ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGNEERING

ASSESSMENT OF THE HYDRAULIC PERFORMANCE OF EXISTING WATER SUPPLY DISTRIBUTION SYSTEM: A CASE STUDY ON FINOTE-SELAM TOWN, AMHARA REGION, ETHIOPI

By:

Yitayal Asmare

A Thesis Submitted to the school of graduate studies in Partial Fulfillment of the Requirements for the Degree of Masters of Science Civil Engineering

(Water Supply & Environmental engineering stream)

Advisor:

Dr.Ing. Geremew Sahilu

Addis Ababa

Addis Ababa, Ethiopia

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Approved by Board of Examiners

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Declaration

This thesis is my original work and has not been presented for a degree any other university and that all sources of material used for this thesis have been dully acknowledged.

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ABSTRACT

This thesis focused on assessment of the hydraulic performance of existing water distribution system: a case study on Finote-Selam town, Amhara region, Ethiopia. The main objective of this study is to check the hydraulic performance of Finote-Selam town water distribution system by assessing demand and production of water, losses of water, hydraulic parameter.

Both secondary and primary data sources were used for this study. Primary data was collected through a face-to-face interview, field survey, and photographs of relevant sites and infrastructures. The secondary data was collected from design document, literatures, journals and reports. Moreover, to analyze existing water distribution system a model was developed by using Water CAD software. The model can be used to identify the zone of higher and lower pressure junctions and velocity though the pipe. The model simulation run was performed for peak and low demand scenarios to analyze the distribution system. For calibration of water distribution system, pipe roughness was considered as the primary calibration parameter in this study.

The analysis shows that the current total domestic water demand in town was 1536.75m^3/day, the water supply coverage was 82.4 % and average per capital domestic water consumption was 37.9 l/c/day. Hence, this result indicates there is a gap between demand and supply. The water loss of the town was 32.18% from the total water production. The apparent loss covers 9.18% while, the real losses covers 23% of the total losses. Simulation results for maximum and minimum pressure and velocity different scenarios were used as a base tool to evaluate the hydraulic performance. Modeling results showed violation of maximum and minimum pressure and velocity criteria at different junctions and pipes. After modifying the existing water distribution system 92.18% of the junctions are in the recommended pressure range and 75.46% of the pipes are in the recommended velocity range.

Generally the result of the analysis shows that the overall hydraulic performance of water distribution 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 velocity and 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 providing more attention to water losses reduction policies and strategies are vital for remedial measures.

Key word: Water demand, Hydraulic performance, Simulation, Water distribution system and water losses.

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ACRONYM/ABBRIVATION

AWRDB	Amhara Water Resource Development Bureau
AWWA	American Water Work Association
CARL	Current Annual Real Loss
CSA	Central Statistical Agency
CWS	Continuous Water Supply
DCI	Ductile Cast Iron
DEM	Digital Elevation Model
DN	Nominal Diameter
DWD	Domestic Water Demand
DWDS	Drinking Water Distribution System
ECAC	Engineering, Computer Application Committee
EPA	Environmental Protection Agency
EPS	Extended Period Simulation
ETB	Ethiopian Birr
GI	Galvanized Iron
GIS	Geographical Information System
GPS	Geographical Positioning System
HC	House Connection
HDPE	High Density Polyethylene
ILI	Infrastructure Leakage Index
IWA	International Water Association
IWS	Intermittent Water Supply
Km	Kilo Meter
L/c/d	liter per capital per day
L/s	liter per second
MDF	Maximum Day Demand
m^3/s	meter cubic per second
MOWE	Ministry Of Water Energy
MOWR	Ministry Of Water Resources
MOWTE	Ministry Of Water, Irrigation and Electricity

NRW	Non- Revenue Water
PHF	Peak Hour Factor
PT	Public Tab
PVC	Polyvinyl Chloride Pipe
R^2	Correlation Coefficient
SIV	System Input Volume
UARL	Unavoidable Annual Real Loss
UFW	Unaccounted For Water
UNICEF	United Nation Child Fund
UTM	Universal Transverse Mercator
UWD	Unaccounted Water Demand
WDN	Water Distribution Network
WDS	Water Distribution System
WHO	World Health Organization
YC	Yard Connection
YSC	Yard Shared Connection

1. INTRODUCTION

1.1. Backgroundof the Study

Water demands in developing countries rapidly increasing with a growing population, higher standard of living situation, rapid industrialization and expansion of irrigation. Problems withaccess to sufficient water are most happening in the developing world due to either the intermittent nature of the system or the poor operational practice in continuous supplies. According to global water supply and sanitation assessment report in 2000, 1.1 billion people of the world population were without access improved water supply. The majority of these people live in Asia and Africa, where two out of five African lacks improved water supply. In Sub- Saharan Africa, 748 million people were relying on unsafe drinking water sources in 2012 of which 173 million obtained their drinking water straight from rivers, streams and ponds. The remaining population relied on unprotected, open wells or poorly protected natural springs (Khatri et al., 2008).

In Ethiopia, urbanization growth rate highly increasing time to time, 18% of the population is urbanizing according to data published by the country's 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.

Water distribution system (WDS) is responsible for delivering water from the source or treatment facilities to its consumers at serviceable pressures and velocity (Walski et al., 2003). It consists of pipes, pumps, junctions, valves, fittings, and storage tanks. An effective WDS requires an adequate supply of water into the system, functional pumping facilities as well as efficient distribution network. Poorly installed water distribution network coupled with lack of proper operations, day-to-day inefficient performance and maintenance always results in distribution network failure.

The most common challenges in water distribution networks 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).

The other major factor which affecting the water distribution system is Non-Revenue Water (NRW). Current statistical surveys indicated that NRW in developing countries is around 45 to 50% of the total system input volume. 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).

Generally, because of rapid growth and high water losses from the distribution network, the total water demand of the system in many developing countries exceeds available production capacity.

According to Finote-Selam 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 assess the hydraulic performance of existing water supply distribution system in Finote-Selam town using a hydraulic model Water CADv8i.Water CADv8i 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 systems is delivery of water from the source or treatment facilities to its consumers to meet the demands with quantity and pressure. Unfortunately, as a water distribution system age, 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 (AWRDB, 2012). Because of significant development of urbanized areas and construction of thousands of small and large-scale water supply and distribution systems in recent decades, many people have access to clean water and adequate sanitation. However, the quality of service in terms of optimum pressure and velocity, which provided by water utilities, is often difficult (CSA, 2007).

Most problems that occurred in developing countries including Ethiopia are intermittent water supply, erratic pressure; high rate of water losses from the distribution systems, Population growth and urbanization, growing urban water demand, infrastructure is aging and deteriorating. 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 pressure in the system (Zyoud, 2003). According to Finote-Selam town water supply service office, the common problems in the town water supply system was experiencing 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. 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 were observed in the town. These problems affected the performance of existing water distribution networks.

Earlier studies were conducted on water supply system, both at international and national levels focused mainly in rural areas and big cities. However, in small and medium towns like Finote-Selam no adequate research yet carried out. Furthermore, the town is one of the medium levels towns in the country with recent rapid urbanization and high population growth. Therefore, there is a need to evaluate the present status of hydraulic performance of the existing water distribution system of the town.

1.3. Research Aim and Objectives

1.3.1. Main objective

The main objective of this study was to assess the present status of hydraulic performance of existing water distribution system of Finote-Selam town and to recommending the possible improvement measures for water distribution system.

1.3.2 .Specific objectives

1. To evaluate the existing water distribution network in the study area.
2. To evaluate the present water demand and forecast future demand
3. To assess water losses of the existing water distribution system
4. To evaluate hydraulic parameters of the existing distribution system
5. To recommend the possible improvement measures

1.4. Research Questions

The general and specific objectives of the study would be achieved by way of seeking answers to the following questions.

- What is the existing condition of the distribution network in the study area?
- Is the existing water supply satisfied current demand and future demand for the next decade?
- How much water losses are in the water distribution network?
- How to simulate hydraulic parameters of the existing distribution system?
- What are the possible improvement measures?

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. There have been few studies on the performance of water distribution system assessment in Ethiopia, but none has been done in the present study area. The current study aims to assess the hydraulic performance of existing water distribution system in Finote-Selam town. The research findings can strongly help, decision or policy 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 other research 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. Limitation of the Study

The available funding for the study was not enough for carrying out field data collection for the entire distribution network for calibration and validation. Also testing of water meter was costly and due to limited funds, thus the researcher gathered required data through document review.

There was shortage of well-documented data sources and adequate report especially in the study area Finote-Selam town water utility 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.

1.7. The 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.

1.8. Organization of the Study

The entire thesis work has been documented in this report in a comprehensive and systematic order so that it could be easily understood and be able to summarize and represent the result in the most convenient way. This thesis contains five chapters.

Chapter one: Introduction-a description of the background of the study, statement of problem, the purpose of the study, the research objective and research question that guided the study. It also covers the significance of the study, limitation of the study and scope of the study.

Chapter two: was review of relevant studies and theories done by scholars related to factors influencing the hydraulic performance of the existing water distribution system. Under this section, a literature review was discussed under urban water supply, performance evaluation of urban water distribution system, water supply modes, water losses and its component.

Chapter three: was described of the research methodology used to conduct the study.

Description of the study area and the research design, method of data collection, data analysis, and model calibration and validation material used for data collection, processing and evaluation are explained. There is also a description of ethical consideration and data quality assurance

Chapter four: data analysis, presentation, interpretation and discussion of the findings of the research study. The findings of the study as per the study objective are presented in the form of tables and graphs and interpretation, explanations, discussions of the same provided after each table and graph.

Chapter five: was conclusion and gives recommendations based on the study findings.

2. LITERATURE REVIEW

2.1. Urban Water Supply

Safe drinking water is the birthright of all humankind as much a birthright as clean air (AWRDB, 2012), while access to clean water can consider as one of the basic needs and rights of a human being. The health of people and dignified life is based on access to clean water.

However, the majority of the world's population in both rural and urban settlements does not have access to safe drinking water. 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). The primary goal of all water supply utilities is to provide customers with a private connection to the piped water supply network.

2.2. Urban Water Demand

Water demand is the volume of water requested by users to satisfy their needs. In simplified way, it is often considered equal to water consumption; also the two terms conceptually do not have the same meaning. In most developing countries, the theoretical water demand considerably exceeds the actual consumptive water use (Zewdu, 2014). According to Abu-Madi and Trifunovic (2013) water demand was the algebraic sum of the quantity of water utilized by consumer and the amount of water physically lost from the system. 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 was increase with time because of the population growth. Therefore new water resource is developed in order to meet the increasing water demand at present and future time.

2.2.1. Types of urban water demand

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.

2.2.1.1. Domestic water demand

Domestic water demand includes the water required in private building for drinking, cooking, bathing, flushing and washing clothes(WHO, 2000) . Domestic water consumption was various according to the living standard to consumers economic status of the community, climatic condition, mode of service, affordability and accessibility of service. Daily per capita water consumption in Ethiopia is generally very low throughout the country. Actual water demand is expected to be greater than present consumption if greater supplies were available to the community (MOWE, 2011).

2.2.1.2. Non-domestic Demand

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

Industrial water demand: represents the amount of water demand required by industries and factories in the cities.

Commercial and institutional water demand; in addition those of household consumers, the water requirement of towns include the need of such commercial and institutional consumers as public schools, clinics, hospitals, offices shops and hotels.

