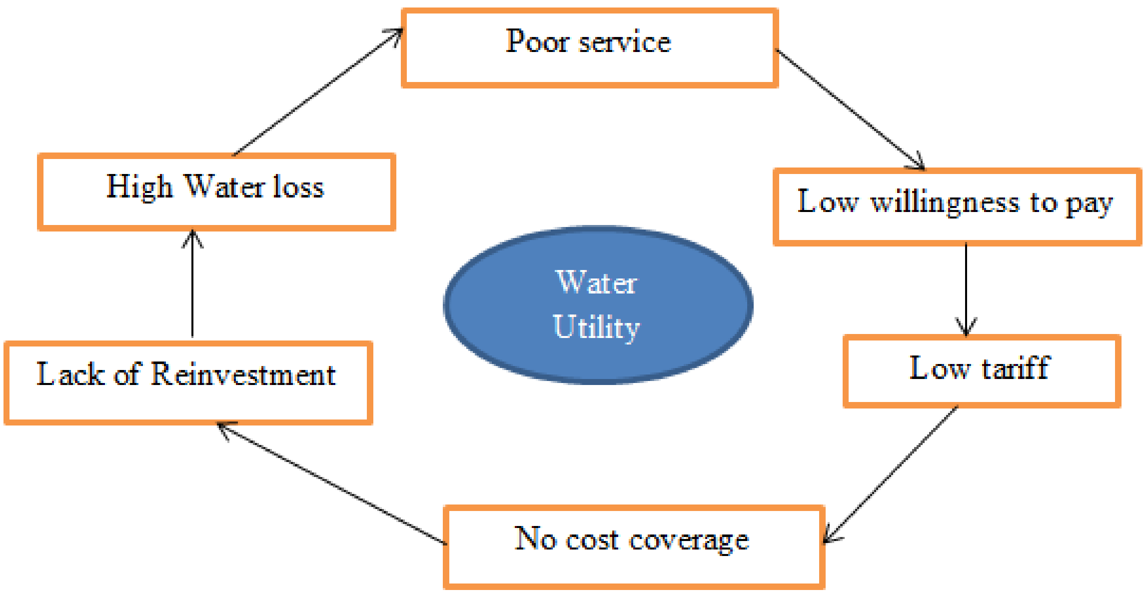

Figure 2. 2: Performance of urban water supply service source (Sharma, 2008)

2.4.2. Operational and maintenance performance

Operation and maintenance is the main challenge of urban water supply system. As per" Making your water supply work operation and maintenance of small water supply systems.

Operation and maintenance are described as follows,

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

- Major operations required to convey safe drinking water to the users, e.g. starting and stopping a motorized pump, the supply of fuel and the control of valves.

- The correct handling of facilities by users to ensure long component life The proper operation of a supply results in its optimum use and contributes to a reduction in breakdowns and maintenance needs.

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

- Preventive maintenance - regular inspection and servicing to preserve assets and minimize breakdowns.
- Corrective maintenance - minor repair and replacement of broken and worn out parts to sustain reliable facilities.
- Crisis maintenance - unplanned responses to emergency breakdowns and user complaints to restore a failed supply.

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

2.4.3. Customer perception

It is important to maintain the public's confidence in the quality of drinking water and the services provided by a utility. Satisfied customers will pay their bills promptly and will provide political support for necessary rate increases or bond issues. In order to evaluate a WDS, it would be ideal to identify all major customers with their preferences, expectations, needs and requirements and then to explore the ways of meeting their expectations with consideration to associated consequences. Major customers may need those facilities that constitute significant portion of supply demand in a region (e.g., residential, Industrial, and firefighting users, public health officials). An ideal approach might be to investigate the quantity of water needed for each Individual customer, the period they need water for, and the appropriate level of water quality that is suitable for their need. The estimation of the quantity of water should reflect customer preferences and expectations efficiently.

2.4.4. Water supply mode in distribution system

Water distribution system is designed to supply the maximum hourly demand. In developing countries the water distribution systems are designed for continuous water supply (CWS) with peak factors in the range of 2.0 to 3.0, whereas in actual practice due to non-availability of adequate quantity of water at source and financial constraints, it is not practically possible to operate drinking water systems for 24h/day (Batish R, 2003).

2.4.4.1. Continuous water supply system

In the continuous water supply systems, water directly conveyed through the distribution network continuously without interruptions. The consumers use water at any time without any need. The main factors required to achieve continuous water supply system are summarized as follows:

❖ Enough water at the source: to meet consumer requirements for water.
❖ A good and reliable distribution network: to guarantee enough water with acceptable pressure to all consumers.

❖ Effective system parameters: capable pump stations and suitable pipe diameters

❖ Successful monitoring policy: to discover any interruption, and to detect damaged pipes early as possible, to reduce leakage.

The water distribution network in the continuous supply systems should be designed to with stands the range of pressures corresponding to the minimum and maximum supply conditions.

2.4.4.2. Intermittent water supply system

Most developing countries have intermittent water supply and sometimes a large quantity of water was received by only a few zones and consumers, leading to inequitable water supply (Manohar U and Mohan Kumar, 2013).The distribution system is usually designed as a continuous system based on the assumption of continuous supply. However, in most developing countries water supply is not continuous but intermittent (Dighade et al., 2014) Intermittent water supply (IWS) systems can be defined as a piped water supply service that is available to consumers less than 24 hours per day. IWS creates high peak factors in the distribution system which causes low pressures at a number of locations. Intermittency generates inequitable water distribution due to pressure dependent flow conditions, with obvious disadvantages for consumers located far away from the supplying points or at higher altitudes in the area. Serious problem was arising from intermittent supplies, which is generally ignored, is the associated high levels of contamination. IWS creates doubts in the minds of the consumers about the reliability of water supply (Lambert 2003).

2.4.5. Types of water distribution systems

A water works distribution system includes pipes, valves, hydrants and appurtenances for conveying water; reservoirs for storage, equalizing and distribution purposes; service pipes to consumers ,meters and other parts of the conveying system after the water leaves the main pumping station or the distribution reservoirs. According to (Walski et al., 2003) the water distribution networks can classified as explained below;

2.4.5.1. Branched system

This type of distribution networks is the most economical system and Common in the developing countries due to its low cost. In this system, when there is need for developing the network, new branches follow that development and new dead ends will be constructing as shown in Figure below

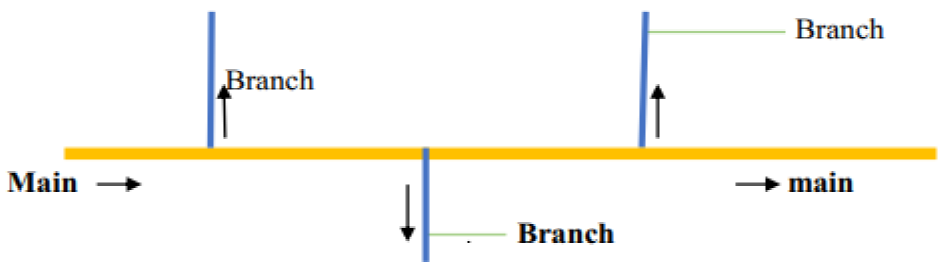

Figure 2. 3: Branched or Dead end system

2.4.5.2. Grid systems

It is an improvement over the branch system, caused by connecting the ends of the various branched pipes so as to eliminate the dead ends. The water then circulates freely through the system. Such a system is very useful for a city laid out on a rectangular plan.

There are no dead ends in this type of distribution networks. The maintenance operation doesn't affect the interruption of the system as in the branching system.

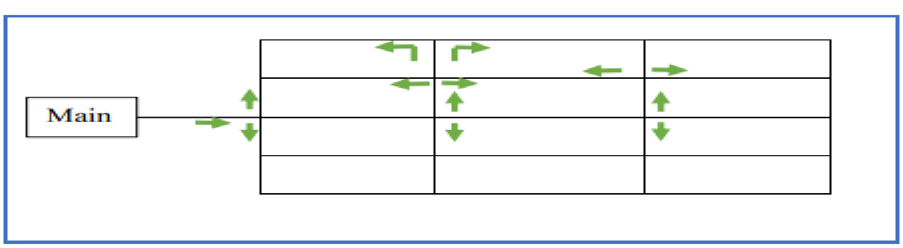

Figure 2. 4: Grid Iron systems

2.5. Water Losses in Distribution System

There are two types of water losses in distribution system (Dighade, et al. , 2014).These are real losses and apparent losses. Real losses consist of water lost through burst pipes, leaking joints, fittings, service pipes, and connections. A high level of real loss reduces the amount of precious water reaching to customers and increases the operating costs of the utility. Apparent losses result from illegal connections, under-registration of customers meters, inaccurate meters, stopped meters, vandalized meters, by passed meters, billing errors, inadequate meter reading policy, bribery and corruption of meter readers. Losses are categorized depending on the places where it loss. Therefore, the water balance can guides water loss estimation in the distribution system while also indicating the level of accuracy of the Non- Revenue Water calculation.

2.5.1. Effects of non-revenue water

The main concern of NRW is the physical loss of water after a huge investment involved in the whole process of withdrawing the water, treatment and delivery to the distribution network in addition to the revenue loss (Sastry, 2006). This is also supported by (Fallis et al, 2011) who classify water lost on its way to consumers as an economic cost as the lost amount of water must be provided again and technically the production capacities of installations must be increased. This is a huge financial burden on the water utilities, in light of the increasing financial scarcity (Liemberger, Frauendorferand, 2010). Real losses have also been identified as a route of contamination in the water distribution systems.

2.5.2. The benefits of reducing non-revenue water

Reducing water loss used for water utility and customers. Quantifying the water losses items of both physical and non-physical water losses in the network were to improve the system efficiency represents an important issue that managers need to consider (Motiee et al., 2007). Water loss reduction should be the aim of every water utilities since it leads to improved economic and ecological efficiency and better service for customers (Fallis et al., 2011). The reduction of apparent losses was increased income for the water utility (McKenzie R and Seago, 2005). Water loss reduction also results in an extended life span of pumps and equipment due to reducing pumping. Reduction of water loss results in the need for less water production, translating into cost savings in operation and maintenance.

2.5.3. Leaks in water distribution systems

Leakage is often a large source of unaccounted for water (UFW) and is a result of either lack of maintenance or failure to renew ageing systems. Leakage may also be caused for poor management of pressure zones, which result in pipe or pipe-join failure. Although some leakage may go unnoticed for a long time, detection of visible leakage also requires good reporting which also needs a strong public participation. Although leakages after water meter has its own contribution to the overall wastage of water, it is not considered as of the total unaccounted for water, as it would be paid for. It is important to distinguish between total water losses (sometimes called unaccounted for water (UFW) and leakage. Total water loss describes the difference between the amount of water produced and the amount which is billed or consumed. Leakage is one of the components of total water lost in a network, and comprises the physical losses from pipes, joints and fittings and also from over flowing service reservoirs (WHO, 2001).

2.5.3. Major factors contributing to high level of water loss

There are several reasons for the high level of water loss in town. These factors are given below, and some advisory solutions were briefly proposed below.

A) Water scheduling: The problem of water scheduling caused by an intermittent supply results in leakage, with a cyclic pressure situation created due to having the supply turned on and off in the corner of the town increased levels of leakage are experienced due to stress being inflicted on the pipes causing them to rupture. There is clear irony in this situation as the problem of water scheduling is caused by water shortages. Due to high levels of water loss, a continuous supply is not available resulting in water schedules.

B) Customer side leakage: Because of the nature of the water storage systems in the country and the generally low rates paid by customers, there is little incentive to conserve water.

Consequently, storage tanks and fittings remain unrepaired for long periods there by contributing to significant loss. It is a significant component of water loss and a strain on the delivery of water. And the customer side leakage also more affected the Authority because the water is not used by the customer so the customer is not paid and they complain to the water office, the office give instruction to the branch and the bill is dismissed, finally the office is loss the money and the office are not collect the revenue at the end the month. These types of leakage are mostly happened on the expansion area or in the under constructions area.

C) Illegal connections: There are a significant number of illegal users of water within distribution system in the town especially in the expansion areas or construction areas. The number of households who do not pay water rates but receive water from its distribution system is not known the office. As a consequence, they contribute significantly to apparent losses and revenue loss to the water office. These connections are often poorly laid just a few inches below the surface and will break easily resulting in real losses taking placed in the form of leakage. Illegal connections are therefore of significant concern of water utilities.

2.5.4. Strategy for water loss management in developing countries

In many developing countries the concept of water loss management has received very little attention compared with the severity of the problem of water losses. A problem solving approach was implemented for water loss management, which is practicable and achievable, can be applied to any water distribution system in developing countries (EPA, 2010). The key developing strategy for management of water loss is to gain a better understanding of the reason for water loss and the factors which influence its component (Makaya E and Hensel O, 2015). A well implemented water loss management strategy can protect public health by eliminating the threat of sanitary defects. Water loss management strategy can be flexible and tailored to the specific needs and ability of water utilities.

2.6. Need for Hydraulic Modeling

In most of the cases, town water supply systems have poor data and recording system comparing to city of which their system is designed using consultant firms. Similarly, from the experience observed design of town water supply systems is conducted manually observed design of town water supply systems is conducted manually with almost on recording and controlling systems. In most of the time data and design documents are found on the hands of individuals who are personally interested. And, most communities do not have information regarding their network system. In such cases, when one wants to assess the performance of the system and the structure in the distribution system, it is advantageous to use user friendly computer models to connect it with data base. Computer models make use of hydraulic simulation software which imitating the real-time system behavior and predicting the performance of the future using "what if" scenarios (Haestad, 2003). In the town area like the one suggested to the research hydraulic simulation models are useful to provide decision support in operation, maintenance and management of the systems. A water distribution system is a pipe network which delivers water from single or multiple supply sources to consumers. Typical water supply sources include reservoirs, storage tanks, and external water supply at junction nodes such as groundwater wells. Consumers include both municipal and industrial users. The pipe network consists of pipes, nodes, pumps, control valves, storage tanks, and reservoirs.

Hydraulic analysis of flows and pressures in a distribution system has been a standard form of engineering analysis since its development by Hardy Cross in 1936. The demand usually reaches a peak in the morning when people are at home and preparing their Meal and its second peak in the evening Maximum water use and minimum water use, usually related to average water use by multiplication of peaking factors (Melaku, 2015).Water CAD views the water distribution system as a network link.

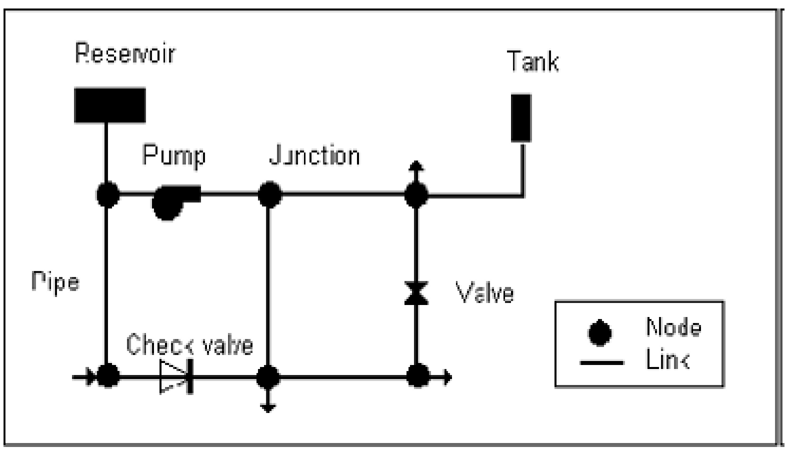

Figure 2.5: Illustrates a node-link representation of a simple water distribution network

2.6.1. Bentley water CAD/GEMS application

Due to the rise of advanced computing techniques and applications. There are various computer software's developed for the purpose of design and analysis of models for a water distribution networks like EPANET, Water CAD, Water GEMS, etc. Among this application software's Bentley Water GEMS/CAD at the current time is a well-known throughout the world due to its availability, functionality, user interference, compatibility, etc. The advantages of Water GEMS V8i over other software's its tools for a simplified model building with geospatial modules like water quality modeling, fire flow analysis, optimization and scenario management, etc. Water GEMS V8i is thus easy to use as a multipurpose water distribution schemes as well as quality modeling. In addition the main advantage of Water GEMS application is its various tools like

Darwin designer for analyzing cost of pipes and pipe catalogue tools which are found to be very effective for modeling, design and optimization of water distribution network with respect to strong data management and integration along with AutoCAD, ArcGIS and other related software packages (Bentley Systems, Incorporated, 2014). Moreover, the choice of software's for modeling distribution network is based on the overall cost of project, data required by software's, specificity of the software related to types of distribution networks it can handle as well as its computational requirements.

2.6.2. Pipe diameters computation

Every pipe is connected to two nodes at its ends. In a pipe network system, pipes are the channels used to convey water from one location to another. The physical characteristics of a pipe include the length, inside diameter, roughness coefficient, and minor loss coefficient. The pipe roughness coefficient is associated with the pipe material and age. The minor loss coefficient is due to the fittings along the pipe. When water is conveyed through the pipe, hydraulic energy is lost due to the friction between the moving water and the stationary pipe surface. This friction loss is a major energy loss in pipe flow and is a function of flow rate, pipe length, diameter, and roughness coefficient.