Unaccounted water demand: is the amount of water physically lost from the system and theft (Motiee et al., 2007). According to MOWE (2011)water losses are a function of the quality of construction the type and age of pipes in the distribution network and pressure within the system.

2.3. Water Losses in Distribution System

Water losses occur on all the systems. It is only the volume that varies; and it reflects the ability of a utility to manage its network (EPA, 2010). According to (Lambert, 2002) the actual quantity of water lost from the water distribution system was varied from utility to utility depending upon local factors such as topography, length of mains, number of connection and standard of service and upon how well the system is being operated and maintained. In developing countries more than 40% of treated water was lost as non-revenue water (Bogale, 2016).

The are many factors contributing to water losses in water distribution system ,such as ageing infrastructure, high pressure, external and internal pipeline corrosion, service tank overflows, poorly designed and constructed WDSs metering errors illegal use and poor operation and maintenance practices (Sharma, 2008). The water losses in the distribution system vary widely between different countries, regions and system from as low as 3-7% to as high as 50% of distribution input volume in the well maintained system developed countries and less maintained system in developing countries respectively(Lambert, 2002).

A high level of real losses reduces the amount of precious water reaching customers, increase the operating costs of the utility and makes capital investment in new resource schemes larger. Reducing water losses are a special concern of every water supply utility.

2.3.1. Component of water losses

According to Babić (2011) water losses have two main components: apparent losses and real losses. Real losses consist of water lost through burst pipes, leaking joints, fittings, service pipes, and connections, whereas apparent losses result from illegal connections, under-registration of customers' meters inaccurate meters, by passing meters, billing errors, inadequate meter reading policy, bribery and corruption of meter readers. Real losses increase the water utility production costs and water resource since they represent water that is extracted and treated but never reaches beneficial use. It is recommended as a standard practice to split water losses into real and apparent losses when studding water losses (McKenzie and Seago, 2005).

2.3.1.1. Apparent losses

Apparent losses are commercial losses which are from an improper recording of total water consumed due to meter errors, inaccurate assumption of unmeasured and unauthorized consumption and these deficiencies is attributed to administrative inefficiencies of the water utility (Motiee et al., 2007). According to Lambert and Hirner (2000) these losses occur as a result of errors in water flow measurement, errors in water accounting and unauthorized use or theft. Assessment of apparent losses has a direct impact of real losses and therefore it is important to pay attention to both components of water loss.

According to Seago et al. (2004) apparent losses recommended limit was 20% of the total water losses from the water distribution system in South Africa. On the other hand, according to Lambert and Taylor (2010) the amount of apparent losses from the water distribution system was 30 to 40% of the total losses.

2.3.1.2. Real losses

Real losses are "the annual volumes lost from transmission and distribution system through all types of leaks, bursts and overflows on mains, service reservoirs and service connections up to the point of customer metering". Real losses are attributed to varying pressure, inefficient leak detection system, poor workmanship and maintenance of the distribution network (Sharma, 2008). According to Tabesh and Asadiani Yekta (2005), real losses are categorized as water losses from reported and unreported bursts, background losses, reservoir leakage and overflow and leakage from connections.

2.3.2. Causes of water losses

There are many factors contributing to water losses in water distribution system, such as ageing of infrastructure, high pressure, and external and internal pipeline corrosion, service reservoir over flow, poorly designed and constructed, WDS metering errors and poor operational and maintenance practice.

2.3.2.1 Causes of real losses

Real losses are water volumes lost within a given period through all types of leaks bursts and overflows. It can be classified according to their location within the system and their size and runtime (Fallis et al., 2011). Leakage from transmission and distribution mains may occur at pipes, joints and valves (McKenzie and Seago, 2005). Real losses from transmission and distribution mains have short to medium run times because of it repaired within the shortest time possible. Leakage from service connections up to the point of consumer and on storage tanks is difficult to detect due to their comparatively low flow rates and often have long run times.

2.3.2.2. Cause of apparent losses

Apparent losses are caused by different factors, such as metering inaccuracies due to broken or incorrect customers and bulk water meters, data handling and accounting errors and poor customer accountabilities in billing systems and unauthorized consumption due to water theft and illegal connections (Xin et al., 2014). Apparent loss may consider as all water that was successfully delivered to the consumer but which is not metered or recorded correctly and these causes an error of consumer consumption (Lambert and Taylor, 2010).

2.3.3. 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(Frauendorfer and Liemberger, 2010). Real losses have also been identified as a route of contamination in the water distribution systems.

2.3.4. 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 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.

2.3.5. Water Losses evaluation

In a developed country water losses have been assessed before and after leakage detection surveying by two different approaches; which are top-down annual water balance and bottom-up approach based on minimum night flow analysis (Dighade et al., 2014). In developing countries mostly top-down water losses auditing was conducted as per the guide-line suggested by IWA. Due to lack of accurate input data and advanced technology and equipment, it is very difficult to detect real losses in the distribution system as a result; separation of water loss into real and apparent loss was a big challenge for strategic planning (Dighade et al., 2014). The assessment of real loss by the bottom-up approach during the night does not hold the good result because in intermittent water supply system consumer always keep tap open in house connections to fill storage tank.

2.3.6. 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 and Hensel, 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.

There are different components to effective management water loss strategy:-

- Water auditing
- Intervention
- Upgrading the network
- Evaluation.

Water auditing

Water auditing determines the amount of water lost from a water distribution system due to leakage and other reasons. To a quantify water lost from water distribution systems, water utilities should undertake water auditing where the total water supplied was compared with the amount of water billed (Lambert, 2001).

Upgrading the network

The aim of upgrading the network was to bring the infrastructure management to a stage where utility practitioners can be reduced losses and improve network performance. One of the fundamental network management was zoning. The principle of zoning is well established by dividing the network into smaller parts that the utility workers can be understood and more easily analysis pressure and flow profiles and problem areas (MOWR, 2006b).

Intervention

The intervention process puts the options selected in to action. More than one action selected was beneficial to water utilities. Selecting the order of these actions should be based on budget constraint, public benefits and priority of other scheduled capital improvements (EPA, 2010). Intervention can include:-

- Gathering future information
- Metering assessment, testing or meter replacement program
- Detecting and locating leaks
- Repairing or replacing pipe
- Operational and maintenance program
- Administrative processes or policy changes

Evaluation

Evaluation is necessary to ensure that whatever the intervention was, it succeeded in its goal (Liemberger et al., 2007). The major portion of the evaluation was benchmarking (EPA, 2010).

2.4. Urban Water Demand Forecasting

Water demand was forecasted in time. Many water resource projects have a relatively long useful life. Therefore, in studies of water demand forecasting the plan should extend to about 50 years for long term. In medium scale development plans, a lead-time of 15 to 25 years may apply (Karamouz et al., 2003).

2.5. Water Supply Distribution Network

Water distribution system is the systems of urban water supply networks that transport potable water from the treatment plant to consumers in the demand areas. Water utilities worldwide face increasing challenges to preserve the hydraulic and water quality integrity of their water distribution networks. These challenges stem from growing populations and migration to urban cities that continue to increase the load on aging, inefficient, and already strained infrastructures (AWWA, 2005).

Water distribution Networks are very important lifeline infrastructure systems, where failures are inevitable. Typical WDNs consists of a network of pipes, nodes linking the pipes, storage tanks, reservoirs, pumps, additional appurtenances like valves. Water distribution systems represent a major portion of the investment in urban infrastructure and a critical component of public works. The main goal is to design water distribution systems to deliver potable water over spatially extensive areas in required quantities and under satisfactory pressures. Therefore, hydraulic models for water distribution networks have become indispensable tools for understanding system behavior by simulating pressures and flows at different locations and times in the networks. The design of water distribution systems in general based on the assumption of continuous supply. However, in most of the developing countries, the water supply system is not continuous but intermittent (Khatri et al., 2008). A well-planned water distribution network is very essential in the development of urban areas. The network is built to satisfy various consumer demands while meeting minimum pressure requirements at certain nodes(Liong and Atiquzzaman, 2004). For lower pressures, there cannot be a water delivery and for higher pressures, there can be an excessive amount of leakage. To provide this, the service area is divided into different pressure zones.

2.6. Problems of Water Distribution System

Water flow is a function of several things, including the size and shape of the opening, and the pressure at the opening. Typically, city water supplies are at 40 to 70m, (static pressure). Older private systems are set to maintain water pressure between 20m and 40m, which is too low for some lifestyles; plumbers can set systems higher if the pump is capable of delivering higher pressure (MOWR, 2006b).

2.6.1. Water pressure drop due to elevation

Elevation is the source of pressure loss in a residential plumbing system. Energy is required to push the water uphill. For every 0.305m of elevation increase in a pipe, approximately 0.434m is lost. With no water flowing, the static pressure available at the street main may be 60 psi, but the static pressure at the second floor basin would be 52psi.

2.6.2. Water pressure drops due to corrosion

When the water pressure is poor in the distribution system, the most common cause is corroded galvanized steel piping. The only solution is to replace this pipe typically with copper coated pipes. It is wise to replace with a larger diameter pipe on the main feeds at least to improve pressure. When galvanized steel pipe is present, and pressure is low, it is common for accessible pipes running across the basement ceiling to be replaced first (Hutton et al., 2007).

2.6.3. Water pressure drops due to distance from the source

If more water is flowing, the pressure drops more at each point along the pipe (Hutton et al., 2007). The more fixtures flowing at once, the greater the pressure drop at all fixtures and the lower the flow at each fixture (Rossman et al., 1993).

2.7. Performance Evaluation of Urban Water Distribution System

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 (Tabesh and Doulakhah, 2006). Evaluating the performance of water supply systems is an important for the 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 city with reasonably sufficient pressure head and the requisite amount of water for various types of demand. The performance of urban water supply scheme was evaluated based on four performance measures: Hydraulic, Structural, Water quality and Customer perception.

2.7.1. Hydraulic performance

The hydraulic performance of a water distribution system is the ability to provide a reliable water supply at an acceptable level of service that is, meeting all demands placed upon the system with provisions for adequate pressure, fire protection, and reliability of uninterrupted supply (Tabesh and Doulakhah, 2006). Thus, hydraulic simulation modeling is nowadays the most common tool used by water supply engineers and managers.

2.7.2. Structural (physical) performance

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 (Tabesh and Doulakhah, 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.

2.7.3 .Water quality

Water quality deteriorates as it travels through a drinking water distribution system (DWDS). Parameters and reactions that are considered of interest include disinfectant residual and the disinfectant by-product formation, nitrification, bacterial re-growth, corrosion, sedimentation, temperature, and taste and odor.

2.7.4. Customer perception

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. The estimation of the quantity of water should reflect customer preferences and expectations efficiently. The more closely customer needs are met, the higher the level of satisfaction of customers and the better the water utility is managed (CSA, 2007).

2.8. Water Distribution System Modeling

Analysis of Water distribution network provides the basis for the design of the new system the extensions, and control of existing systems. The flow and pressure distribution across a network are affected by the arrangement and size of pipes and the distribution of demand flows. WaterCADV8i could show pressure, demands and hydraulic grade in different nodes as well as flows, velocities, gradient and pressure different pipes throughout the different system.

2.9. 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 24 h/day (Batish, 2003).

2.9.1. 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’s 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.

2.9.2. 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 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 et al., 1999).

2.10. 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;

2.10.1. 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 2.1.