2.6.3. Principles of pipe network hydraulics

The main reason for modeling a system is to assist designers, managers and planners to explore the governing laws of such systems and accurately analyze their behavior. Hence, models are employed to resolve problems in the system's design and operation (Bogale, 2016).Hydraulic principle water flow in a distribution network satisfies two basic hydraulic principles such as: conservation of mass, and conservation of energy.

2.6.3.1. Conservation of mass

The principle of conservation of mass dictates that the fluid mass entering through any pipe will be equal to the mass leaving the pipe. In network modeling; all out flows are lumped at the nodes or junctions (Walski et al., 2003). Mathematically the continuity equation at the node in the system is expressed as:

$\sum Qin\Delta t-\sum Qout\Delta t-\Delta Vs=0$ ……………………………………2.1

Where, $\sum Qin$ =Total inflow (volume/time)

$\sum Qout$ =Total outflow (volume/time)

ΔVs =Change in storage volume

Δt =Change in time

2.6.3.2. Law of conservation of energy

According to Bernoulli's equation; the principle of conservation of energy dictates that the difference in energy between two points must be the same regardless of the path that is taken (Walski et al., 2003). For a hydraulic analysis of water distribution network, the energy equation between two sections is expressed in terms of head. The energy at any point in a distribution system is the sum of three components, pressure head, velocity head, and elevation head.

$$Z1+P1/\gamma+V1^2/2g+\sum hp=Z2+P2/\gamma+V2^2/2g+\sum hl \quad \ldots\ldots\ldots\ldots\ldots\ldots 2.2$$

Where, Z=Elevation head, P=Pressure

γ = Unit weight of water

V=Flow velocity in pipe

g=Acceleration due to gravity

hp=Head added at pump

hl=Head loss in a pipe

2.6.4. Water distribution network simulation

'The term simulation refers to the process of imitating the behavior of one system through the function of another. It can be used to predict system responses to event under a wide range of conditions without disrupting the actual system. Using Water distribution network simulation, problems can be anticipated in proposed or existing systems, and can be evaluated before time money and materials are invested in real world project" (Walski et al., 2003). According to Walski et al. (2003) there are two basic types of model simulation in Water distribution network.

Steady-state simulation: it represents a particular view of point in time and is used to determine the operating behavior of a system under static conditions. It provide information regarding the equilibrium flows, pressures, pump operating characteristic and other variables defining the state of the network for a unique set demand and boundary condition. Generally this type of analysis used to analyze specific worst-case conditions such as peak demand time, fire protection usage, and system component failures in which the effect of time are not particularly significant (Walski et al., 2003).

Extended-period simulation: determine the dynamic behavior of a system over a period of time, computing the state of the system as a series of steady state simulation in which demand and boundary condition do change with respect to time. It used to evaluate system performance over time and allows the user to model pressure and flow rate changing, tanks filling and regulating valve opening and closing throughout the system in response to varying demand condition sand automatic control strategies was formulated (Walski et al., 2003).

2.6.5. Model Calibration

Calibration is the process of comparing the model results to field observations and, if necessary, adjusting the data describing the system until model predicted performance reasonably agrees with measured system performance over a wide range of operating conditions. Even though the required data have been collected and entered into a hydraulic simulation software package, the modeler cannot assume that the model is an accurate mathematical representation of the system. The hydraulic simulation software simply solves the equations of continuity and energy using the supplied data; thus, the quality of the data will dictate the quality of the results. The accuracy of a hydraulic model depends on how well it has been calibrated, so a calibration analysis should always be performed before a model is used for decision making purposes (Amedework, 2012).

Pipe roughness:-it varies with material types, corrosiveness of water and aging of the pipe. The Hazen Williams equation was developed for the action of friction at the pipe wall; because its formula used a pipe carrying capacity factor C. Different pipe materials have different range of C values. Pipe roughness was increase with decrease in C value. Usually the newer pipes are smoother and therefore have the large C values than the older pipes. For distribution modeling network in this study Hazen-Williams C factor was assumed a bit conservative from the standard ranges in order to account the system uncertainties and to incorporate minor loss effects.

Table 2. 1: Hazen-William roughness coefficients for pipe (Chase et al, 2003)

Pipe material	Hazen-Williams C factor
	Typical range
PVC	120-150
HDPE	120-150
GI	100-130
DCI	100-120

Nodal demand distribution:-The second major calibration parameter that dictates the calibration process is the average demand to be assigned to each junction node. Initial average estimates of nodal demands can be obtained by identifying a region of influence associated with each junction node, identifying the types of demand units in the service area, and multiplying the number of each type by an associated demand factor. Alternatively, the estimate can be obtained by first identifying the area associated with each type of land use in the service area and then multiplying the area of each type by an associated demand factor. In either case, the sum of these products will provide an estimate of the demand at the junction node.

Model Validation

Model validation is comparison of model results with numerical data independently derived from Experiment or observation of the environment. The model validation work was taken manually using the correlation coefficient equation (R^2) method as shown below:

$$R^2 = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})2\sum(y-\bar{y})2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.3$$

Where R^2=correlation coefficient, x and y are the simulated and field measurement pressure values and $\bar{x}$ and $\bar{y}$ are the average value of simulated and field measurement pressure value respectively. Coefficient of determination (R^2) describes the degree of Co-linearity between simulated and measured data. R^2 was ranging between 0 and 1, which describes the proportion of the variance in the measured data, which is explained by the model, with higher values indicating less error variance. Typically, $R^2 > 0.5$ is considered acceptable (Santhi C, 2001).

3. MATERIALS AND METHODS

3.1. Description of Study Area

Aleta-Wondo is a Town in southern Ethiopia, located center of Sidama Region; on found the road connecting Negelle Borena and Hawassa. It is far from 334 km from Addis Ababa and 64 km to Hawassa. Aleta Wondo has latitude and longitude $6^0$36"1E and $38^0$25"1N respectively and average elevation of 1950 m above sea level. It is the administrative center of Aleta-Wondo Woreda. The map of study area is given figure below.

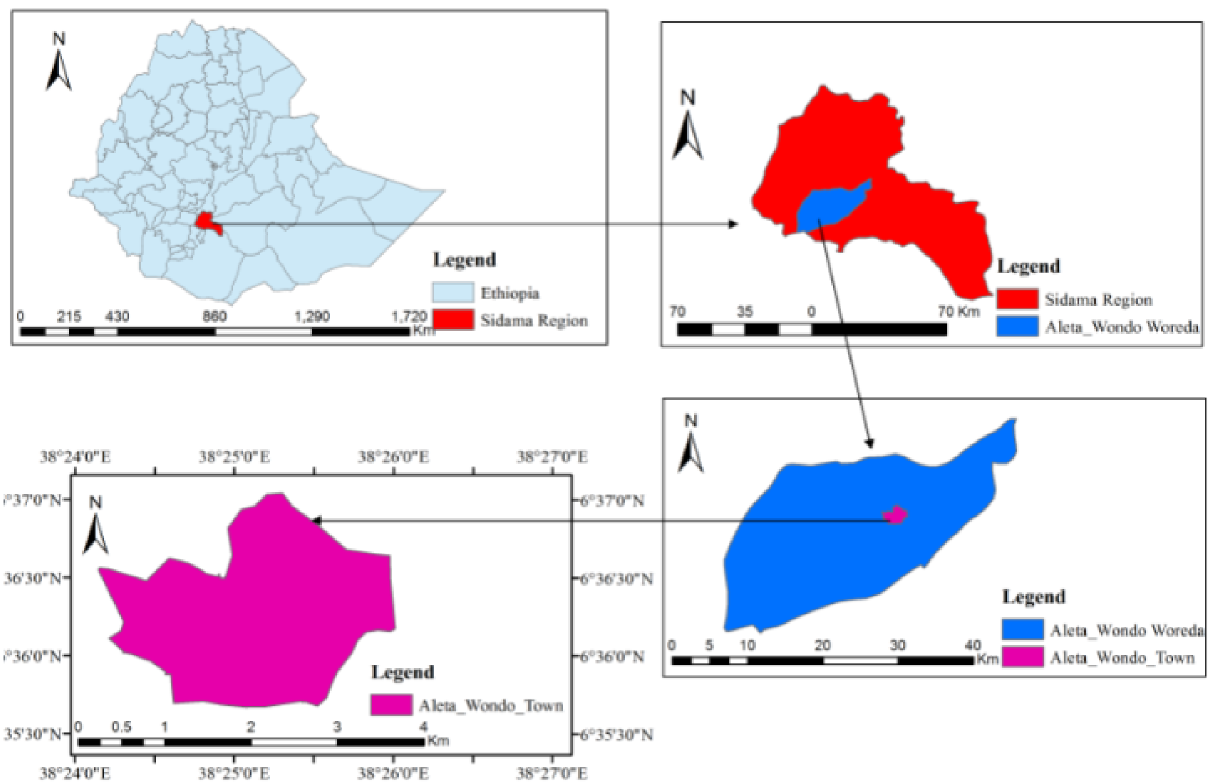

Figure 3.1: Map of study area

3.1.1. Demography

Based on the figures from bureau of finance and economy development, Aleta-Wondo Town has an estimated total population of 58,471 of whom 28,390 were males and 30,081 were females.

The Central Statistical Authority (CSA) is a recognized Ethiopian organization to determine the official population figures and growth rates that should be taken for any development activity throughout the country. The standard approach to forecasting would normally involve a detailed analysis of past population trends.

This approach requires detailed information on the present consumption patterns and future economic development scenarios. Population data of areas of Aleta-Wondo Town to collect from Town Finance and Economic Development Office which has two purposes: primarily, to know the present population that is served by the existing water supply system. Secondly, to forecast the future population of the area to be served from water supply system within the expected design period.

3.1.2. Climate

The wet period runs from June/July to August/September. Maximum temperatures are observed in December-March while minimum are recorded in July- August. The minimum temperature of the town is 17^0C and maximum temperature 26^0C. The mean annual rainfall of the town is about 905mm or it is Woina Dega atmospheric condition.

Table 3.1: Annual average monthly rainfall of AWT for year 2019

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean rainfall(mm)	12	18	86	98	81	73	235	250	196	37	21	9

The average annual rainfall is and elevation ranges from1100-2800 m.a.s.l (AWTADO, 2018).

3.1.3. Material

This research was conducted on analysis of existing water supply in distribution system with in loss and consumption to achieve the goal of the research the materials that are used.

- Water GEMSV8i software to determine velocity, nodal pressure and other parameter.
- Arc GIS for delineation of the study area,
- GPS to check coordinates points of reservoir and sources of water supply
- Pressure gage: to measure the pressure at the nodes and pump outlet
- DEM, calculator, and AutoCAD 2007

3.1.4. The Research design

The water per capita consumption supply of the Town would first evaluate consumption with in specific year. After evaluating the water per capita consumption, the percentage of the water loss would estimate. The total water produced and actual water consumption as aggregated from the individual contracts (customer meters) was used as an input for water losses analysis. After evaluating the total water losses, the possible causes of water losses were try to be identified. Then the performance of water distribution network evaluated standard guidelines. After all the parameters fundamental to run the simulation are arrive within the demonstrate, will be giving using water GemsV8i computer program. Lastly, estimating the current and future water demand of the Town was conducted by considering per mode of service.

3.1.5. The Town water source system

The Town's main source of drinking water is ground water with the yield of water 19.4l/s deliver from the source. This ground water supplied to the population is abstracted from the bore hole by pump. After the water is pumped to service reservoir, then from the storage reservoir water is distributed to the consumer by gravity system.

Table 3.2: Description of existing boreholes (Source: Aleta-Wondo water utility)

Borehole	X(m)	Y(m)	elevation	Depth	static water level	Draw Down(m)	Yield(l/s)
BH1	437473	731218	1919	148	67.35	14.5	4
BH2	436220	730653	1908	154	72.06	22.24	3.2
BH3	435268	733771	1837	145.5	57.3	15.37	7.2
BH4	436049	732006	1883	162	85.16	3.52	5

There are springs source developed on spot and open, serving as water sources for some part of the Town population. These springs have low yield, generally below 0.1 l/s. typical example of the springs in the Town is Masa spring, which is found in Mesalemia kebele, at UTM location of 0434611E, 0729596N and 1983m elevation. It is constructed/ capped on spot/ in 1994 EC and has estimated yield of 0.08 l/s. Water from this spring has better for drinking purpose.

3.1.6. Existing distribution system

The existing water distribution system of the Town is gravity system. The water from the source is taken by pump and the water from the lower elevation is taken to storage reservoir by pump. Then, the stored water is distributed (PVC, DI and GI) to the Town by gravity. The water distribution network of the Town consists of about 23.88 km of water pipes ranging in diameter from 2 to 8 inches. The existing distribution system consists of a variety of pipe types: ductile iron, PVC and galvanized iron. In the Town water supplied to user by intermittently and managed by water supply staff using controlling valve in order to supply costumer twice a week.

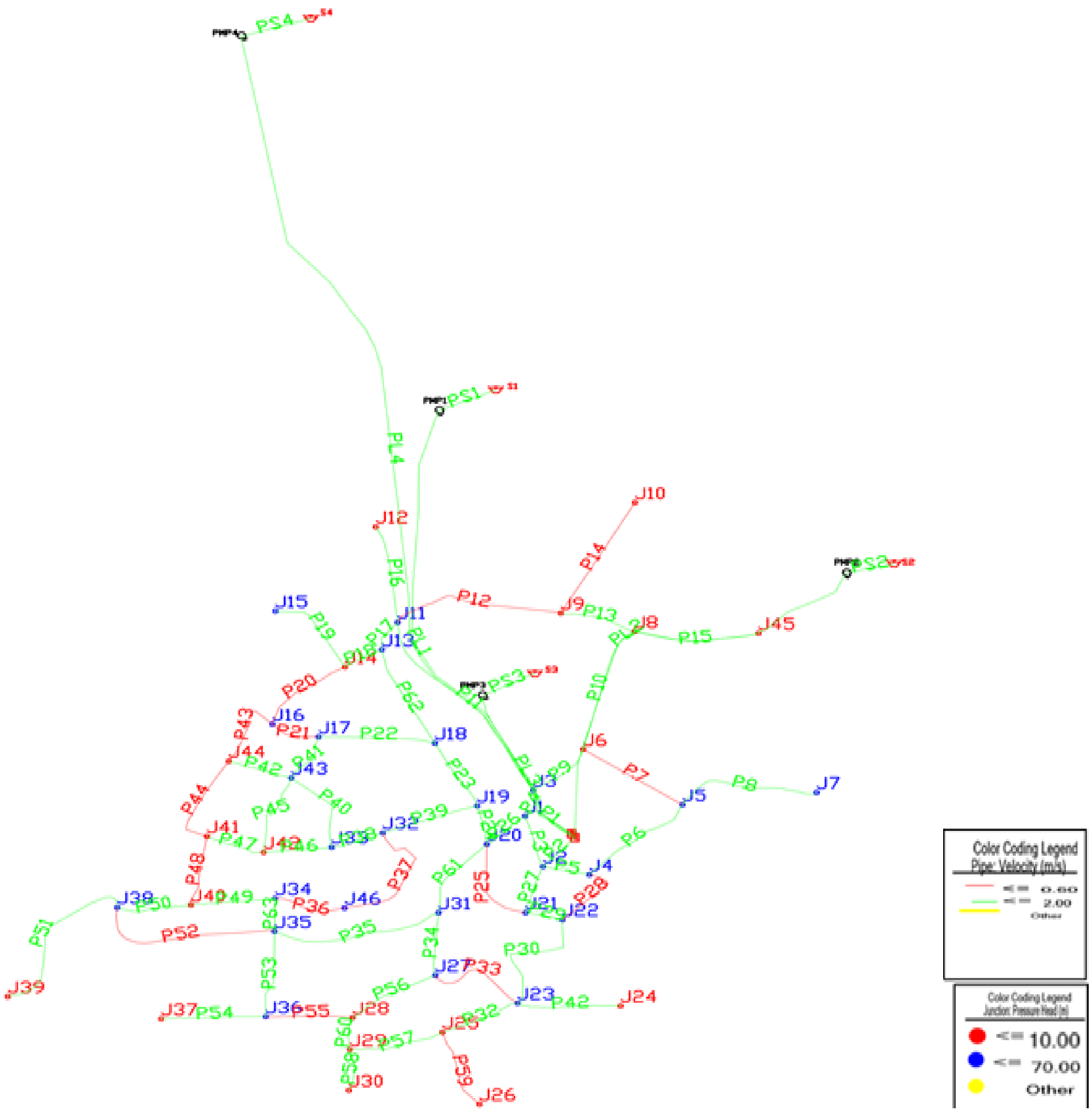

Figure 3.2: Existing distribution system of the Town

3.2. Data Collection

Primary data were collected though face-to-face interview with Aleta-Wondo Town water supply office, field observations and measurement, photographs of relevant sites was taken. Collection of all the required input secondary data from the concerning bodies would be conducted to accomplish this study. Secondary data were collected from reviewing of documents from SNNWR, South water design and supervision office, journals, reports, and internet.

3.2.1. Water consumption

In order to evaluate the water loss in the distribution system, consumption data of each customer are collected from billed data. It was collected five year productive and consumptive data from Town water supply office. Even for the existing water distribution systems, the nodal demands change due to many factors, such as new users or an increase in the number of existing users. In conjunction elevation readings are also take at same zones that is planned to verify the relation between pressure and elevation.

3.2.2. Water production

The water production consumptive five year has been evaluated as total annual water supplied to the water distribution system (WDS). The production of water depends on four-supply bore holes, which are administrated by Aleta-Wondo Town water service office. The designed gross water four boreholes connected and produce capacity of these boreholes are 19.4 liters per second (l/s) for average working time is 18hr/day.

3.2.3. Existing water distribution network

The existing water supply of the study Town can be estimated using documented data of the scheme. To obtain the existing supply, all yield of the scheme are summed up to know supply and demand variation.

The entire town water supply network including their attribute like pipe length, diameter, material types, roughness coefficient of the pipes, Junction point, pumps characteristics, two reservoirs and their volume $150m^3$&$300m^3$ sections has been collected from the South design and supervision office.

3.3. Data Analysis

To analyze the data which is collect from different sources, both qualitative and quantitative methods was used. From the quantitative methods, the descriptive statistical methods like percentage, graphs and cross tabulation was used in order to come up with the appropriate result. The computer software application water GEMS model and excel was used to analyze the data obtained from office. The field survey data for distribution system was evaluated by using the engineering software such as Water *GEMSV8i*, Global Mapper and GIS. The method of analysis was based on nodal pressure and velocity parameters. During data analysis, the nodal pressure and pipe link velocity were determined to identify higher or lower pressure zone of the area. The standard value of nodal pressure and velocity was determined. The value which was under normal value was taken as acceptable and below and above the standard values was taken as unacceptable.

3.3.1. Analysis of existing water supply system of the Town

Average per capita consumption was used to assess the domestic water supply coverage of the Town. Data on individual domestic water consumptions, total water consumption (m^3) and total production (m^3) is collect from Aleta-Wondo Town Water Supply office bill documents for analyzing average per capita consumption. The following formula was applied for the determination of per capita consumption (liter/person/day) (Berhe, 2005).

$$\text{Domestic Consumption (L/p/d)} = \frac{\text{Annual consuption(m3)} * \text{1000L/m3}}{\text{Population number} * 365} \ldots\ldots\ldots\ldots\ldots 3.1$$

Level of water connection is an important element in the evaluation of domestic water supply coverage. In order to compare the distribution of the water connection among the different kebeles; the total numbers of connections per kebele are converted to connection per family using the population data and average family size of each kebele.

$$\frac{\text{Total Active connection} * \text{Average family size}}{\text{Total Population}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

3.3.2. Population projection and water demand analysis

Water supply coverage is usually evaluated based on the quality, quantity, paying capacity of the people, distance, etc. but the intention of this research is to evaluate all those but related to the quantity of the supply and level of connection that are related to the water loss. In this part of the analysis, the number of domestic connection per family and the average daily per capita consumption is used to analysis the domestic water supply coverage for the Town. The level of coverage has been also compared with other Town of developing city. Beside to the statistical analysis for the Town, the distribution of the average daily per capita consumption and connection per family has been evaluated.

3.3.2.1. Population projection

Several models are used to forecast the population. In projecting the future population, geometric increase method and regional population growth rate will use to all towns in Ethiopia for every five years interval (Amedework, 2012). Therefore, the geometric increase method was adopted for this scenario for the purpose of future population forecast of the Town. Because this, method is mostly applicable for growing Towns having vast scope of expansion, like Aleta-Wondo Town. It was taken data SNNPR (CSA, 2007).

Population for the next twenty (until 2040) years is to project by using geometric increase method as follows.

$$Pn = \mathrm{Po}(1+\frac{r}{100})^{n} \quad \text{……………………………………………..3.3}$$

Where, Po= initial known population i.e. the population at the end of last known census; Pn= population after n years; r= growth rate and n= number of years of the concerned period.

Table 3.3: Urban growth rate for SNNPR

Year	2020	2021	2025	2030	2035	2040
Population Growth Rate	4.69%	4.69%	4.48%	3.97%	3.59%	3.16%

(Source: CSA, 2007)

3.3.2.2. Water demand projection

The domestic water demand is the portion of that municipal water supply, which is used in home and largest portion of total demand for most water system (DOH, 2009). There are four modes of services identified for domestic water consumers of the Town. These are house connection (HC), yard connection own (YCO), Neighborhood connection (NC) and public tap user (PTU). The per capita water demand for various demand categories of the Town was adopted by taking into account the different development factors and standards used by the Ministry of Water Resources (MoWR, 2006b). In projecting the domestic water demand of the town, the following procedures were used.

1. Population percentage distribution by mode of service

Although the standard approach for formulating the percentage of population served by different modes would normally involve a detail analysis of past consumption trends based on office expert household survey, the base year (2020) percentage of population by mode of service was adopted from Aleta-Wondo Town records and documents. The distribution of population each mode of service determined by considering socio-economic situation and living standard of the Town. After establishing the population, distribution for the base year 2020 forecast were made to 2040.

2. Projection of consumption by mode of service

Distributions of mode of service will establish based on available data. The forecast envisages decrease in the public tap and neighborhood users. The assumption was that more people would have yard connection. Besides, the number of house connection would increase in certain amount. Due to this, a significant increase of yard connections was estimated.

3. Establishment of per-capita water demand (l/c/d) for each mode of service

The per capita water demand is the most important parameter to estimate the total water demand of the Town. The per capita water demand varies with the level of water service, mode of service, affordability, climatic condition and socio- economic factors. The values are used to establish domestic per capita water demand by mode of services of Aleta-Wondo Town.

4. Projection of domestic water demand

Estimation of water demand per mode of service and estimation of population by mode of service was used to calculate the average per capita water demand. The average per capita domestic water demand for each year will computed by combining water demand by mode of service and population percentage distribution by mode of service for the year 2020 to 2040.

3.3.2.3. Adjustment to climate

In addition to per-capital water demand and mode of services which influence the quantity of water consumption, the climate also affected the water consumption which is given below

Table 3.4: Climate Adjustment factor (MOWR, 2006**)**

Altitude	Factor
>3300	0.8
2300-3300	0.9
1500-2300	1
500-1500	1.3
<500	1.5

3.3.2.4. Adjustment for socio-economic activity

The domestic water demand also depends on the socio-economic situation of the area. Thus per-capita domestic water demand was modified using appropriate factor. The demand adjustment factors in socioeconomic situations were given in table.

Table 3.5: Demand adjustment factor for socioeconomic situation (AWRDB, 2012)

Group	Description	Factor
A	Towns enjoying living standard and with very high potential development	1.10
B	Towns having a very high potential for development, but lower living standard at present	1.05
C	Towns under normal Ethiopia condition	1.00

Aleta-Wondo Towns were considered as Towns under normal Ethiopia conditions and therefore the Town was categorized with the Town of group C with a factor of 1.00

3.3.2.5. Nondomestic water demand

Commercial and institutional water demand (CIWD*)*

This category includes water required for various public water utility purposes like hotels, hospitals, parks, playground, gardening sprinkling on road street foundation, banks, mosques Churches, etc. This demand is recommended 10% of the domestic demand. Therefore, in this study institutional demand was taken as 10% of the domestic demand.

$$CIWD = 10\% * \text{DWD} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.4$$

Fire demand Fire demand is the quantity of water required for fighting a fire that may break out at commercial center, stores, cities etc. For this study, it was take as 10%.

Industrial Water Demand

Small scale industries water demand varies considerably with the type of industry and even for the same industry depending upon the age of the technology used. This makes demand estimation difficult. Most of the time big industries, universities, and institutions generally have their own water supply arrangements from the private tube-wells. Small-scale industrial enterprises will not be categorized separately but should be included in the allowance for institutional and commercial demand (MOWR, 2006)

Unaccounted water demand/System Loss

This includes the quantity of water due to wastage, losses, etc. Losses from water supply systems vary considerably according to diverse factors. Loses are a function of the quality of construction, the type and age of the pipes in the distribution network, and pressure within the system (MoWE, 2011). For urban schemes, losses equivalent to 25 per cent of the total domestic, commercial and institutional and industrial water demand was assumed. Total water demand for the Town is the sum of all the demands calculated below.

Total water demand (TWD) = DWD + CIWD +IWD+ UWD ………………………3.5

3.3.2.6. Variation of water use

The rate of water use varies from season to season, from day to day and from hour and hour. Therefore, to satisfy this variation of demand the average day demand was scaled up by certain factors to get the maximum day demand and peak hour demand. These scaled up water demand figures are used to determine the capacities of pump stations, rising main and pipe distribution network.

Maximum day demand; the maximum day demand is the highest demand of any one 24-hour period over any specific year. It represents the change in demand with season the maximum day factor (MDF) utilized to calculate the maximum day demand is dependent on the population of the Town.

Peak hour demand; the peak hour demand is the highest demand of any one hour over the maximum day. The peak hour factor (PHF) utilized to calculate the peak hour demand. The MDF and PHF are given in the below Table.

Table 3.6: Maximum day factor and peak hour factor. (MoWR, 2006)

Total population	MDF	PHF
0-20000	1.3	2
20001-50000	1.25	1.9
50001 -100000	1.2	1.8
>100000		1.7

For Aleta-Wondo Town the population was 58,471 in the year 2020. Therefore 1.2 MDF and 1.8 PHF value was taken to calculate maximum day demand and peak hour demand respectively, since the population of the Town was 50,001 above. In demand analysis, knowing the maximum daily demand and peak hour demand are very crucial.

3.3.3. Water loss analysis

Water loss is hard to calculate or forecast in water distribution network design, but it is important to assume this amount of water. However, a leakage- free network is not a realizable technical or economic objective, and a low level of water losses cannot be avoided, even in the best operated and maintained systems, where water suppliers pay a lot of attention to water loss control. So minimizing the leakage amount is an important target for water industry, since it is not only an issue related to town long term planning and environment, but also related with financial and economic issues.

The total annual water produced and distributed to distribution system and the water billed that will aggregate by the individual customer meter readings are used to quantify the total water losses of the town (EPA, 2010).

$$\text{Total Water loss\%} = \frac{\text{Total Produced} - \text{Total Billed}}{\text{Total Produced}} * 100 \ldots\ldots\ldots\ldots 3.6$$

This study was aimed to propose an effective water loss management and water supply coverage in Aleta-Wondo Town. Thus, water loss approach was advised for present study to manage water loss problem in the Town. In the study, in addition to technical loss, some engineering proposals for the effective control of nontechnical loss and general water economy are suggested.

3.3.4. Hydraulic modeling

Water GEMSV8i would be used for the purpose of understanding pressure regime, demand, velocity, and head loss and overall systematically studding and better understand network operation. Hydraulic performance analysis was carried out for extended period using Water

GEMS. GIS location Map showing the Town water sources, reservoirs and boost stations is produced by taking GPS readings of the existing water sources, reservoirs and pumping stations. The analysis is beginning by feeding the diameter& length of pipes in to software and Junction co-ordinate and demand then produce pressure, velocity and head loss are in the distribution system. By using the land use map, the area that was supplied for each node is marked, measured, and tabulated under each category. The total water demand for each category was computed. The demand area ratio for each category is computed assuming the population distribution is uniform. The main hydraulic parameters in water distribution networks are the Pressure and the flow rate, other relevant design factors are the pipe diameters, velocities, and the hydraulic gradients.

3.3.4.1. Hydraulic parameters

The main hydraulic parameters in water distribution networks are the Pressure and the flow rate, other relevant design factors are the pipe diameters, velocities, and the hydraulic gradients. **Pressure:-**Water distribution networks must maintain adequate water pressure throughout the network. The water pressure on nodes depends on the adopted minimum and maximum pressures within the network, topographic circumstances and the size of the network. Water pressure was typically maintained between 25 and 75psi (Mays et al., 2000). The minimum pressure should maintain to ensure that customers‟ demand provided at all times. The maximum pressure also contains a limitation of leakage and lead to water loss in the distribution system. The operating pressure in the distribution network is given in Table below.

Table 3.7: The Operating pressure in the distribution network (MOWR, 2006b)

Pressure	Normal condition	Exceptional condition
Maximum	60m of H_2O	70m of H_2O
Minimum	15m of H_2O	10m of H_2O

3.3.4.2. Pipe velocity in water supply network

It is the quantity of water passes within a certain time through certain section. Velocity is directly proportional to the flow rate. For a known pipe diameter and a known velocity, the flow rate through a section can estimate. Low velocities affect water consumption and severe to diseases problem. Different design guide line has been developed by different researchers for the standard velocity in pipe flows. They recommended optimum velocities for pipe flow in transfer and distribution mains are presented in Table below.

Table 3.8: Pipe velocity range from various sources

Distribution type	MoWR (2006)	World bank(2012)	OWWDSE(2010)
Maximum transfer main velocity	2m/s	3m/s	2.5m/s
Maximum velocity in distribution	2m/s	1.5m/s	0.8-1.2m/s
Minimum velocity in distribution	0.6m/s	0.4m/s	0.5m/s

Flow:-It is the quantity of water passes within a certain time through certain sections. Velocity is directly proportional to the flow rate. For a known pipe diameter and a known velocity, the flow rate through a section can estimated. Maximum velocities in distribution system is 2 m/s and minimum 0.6m/s. Low velocities affect water consumption and severe to disease problems.

3.3.4.3. Creating the model in water GEMS

Using water GEMS tool one can specifically consequence all the shape files at once. To draw physically arrange in case the drawings and the measurements are accessible or implication records from AutoCAD and GIS. One exceptionally great includes that Water GEMS offers is the demonstrate builder. Within the Show Builder, one can select the data basis type as shape files and after that click on the browse button. At that point has got to browse to the particular area where the shape files and put away and after that select all of them. One exceptionally imperative viewpoint is to consider mid modeling is that all the geospatial information records utilized among modeling should to have the same geographic projection. The shape files of the water lines, water supplies and, the capacity offices are anticipated with concerning facilitate framework of ortho-images of study town.

The distinguishing and correcting data errors related to network data, demand data and operational data, which occur during data gathering process, data preparation and data analysis processes were undertaken. The input data should be entered into the software using different techniques these were model builder from dxf. File to software, use the properties editor for each element by individually opening the properties editor or used flex table for similar element data used by model builder so that the total input data for the analysis of distribution system included: - Nodes(Elevations and base demand), Pipes (Pipe diameters, lengths, material type), Tanks(Base ,minimum and maximum elevation and 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) and Hazen -Williams pipe coefficient values, and other necessary values used by flex table.

Table 3.9: Input parameters and the primary tool for model.

Label	Type	Primary modeling purpose	Input data
Reservoir	Node	Provides water to the system	Hydraulic Grade line, water surface elevation
pump	Node/Link	Provides energy to the system and raise the water pressure to overcome elevation deference and friction loss.	Elevation, pump definition (characteristics of max, operation and design discharge, head efficiency)
Tank	Node/Link	Store execs water within the system and release that water at time of high usage	Base elevation, maximum elevation, minimum elevation and Diameter
Valve	Node/Link	Controls flow or pressure through a pipe and results in losses of energy in the system	Elevation, diameter, valve type
Pipe	Link	Transport water from one node to another node	Elevation, Diameter, material and roughness coefficient
Junction	Node	Discharge the demand required or recharge inflow water from the system	Elevation

3.3.4.4. Model Performance Measures

A) Coefficient of Determination (R^2)

The coefficient of determination describes the degree of collinearity between simulated and observed pressure. (R^2) describes the proportion of variance in measured data explained by the model. R^2 ranges from Zero to one, with higher values indicating less error variance and typically value greater than 0.5-1 (1 inclusive) are considered acceptable (Cincinnati, O., (2005))

The model performance was taken manually using coefficient of determination (R^2) method

$$R^2 = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})2\sum(y-\bar{y})2}} \quad \text{……………………………………..3.7}$$

Where: R^2= is the Correlation coefficient, X and Y are measured and simulated values, X mean and Y mean are the average value of measured and simulated data respectively.

B) Degree of Accuracy (Error of Difference)

The degree of accuracy varies depend on the size of the system and the amount of field data and testing available to the modeler Behute, (2016) states that the average difference of ±1.5 m to maximum of ±5 m represents for good data set and ± 3 m to 10 m far bad data set would be a reasonable target. This is in terms of comparing the observed versus the calculated pressure heads in the system.