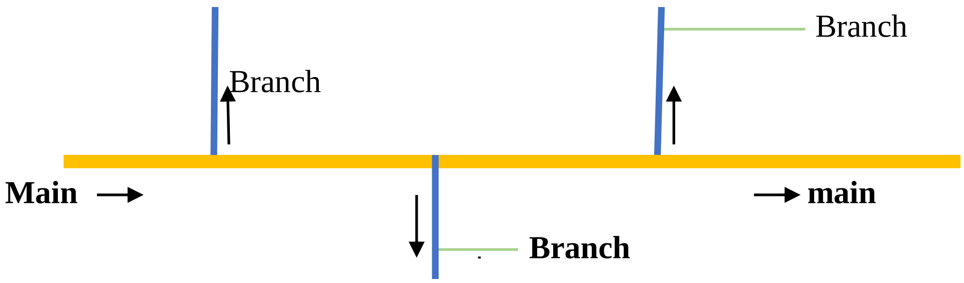

Figure 2.1 Branched or Dead end system

2.10.2 .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 (Figure 2.2).

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.

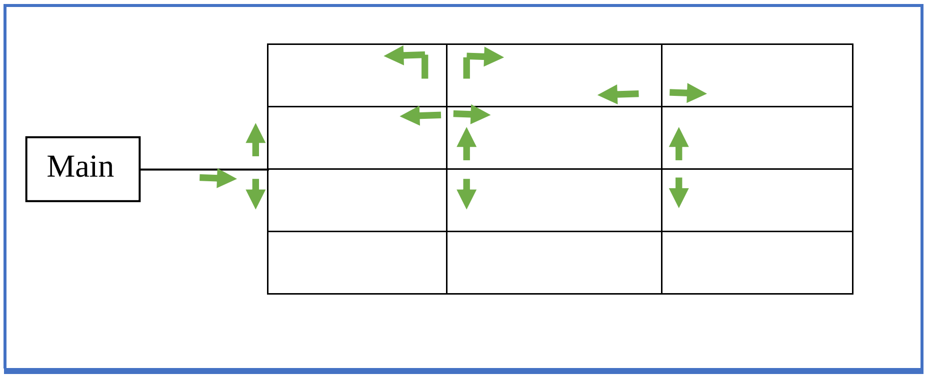

Figure 2.2 Grid Iron systems

2.11. Methods of Water Distribution

There are three methods of water distribution system delivered from the source to consumers' house (Zyoud, 2003). These are gravity distribution, distribution by pumping without storage and distribution by means of pumps with storage.

2.12. Water Distribution Network Elements

2.12.1. Pipes

The main components of water distribution system are the pipes. They can be found in different lengths, material and diameter lay down in the network. The pipes are mainly grouped into three such as, transmission line pipe, distribution line pipes and service pipes.

The transmission line pipe is the pipe between the source and the storage element; it carries water from the source or pump station to the storage tank while the capacity is enough for both serving the consumers and carrying excess water to the storage tank. The distribution line deliver water to the pressure zone and distribute the water to service nodes. On the other hand service pipes are the pipes the mainly deliver water to the consumers.

2.12.2. Pumps

A pump is a hydraulic machine that adds energy to the water flow by converting the mechanical energy into potential energy to overcome the friction loss and hydraulic grade different within the system. Most pump used in the water supply systems are centrifugal in nature ,and are installed to improve the water distribution ,if gravity is insufficient to supply water at an adequate pressure. The pump characteristics are presented by various performance curves such as, power head and efficiency requirements that are developed for the friction rate. In most of pumping station two or more pumps are used to ensure reliability, efficiency and flexibility.

2.12.3. Reservoir and storage tanks

In water distribution system reservoir and storage tanks are mainly provided to store excess water during low demand periods in order to meet the fluctuation of water demand, to stabilize pressure and reserve water for emergency requirements. A storage tanks oscillations are directly integrated with the demand and pumping working rate.

2.12.4. Accessory equipment

The Accessory equipment’s in the water distribution system can be classified as valves, hydrants fittings, drainage facility, flow meter etc. all these accessories has been installed at a place where necessary for connecting the network ,controlling and management of the system and for maintenance purposes during failure is occurred (Bhadbhade, 2009).

2.13. 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.

2.13.1. 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:

$$\sum \text{Qin}\Delta\text{t} - \sum \text{Qout}\Delta\text{t} - \Delta\text{Vs} = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.1$$

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

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

ΔVs=*Change in storage volume*

Δt=*Change in time*

2.13.2. 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 such as:

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

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

2.14. Head Losses

There are different factors that cause the energy losses .the main reason of energy loss is due to internal friction between fluid particles traveling at different velocities (Zyoud, 2003). Also minor loss and water hammer are the cause of energy loss. The head loss in a pipe is expressed in the following equation:

$hL = CfLQ^{1.852}/C^{1.852} D^{4.87}$ ………………………………………………………………**2.3**

Where, hL=head loss due to friction (ft, m)

L=Length of the pipe (ft, m)

C=Hazen-Williams friction factor

D=pipe internal diameter (ft, m)

Q=flow rate in pipes (cfs, cms)

Cf=unit conversion factor (4.73-English, 10.70-SI)

2.15. 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).

2.16. Model Calibration and Validation

Model calibration is the process which lies in matching the simulated and observed pressure and head loss as a result of loading under various demand conditions for a specified time horizon to an established degree of accuracy'. Calibration is achieved iteratively by adjusting network and/or loading parameters, while comparing results against gauged data until a suitable level of calibration is achieved.

According to Walski et al. (2003) hydraulic model calibration is the necessary process of modeling and it is calibrated in order to have better confidence, understanding and identifying errors made during the model building process.

A model is considered calibrated when the results produced can be applied with relative confidence to make decisions regarding the design, operation, and maintenance of a water distribution system.

2.16.1. Acceptable levels of calibration

According to Walski et al. (2003) 'regardless of which approach to calibration is adopted a realistic model should achieve some level of performance criteria. Accordingly outlines the criteria for pressure through extended period simulation has been established'.

Pressure

- 85% of field-test measurements ± 0.5 m or ±5% of maximum head loss across system, whichever is greater.
- 95% of field-test measurements±2m or±7.5% of maximum head loss across system, whichever is greater.
- 100% of field-test measurements ±5m, or ± 15% of maximum head loss across the system, whichever is greater.

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

Location: Finote-Selam town is the capital of west Gojjam Administrative Zone of Amhara National regional State which found in the north west of Ethiopia. It is far 390 kilometers from Addis Ababa and 180 kilometers from Bahir Dar, the capital city of Amhara Nation Regional State. The town is located at 10^{0}40'N latitude and 37^{0}16'E longitude and it has average elevation of 1880 meters above sea level with the area of 1,663.14 hectare; Average Annual temperature 18.5ºC; and the Mean Annual Rainfall is 1,885 mm. Water supply and sewerage service in the town is a public institution which is responsible for supplying of portable water and collection, treatment and disposal of water and sludge, yet the disposal of sludge at present are being done by the municipality. The location of the study area is shown in the figure3.1.

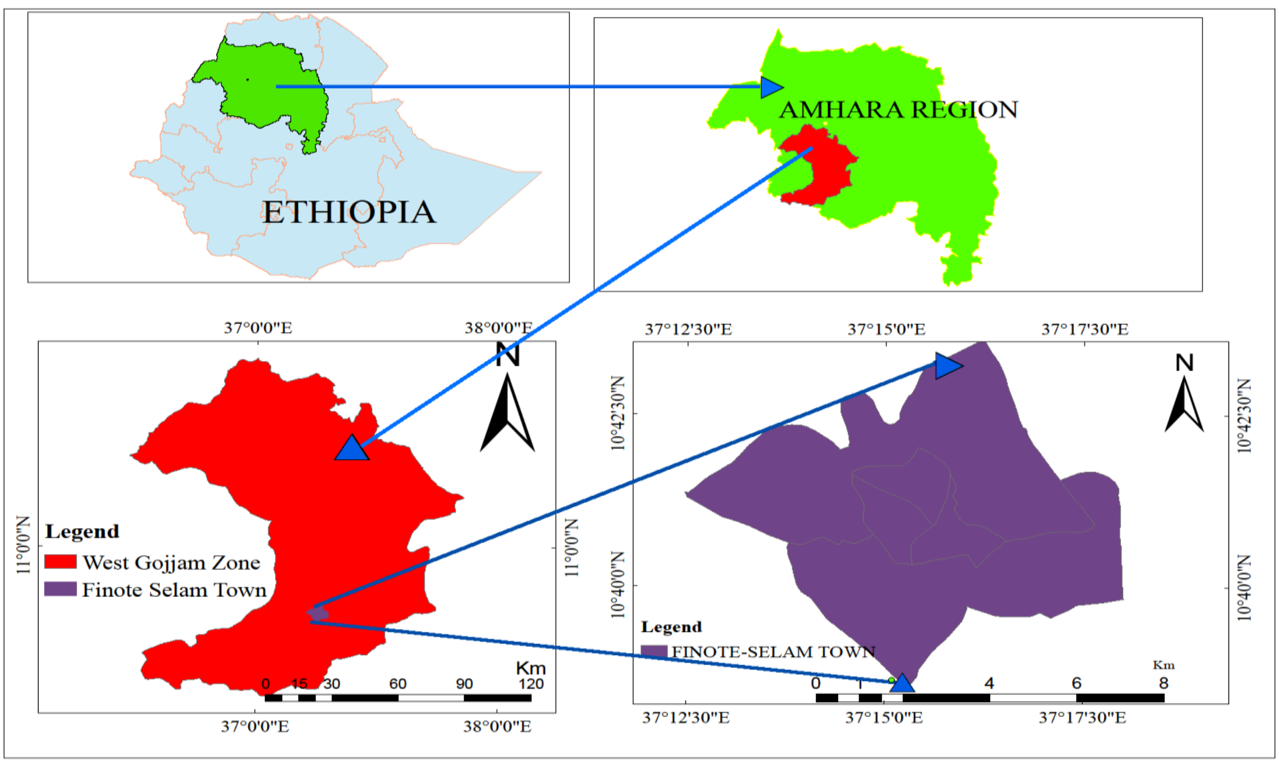

Figure 3.1 Map of Finote-Selam towns

Population: - According to the Ethiopia Central Agency (2007) and the information from the town's Municipal Administration the population of the town was 26,976 and which was projected based on exponential forecasting method for the year 2018.

Topography

The topography in the area of quaternary out crops or possible target zones is moderately rough, with undulating and disconnected high and low micro relief topography. In some sections, the quaternary basalt is highly fractured with block out crop nature, typically featured by bush vegetation. According to the woreda office of agriculture, the topography is classified as: 65% plain, 15% mountainous, 15% undulating, and 10% valley.

Hydrology

There are a number of springs such as, Shembekuma spring, Guray spring and rivers flowing through the town. Among them the data available for two stream gauging station obtained by hydrology department of Ministry of water resource.

3.2. Material

To do this research the following equipment and materials were used for data collection, processing and evaluation.

- ***Water CADV8i*** 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
- Global Mapper to check the elevation of the network,
- End note, is automatically format in text-citation that used as a personal database to gather and store citation records from different information sources.
- Water meter: to measure the flow of water in the pipe,
- Pressure gage: to measure the pressure at the nodes and pump outlet
- DEM, calculator, and AutoCAD 2007

3.3. The Research Design

This study was designed in how important exact information was getting to evaluate hydraulic performance of water distribution system.