C) Average Operating Pressure Measurement

The Pressure readings were taken with a pressure gauge in Aleta Wondo Town on November, 2020 during the morning and day. For each node the record was taken three times at different in single days, the model calibration was undertaken based on the different calibration standard criteria for the hydraulic network system. To calibrate the model some junctions accessible and available for pressure measurement are taken using pressure gauge measuring instrument in the faucet. The pressure measurement using pressure measuring gauge.

3.3.4.5. Procedure of the modeling structure

All the modeling and data's are in terms of SI unit and based on the latest definitions adopted by the IWA. The processes involved in the study by modeling are presented and described schematically below on figure.

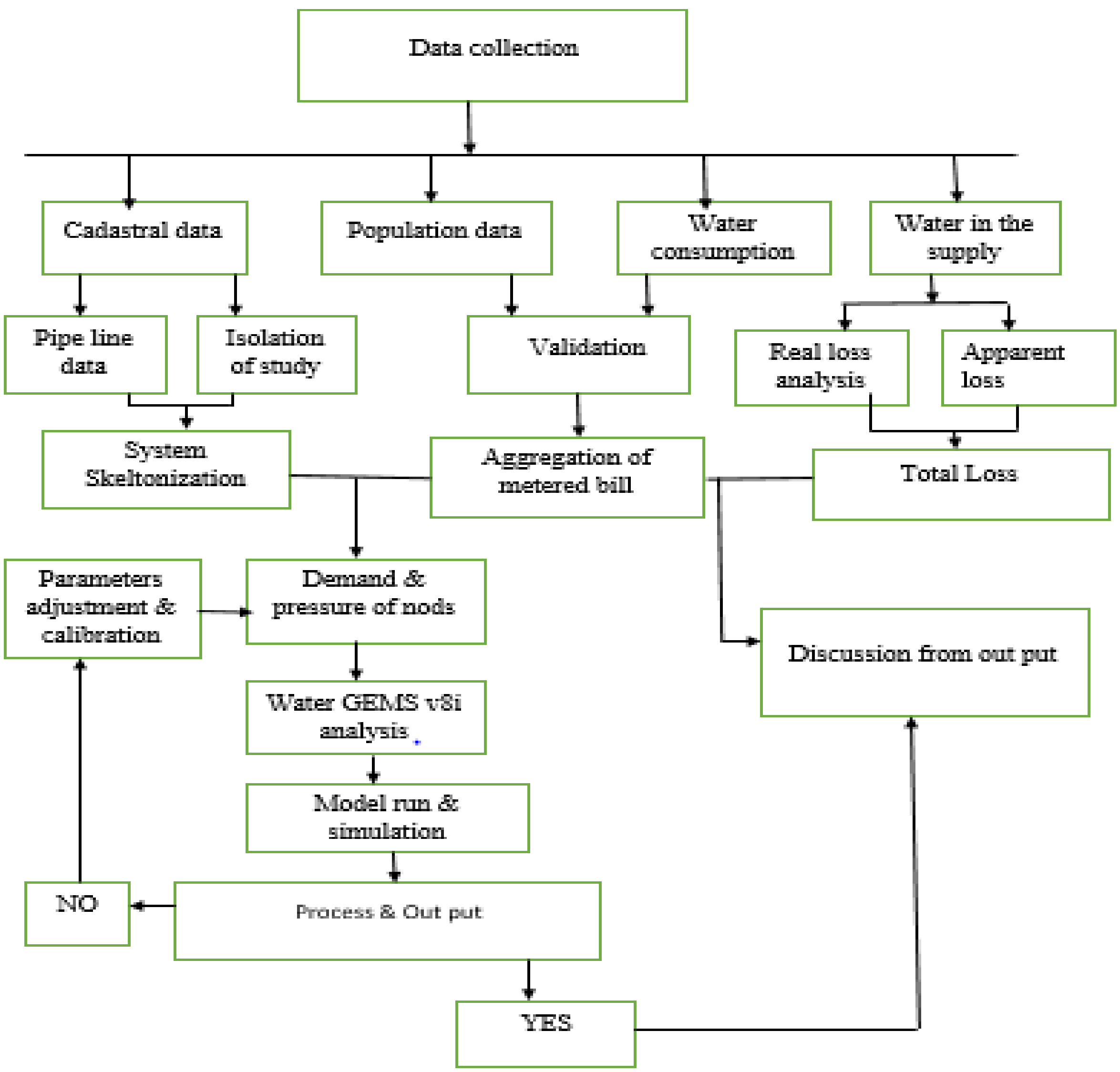

Figure 3. 3: Diagram of water GEMS process/Simulation process

3.3.5. Flow chart of the thesis

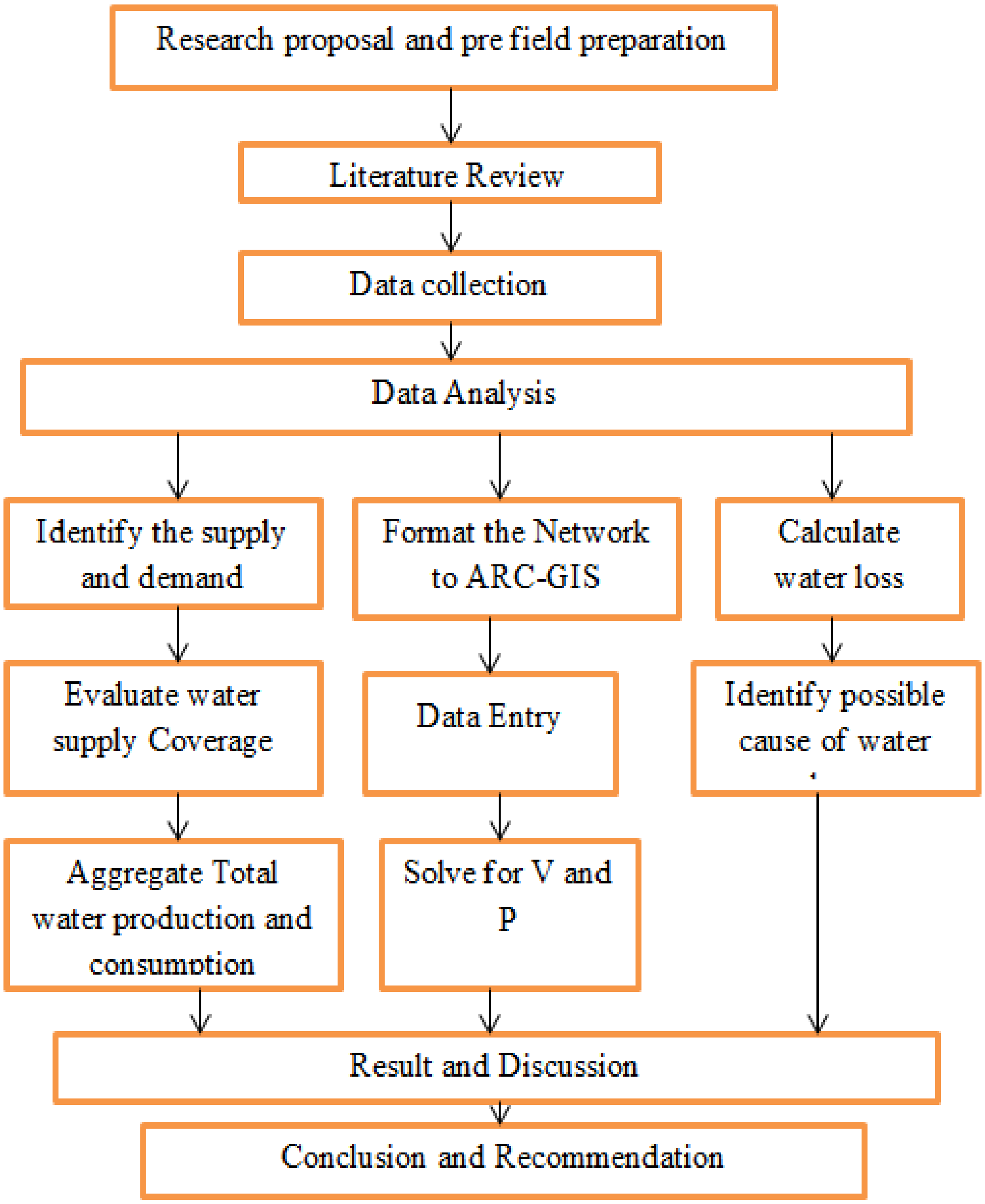

Figure 3. 4: Diagram of study process

4. RESULT AND DISCUSSION

4.1. Evaluating the Current Water Supply of Aleta-Wondo Town

4.1.1. Coverage of potable water

Access to water supply can be evaluated using the amount of water consumed and population distribution by mode of service. In order to evaluate the potable water supply coverage, population percentage served in each mode of service was determined. The domestic water supply of the Town was HC 0.81%, YC 42.76%, YCS 1.71% and PT 54.68%. Therefore the domestic water supply of the town was used by such percentage of the service. Based on this value the domestic water supply distribution system of the Town is lower. The uses of water depend on socio-economic development of society in the Town. There is low income and lack of awareness people to use water to connect to their house and also low production of water from the source due to that intermittent water supply several consumers' uses public tape and yard tape user.

4.1.2. Average daily per-capita water consumption

The per-capita water consumption for various demand categories varies depending of the size of the town and the level of development. In Aleta-Wondo Town, because of the growth of socio-economic activities in both governmental and private sectors, there was high water consumption in the Town. The annual water consumption data were converted to average per-capita consumption using the population data of Aleta-Wondo Town in (2020) by using equation (3.1).

Table 4. 1: Water consumption of Aleta-Wondo Town

year	Population	Consumption(m^3/year)	Per-capita consumption l/c/d
2020	58,471	301,278	14.11

(Source Aleta-Wondo Town water utility)

Based on this the per capita domestic water consumption of Aleta-Wondo Town in the year 2020 was 14.11 l/person/day. Regarding to this value, per-capita domestic water consumption of the Town was not satisfying the standard value. According to the WHO (2011), the optimal water consumption rate per person per day is given as 100 liters. Regarding to this value, the water consumption of the town was only 14.11 l/c/day of the standard value. The quantity of domestic water required in urban area of Ethiopia was taken 60l/c/day for category 3 towns/cities (towns/cities with a population in the range of 50,000 -100,000) (MOVIE, 2015). Based on this value, per- capita domestic water consumption of the town was not satisfies the standard value. From this result, it can be concluded that the per capital water consumption of the Town is very low, so it needs to be improved.

4.1.3. Based On Level of Connection

Level of water connection is an important additional element of evaluating the level of water coverage. In this section the spatial distribution of the connection in relation to number of population was discussed. In areas where water supply coverage is sufficient, volume of domestics water consumption is expected to be linear related to the level of connection. Areas having better level of connection are expected to consume more water as they can easily get it within their compound. The number of domestic connections per family has been also used for analyzing the level of the connection as elaborated below.

The total number of connections water meters in the town were about 3294 up to 2020. In order to compare the distribution among different kebeles, the total numbers of connection per kebele are converted to connection per family using the population data of each kebele. According to the census of the 2007, average family size of 4.9 in urban areas for SNNP region was used for calculating the average number of connection per family.

Like that of the per capita consumption after evaluating for outliers, the average connection per family for the entire town is found to be 0.28 and this implies that at average more than two and half families or nine persons are sharing one connection or water tap.

It is understood that the settlements having more people consume more water than the settlement with the low number of population; as far as all the area are having similar chance of getting water.

4.1.4. Service Coverage

It is defined as the percentage of the population with access to water or services (either with direct service connection or within reach of a public water point) as a percentage of the total population under a utility's area of responsibility. As part of this study, the survey carried out in 2020 the overall connection level (water service coverage) in Aleta Wondo Town was 67% .The primary source of water for the residents living in the areas without network connection was mainly water spring and hand dug well. Water source for the Town entirely relying only on groundwater is not enough. Moreover, the surface water will have the recharging role to the groundwater sources around its area.

To ensure the availability of sufficient quantity and good quality water, it becomes almost imperative in the modern society to plan and built suitable water supply system. The system should provide potable water to the various section of Town in accordance with the water demands.

4.2. Water Demand and Population Forecasting Analysis

4.2.1. Population projection

The water demand of particular Town is proportionally related to the population to be served. According to Town finance and economy office the population of Town was 58,471 and annual growth rate for urban population of SNNP region was 4.69% in the year of 2020. Using CSA (2007) census data as a base, the current (2020) population and the population at the end of the design period (2040) of the Town was estimated using a geometrical population forecasting method as given below Table.

Table 4. 2: Population Projection of Aleta-Wondo Town

Description	Year					
	2020	2021	2025	2030	2035	2040
Population Growth Rate	4.69%	4.69%	4.48%	3.97%	3.59%	3.16%
Projected/Forecasted population	58,471	61,213	72,796	86,302	99,245	108,935

Therefore, based on the above Table the total population of the Aleta-Wondo Town was estimated 58,471 at 2020 year and 108,935 at the end of the design period (2040).

4.2.2. Population distribution by mode of service

Depending on living standard and hardship of water collecting there are four types mode of connection in a water supply system. These include House connection, yard owned connection, and yard shared connection and public tape & fountain. From the data obtained from Aleta-Wondo Town water utility office the existing mode of service at the year 2020 was estimated. As clearly depicted in design criteria house and yard connection users increase yearly, whereas public fountains users decrease. Currently, in the Aleta-Wondo Town all types of mode of service connection are available.

The mode of services projection is made based on the target period (2040) of at which the Town the communities will get sufficient amount of water they require considering the current mode of services. In the future as a result of development of the Town associated with willingness of residents to have their own connection and pay more for the water they use; it is forecasted that at the target year of 2040, the percentage of users in house connection mode of services 11.86%, yard connections owned 79.76%, yard connections shared 5.11% and public fountain users 3.28% from the current mode of service.

Table 4. 3: The population projection per mode of service.

Description		Year					
	Unit	2020	2021	2025	2030	2035	2040
Population Growth Rate		4.69%	4.69%	4.48%	3.97%	3.59%	3.16%
Projected population	No	58,471	61,213	72,796	86,302	99,245	108,935
Population Percentage Distribution by Mode of service							
HTU	%	0.86	1.41	3.61	6.36	9.11	11.86
YTU	%	42.76	44.61	52.01	61.26	70.51	79.76
NTU	%	1.71	1.88	2.56	3.41	4.26	5.11
PTU	%	54.68	52.11	41.83	28.98	16.13	3.28
Total	%	100.00	100.00	100.00	100.00	100.00	100.00
Population served by							
HTU	No	500	860	2624	5485	9036	12914
YTU	No	25000	27305	37858	52865	69974	86882
NTU	No	1000	1151	1864	2943	4228	5567
PTU	No	31971	31897	30449	25009	16007	3571

4.2.3. Per-capita domestic demand by mode of service

Determining the amount of water needed in the future is one of the key building blocks of the regional and state water planning processes. Capita demand of water is a collective amount of water required for various daily consumptions, such as drinking, cooking, ablution, washing utensils and clothes, flushing toilets, etc. It is obvious Per Capita Water Demand increases from time to time based on the growing, awareness and improvement of the living standard of the consumers. For this Town the projected population ranges up to category-3 towns/cities (towns/cities with a population 50,000-100,000) and the minimum/average service level is 60 l/c/day. Therefore, Ministry of Water Resources (2015) guide line base above table. Adjustment is made for per capita demand of each mode of services to fulfill the gap to achieve the Growth and Transformation plan II. So, the adjusted per capita water demand for each mode of service is summarized as the following Table.

Table 4. 4: Projected per capita demand

Year	Unit	2020	2021	2025	2030	2035	2040
Per Capita Demand by Mode of Services							
HTU	l/c/d	96	98	106	115	125	134
YTU	l/c/d	48	48	50	53	55	58
NTU	l/c/d	58	59	62	67	72	77
PTU	l/c/d	38	39	41	43	46	48

The average per capita domestic water demand for each year was computed by combining water demand by mode of service from the year 2020-2040. As shown the table (4.6) below the total domestic water demand was forecast by each mode of service throughout the design period.

Table 4. 5: Domestic water demand determination

Description		Year					
	Unit	2020	2021	2025	2030	2035	2040
Population Growth Rate		4.69%	4.69%	4.48%	3.97%	3.59%	3.16%
Projected/Forecasted population	No	58,471	61,213	72,796	86,302	99,245	108,935
Population Percentage Distribution by Mode of service							

HTU	%	0.86	1.41	3.61	6.36	9.11	11.86
YTU	%	42.76	44.61	52.01	61.26	70.51	79.76
NTU	%	1.71	1.88	2.56	3.41	4.26	5.11
PTU	%	54.68	52.11	41.83	28.98	16.13	3.28
Total	%	100.00	100.00	100.00	100.00	100.00	100.00
Population served by							
HTU	No	500	860	2624	5485	9036	12914
YTU	No	25000	27305	37858	52865	69974	86882
NTU	No	1000	1151	1864	2943	4228	5567
PTU	No	31971	31897	30449	25009	16007	3571
Per Capita Demand by Mode of Services							
HTU	l/c/d	96	98	106	115	125	134
YTU	l/c/d	48	48	50	53	55	58
NTU	l/c/d	58	59	62	67	72	77
PTU	l/c/d	38	39	41	43	46	48
Domestic Water Demand by Mode of Services							
HTU	M^3/d	48.00	84.22	277.13	631.83	1,127.74	1,735.6
YTU	M^3/d	1,200.	1,323	1,908	2,791.29	3,862.55	5,004.4
NTU	M^3/d	57.60	67.42	116.48	198.34	305.64	429.67
PTU	M^3/d	1,227	1,240	1,245	1,085.1	734.51	172.79

Total Domestic Demand	M^3/d	2,533	2,716	3,546.	4,706.6	6,030.44	7,342.5
	l/s	29.32	31.44	41.05	54.48	69.80	84.98

Based on the above Table 4.6, the total domestic water in 2020 year was 2,533.29 m^3/day and for the year of 2040 were 7,342.58 m^3/day.