First, estimating the current and future water demand of the town was conducted by considering per mode of service. After that, the per-capita water consumption of the town can be evaluated with annual consumption with in specific year. Then the percentage of the water loss was estimated. The total water produced and actual water consumption as aggregate from the individual contracts (customer meters) was used as an input for water loss analysis. The water loss analyses, both apparent and real, were carried out by using the top-down water balance approach. Then analysis the simulation, calibration and validation of the model and determine the hydraulic parameter. Finally, the performance of water distribution network was evaluated by the standard guidelines. Also based on calculated performance indicators and key statistical comparison is made, and strategies for loss reduction are developed for international experiences.

3.4. Data Collection

3.4.1. Primary data collection

Primary data was collected through a face-to-face interview with utility worker, field survey such as field observations and data measured by GPS, Water meter and Pressure gage, photographs of relevant sites and infrastructures.

Pressure Measurement:-throughout the entire day was conducted at different zones in the distribution system. At location where pressure gauges were installed, elevation readings were also taken. Critical times were selected while pressure gauges were taken. These critical times were fixed based on the demand rate of the users which covers the time between 8:00-12:00 (early mid noon) 2:00-6:00 (afternoon) 8:00-12:00 (early mid night) and 2:00-4:00 (early morning) (Lambert, 2003).

Field observations: - would the other method which was help in this study. During the field visit different users such as private tap and public fountain users including the sites and infrastructures was visited to collect different information's and data should be recorded

3.4.2. Secondary data collection

The secondary data was collected from document in Finote-Selam water utility offices, Amhara water design and supervision work offices, Finote-Selam administrative office, literatures, journals and reports.

3.4.2.1. The town existing water distribution network

The entire water supply network of the town, including their attribute like pipe length, diameter and material type, Pipes roughness coefficient, and reservoir and tank section has been collected from Finote-Selam water utility offices. The as built drawing of the town was also collected from Amhara design and supervision work offices.

3.4.2.2. Water pump station

A pump is a hydraulic machine that adds energy to the water flow by converting the mechanical energy into potential energy to overcome the friction loss and hydraulic grade different within the system. In source of water pumping station there were four surface horizontal centrifugal types of pumps (two operational and the other standby) and two Submersible centrifugal types of pumps.

Table 3.1 Pump description

Source	Elevation (m)	Pump type	Pump Power (Kw)	Discharge (l/s)	Discharge (m3/hr)	Head(m)
Abatir Spring	1898	Booster Pump	9.2	1.5	5.4	150
Shembekuma Spring	1897	Booster Pump	9.9	2	7.2	210
BH FS-1	1839	Submersible	11	3.2	10.8	90
BH FS-2	1828	Submersible	13	30.2	108.72	250
Total				36.9	2391.12	

(Source: Finote-Selam water office)

3.4.2.3. Water production

The water production has been evaluated as the total annual water supplied to the water distribution system (WDS). The production of water is administered by Finote-Selam town water utility office. According to the water utility office of the town, the design gross water production capacity of developed spring and boreholes is 3,013.2 m^3 /day but, currently around 2,391.12 m^3 /day production is produced from developed spring and boreholes with average working for 18 hours per day.

Table 3.2 Water source production of the town

Name of source	Drilled Year	Potential Yield (l/s)	Yield (l/s)	Elevation (m)	Daily production (m3)	Yearly production (m3)
Abatir Spring	2004	2	1.5	1898	97.2	35478
Shembekuma Spring	1988	5	2	1897	129.6	47304
BH FS-1	2008	4.5	3.2	1839	207.36	75686.4
BH FS-2	2010	35	30.2	1828	1956.96	714290
Total		46.5	36.9		2391.12	872759

(Source: Finote-Selam water office)

3.4.2.4. Transmission pipe line network

The rising main transmit clear water simultaneously into the distribution network and service reservoir. The water from the sources is transmitted to the reservoir by DCI and GS pipes. The line from Abatir collection chamber to the service reservoir was laid with diameter of 80mm GS pipes 1.7 km in length. The line from Shembekuma collection chamber to the service reservoir was laid with diameter of

100mm GS pipes 1.1 km in length. The line from Borehole 2 (Gocha) to the service reservoir was laid DN250 DCI pipes 3.27 km in length. The line from Borehole 1 (Kera) to the service reservoir was laid DN250 DCI pipes 1.3 km in length.

3.4.2.5 Reservoirs

The information on location of most of the water reservoirs were collected in conjunction with the main water network on the town. The reservoir's data including their capacity years of construction and material of construction were also collected. A concrete and masonry reservoirs were constructed in Finote-Selam with capacities of 100 m3 and 50 m^3 respectively. Both the reservoirs are located at Kidane-Miheret area at an elevation of 1927 meters above sea level and UTM E309466 N1182449. The 100 m3 was built in 1990 while the 50 m^3 reservoir is constructed in 1996. A reservoir provides the upstream energy or hydraulic head by its water surface elevation, and any amount of water volume required for the system continuity. From these reservoirs, the treated water is distributed to the whole town by gravity.

3.4.2.6. Distribution pipe line network

As per information obtained from the town water service office and based on as built drawing; the existing distribution system consists of a network of mains with total length 42,347 meters. The system contains pipe ranging from 25mm to 350mm in diameter, although the majority of the system consists of 50 and 80 mm in diameter of pipe. The material type of the water distribution network of town was consisting of PVC, HDPE, GI and DCI.

3.4.2.7 .Water consumption

In order to evaluate the water loss in the distribution system consumption, data of the entire customer were collected from billed data. The rate of water consumption at a node depends on the population served by the node, type of demands (domestic, public, commercial etc.) and time of the year. According to the water utility office of the town, the water consumption of the town was 590,639 m^3 /year for the entire consumer.

3.4.2.8. Water supply duration

According to Finote-Selam town water service office report, the design of water distribution of the system was based on continuous supply to its consumers. However due to large water demand and frequent power–supply shutoff events, averagely 3 times a week supplied water to the consumer.

3.4.2.9. Population data

According to CSA (2007), the number of the population of the Finote-Selam town was collected from planning commission of the town. But for the year 2018 the number of the population of the town was forecasted using an exponential method by using the base year of 2007. From commen methods of population forcasting, Exponential increase method is selected. This method is used by the central statistics Authority of Ethiopia. Because percentage error of Exponential increases method is the lowest value (minimum value) than other methods. Also this method is good for developing countries as well as developing town or city like Finote-Selam town. Exponential increases method is growth rate of population for calculation of the future population of town and also corresponding to population growth rate of given town. For these reason Exponential increase method is best method for forecasting Finote-Selam town population for water supply, sewerage system and any infrastructure of the town based these population numbers.

3.4.2.10. Town master plan

The town master plan was taken from the town administration office. Water demand for each node was determined by using master plan and counting of each house and multiplying by member of household.

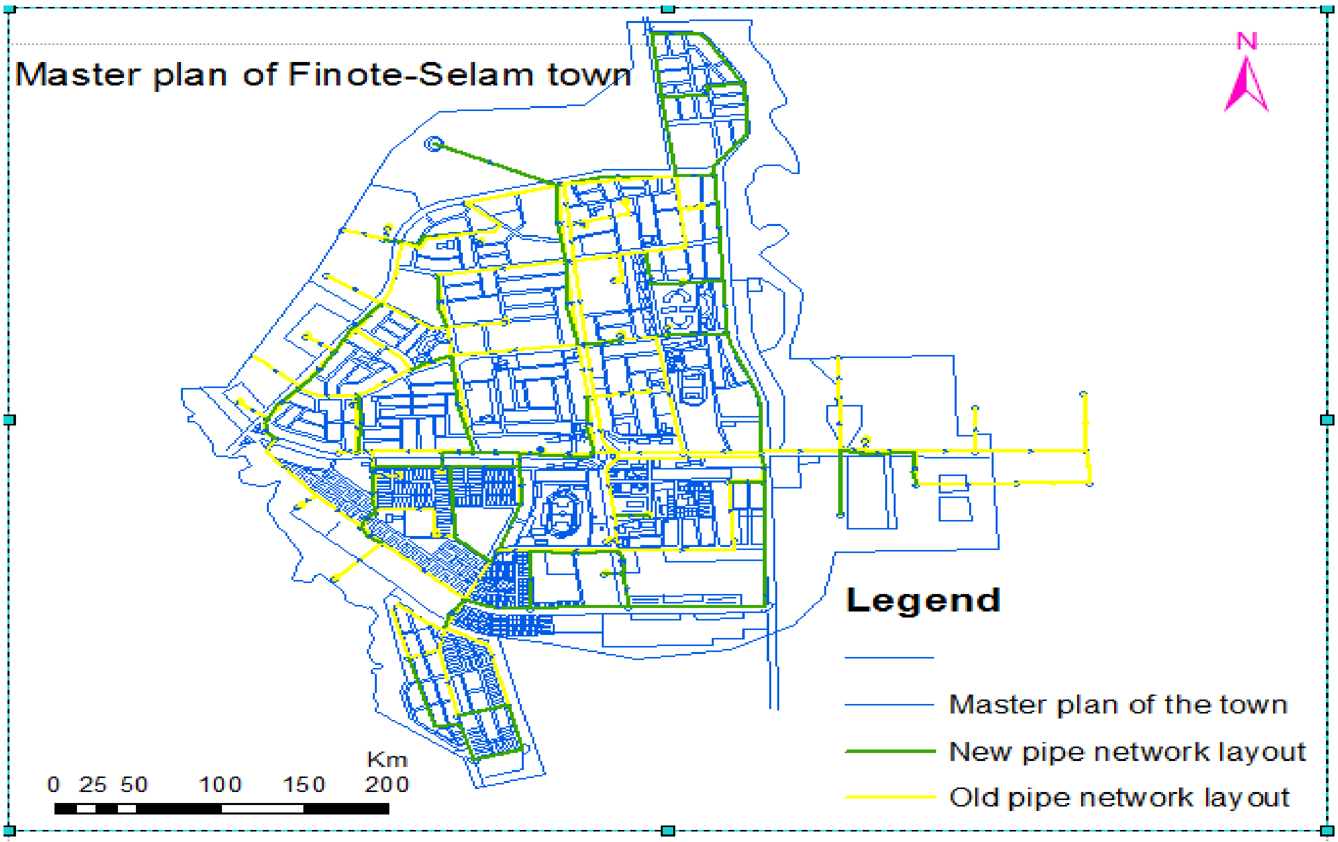

Fig 3.1 master plan of Finot-Selam town

3.4.2.11. Node Elevation

Node elevation is one of the significant requirements to simulate the hydraulic characteristics of water in the distribution system. Node elevation data was collected from the town water service office, which was prepared as the design report of the town.

3.5. Data analysis

To analyze the data which is collected from different sources, both qualitative and quantitative methods were 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. Micro soft excel was used to analyze the data obtained from the office. The field survey data for distribution system was evaluated by using the engineering software such as *Water CADV8i*, 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.

3.5.1. Analysis of Existing Water Supply System of the Town

3.5.1.1. Finote-Selam town population projection

Several methods are used to forecast the population but, their result varies from one method to another. Selection of appropriate method for particular town needs to consider over all current situation of the targeted town. Because of Finote-Selam town was fast growing town, where relatively high economic activities was observed at the same time continuous expansion of town due to various reasons was experienced, exponential method of population forecasting is preferably used. It is expressed as follows:

$$Pn = Po * e^{rn} \qquad \text{……………………………………………..3.4}$$

Where: P_n = Estimated population

Po = Base population

r = Growth rate and,

n = Number of year

e = constant e, the base of natural logarithm

3.5.1.2 .Water demand analysis

The water demand forecast was used for to ensure better water management, furthering and distribution of the resource there by preventing crisis often associated with water accessibility, to overcome challenges of urban and suburban growth and to provide information about the past and future water use (Ogunbode and Ifabiyi, 2014). Water demand was classified into two major categories as domestic and non-domestic water demand.

3.5.1.3. Domestic water demand analysis

The domestic water demand was the portion of municipal water supply, which is used in the home and largest portion of the total demand for most water systems (Keshavarzi et al., 2006). There are four modes of services identified for domestic water consumption of Finote-Selam town such as, house connection, yard connection, yard shared connection and public tap. The per capital water demand for various 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).

3.5.1.4. 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 the office expert household survey, the base year (2018) percentage of population by mode of service was adopted from the town records and documents. The distribution of population for each mode of services was determined by considering socio-economic situation and living standard of the town.

3.5.1.5. Establishing of per-capital water demand for each mode of service

The per-capital water demand was the most important parameter to estimate the total water demand of the town. It varies with the level of water service, modes of service, affordability, climatic condition and social-economic factors. The values in table (3.3) were used to establish domestic per-capital water demand by mode of service of the town.

Table 3.3 Water consumption by mode of service (AWRDB, 2012)

Mode of service	Per capital water demand (l/c/day)
House connection	70
Yard connection	40
Yard shared connection	30
Public tap	25

These values were given for the year of 2012; to convert into the base year (2018), the annual rate of projection was 2% for public tap user and yard shared connection user while for house connection and YC 3% was adopted by considering the living standard and socioeconomic activities of the town.

3.5.1.6. 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 the table (3.4).

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

3.5.1.7. Adjustment for socio-economic activity

The domestic water demand also depends on the socio-economic situation of the area. Thus per- capital domestic water demand was modified using appropriate factor. The demand adjustment factors in socio-economic situations were given in table (3.5).

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

Finote-Selam 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

3.5.1.8. 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 capital water demand. The average per capital water demand for each year was computed by combining water demand and population percentage distribution by mode of service.

3.5.1.9. Non domestic water demand

Commercial and institutional water demand

This category includes water required for various public and commercial water utility purposes like hotels, hospitals, parks, churches and mosques, commercial center, recreational area, bus station. The portion of water consumptions for commercial and institution usually ranges between 10-20% of the total water demand in urban water supply (Tabassum et al., 2016). Based on the past trend of Finote-Selam town the public and commercial water demand was 15% of the domestic water demand.

Fire demand

Fire demand was the quantity of water required for fighting a fire that may break out at different area. Demand water for firefighting purpose should be assessed on a town situation basis, which, depending on the existence of equipment and the capacity of any firefighting service. According to AWRDB (2012) the fire water demand was taken as 5% of domestic water demand for medium town.

Unaccounted water demand

Unaccounted water demand includes the quantity of water due to wastages and losses. Losses from water supply systems vary considerably according to diverse factors. As computed the past years production and consumption records of water supply service; the non-revenue water of Finote-Selam town gradually decreases. Based on the past trend of Finote-Selam town the non-revenue water was reduced by 3% in each year.

3.5.1.10. 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 table (3.6).

Table 3.6 Maximum day factor and peak hour factor (AWRDB, 2012)

Total population	MDF	PHF
0-20000	1.3	2
20001-50000	1.25	1.9
50001 and above	1.2	17

For Finote-Selam town the population was 42,689 in the year 2018. Therefore 1.25 MDF and 1.9 PHF value was taken to calculate maximum day demand and peak hour demand respectively, since the population of the town was 20,001-50,000. In demand analysis, knowing the maximum daily demand and peak hour demand are very crucial (AWRDB, 2012).

3.5.1.11. Estimation of domestic water consumption

Average per-capita water consumption was used to assess the domestic water supply coverage of the town. Data on individual domestic water consumptions, total water consumption (m3) and total production (m3) were collected from Finote-Selam town. Water Supply and sewerage office bill documents were used for analyzing average per-capita water consumption. The following formula was applied for the determination of per-capita water consumption (liter/person/day) (Desalegn, 2005).

$$\text{Domestic consumption } (L/P/d) = \frac{\text{Annual consumption(m3)} * 1000L/m3}{\text{population number} * 365} \ldots\ldots\ldots..3.1$$

3.5.2. Water loss analysis

There are two different approaches to assess water losses. The first is top-down annual water balance and the second is bottom-up approaches based on minimum night flow analysis. In developing countries, mostly top-down water audit is conducted as per the guideline suggested by IWA (2000), because of the assessment of real loss of bottom-up approach during the night does not hold the best result since, in intermittent supply system consumer always keeps tap open in the house connection to fill storage tank.

The total annual water produced and distributed to the distribution system and the water billed that was aggregated from the individual customer meter readings were used to quantify the total water losses of the town (EPA, 2010).

$$NRW = \frac{\text{(Water produced} - \text{water consumption)} \times 100}{\text{Water produced}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.3.2$$

During field visits, the utility does not have any recorded data related to average leak flow, the number of repeated bursts and average leak duration due to this, physical loss in the main was assessed based on available data`, and it was adopted by considering the minimum achievable annual physical losses (unavoidable annual real loss) in the system (Farley et al., 2008).

UARL (liters/day) =$(18*Lm+0.8*N_C+25*L_P)*P$……………………………… ……..3.3

Where, Lm=mains length (km),

NC=number of service connections,

LP=total length of private pipe, property boundary to customer meter (km), and

P=average pressure (m)

3.5.3. Model development

Given the nature of the research, the model was constructed to simulate base/normal network operation conditions. The construction process began with assembling the required data to populate the model. Data required included; the geographic configuration of the network mains, the geospatial distribution of demands, physical element attributes and other relevant data.

The modeling process are input data collection, model building in Bentley Water Cad, data entry (Elevations, XY coordinates, base demand, pump data, tank data and pipe data),model testing and hydraulic modeling and problem analysis. Input data for the analysis of distribution system included:-

- Nodes:- Elevations and base demand
- Pipes: - Pipe diameters, lengths, material type and the friction coefficient factors
- 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

3.5.4. Demand Distribution

The regular water peak demand of this study area was distributed among the nodal nodes which applying the proportional area distribution method by using water CAD v8i. The proportional areas for each node were determined by generating Thiessen Polygon for that node using manual loading. For this purpose, at first the bounding areas for demand distribution were determined over the geo-referenced aerial image by using Global Mapper software. Then this bounding polygon was segmented into Thiessen Polygons for the model nodes.

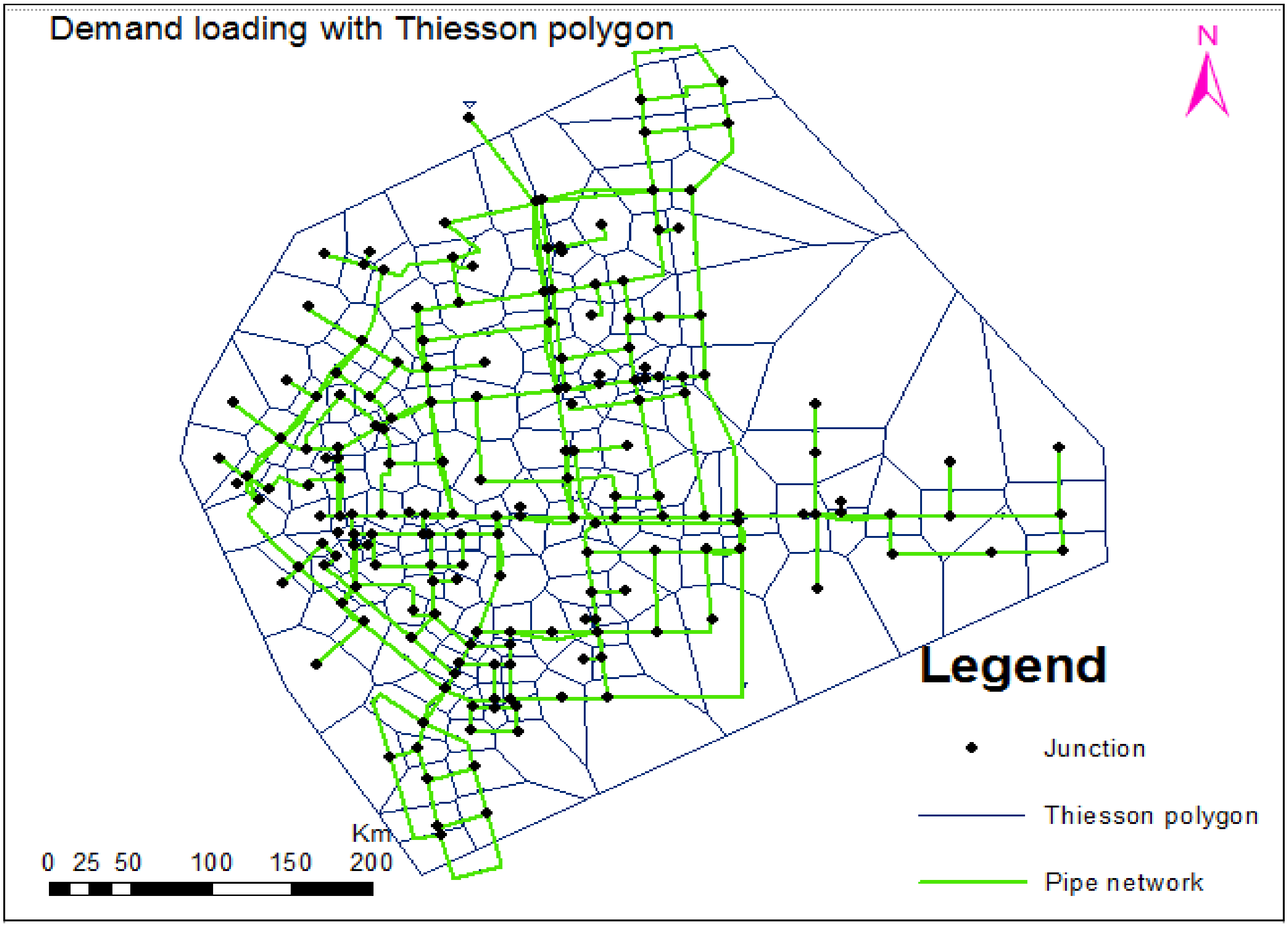

Figure 3.3Thiesson polygon

3.5.5. Modeling the existing distribution system

3.5.5.1. Water CADV8i

Water CadV8i is a powerful tool for design, analysis and improves the urban water distribution system. It is selected for this study because it is aided with good quality of manual, integration with the other external software, like Auto CAD, GIS and Microsoft excel, requires less effort and shorten time to build the model than others do, rule based controls and ground elevation extraction from shape files and Auto CAD drawings. The other capabilities of water cad software are evaluating the hydraulics for different demands at a single node with varying time patterns, solve for different frictional head loss using Hazen-William, Darcy Weisbach and Chezy-Manning equation (Bhadbhade, 2009). In order to analyze the distribution network system, the available data and the plan of the distribution network of water supply system was reviewed. The modeling process was an input data collection, model building, data entry, and model test and problem analysis. The input parameter needed by Water CAD8i for performing the hydraulic simulation is pipe characteristics, pipe lengths, junction water demands, junction and reservoir elevations and pump characteristics. After performing the hydraulics simulation for a particular time period, such as 24 hours, Water CAD produced output data such as pipe water flows, junction water pressure and change in reservoir elevations during the 24 hours with an interval of one hour.