This high gap has effect of the customer for the town Water scarcity generates sanitation problems by forcing people to drink unsafe water. Lack of water causes other diseases such as trachoma (an eye infection that can cause blindness), plague and typhus. It also cases Local conflicts - sometimes resulting in warfare - are triggered over water resources And growing needs, these tensions could multiply in the future for the user.

To alleviate this gap from the town to Identify an appropriate water source for a given context. Every community is unique, and there is no one-size-fits-all clean water solution. One sustainable way to solve the town water crisis is to first identify the most appropriate water source to Construct or rehabilitate high-quality water point structures when identifying the best water solution.

Good construction of and better quality Operation &Maintenance for the urban water supply system can be achieved. This will result in more functional water distribution system. Continual and more reliable water supply system can be put into operation in place of the less reliable and intermittent one. Rising water tariff is also a solution to low piped-water coverage. By raising tariff there will be revenue available for public authority in charge of urban water to extend distribution and service system to urban area that are not yet served with piped-water.

4.2.4. Socio-economic and climatic adjustment factor

Aleta-Wondo Town is considered as a Town of "high potential growing town under normal Ethiopia conditions and it is categorized with the Towns of group C. Based on this value, the socio economic adjustment factor was 1. In addition to this, the town was found the altitude range 1500-2300 above sea level.

Climate variability and change affect the availability of demand and quality of water, and runoff or temperature extremes. Different sources of uncertainties stemming from the climate change; such as future temperature, precipitation, sunshine duration, wind speed, relative humidity, evaporation rate, transpiration rate, soil moisture content will have significant impact on future water consumption. The extreme events (drought or frequent flood) will have also considerable impact on future demand.

The average annual temperature and average altitude falls temperate zone. Hence based on this criterion Aleta-Wondo Town climatic factor is 1.

Table 4. 6: Climatic adjustment factor

Year	Unit	2020	2021	2025	2030	2035	2040
Adjusted Domestic Water Demand (ADD)	M^3/d	2,533.29	2,716.17	3,546.93	4,706.65	6,030.44	7,342.58
	l/s	29.32	31.44	41.05	54.48	69.80	84.98

Based on the above 4.7 Table the domestic water demand of the study area was 2,533.29m^3/day in the year 2020 and 7,342.58m^3/day in 2040. After the domestic water demand was projected, water loss, public and commercial and industrial water demand were computed to analyze the total water demand of the town. But at this time there is no industrial water demand in Aleta-Wondo Town. It is equal to adjusted water demand due to socio economic factor 1 in otherwise it multiplied by that factor and different from adjusted domestic water demand.

4.2.5. Non domestic water demand

Commercial and institutional water demand:-Based on the past trained of Aleta-Wondo Town, the public and commercial water demand of the town was 15% of the domestic water demand.

Industrial water demand:-According to Aleta-Wondo water utility report; there is no industrial water demand at this time. The development plan of the Town was allocated areas for industrial development. Industrial water demand may be estimated on the bases of proposed industrial zoning and the type of industries most likely to develop with in the area. If there is no data available for specified industries, the water demands for small scale industries were considered 5 to 10% of the total domestic water demand (AWRDB, 2012).

The water demand for medium and large-scale industries is recommended to have their own and separate sources and distribution system. For small industrial water demand for Aleta-Wondo Town is estimated to be 5% of average domestic day water demand.

Firefighting:-Water demand for firefighting purposes shall be assessed based on the existence of equipment and the capacity of any firefighting services. Fire demand can be expressed as a function of population and it is estimated by using empirical formula. But, in Ethiopia, the Fire

Fighting Demand is generally taken care of by increasing the size of service reservoirs by 10 % (MOWR, 2006b). According to (Kassa, 2017) the water demand for firefighting for medium Town was considered 5% of the total domestic water demand.

Public and Institutional Water Demand; Public water demand is water required for public purposes including recreational areas, watering of public gardens and parks, fountains, public toilets, railways, churches, mosques and bus stations while institutional demand includes water required for offices, schools, hospitals, day-care centers, military camps, prison houses and other similar organizations. Public and institutional water demand for Aleta-Wondo Town has been estimated to be 20% of adjusted domestic day water demand.

Commercial Water Demand; Hotels, bars, restaurants, traditional winery houses, small shops, and workshops are among the existing commercial activities in the Town. The adopted commercial demand is 20% of average domestic day demand.

Livestock Water Demand; in designing water supply projects, water demand calculation has greater role. However, the use of improved domestic water sources for livestock is not encouraged. It is assumed that most of the animals will be watered from such natural sources as rivers, streams, lakes, ponds, and springs in the vicinity (MoWR, 2001). Therefore, in the town there are perennial streams located at west and east side around the town not projected.

Table 4. 7: Non domestic (Institutional, commercial and allowance of small scale industries)

Description	year						
	Unit	2020	2021	2025	2030	2035	2040
Non Domestic Water Demand							
Commercial & Institutional Water Demand with allowance of small scale industry (25% of ADD)	M^3/d	633.32	679.04	886.73	1,176.66	1,507.61	1,835.65
	l/s	7.33	7.86	10.26	13.62	17.45	12.75

Unaccounted water demand; unaccounted for water is a quantity of water that does not generate income for the utility. It includes system leakage, water taken by illegal connections, faulty water meters, overflow from reservoirs, unmetered connections and flushing. Non-revenue water reduction principle contributes for minimization of unaccounted for water volume. The percentage of accounted for water varies between 15% and 25% from starting year to the final design year and will be used in this demand projection (OWWDSE, 2010).

Average Daily Demand; Average daily demand for water supply is the combined total of domestic demand, institutional, commercial, and industrial and livestock demand and Non-revenue (system losses).

4.2.6. Peak hour and maximum day factor

The rate of water demand keeps changing from season to season, from day to day and from hour to hour. In hot season, more water is consumed for drinking, bathing and washing clothes than in wet season. The consumption of water is high at weekends and holidays than on normal days, and also more water is required in morning and evening than early in the afternoon and late at night. Therefore, to account these fluctuating water demands, it is necessary to adjust the average day demand by certain factor to get the maximum day demand and the peak hour demand.

The maximum day water demand is the highest demand of any one 24-hour period over any specified year. The ratio of the maximum daily consumption to the mean annual daily consumption is the peak day factor. Thus the maximum daily demand is determined by multiplying peak day factor by the average daily demand. It is recommended to 1.0 to 1.3 (MoWR, 2006). Based on this criterion for Aleta-Wondo 1.2 maximum day factor is considered.

Table 4. 8: Average daily and maximum day water demand of Aleta-Wondo Town

Year	Unit	2020	2021	2025	2030	2035	2040
Average Day Water Demand	M^3/d	3,641.60	3,921.47	5,209.55	7,059.97	9,234.12	11,472.79
	l/s	42.15	45.39	60.30	81.71	106.88	122.16
Max Day Factor		1.2	1.2	1.2	1.2	1.2	1.2
Max Day Demand	M^3/d	4,369.92	4,705.76	6,251.46	8,471.97	11,080.94	13,767.35
	l/s	50.58	54.46	72.35	98.06	128.25	146.60
	M^3/hr.	182.08	196.07	260.48	353.00	461.71	573.64

The total water demand of the town was determined by summing up the adjusted domestic water demand and Non-domestic water demands as shown in table above. Therefore the total maximum water demand is 4,369.92m^3/day and 13,767.35m^3/day in the year 2020 and 2040 respectively. The design maximum water production capacity of the source was 4,369.92m^3/day, but the current average daily production was 1257.76 m^3/day which is very low due to reduction of water from the source, pump failure and lack of maintenance less water production to compare population with in Town. It is far lower than the demand. Currently the gap between existing supply and demand was 3,112.16m^3/day. The gap will be 12,509.59m^3/day for coming twenty one year period. This indicate the need for the development of additional water sources to satisfy the 12,509.59m^3/day water demand of Aleta-Wondo Town for coming 21 years period.

4.3. Water Loss Analysis

Losses are a function of the quality of construction, the type and age of the pipes in the distribution network and pressure within the system. One of the major challenges of water utilities is a high amount of water loss in the distribution network. It is difficult to meet the required demand due to the high amount of water loss. The total amount of water produced, supplied to the distribution system and water billed that was aggregated from the individual customer meter readings were used to determine the total water loss from the Town. The quantities of water produced and consumed are obtained from the water supply office.

Table 4.9: Water production and consumption of Aleta-Wondo Town.

Year	Produced(m^3/year)	Consumed(m^3/year)	Loss (m^3/year)	Loss (%)
2016	402,671	301,920	100,751	25
2017	413,890	306,247	107,643	26
2018	421,143	302,480	118,663	28
2019	428,296	303,207	125,089	29
2020	434,920	301,278	133,642	31

(Source Aleta-Wondo town water utility office)

Based on the above table water loss increase from year to year, the total the annual NRW was 133,642m^3/year of the total production in 2020. The total water loss has been expressed in terms of based on percentage of system input volume, length of main pipe and the number of connections.

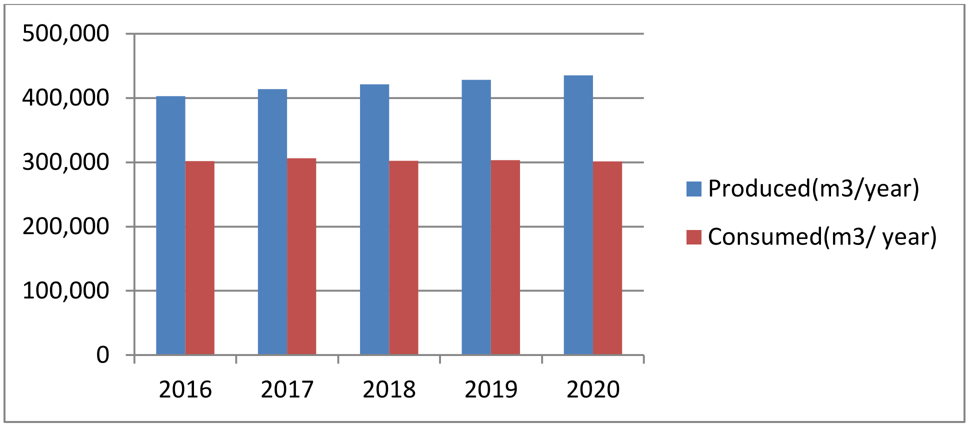

Figure 4.1: Water production and Consumption of the Town.

A case study was shown by Metaferia consulting engineers for water Audit Ethiopia in 2010 in six towns which reveals the extent of leakage of each town. When compare Aleta Wondo Town with those three towns like Assosa, hosanna and, wolkeite it lower than from those. Regardless of the magnitude of that greatly varies from town to town or from one area to another area. The main cause for loss and leakage is unaccounted for because of measurement errors, including inaccurate meters, and unmeasured uses are also some of the causes of water loss and leakage.as shown in the graph below.

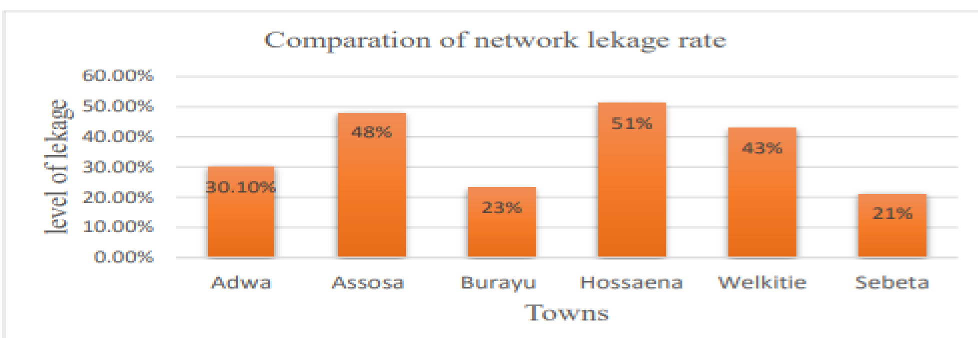

Figure 4.2: Uncounted for water for some Ethiopia Towns

4.3.1. Total water loss expressed as a percentage

The total annual water production and distributed to the distribution system within the specified year (2020) was 434,920m^3/year and the yearly NRW was 133,642m^3/year which was 31% of total water production. The total water losses of the Town can be estimated by subtracting unbilled authorized consumption from NRW. The average tariff of water in the Aleta-Wondo Town was 4.5 ETB /m^3, based on this average water tariff value the water loss was estimated to be 601,389ETB for year 2020. According to McKenzie and Seago (2005) classification and descriptions of water losses as acceptable, if the loss is <10%, intermediate, the loss is 10-25% and matter of concern, the loss is>25%.Thus, an average water loss in town was 31%, which is greater than 25% that showing a matter of concern, the reduction was needed.

Table 4.10: Classifications and description of water losses

Water losses	Levels and action needed
<10%	Acceptable, Monitoring and control
10-25%	Intermediate, could be reduced
>25%	A matter of concern, reduction needed

(Source: (McKenzie and Seago, 2005)

GIS monitoring systems and databases are particularly helpful in reducing water losses. Monitoring information is very useful in the evaluation of network operation parameters, its technical condition, and allows for the analysis and It is particularly important to monitor night flows, which allows for detecting excessive flows and water consumption resulting from failures or theft. Evaluation of water losses the examined area and for the control of pressure in the network. Correct separation of metered area to allows for identification of the areas with high flows. Regularly extend their networks with new measurement chambers, located in selected places in the network, equipped with modern control and measurement devices. The intervention process addresses the findings of the water audit through implementation of controls to reduce or eliminate water losses.

4.3.2. Water loss expressed as the length of the main pipe

One of the best indicators of water loss in the distribution network system was determining loss as per length of the main pipe. According to the Town water utility report, the total length of water distribution line was estimated around 23.788km. The water loss per kilometer length of main pipe was determined as 133,642m^3/year÷(23.788km×365days) is 15,392 liters/km/day. According to Farley et al. (2008), the performance indicator of physical loss target matrix describes as a good condition system if water loss per length of main pipe<10,000 liters/km/day, average condition if between 10,000-18,000liters/km/day and bad condition if >18,000liters/km/day. In line of this, the town water loss per length of main pipe was 15,392 liters/km/day, which shown as average condition.

4.3.3. Water loss expressed as per number of service connection

The total number of service connection of Aleta-Wondo was 1419 which were obtained from Town water utility. The water loss per number of service connection was determined as 133,642 m^3/year×1000liters÷1419×365days)=258 liters/connection/day. According to Farley et al. (2008), the performance indicator of physical loss target matrix describes as a good condition system if water loss per length of main pipe<150 liters/connection/day, average condition if between 150-450liters/connects/day and bad condition if >450liters/connection/day. In line of this, the town water loss per length of main pipe was 258 liters/connection/day, which shown as average condition.

4.3.4. Unbilled authorized consumption

Unbilled authorized consumption is the volume of water used by operational purpose; water used firefighting and water produced for free to water supply service workers. According to Aleta-Wondo Town utility report (2020), the total volume of unbilled authorized consumption of water was 1,693m^3/year.

4.3.5. Estimating apparent losses

Apparent losses consist of unauthorized consumption, metering inaccuracies and data handling errors Lambert (2001) and is aggregated 5,859m^3/year+45,008.15m^3/year+753.195m^3/year, which is equal to 51,620.34m^3/year. This loss amount was 38.7% of the total production of water that is about the total system loss as detailed in the following sub-section.

4.3.5.1. Unauthorized consumption

Unauthorized consumption includes illegal connection, unauthorized use of fire hydrants, meter bypassing and poor billing collection system. It is difficult to estimated unauthorized consumption. According to the water service office 2020 report, the amount of unauthorized consumption of the town was 5,859.6m^3/ year.

4.3.5.2. Customer meter inaccuracies

Water meter inaccuracies are considered to be a significant component of apparent losses in the water supply system (Rizzo and Cilia, 2005). According to the water service office 2020 report, the total amount of customer meter in the distribution system was 3245 in number. From this total, 1,057DN15mm (Class B, dry dial, multi-jet type), 1,863 DN20mm (Class B, dry dial, multi-jet type), 325 DN25mm (Class B, dry dial, multi-jet type) were installed in the distribution system. As per the town water utility annual report, 27% of these water meters manufactured in India, 33% was manufactured in Poland and the remaining 40% was manufactured in Israel. According to south nation nationality people regional water, mineral and energy bureau, the organization report, meter testing flow rate of was taken 200 l/c/day for all customer meter as testing bench. Whereas, As per the town water utility annual report, the average meter reading per connection of Aleta-Wondo Town was 162 l/c/d. Table 4.12 Water losses as results of metering inaccuracies.