3.5.6. Hydraulic network simulation

Hydraulic simulation was the simulation of hydraulic and water quality behavior of each system. Hydraulic simulation was determines the hydraulic parameters such as velocity, pressure, head loss, flow etc. Most small and medium towns do not have complex network as compared to cities; however, they have poor data records regarding to water distribution system. Computer models, making use of hydraulic simulation software are capable of representing the behavior of real time system and have a capability of predicting the performance of the same system for future “what if scenarios (AWWA, 2005). Simulation can be used for analysis of the existing system to improve the supply in terms of pressure, flow and minimize leakage. It is also important to make decision about the network augmentation requirements due to increase in water demand or expansion of a water servicing area.

There are various types of simulation that a model may perform, depending on what the modeler trying to observe or predict. The two most types of simulation are:-

3.5.6.1. Steady-state simulation

It is the simplest simulation type and solves the system of equations as if the system is in equilibrium. It provides information regarding the equilibrium flows, pressure and other variables defining the state of network for the unique set of hydraulic demands and boundary conditions. Steady state models are generally used to analyze specific worst-case condition such as peak demand time, fire protection usage, and system component failures in which the effect of time are not particularly significant (CAD/GEMs, 2008)

3.5.6.2. Extended-period simulations

Extended-period simulations (EPS) break up the simulation into time-steps. Each time step may feature different values for the dynamic variables (tank levels, pump operation, and junction demand). The amount of water that is consumed in the morning when everyone is getting ready for work is different at midnight. EPS allows simulating the system response over time through hydraulic time steps. The EPS was chosen for this analysis because of its capability to model varying demands. The total simulation time was 24 hours with a one-hour time-step.

3.5.7. Model calibration

Model calibration involves adjusting model parameter values until an acceptable match is achieved between measured (field) data and the model predicted values (Walski, 1983). Calibration runs were finished when the model outputs agree with field data according to predefined requirements. The main parameters adjusted during the calibration process where pipe roughness coefficients, nodal demands, pattern of demand, pump curves and initial water tank levels. According to (Walski et al., 2003), the calibration process was performed by adjusting sensitive parameters related to flow; like pipe roughness coefficient, water demand and pattern of demand and other. Until it was becoming within the acceptable limit of 85% of field test measurements (it should be within 0.5 m or 5% of the maximum head loss across the system.

Therefore, in this study the model data quality analysis was done by comparing and calibrating the compute pressure and flow rate data with the measured data.

3.5.7.1. Sample location

According to (Walski et al., 2003), sampling location is done randomly and the following limiting criteria often used

- Sampling points should be at the extremities of the network, a considerable distance from the boundary nodes in the network (reservoirs and tanks).
- Selected points should also have relatively high discharges and pressures.

The actual values of the minimum distance from boundary nodes, minimum discharge and minimum pressure are relative and unique to a given mode.

3.5.7.2. Sample size

Ideally, during water distribution model calibration process was adjusted for each link and node; however 2%-10% of representative sample measurement can be made available for the use of model calibration due to limited financial and labor requirement for data collection.

In general, international proposed guidelines stipulate that for a medium to highly detailed network model (medium to low skeletonization), the following limits should be adopted (AWWA, 2005):

- 3% of nodes in the network should be tested for pressure readings
- 5% of the pipes in the network should be tested for flow readings.

In the study area there are 269 total numbers of junctions in the network. However the minimum acceptable sample size was 3% of the total junction. Hence the sample size of the network was 0.03 x 269 = 8.07 which is approximately 8 junctions. Therefore, for this study area eight representative sample measurements were taken from the whole water distribution system for calibration. The following figure shows the location of the sample and the sample size pressure node, field test on the distribution network for calibration processes.

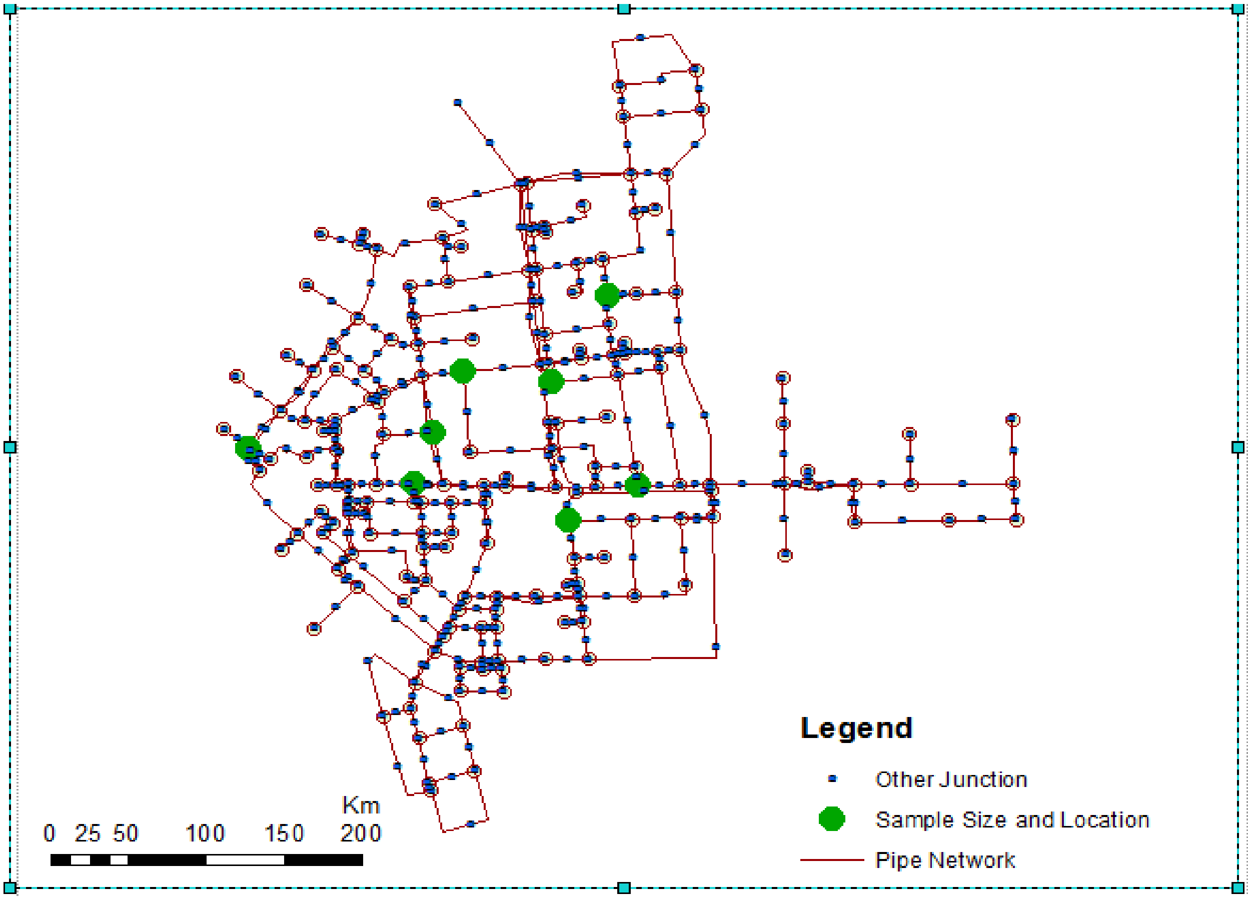

Figure 3.4 Samples location and sample size in the distribution system

3.5.7.3. Pressure measurement

Pressures were measured in the field in order to compare with the result of distribution model. Critical times were selected during pressure measurement with a pressure gauge. Pressure readings were done in May 24, 2018 using pressure gauge commonly taken both at high and low pressure zone of the selected points in the distribution network. But, it was difficult to take measurements at a direct connection to the water main nodes, due to size of pressure gauge available, which is 25mm.Therefore, the measurements were taken at a location other than the direct connection to the water mains, nearer to the supply main nodes at the home's faucet.

3.5.7.4. Calibration Parameter

Once the data for the computer network model was assembled and encoded, the associated model parameters were determined prior to actual model application. In general, the primary parameters associated with a hydraulic network model included pipe roughness and nodal demands. Due to the difficulty of obtaining economic and reliable measurements of both parameters, final model values were normally determined through the process of model calibration.

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. This was ensured adequate reliability of the model results against the impact of pipe friction of the system pressure. Table 3.7 lists the typical range of C values and the selected C value applied in this study for different pipe materials.

Table 3.7 Typical range of C values for different pipes

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

Initial estimates of pipe roughness values may be obtained using average literature values or directly from field measurements. Various researchers and pipe manufacturers have developed tables that provide estimates of pipe roughness as a function of various pipe characteristics such as pipe material, pipe diameter, and pipe age. As a result, initial estimates of pipe roughness for all pipes other than relatively new pipes should normally come directly from field testing. Even when new pipes are being used it is helpful to verify the roughness values in the field since the roughness coefficient used in the model may actually represent a composite of several secondary factors such as fitting losses and system skeletonisation.

For calibration of water distribution system, pip roughness was considered as the calibration parameter in this study. Models were simulated considering the starting roughness coefficient (C) of 100 and modified at each simulation at an interval of 5 up to 150 for newly built pipes and matched with observed data.

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.

3.5.8. Model validation

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

$$R^2 = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5$$

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 et al., 2001).

3.5.9. 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 (Samani and Taghi Naeeni, 1996).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 (3.8).

Table 3.8 the operating pressure in the distribution network (MOWR, 2006b)

Pressure	Normal condition	Exceptional condition
Maximum	60m of H2O	70m of H2O
Minimum	15m of H2O	10m of H2O

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 0.6 m/s. Low velocities affect water consumption and severe to disease problems.

$$V = \frac{4Q}{\pi D^2} \qquad \text{……………………………………………………..3.6}$$

$$D = \sqrt{\frac{4Q}{\pi V}} \qquad \text{…………………………………………………..3.7}$$

Where, D= diameter of the pipe (m); Q= discharge (m3/se) and V= velocity (m/sec).

3.6. Ethical Consideration

Before conducting the data collection activity, the researcher tells the purpose of the study and was informed the concern bodies. Thus, the collection of data was undertaken after obtaining permission from the concern office. With regard to data collection in different concerned bodies, first the study objective was clearly explained, each concerned bodies were told that the information provide confidential and use only for research purpose.

3.7. Data Quality Assurance

In order to increase the quality of data, the researcher prepared a fieldwork manual to check every day progress the data handling good. The researcher has checked the reliability and accuracy the data as well.

4. RESULT AND DISCUSSION

4.1. Evaluating the Current Water Supply of Finote-Selam Town

4.1.1. Coverage of potable water

Access to water supply may 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 HC coverage of domestic water supply of the town was 13.6%, YC 38.1%, YSC 5.8% and PT 24.9%. Therefore the domestic water supply coverage of the town was 82.4 %. According to MOWR (2006a) the domestic water supply coverage of Amhara region was 69.31%. Based on this value the domestic water supply coverage of the town is higher.

4.1.2. Average daily per-capital water consumption

The per-capital water consumption for various demand categories varies depending of the size of the town and the level of development. In Finote-Selam 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-capital consumption using the population data of Finote-Selam town in (2018) by using equation (3.1).

Per-capital water consumption (L/c/day) =590,639*1,000/42,689*365=37.9 L/c/day.

Based on this the per capital domestic water consumption of Finote-Selam town in the year 2018 was 37.9 l/person/day. According to WHO (2008), the minimum quantity of domestic water required in urban area of a developing country was taken as 20 l/c/day within 0.5km radius. Regarding to this value, per-capital domestic water consumption of the town was satisfies 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 satisfies only 37.9% of the standard value .The quantity of domestic water required in urban area of Ethiopia was taken 50l/c/day (MOVIE, 2015). Based on this value, per- capital 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 was low, so it needs to be improved.