Table 4.11: Water losses as results of metering inaccuracies

Description	No of meter	Total authorized water in 2020	Average meter reading per connection	Meter test flow rate	difference	Total water loss
No of water meter	A	B	C	D	E=D-C	F=A*E
	3295	301,278m^3/year	162l/c/d	200l/c/d	38l/c/d	123,310 l/c/d
Total	45,008.15m$^{3/}$/year					

In case of Aleta-Wondo Town the main reason for this high meter under registration is that the deterioration of water meters with age, resulting inaccurate readings. This highly influenced by the lack of water meter testing and replacement program and unlimited service year for meters in the distribution system.

4.3.5.3. Systematic data handling error

Data handling error in the meter reading and billing system were contributed to apparent losses. It includes billing system entry error, account adjustment, invalid meter consumption reading, poor accounting and other. It is difficult to estimate the value of volume of data handling error. Therefore, it is recommended to take the default value, which is 0.25% of the billed meter volume (Saroj, 2008). Based on the above recommended value the total lost volume of data handling error of the Aleta-Wondo was 0.25%*301,278m^3/year which is equal to 753.195m^3/year.

4.3.6. Estimating real losses

This category includes the volume of water lost through all types of leak, burst and overflows on main, service reservoir and service connection, up to the point of customer metering. Real losses can be calculated as the volume of NRW minus the sum volume of apparent losses and Unbilled authorized consumption. Based on this definition volume of total losses was 133,642m ^{3}/year, which covers 61.3% real loss of the total production which is the total system loss. This result signifies more of the loss in the system as real loss which is mainly caused due to deterioration of the existing distribution system infrastructure.

4.3.7. Quantifying water loss by water balance method

To estimate the water loss by using water balance method for Aleta-Wondo Town in the year 2020 based on international water association (IWA) the water balance components are obtained by using the available data and estimated in the above. The results are summarized in table below.

Table 4.12: Water balance (m^3/year) for year 2020)

System input volume=434,920 m^3/year	Authorized Consumption =301,278m^3/year	Billed authorized consumption =301,278m^3/yr	Billed metered consumption =299,585m^3/year	Revenue water =299,585m^3/ year
			Billed unmetered consumption=0	
		Unbilled Authorized consumption =1693m^3/year	Unbilled metered consumption =1693m^3/year	None revenue water =135,335 m^3/year
	Water loss=133,642m^3/ year	Real loss=82,022m^3/ year	, Unauthorized consumption=5,859.6 m^3/ year	
		Apparent loss=51,620.m^3/ year	Customer meter in accuracies=45,008.15 $m^{3/}$/year	
			Systematic data handling error= 1492m^3/year	

As shown the above Table 4.13 the value of non-revenue water by water balance method high levels which are 31% of system input volume and the water loss was the system input volume which has a serious impact on Aleta-Wondo water supply service offices finances and available water resources.

4.4. Water Distribution Network Simulation

Distribution work starts from the point of water production, where water is produced and made ready to be used (Wonduante, 2013)

4.4.1. Pipe layout schematization

In constructing a distribution network concerned with assigning labels to pipes and nodes, Tanks and pumps Bentley WaterGEMSV8*i* will assign labels automatically. When creating a schematic drawing, pipe lengths are entered manually. In a scaled drawing, pipe lengths are automatically calculated from the position of the pipes' bends and start and stop nodes on the drawing pane. In this network, the modeling of a reservoir connected to service line and simulates a connection to the main water distribution system. Simplifying the network in this way can approximate the pressures supplied to the system at the connection under a range of demands.

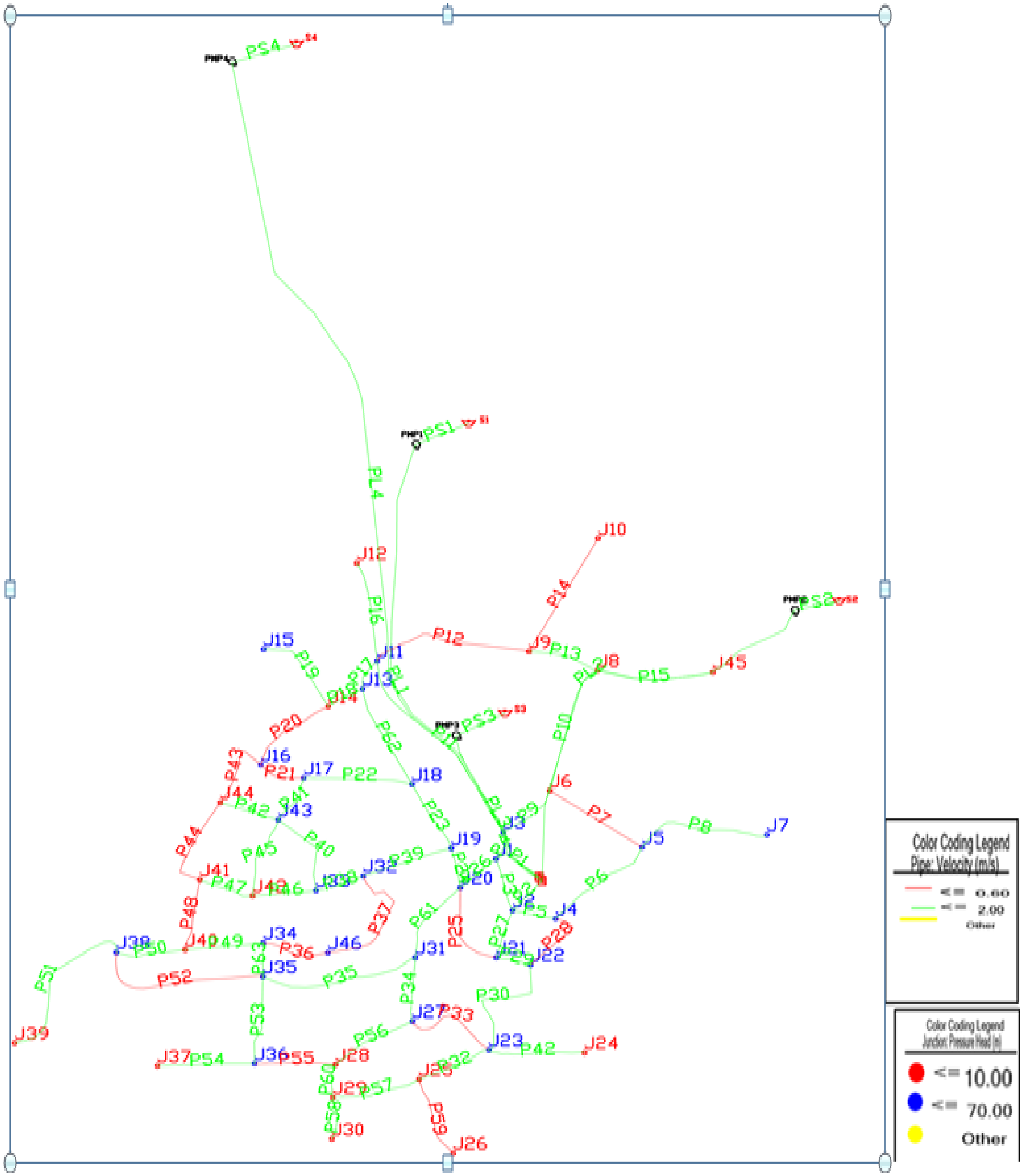

Figure 4.3: Water distribution network map of Aleta-Wondo Town

4.4.2. Pressure analysis

The minimum and maximum operating pressure in the water supply distribution system network in Ethiopia was 15m and 70m respectively (MOWR, 2006a). Pressure influences the water supply capacity of the distribution system. In order to achieve a 15m minimum and 70m maximum operating pressure, it is necessary to provide pressure controlling valve establishing boosting station and replacing the old pipe with the new one. The maximum pressure in the main is considered not to exceed 80m to limit leakage and stresses on pipes (Mosissa, 2008). There is no defined maximum and minimum pressure ranges designed by the Town's water utility. Therefore, literature review based recommendation for optimal and minimum pressure was used to assess hydraulic performance of water distribution system. According to Totsuka *et al., (*2004) those consumers further away from supply points was always collect less water than those nearer to the source due to pressure losses in the network is increasing as far from the source.

4.4.2.1. Pressure head adequacy

Based on the WaterGEMSV8i simulation results the extreme pressure values in base scenarios and patterns are evaluated. The most of pressure head in nodes of distribution network out of pressure range limit of pressure head as per the design criteria during analysis except some 16 nodes describe the pressure recommended range. Due to this town water supply customers do not get water properly at the peak hour. The Town utility operation maintenance team always shifting the supply as intermittent flow. During hydraulic modeling of water pressure of Aleta-Wondo Town, 46 nodes (junctions) and 76 pipes were identified. Specific area and nodes distribution in the Town.

From the pressure simulation result 65.21% pressure head<15m. The remaining 34.79% within the optimum range of the design set criteria according to MoWR, 2006. Due to this Town water supply customers do not get water properly at the peak hour. The Town utility operation and maintenance team always shifting the supply as intermittent flow.

Situations that give rise to insufficient pressures should always be avoided. Hence, pressure in the distribution system is one of the factors for intermittent water supply. For this study, most negative pressures are found; the system was disconnected during peak demand time and water was not reaching to customers. Whereby, these was mainly as a result of; there is demand concentration (greater demand than the design demand), inadequate pipe capacity (small diameter), and availability of residences on higher ground of the Town.

The contour map of pressure clearly shows the pressure difference in the whole systems. As it is shown in the below Figure 65.21% below the recommended pressure ranges most part of Town do not reach during peak hour. 34.79% of pressure junction that is the less of the area has pressure within the optimum range during steady state analysis. Pressure contour of Aleta-Wondo Town is given in Figure 4.4.

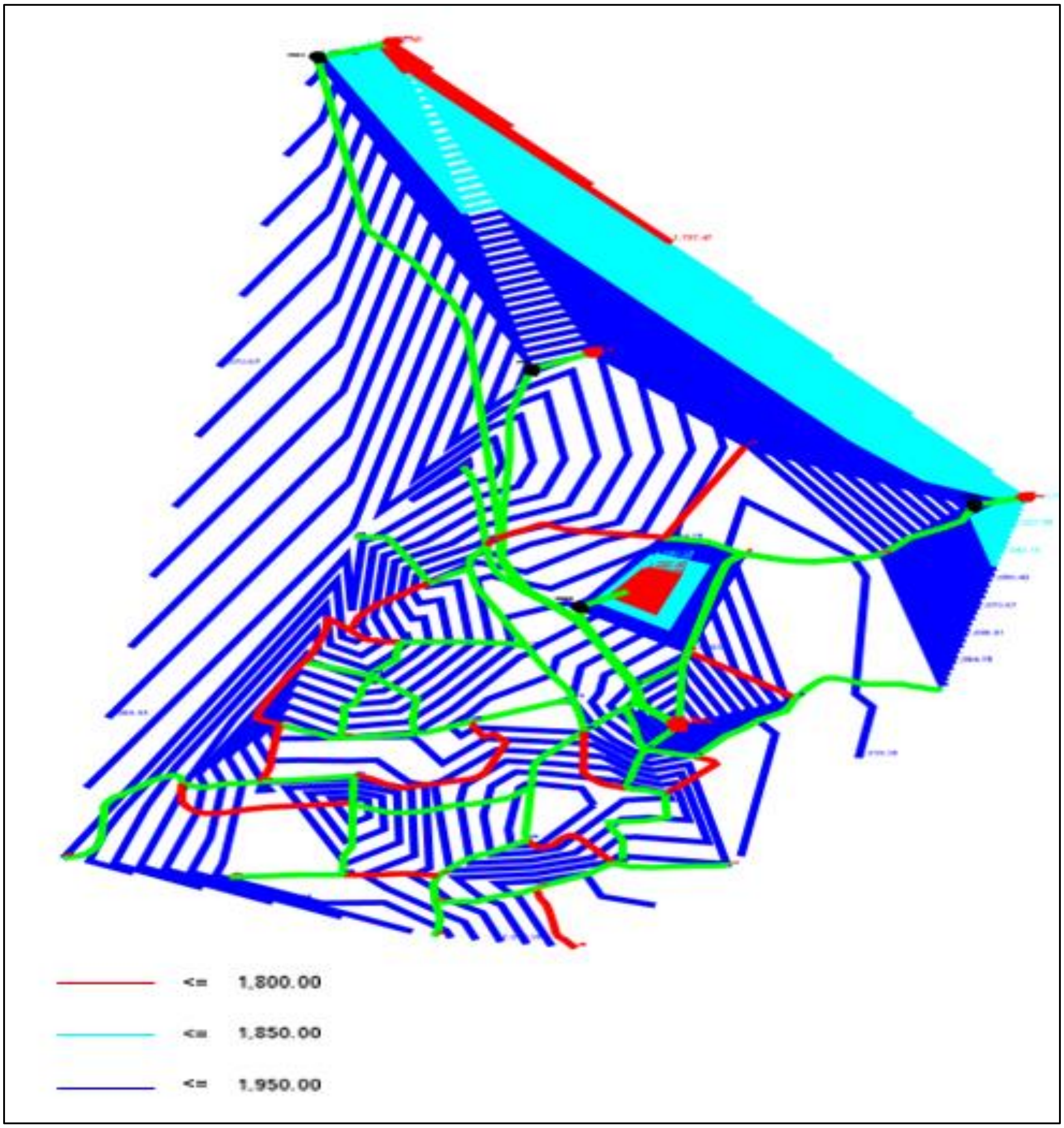

Figure 4.4: Contour map of simulation with elevation range

The pressure distribution systems affect the capacity of water supply to the Town. The Ethiopian guideline criteria for the minimum and maximum operating pressure value in the distribution network are 15 and 70 m respectively (MOWR, 2006).

Lower pressure can cause reduction of quantities of water supplied to the consumer and entry of a contaminant or self- deterioration of water quality within the network itself a severe damage to public health (Geldreich, 1991). The most junction recorded lowest pressure after hydraulic simulation result of Aleta-Wondo Town.

The pressure distribution of the most junctions is insufficient pressure at peak hour consumption. Booster tank with pump is required to access the water to the consumer at peak consumption.

The pressure distribution of selected nodes at peak hour consumption is given in Figure below.

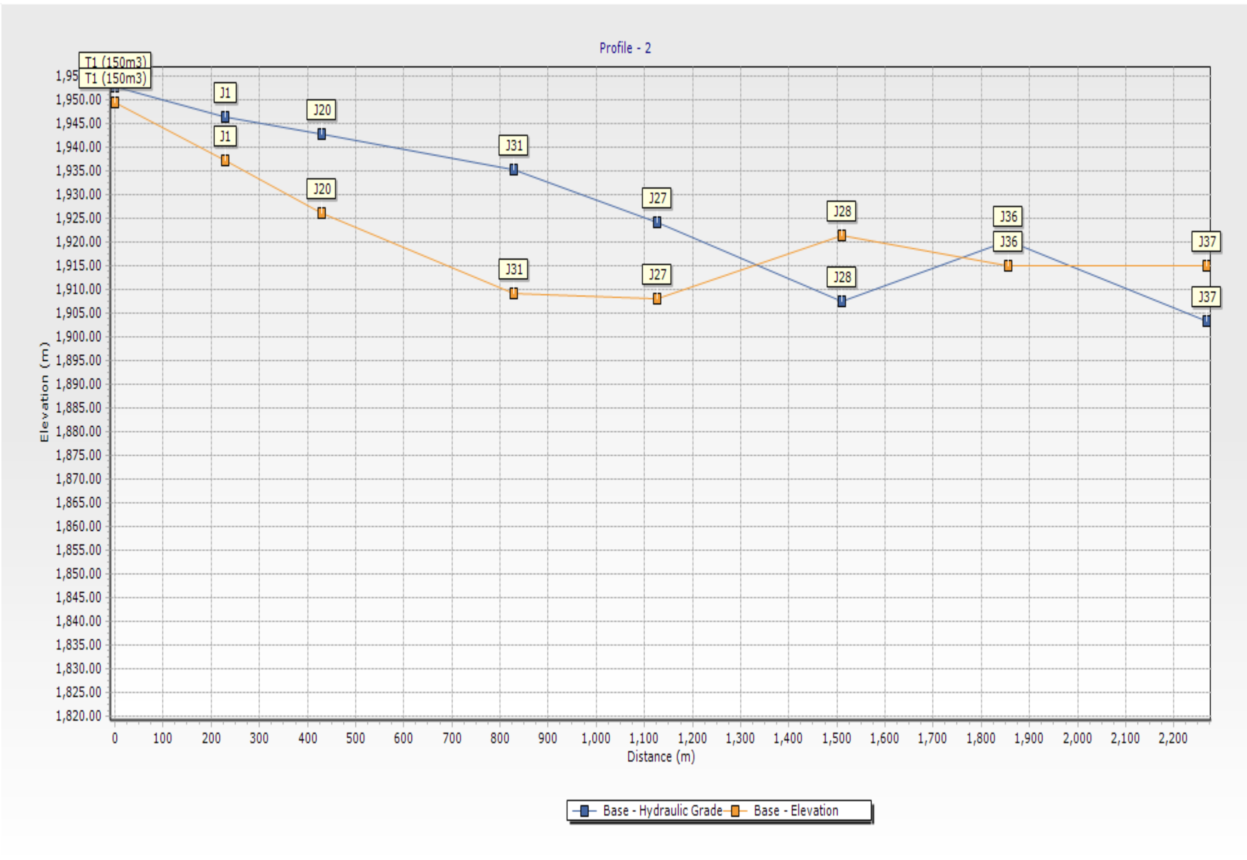

Figure 4.5: Some selected profile along R-J1-J31-J27-J28-J36 and J37

From the above figure at the J28 and J37 the hydraulic grade line below the nodal elevation. This indicates that the water cannot reach the consumer around the area. Households located on higher elevations and close to reservoir site have get water at low water pressure (Ermias.T, 2014). Variations of pressure during day and night can create operational problems, resulting in increased leakage and malfunctioning of water appliances. Reducing the pressure fluctuations in the system is therefore required (Byakika, 2012). The effects of distance and elevation in pressure distribution in selected nodes are given above figure.