4.2. Water demand forecasting analysis

4.2.1. Population projection

The water demand of particular town is proportionally related to the population to be served. According to CSA (2007), the population of town was 26,976 and annual growth rate for urban population of Amhara region was 4.1% in the year of 2018. Using CSA (2007) census data as a base, the current (2018) population and the population at the end of the design period (2030) of the town was estimated using an exponential population forecasting method as the table (4.1) below shows.

Table 4.1 Population projection of Finote-Selam town

Year	2007	2009	2010	2015	2018	2020	2025	2030
Growth rate urban		4.5	4.5	4.3	4.1	4.1	4	3.8
Population Projection	26,976	29,516	30,875	38,204	42,689	46,337	53,782	65,558

(Source: CSA (2007) national statistical census document, Amhara region, Finote-Selam town)

Therefore, based on the above table the total population of the Finote-Selam town was estimated 42,689 at 2018 year and 65,558 at the end of the design period (2030).

4.2.2. Population distribution by mode of service

The mode of service is an important element to assess the level of water coverage of the town. Based on the available data obtained from the Finote-Selam Water Supply Service during the field visit in 2018; four major modes of service were identified for domestic water consumers. These are house connections (HC), yard connections (YC), yard shared Connections (YCS) and public fountains (PT). The number of population percentage in each mode of service was indicated below in table (4.2).

Table 4.2 Population percentage in each mode of service

Mode of service	Number of population served in each mode of service	Population percentage served in each mode of service in (2018)
HC	5,800	13.60%
YC	16,265	38.10%
YSC	2,465	5.80%
PT	10,615	24.90%
Total	35,145	82.40%

As shown the above table (4.2) the majority of consumers (38.1%) get their water from private yard connection. About 24.9% of the consumer gets their water from public fountains, 13.6% of house connection, and 5.8% of the yard shard connection. The remaining consumer about 17.6% use traditional water source (like a river, protected and unprotected well or spring,) for their day to day consumption purpose. Based on the past trend of Finote-Salem town, the growth rate of population in each mode of service are reduced by 2% per annual for public and yard shared connection and increased by a 3%per annual for the yard and house connection users.

Table 4.3 The population projection per mode of service.

Year	2018	2020	2022	2024	2026	2028	2030
Growth rate Urban	4.10%	4.10%	4.00%	4.00%	3.80%	3.80%	3.80%
Total population serves	42,683	46,331	50,189	54,369	56,025	60,449	67,749
HC	13.6	14.73	15.64	16.61	17.63	18.72	19.88
YC	38.1	41.27	43.83	46.54	49.41	52.47	55.7
YSC	5.8	5.59	5.38	5.16	4.96	4.77	4.58
PT	24.9	24.21	23.26	22.35	21.47	20.63	19.82
Population served							
HC	5,805	6,824	7,850	9,029	9,879	11,319	13,470
YC	16,262	19,122	21,996	25,301	27,684	31,717	37,,745
YSC	2,476	2,592	2,698	2,808	2,780	2,882	3,103
PT	10,628	11,218	11,676	12,152	12,031	12,472	13,430

4.2.3. Per-capital 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. Based on the working standard of the town the per capital demand of water per mode of service was 70,45,25 and 20 l/c/d for HC, YC, YSC and PT respectively (AWRDB, 2012). Based on the guideline of Ethiopia (MOWR) the per capital demand of Finote-Selam town by mode of service indicated in the table below (4.4).

Table 4.4 Per-capital water demand by mode of service

Per Capital Water Demand by mode of service(l/c/d)	2015	2018	2020	2022	2024	2026	2028	2030
HC	70	76.59	81.33	86.36	91.70	97.37	103.39	109.78
YC	45	49.24	52.28	55.52	58.95	62.59	66.46	70.57
YSC	25	26.55	27.63	29.34	31.15	33.08	35.12	37.30
PT	20	21.24	22.10	23.01	23.94	24.92	25.94	27.00

By using the above tables 4.4 as the base of other water demand calculation the water domestic demand was projected for 2018-2030 by including non-revenue water and other factors. The average per capital domestic water demand for each year was computed by combining water demand by mode of service from the year 2018-2030. As shown the table (4.5) below the total domestic water demand was forecast by each mode of service throughout the design period.

Table 4.5 Domestic water demand determination

Year	2015	2018	2020	2022	2024	2026	2028	2030
Growth rate Urban		4.10%	4.10%	4.00%	4.00%	3.80%	3.80%	3.80%
Total population serves		42,683	46,331	50,189	54,369	56,025	60,449	67,749
HC		13.6	14.73	15.64	16.61	17.63	18.72	19.88
YC		38.1	41.27	43.83	46.54	49.41	52.47	55.7
YSC		5.8	5.59	5.38	5.16	4.96	4.77	4.58
PT		24.9	24.21	23.26	22.35	21.47	20.63	19.82
Population served								
HC		5,805	6,824	7,850	9,029	9,879	11,319	13,470
YC		16,262	19,122	21,996	25,301	27,684	31,717	37,745
YSC		2,476	2,592	2,698	2,808	2,780	2,882	3,103
PT		10,628	11,218	11,676	12,152	12,031	12,472	13,430
Per Capital Water Demand by mode of service (l/c/d)								
HC	70	76.59	81.33	86.36	91.70	97.37	103.39	109.78
YC	45	49.24	52.28	55.52	58.95	62.59	66.46	70.57
YSC	25	26.55	27.63	29.34	31.15	33.08	35.12	37.30
PT	20	21.24	22.10	23.01	23.94	24.92	25.94	27.00
Demand by modes of services (m3/d)								
HC		444.6	555.0	677.9	828.0	962.0	1170.2	1478.8
YC		800.7	999.8	1221.1	1491.5	1732.8	2108.0	2663.8
YSC		65.7	71.6	79.2	87.5	92.0	101.2	115.7
PT		225.7	248.0	268.6	291.0	299.84	323.5	362.6
Total DWD (m3/d)		1536.8	1874.3	2246.7	2697.9	3086.6	3703.0	4620.9

Based on the above table 4.5, the total domestic water in 2018 year was 1,536.75m^3/day and for the year of 2030 were4, 620.9 m^3/day.

4.2.4. Socio-economic and climatic adjustment factor

Finote-Selam 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 of the town was 1.05. In addition to this, the town was found the altitude range 1500-2300 above sea level. Therefore the climatic adjustment factor of the town was 1 considered.

Table 4.6 Climatic adjustment factor

Year	2018	2020	2022	2024	2026	2028	2030
Total DWD (m3/d)	1536.8	1874.3	2246.7	2697.9	3086.6	3703.0	4620.9
Climatic adjustment factors	1	1	1	1	1	1	1
Socio-economic factor	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Adjusted DWD (m3/d)	1613.6	1968.0	2359.1	2832.8	3240.9	3888.2	4851.9
Adjusted DWD (l/s)	18.7	22.8	27.3	32.8	37.5	45.0	56.2

Based on the above 4.6 table the domestic water demand of the study area was 1,613.59m^3/day in the year 2018 and 4,851.95 m^3/day in 2030.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 Finote-Selam town.

4.2.5. Non domestic water demand

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

Industrial water demand:-According to Finote-Selam 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).

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.

Unaccounted water demand:-As computed the past years production and consumption records of water supply service; the NRW of town gradually decrease. The average NRW of the town in 2018 was about 32.33% of the total demand. Based on the past trained of Finote-Selam Town the NRW was reduced by 3% in each year.

Table 4.7 Total water demand

Demand (m3/d)	2018	2020	2022	2024	2026	2028	2030
Domestic water demand	1,613.6	1,968.0	2,359.1	2,832.8	3,240.9	3,888.2	4,851.9
Public and commercial water demand 15%DWD	242.0	295.2	353.9	424.9	486.1	583.2	727.8
Industrial water demand (5% DWD)	80.7	98.4	117.9	141.6	162.1	194.4	242.6
NRW in each year	32.33%	31.07%	29.26%	27.56%	25.96%	24.46%	23.04%
NRW demand	521.7	611.4	690.3	780.8	841.4	950.9	1117.7
Firefighting (5%DWD)	80.7	98.4	117.9	141.6	162.1	194.4	242.6
Total demand (m^3/day)	2458.0	2973.0	3521.2	4180.1	4730.5	5616.7	6940.0

4.2.6. Peak hour and maximum day factor

For this research the peak hour factor was taken 1.9 up to the year of 2022 because of the population range of Finote-Selam town was from 20,001-50,000 and 2022-2030 the peak hour factor was taken 1.7 because of the population of the study area was above 50,001. Also the maximum day demand factor was about 1.15 was adopted because maximum day demand factor should be in the range of 1-1.3.

Table 4.8 Peak hours and maximum day demand

Demand analysis	2018	2020	2022	2024	2026	2028	2030
Total demand (m^3/day)	2457.9	2973.0	3521.2	4180.1	4730.5	5616.7	6940.0
Peak hour factor	1.9	1.9	1.9	1.7	1.7	1.7	1.7
Peak hour demand (m^3/day)	4670.2	5648.8	6690.3	7106.2	8041.9	9548.3	11798
Maximum day factor	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Maximum day demand (m^3/day)	2826.7	3418.9	4049.4	4807.1	5440.1	6459.2	7981

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 (4.7) and (4.8).Therefore the total maximum water demand are 2,826.68m3/dayand7, 981 m^3/day in the year 2018 and 2030 respectively. The design maximum water production capacity of the source was4,017.6 m^3/day, but the current average daily production was 2,391.12 m3/day which is very low due to less working hour, reduction of water from the source, pump failure and lack of maintenance. It is far lower than the demand. Currently the gap between existing supply and demand was 435.56 m3/day. The gap will be 5,589.88 m3/day for coming 12 years period. This indicate the need for the development of additional water sources to satisfy the 5,589.88 m3/day water demand of Finote-Selam Town for coming 12 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 town water supply office, which given table (4.9).

Table 4.9 Water production and consumption of Finote-Selam town with percentage of NRW

Year (G.C)	Production (m3/year)	Consumption (m3/year)	NRW	
			m3/ year	Percentage
2010	866,100	549,948	384,202	44.36
2011	866,236	556,800	328,823.2	37.96
2012	867,103	563,886	316,145.8	36.46
2013	867,990	568,895	312,302.8	35.98
2014	871,106	570,787	314,643.5	36.12
2015	871,335	575,360	299,303.6	34.35
2016	872,305	579,975	285,069.3	32.68
2017	872,650	584,631	291,901.4	33.45
2018	872,589	590,640	282,119	32.33

(Source Finote-Selam town water utility)

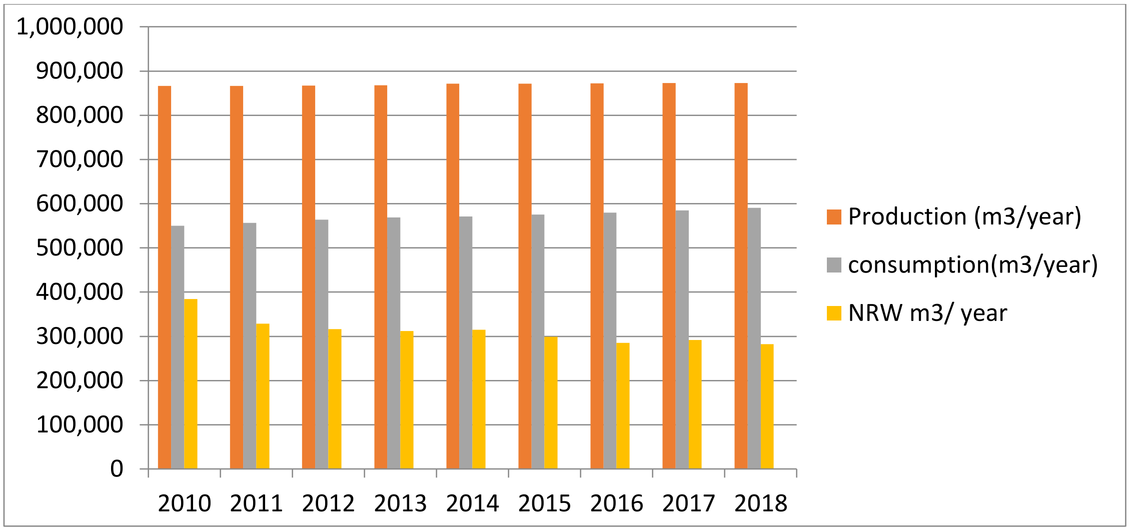

Figure 4.1 Water production and consumption of the town with percentage of NRW

Based on the above table (4.9), the total the annual NRW was 282,119 m^3/year of the total production in 2018. 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.