According to Totsuka.et al.,(2004), those consumers furthest away from supply points will always collect less water than those nearer to the source due to pressure losses in the network is increasing as far from the source. In the case of Aleta-Wondo Town, the main cause of water supply interruption was water Shortage from the source, lack of maintenance, improper function of pump and interruption of electric power in pumped pressure system.

4.4.3. Velocity

Control on the flow velocities in water distribution networks should be maintained in order to avoid structural problems or undesirable hydraulic regimes caused by high velocities, or in order to minimize the unfavorable consequences of too low velocities on the quality of the transported water (Tamminen et.al, 2008). According to Andey and Kelkar (2007) velocity of flow in the pipe below 0.6m/s causes" water stagnation, sediment accumulation and bacteriological growth in the pipe, on the other hand velocity of flow in the pipe above 2m/s causes head loss as well as water hammer. Velocity in water distribution system was varied with the demand pattern change. At Velocity distribution for selected pipe Velocity range can also be adopted as a design criterion. Low velocities are not preferred for hygienic reasons, while too high velocities cause exceptional head-losses. Figure 4.6, shows velocity is decreasing from the main line to the sub distribution line (for selected pipe).

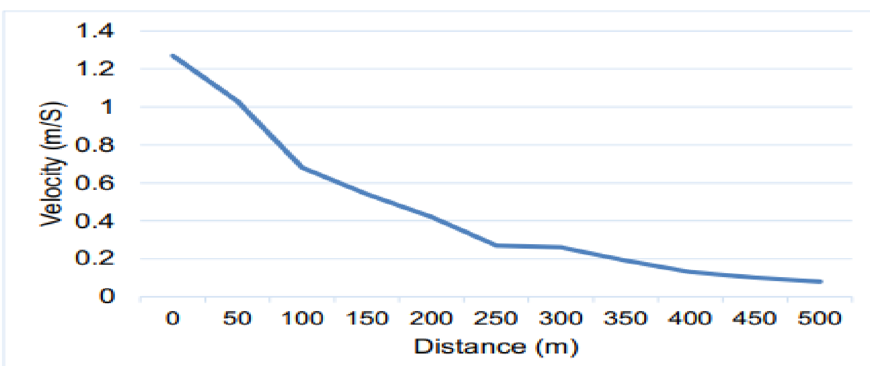

Figure 4.6: Velocity variations between the node at the main line and sub distribution line

Different design guide line has been developed by different researchers for the standard velocity in pipe flows. According to Ethiopian Topographical Condition the allowable velocity in distribution system indicated by the MoWR (2006) water supply design criteria recommended pipe flow velocity to be a minimum of 0.6 m/s and maximum of 2 m/s. peak consumption time the values are different as compare low consumption time. The Town water supply distribution system of velocities during peak and low consumption time were summarized in table and (4.14) below.

Table 4.13: Simulated results of velocity Aleta-Wondo Town

Velocity range (m/s)	(%)	Justification
<0.6	18	Scour problem on pipe water, stagnation, sediment accumulation
0.6-2	82	No problem
>2	0%	

Most of the velocity with in the design criteria range. 18% velocity pipe flow during peak hour demand fall with in design set criteria according to MoWR, 2006 In the pipes of P7, P12, P14, P20, P25, P36, P37, P41, P43, P44, P45 and P48.

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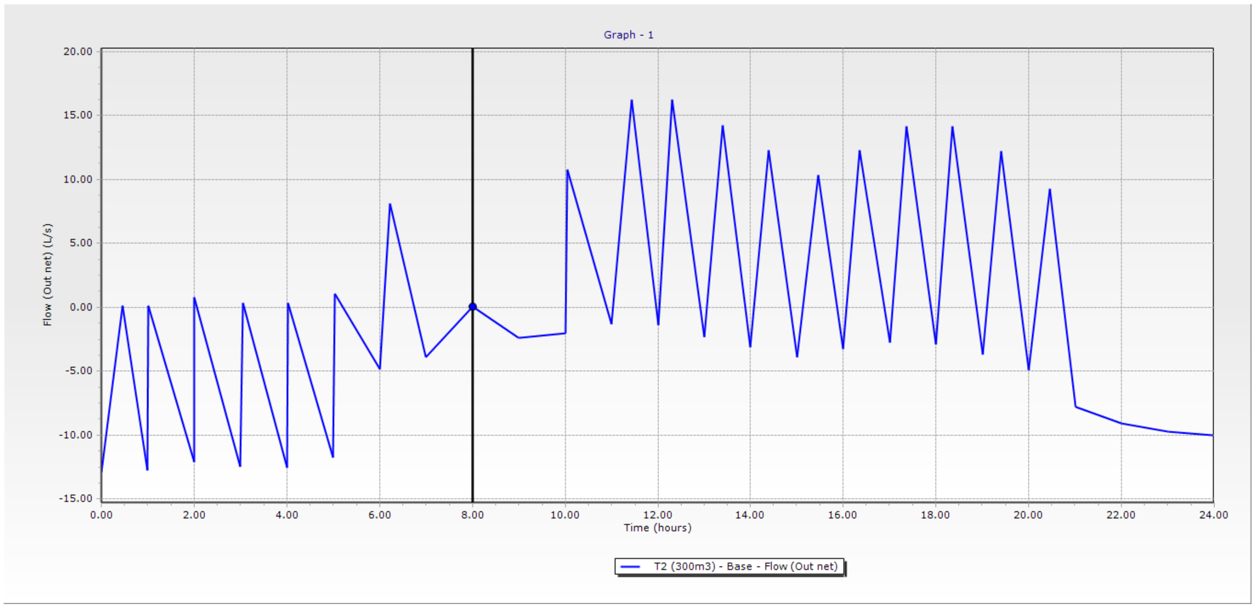

Figure 4.7: Shows velocity in distribution network is in high consumption time for selected pipe

4.4.4. Pump Curve

A pump curve represents the relationship between the head and flow rate that a pump can deliver water. Pump head is the head gain imparted to the water by the pump and plotted on the vertical of the curve in meter. Flow rate is plotted on the horizontal in litter per second. A valid pump curve must have decreasing head with increasing flow. An efficiency curve determines pump efficiency in vertical percent as a function of pump flow rate in horizontal flow.

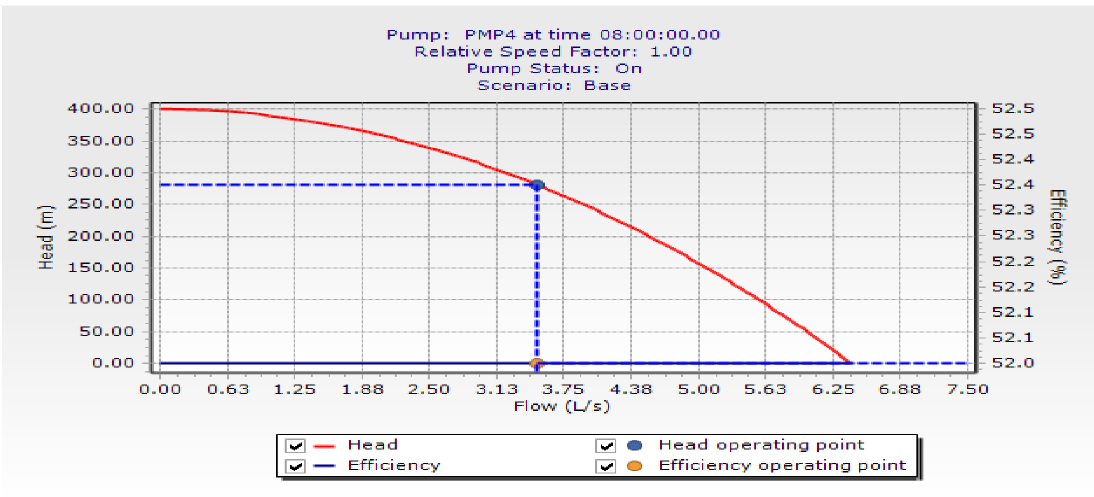

Figure 4.8: Pump curve

Pump head is the head gain imparted to the water by the pump and plotted on the vertical of the curve in meter. Flow rate is plotted on the horizontal in litter per second. A valid pump curve must have decreasing head with increasing flow. An efficiency curve determines pump efficiency in vertical percent as a function of pump flow rate in horizontal flow. Figure 4.8 shows as the blue line the head increases the amount of discharge pushed by the pump decreases. When the head decreases the pump can push high amount of discharge to a lower elevation so that pump curve indicates decreasing head with increasing flow illustrate by red line.

4.4.5. Demand Pattern

Demand pattern is one of critical component at the system, from which is identified how much capitals consume to describe in graph. As far as distribution of water is concerned, the property of hydraulic parameters in distribution network allowable limit was known. The driving forces of hydraulic parameters are demand of water consumptions.

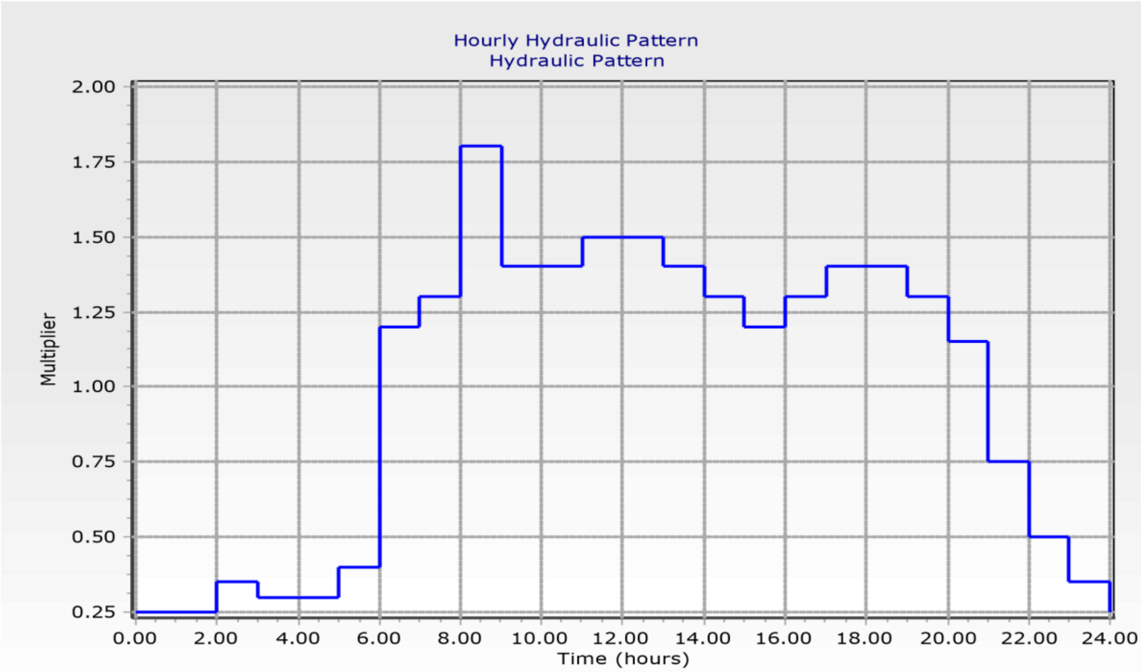

Figure 4.9: Demand pattern

4.4.6. Hydraulic model calibration result based on difference error

In this research, the pressure data measured at the near to node home faucet of the system is used to assess the model performance. The model performance measure Such as the degree of accuracy (error of difference) and the coefficient of determination (R^2) are two techniques to be considered for the calibration model check as mentioned below the results. The observed and simulated pressure giving a correlation coefficient of the determination which ranges between 0 and 1, describes the proportion of the variance in the measured data which is explained by the model with higher values indicating less error variance. The diagonal line on the plot represents the line of perfect correlation in figure below here, generally, all the points should align themselves on this line, and all observed pressure should be equal to computed pressure giving a relationship coefficient of 1 that is the best correlation between observed and simulated. All observed pressures were equal to the simulated pressures, giving a link coefficient of one that is the best correlation between observed and simulated. The coefficient of determination (R^2) value was 0.9657, it indicates that observed and simulated relation is strong as values tend to one. The observed and simulated pressure relationship plot is shown in the figure below.

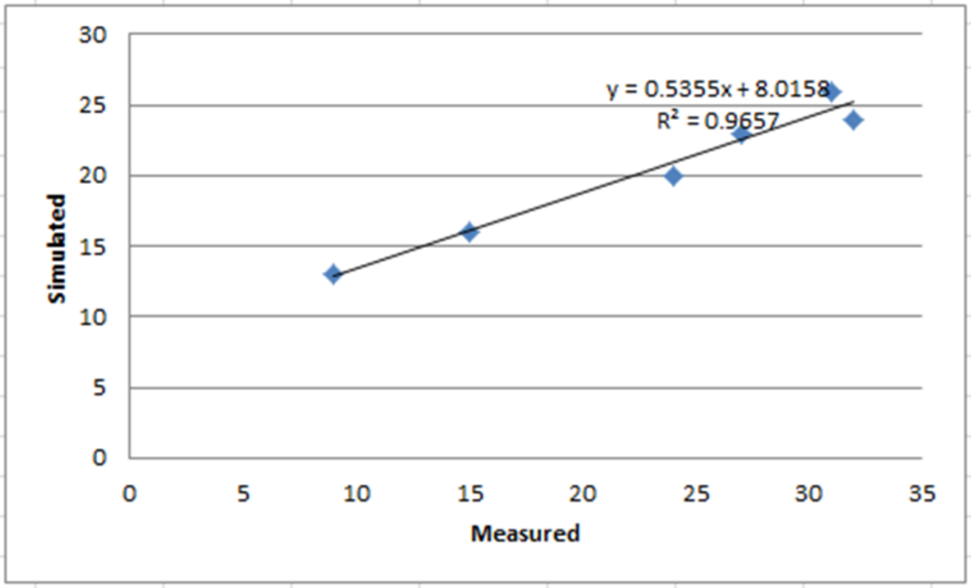

Figure 4.10: Correlation between observed and simulated pressure relationship plot

Table 4.14: Junction pressure calibration based on degree of accuracy criteria

S/N	Sample location Junction Id	Observed pressure (m)	Simulated pressure (m)	Difference Pressure Error (m)	Measured Time	sample Location (m)		
						X	Y	Z
1	j-4	27	23	4	3:10:00	436,644.5	729,805.9	1,924.9
2	j-11	24	20	4	4:55:00	435,824.9	730,872.2	1,915.5
3	j-27	15	16	-1	6:15:00	436,035.8	729,329.	1,907.
4	j-31	31	26	5	7:30:00	436,048.5	729,625.5	1,908.9
5	j-35	32	24	8	9:20:00	435,402.12	729,536.6	1,904.1
6	j-43	9	13	-4	10:00	435,466.7	730,264.8	1,905.6

Average=2.5

The difference average pressure error is from the table above pressure simulated to the observed value. Hence the model is acceptable calibrated with in satisfied the setting pressure calibration and validation criteria under average level (± 1.5 m and maximum difference ± 5 m) so our value is between the allowable range and it indicates it is a good data observed vs simulated pressure.

5. SUMMERY AND CONCLUSION

5.1. Summery

This study was conducted to analyze the existing water distribution system of Aleta-Wondo Town. The total population of the Town was estimated at 58,471 in year 2020 and become 108,935 at the end of design period (2040). The current maximum day water demand and the maximum day water demand at the end of design period (2040) of the Town shall be 4,369.92 m^3/day and 13,767.35 m^3/day respectively.

The finding of this study revealed that the water supply coverage of the Town was average per capita domestic water consumption of the Town in 2020 was 14.11 l/person/day and level of connection per family was evaluated. The total water loss has been evaluated on percentage of system input volume, length of mains and number of connections. Generally, based on the analysis results the total water loss from the system in 2020 was 133,642 m^3/year that account 31% from the total water production in the study area. The total apparent loss volume includes the loss due to unauthorized consumption, metering inaccuracies and data handling errors and was aggregated to 51,620.24m^3/year which covers 38.7% from the total losses. Real loss includes the volume of water lost through all types of leaks, bursts and overflows on service reservoirs. In this study the real loss volume was found to be 82,022m^3/year which covers 61.3% from the total losses. Real losses are the dominant component of water losses in Aleta-Wondo water distribution system. High levels of water losses have a serious impact on Aleta-Wondo water service finance as well as on available water resources in water scarce environments.

At peak hour consumption, of the nodes are below the desirable minimum pressure, none of the nodes are exceeded maximum allowable pressure, junctions and 65.5% were insufficient pressure head and 34.5% of nodes have pressure within the recommended limit.

For peak hour consumption 18% of the pipes are below needed minimum velocity and there was no number of the pipes velocity is exceeded maximum acceptable velocity and 82% of pipes are in suggested velocity range.

The result of the analysis showed that the whole technical performance of existing water distribution of the town was unsatisfied which is reflected by low water production rate, low water consumption, and high level of non-revenue water, low service coverage, not pressure in permissible range.

5.2. Conclusion

From this thesis some water distribution and related issue are known in the Town with in water supply coverage and demand, water loss in distribution and distribution network performance. The current water production of the town is not satisfying the water demand. Moreover, the existing distribution system in the town is old and high amount of water loss in addition to the shortage of the water. Moreover, a lot of unplanned connection along the gravity main line, poor water management and under estimation of the demand during the construction of the water system has contributed enormously for the shortage of potable water in the Town. The existing water distribution system of Aleta Wondo Town was established for an estimated population of 38,147. But, as compared with the current population figure of 58,471 it was served beyond the design life and low coverage in the Town.

The current water supply coverage is below the recommended value in addition to this the existing reservoir cannot enough population of the Town, but the current population number is around 58,471 so it indicated that design consideration problem for mode of service and governmental organization demand for parallel increasing of water demand and living standard of the community. The main reason for the decline of average consumption per connection is the increasing of connections was not supported with proportional increase in supply.

The performance analysis of water supply demand is unbalance due to increasing population in the Town and expands of the Town. Existing Water supply system design period completed without considering current dwellers of the town.

Despite the low water supply coverage of the Town, the total water loss is found to be high enough up to 31%. The total water loss was computed by subtracting the consumption from the water supplied. The water loss of the town is additional key factor to increase the gap to water supply and demand, water loss increase from time to time with in the town. In addition to reduce the income from the revenue, water loss by unbilled authorized, metering inaccurate, water loss by leak pipe due to long age pipe, Customer side leakage, Water meter and data handling error and different construction area break water distribution lines. Problems of timely maintaining and replacing aged meters were one of the critical problem of increasing NRW because the concerned bodies are do not replacing aged water meter at the right time.

In general, the simulated hydraulic result indicated that the current hydraulic performance of Aleta Wondo Town distribution system is not satisfactory. But it doesn’t mean that the system is not functional. Rather the frequency of service interruption is relatively high. This interruption is partly contributing for the current water shortage in the Town.

Recommendation

To satisfy continuous rising of water demand several measures should be taken and for the existing situation of Aleta-Wondo Town water supply distribution system and the resources take a seriously such as the following.

- So as to alleviative water scarcity of the Town additional borehole should be drilled to fulfill the current gap between water demand and water supply.
- Manage the demand by controlling waste or loss from pipe leakage and consumption through the use of meters and tariffs that are set in accordance with the volume of water consumption.
- Water loss is not only designing problem but it can be reduced by creating awareness and changing behavior of people by educating them to be owner ness feeling.
- In order to reduce the gap between water supply and demand government give attention and allocate budget for water supply enterprise.
- The water supply office strongly organizes maintenance and operational case team in order to reduce water loss from distribution system.
- Documentation of data’s with simple and reliable method is another way of creating a well-organized management for every piece evident shall be recorded and documented for setting out different target plans and performance comparison.

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Appendix A

Junctions (nodal) pressure result; for peak demand time

Label	X (m)	Y (m)	Elevation (m)	Hydraulic Grade (m)	Pressure (m H2O)
J1	436,390.45	730,083.41	1,936.97	1,946.21	9
J2	436,462.53	729,844.68	1,931.32	1,951.77	20
J3	436,421.56	730,207.11	1,935.27	1,945.30	10
J4	436,644.55	729,805.90	1,924.97	1,947.95	23
J5	437,012.65	730,137.83	1,940.86	1,938.97	-2
J6	436,620.47	730,400.17	1,934.59	1,942.50	8
J7	437,542.20	730,195.23	1,937.22	1,929.65	-8
J8	436,822.24	730,957.90	1,920.38	1,935.77	15
J9	436,530.70	731,045.43	1,915.80	1,926.72	11
J10	436,825.24	731,569.59	1,928.41	1,920.47	-8
J11	435,887.21	731,002.21	1,908.43	1,930.21	22
J12	435,801.14	731,455.23	1,891.30	1,896.09	5
J13	435,824.94	730,872.25	1,915.50	1,912.12	-3
J14	435,678.96	730,790.19	1,913.93	1,903.41	-10
J15	435,404.46	731,055.65	1,892.65	1,895.93	3
J16	435,393.25	730,519.61	1,895.64	1,909.17	14
J17	435,575.30	730,458.51	1,903.03	1,918.75	16
J18	436,034.32	730,429.74	1,921.75	1,931.58	10
J19	436,200.94	730,132.52	1,928.71	1,937.21	8
J20	436,240.27	729,950.12	1,925.91	1,942.56	17
J21	436,392.30	729,626.23	1,911.39	1,946.63	35
J22	436,537.58	729,592.93	1,912.60	1,941.52	29
J23	436,361.36	729,196.53	1,923.64	1,932.86	9
J24	436,767.71	729,184.03	1,942.75	1,927.66	-15
J25	436,064.32	729,059.48	1,928.36	1,926.32	-2
J26	436,210.35	728,718.19	1,928.41	1,913.14	-15
J27	436,035.82	729,329.31	1,907.84	1,924.13	16
J28	435,710.08	729,129.47	1,921.14	1,907.45	-14
J29	435,698.96	728,976.17	1,917.77	1,903.86	-14
J30	435,694.04	728,783.39	1,911.19	1,896.75	-14
J31	436,048.51	729,625.53	1,908.91	1,935.14	26
J32	435,827.56	730,004.93	1,927.08	1,928.11	1
J33	435,627.10	729,937.29	1,922.81	1,925.00	2
J34	435,403.66	729,693.69	1,917.38	1,921.19	4
J35	435,402.12	729,536.69	1,904.16	1,928.40	24
J36	435,365.90	729,132.10	1,915.00	1,920.06	5

J37	434,953.80	729,122.37	1,915.00	1,903.13	-12
J38	434,779.73	729,650.72	1,903.78	1,908.77	5
J39	434,348.32	729,227.90	1,895.00	1,892.08	-3
J40	435,071.34	729,662.14	1,916.47	1,914.04	-2
J41	435,133.58	729,987.48	1,924.42	1,913.76	-11
J42	435,358.36	729,912.25	1,922.42	1,918.74	-4
J43	435,466.77	730,264.89	1,905.66	1,918.74	13
J44	435,220.69	730,344.61	1,907.90	1,909.55	2
J45	437,311.75	730,950.33	1,939.13	1,918.55	-21
J46	435,677.84	729,648.72	1,920.15	1,919.49	-1

Appendix B

Pipe Report @ Peak hour during 8:00hr.

Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-42	411	J23	J24	40	PVC	130	0.72	0.57
P1	229	T1 (150m3)	J1	125	PVC	130	22.07	1.8
P2	185	T2 (300m3)	J2	140	PVC	130	12.86	0.84
P3	250	J2	J1	65	PVC	130	3.5	1.05
P4	141	J3	J1	110	PVC	130	-7.17	0.75
P5	186	J4	J2	65	PVC	130	-3.35	1.01
P6	507	J5	J4	50	PVC	130	-1.55	0.79
P7	472	J6	J5	25	PVC	130	0.16	0.32
P8	592	J5	J7	40	PVC	130	0.81	0.64
P9	286	J3	J6	75	PVC	130	3.27	0.74
P10	608	J6	J8	63	PVC	130	2.21	0.71
P11	983	J11	J3	63	PVC	130	-2.64	0.85
P12	693	J11	J9	25	PVC	130	0.13	0.26
P13	309	J9	J8	40	PVC	130	-1.13	0.9
P14	601	J9	J10	32	PVC	130	0.36	0.45
P15	498	J8	J45	25	PVC	130	0.36	0.73
P16	466	J12	J11	25	PVC	130	-0.54	1.1
P17	152	J13	J11	32	PVC	130	-1.34	1.67
P18	168	J14	J13	40	PVC	130	-1.54	1.23
P19	422	J14	J15	40	PVC	130	0.86	0.69
P20	408	J16	J14	25	PVC	130	0.22	0.45

P21	202	J16	J17	25	PVC	130	-0.43	0.87
P22	462	J17	J18	40	PVC	130	-1.1	0.88
P23	342	J18	J19	63	PVC	130	-2.74	0.88
P24	187	J19	J20	90	PVC	130	-9.45	1.49
P25	418	J20	J21	25	PVC	130	-0.18	0.37
P26	201	J1	J20	125	PVC	130	17.5	1.43
P27	230	J2	J21	75	PVC	130	5.11	1.16
P28	337	J4	J22	40	PVC	130	0.9	0.72
P29	150	J21	J22	63	PVC	130	4.07	1.31
P30	602	J22	J23	75	PVC	130	4.03	0.91
P32	330	J25	J23	50	PVC	130	-1.65	0.84
P33	434	J27	J23	40	PVC	130	-0.92	0.74
P34	298	J31	J27	40	PVC	130	1.28	1.02
P35	684	J31	J35	90	PVC	130	5.31	0.83
P36	292	J34	J46	25	PVC	130	0.14	0.28
P37	610	J46	J32	25	PVC	130	-0.22	0.45
P38	212	J33	J32	75	PVC	130	-4.08	0.92
P39	395	J32	J19	75	PVC	130	-5.2	1.18
P40	408	J33	J43	50	PVC	130	1.44	0.73
P41	237	J43	J17	40	PVC	130	-0.04	0.03
P42	259	J44	J43	32	PVC	130	-0.7	0.87
P43	369	J44	J16	50	PVC	130	0.33	0.17
P44	457	J41	J44	25	PVC	130	0.18	0.36
P45	390	J42	J43	50	PVC	130	0.03	0.01
P46	270	J42	J33	50	PVC	130	-1.79	0.91
P47	241	J41	J42	40	PVC	130	-0.94	0.75
P48	334	J40	J41	25	PVC	130	0.05	0.1
P49	334	J40	J34	50	PVC	130	-1.72	0.88
P50	298	J38	J40	40	PVC	130	-0.86	0.69
P51	758	J38	J39	32	PVC	130	0.54	0.67
P52	758	J35	J38	25	PVC	130	0.31	0.63
P53	413	J35	J36	50	PVC	130	1.67	0.85
P54	412	J36	J37	32	PVC	130	0.76	0.94
P55	345	J28	J36	25	PVC	130	-0.37	0.76
P56	385	J27	J28	40	PVC	130	1.4	1.11
P57	381	J29	J25	25	PVC	130	-0.48	0.98
P58	198	J29	J30	32	PVC	130	0.7	0.87
P59	381	J25	J26	25	PVC	130	0.36	0.73
P60	156	J28	J29	40	PVC	130	1	0.79
P61	398	J20	J31	90	PVC	130	7.49	1.18
P62	493	J13	J18	32	PVC	130	-0.74	0.92

P63	157	J34	J35	50	PVC	130	-2.6	1.32
PL1	2,237	PMP1	T1 (150m3)	80	GI	120	6.03	1.2
PL2	1,989	PMP2	T2 (300m3)	65	GI	120	6.16	1.86
PL3	785	PMP3	T2 (300m3)	65	GI	120	3.18	0.96
PL4	4,169	PMP4	T2 (300m3)	65	GI	120	3.5	1.06
PS1	247	PMP1	S1	80	GI	120	-6.03	1.2
PS2	195	PMP2	S2	65	GI	120	-6.16	1.86
PS3	234	PMP3	S3	65	GI	120	-3.18	0.96
PS4	288	PMP4	S4	65	GI	120	-3.5	1.06

Appendix C

Junction Report during Night time (1:00PM)

Label	X (m)	Y (m)	Elevation (m)	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
J1	436,390.45	730,083.41	1,936.97	0.13	1,953.38	16
J2	436,462.53	729,844.68	1,931.32	0.13	1,952.71	21
J3	436,421.56	730,207.11	1,935.27	0.18	1,953.36	18
J4	436,644.55	729,805.90	1,924.97	0.13	1,952.64	28
J5	437,012.65	730,137.83	1,940.86	0.13	1,952.49	12
J6	436,620.47	730,400.17	1,934.59	0.13	1,953.27	19
J7	437,542.20	730,195.23	1,937.22	0.11	1,952.25	15
J8	436,822.24	730,957.90	1,920.38	0.1	1,953.10	33
J9	436,530.70	731,045.43	1,915.80	0.13	1,952.87	37
J10	436,825.24	731,569.59	1,928.41	0.05	1,952.70	24
J11	435,887.21	731,002.21	1,908.43	0.09	1,952.96	44
J12	435,801.14	731,455.23	1,891.30	0.08	1,952.08	61
J13	435,824.94	730,872.25	1,915.50	0.08	1,952.49	37
J14	435,678.96	730,790.19	1,913.93	0.13	1,952.26	38

J15	435,404.46	731,055.65	1,892.65	0.12	1,952.07	59
J16	435,393.25	730,519.61	1,895.64	0.08	1,952.40	57
J17	435,575.30	730,458.51	1,903.03	0.09	1,952.65	50
J18	436,034.32	730,429.74	1,921.75	0.13	1,952.99	31
J19	436,200.94	730,132.52	1,928.71	0.21	1,953.13	24
J20	436,240.27	729,950.12	1,925.91	0.1	1,953.27	27
J21	436,392.30	729,626.23	1,911.39	0.12	1,952.63	41
J22	436,537.58	729,592.93	1,912.60	0.13	1,952.54	40
J23	436,361.36	729,196.53	1,923.64	0.1	1,952.40	29
J24	436,767.71	729,184.03	1,942.75	0.1	1,952.26	9
J25	436,064.32	729,059.48	1,928.36	0.11	1,952.25	24
J26	436,210.35	728,718.19	1,928.41	0.05	1,951.91	23
J27	436,035.82	729,329.31	1,907.84	0.11	1,952.39	44
J28	435,710.08	729,129.47	1,921.14	0.11	1,951.99	31
J29	435,698.96	728,976.17	1,917.77	0.11	1,951.88	34
J30	435,694.04	728,783.39	1,911.19	0.1	1,951.69	40
J31	436,048.51	729,625.53	1,908.91	0.13	1,953.04	44
J32	435,827.56	730,004.93	1,927.08	0.13	1,952.89	26
J33	435,627.10	729,937.29	1,922.81	0.12	1,952.81	30
J34	435,403.66	729,693.69	1,917.38	0.1	1,952.68	35
J35	435,402.12	729,536.69	1,904.16	0.1	1,952.86	49
J36	435,365.90	729,132.10	1,915.00	0.08	1,952.61	38
J37	434,953.80	729,122.37	1,915.00	0.11	1,952.17	37
J38	434,779.73	729,650.72	1,903.78	0.09	1,952.37	48
J39	434,348.32	729,227.90	1,895.00	0.08	1,951.94	57
J40	435,071.34	729,662.14	1,916.47	0.11	1,952.51	36
J41	435,133.58	729,987.48	1,924.42	0.11	1,952.51	28
J42	435,358.36	729,912.25	1,922.42	0.12	1,952.65	30
J43	435,466.77	730,264.89	1,905.66	0.11	1,952.65	47
J44	435,220.69	730,344.61	1,907.90	0.08	1,952.41	44

J45	437,311.75	730,950.33	1,939.13	0.05	1,952.65	13
J46	435,677.84	729,648.72	1,920.15	0.05	1,952.65	32

Pipe inventory of Distribution from water GEMSV8i Simulation result

Diameter (mm)	Material type	Length (m)
25	PVC	7,599
32	PVC	3,309
40	PVC	2,839
50	PVC	4,249
63	PVC	443
75	PVC	1,734
90	PVC	1,309
110	PVC	539
125	PVC	372
140	PVC	228
160	PVC	201
Total length(m)	PVC	23,788

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