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 (2018) was 872,758.8m3 and the annual NRW was 282,119m3 which was 32.33% of total water production. The total water losses of the town can be estimated by subtracting unbilled authorized consumption from NRW. Based on this analysis the total water losses were 280,885 m^3 /year that accounts 32.21%of the total water production. The average tariff of water in the Finote-Selam town was 2.75 ETB /m3, based on this average water tariff value the water loss was estimated to be 772,433.75 ETB for every year.

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 Finote-Selam town was 32.18%, 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)

The average amount of water, which is actually reached to the consumers, was only 67.82% of the total production. The water supply system efficiency is acceptable if above 75% of water produced reaches the consumer (McKenzie and Seago, 2005). Based on this, the efficiency of Finote-Selam town water supply system is not acceptable because of only 67.82% of the total production reaches the consumer which is below 75%.

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 42.36km. The water loss per kilometer length of main pipe was determined as 280,885 m3/year÷ (42.36 km×365days) =18,166.85 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 18,166.85liters/km/day, which shown as bad condition.

4.3.3. Water loss expressed as per number of service connection

The total number of service connection of Finote-Selam town was 6,015 which were obtained from town water utility. The water loss per number of service connection was determined as 280,885 m3/year ×1000liters÷ (3,015×365days) = 255.24 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 255.24 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 Finote-Selam town utility report (2018), the total volume of unbilled authorized consumption of water was 1,047m^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 8,859m^3/year+57,526.92 m^3/year+1,476.6 m^3 /year, which is equal to

67,863.12m^3/year. This loss amount was 7.8% of the total production of water that is about 24.16% 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 2018 report, the amount of unauthorized consumption of the town was 8,859.6m3/ 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 2018 report, the total amount of customer meter in the distribution system was 4,776 in number. From this total, 1,757 DN15mm (Class B, dry dial, multi-jet type), 2,863 DN20mm (Class B, dry dial, multi-jet type), 256 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 Amhara 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 Finote-Selam town was 167 l/c/d.

Table 4.11 Water losses as results of metering inaccuracies

Description	Number of meters	The total authorized water in 2018	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=E*A
	4.776	590,640m^3 /year	165 l/c/d	200 l/c/d	33 l/c/d	157,608 l/c/d
Total						57,526.92 m^3/year

Water losses as a result of metering inaccuracies were analyzed using the comparison of testing bench value and the average water reading value of customer meter that obtained from authorized consumption water in 2018. As shown in table 4.11 the total customer meter in accuracies lost in the town of water utility was estimated 57,526.92 m ^{3} /year.

Generally, in case of Finote-Selam 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 mater 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 Finote-Selam town was 0.25%*590,640m^3/year which is equal to 1,476.6 m^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 real losses were 213,020.88m^3 /year, which cover 24.41% of the total production which is 75.84% of 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 Finote-Selam town in the year 2018 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 2018

<table>
<tr><td rowspan="8">System in put volume =872,759 M^3/year</td><td rowspan="4">Authorized consumption =591,687 M^3/year</td><td rowspan="2">Billed Authorized consumption =590,640 M^3/year</td><td>Billed metered consumption M^3/year=589,405</td><td rowspan="2">Revenue water =590,640 M^3/year</td></tr>
<tr><td>Billed unmetered consumption M^3/year=0</td></tr>
<tr><td rowspan="2">Unbilled Authorized consumption =1,047 M^3/year</td><td>Unbilled metered consumption M^3/year=1,047</td><td rowspan="6">Non-revenue water =281,931 M^3/year</td></tr>
<tr><td>Unbilled unmetered consumption M^3/year=0</td></tr>
<tr><td rowspan="4">Water loss =280,885 M^3/year</td><td rowspan="3">Apparent loss =67,863.12 M^3/year</td><td>Unauthorized consumption M^3/year=8,859.6</td></tr>
<tr><td>customer meter inaccuracies =57,526.92 M^3/year</td></tr>
<tr><td>Systematic data handling error =1,476.6 M^3/year</td></tr>
<tr><td colspan="2">Real loss =213,020.88 M^3/year</td></tr>
</table>

As shown the above table 4.12 the value of non-revenue water by water balance method high levels which is 32.33% of system input volume and the water loss was 32.21% of system input volume which have a serious impact on Finote-Selam water supply service offices finances and available water resources.

4.3.8. Performance indicator

4.3.8.1. Unavoidable annual real losses (UARL)

UARL represents the allowable volume of real losses from the system, which estimated a volume of leak that are undetectable or would be uneconomical to repair during the year. This can help to evaluate the feasibility of real loss minimization (provides better understanding of real loss component).the total length of main pipes was 42.36km, number of service connections was 3015 and the average pressure 31.24mfrom the result of Water CAD was used in the calculation of UARL. Based on the analysis, unavoidable annual real losses of Finote-Selam town was determined as:

UARL= (18×Lm+0.8×Nc+25×Lp) ×P

= (18×42.36+0.8×3,015+25×0) ×31.24

=99.68m^3/day or 36,382.72m^3/year

Where, UARL = unavoidable annual real losses (l/d)

Lm = length of main pipes (km)

Nc = number of service connections (main to meter)

Lp = Total length of private pipe, property boundary to customer meter (km);

P=average operating pressure (m)

4.3.8.2. Infrastructure leakage index (ILI)

ILI is the measure of how well a distribution network was managed, maintained, repaired, and rehabilitated) for the control of real loss, at the current operating pressure. It can be calculated as the ratio of current annual volume real losses (CARL) to unavoidable annual real losses (UARL) (Lambert *et al*., 1999). According to Farley*et al*., (2008), the performance indicator of physical loss target matrix for developing countries categorized as good ,when ILI was between 1-4, which could be a further loss reduction may be uneconomical and careful analysis needed to identify cost-effective improvements. Based on this, the ILI for Finote-Selam town was 7.72 which found in good condition. In another way, the value of ILI indicates that the current annual real losses were 7.72 times as high as unavoidable annual real losses for the system.

4.3.9. Pipe network of distribution system

The distribution system consists of a network of mains with total length 42,347 meters. The system contains pipe ranging from 25 to 350mm in diameter, although the majority of the system consists of 50 and 80 mm in diameter of pipe. The distribution network in material type was given in table (4.12).

Table 4.13 Distribution network of the town pipe material type

Pipe material	Length (m)	Percentage of total
PVC	18,838	44.48%
HDPE	11,242	26.55%
GI	10,183	24.05%
DCI	2,084	4.92%
Total	42,347	100.00%

Pipe throughout the distribution system mainly consists of PVC, DCI, HDPE and GI. From the total length of distribution system the percentage of each material was approximately 44.48% PVC, 26.55% HDPE, 24.05% GI and 4.92% DCI. The most widely used pipe material present in the system was PVC.

Table 4.14 Distribution network of the town, according to size of pipes

Diameter (mm)	Length (m)	Percentage of total
25	2,663	6.29%
50	16,967	40.07%
80	11,602	27.4%
100	4,413	10.42%
150	3,839	9.07%
200	2,185	5.16%
250	322	0.76%
350	367	0.87%

As shown the table (4.14), 50mm diameter of the pipe was the major pipes used in the distribution system, while 250mm diameter of the pipe was the least quantity used in the distribution system.

4.4. Water Distribution Network Simulation

Distribution network starts from the point of water production, where the water is produced and made ready to be used (Mekonnen, 2017). Figure 4.2 below shows the distribution network of Finote-Selam town.

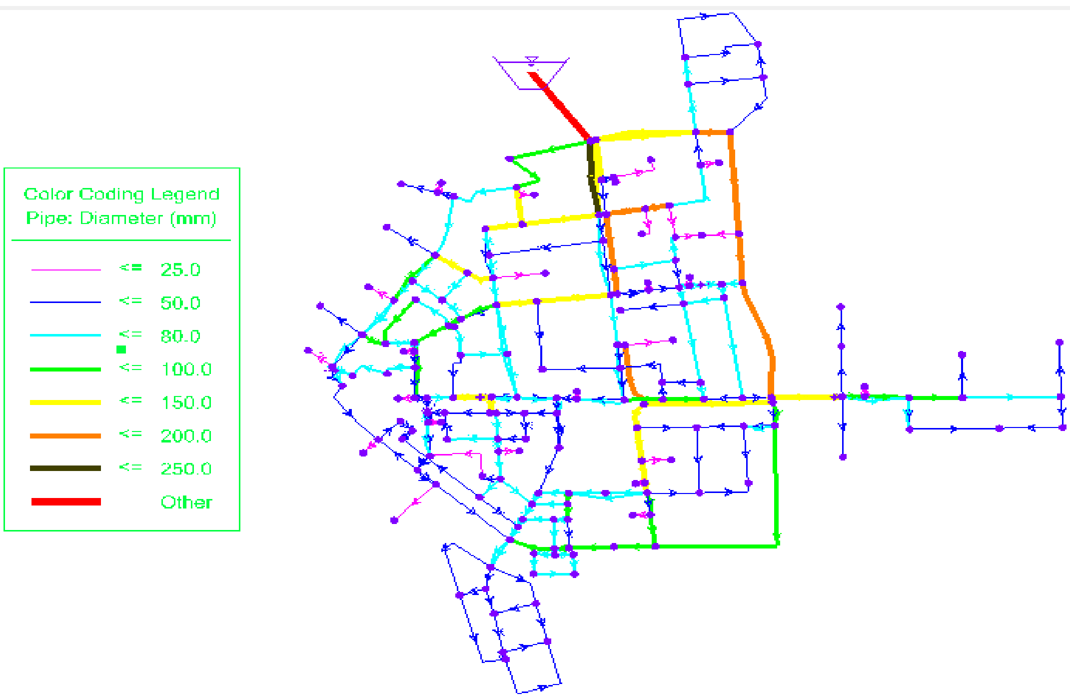

Figure 4.2 Water distribution network map of Finote-Selam town

4.4.1. 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 15mminimum 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. Pressure was increased as elevation decrease and vice versa. Household located at a higher elevation and close to reservoir site has got water at low water pressure (Mekonnen, 2014). The figure below shows pressure and elevation has an indirect relationship by taking samples from the water supply junction.

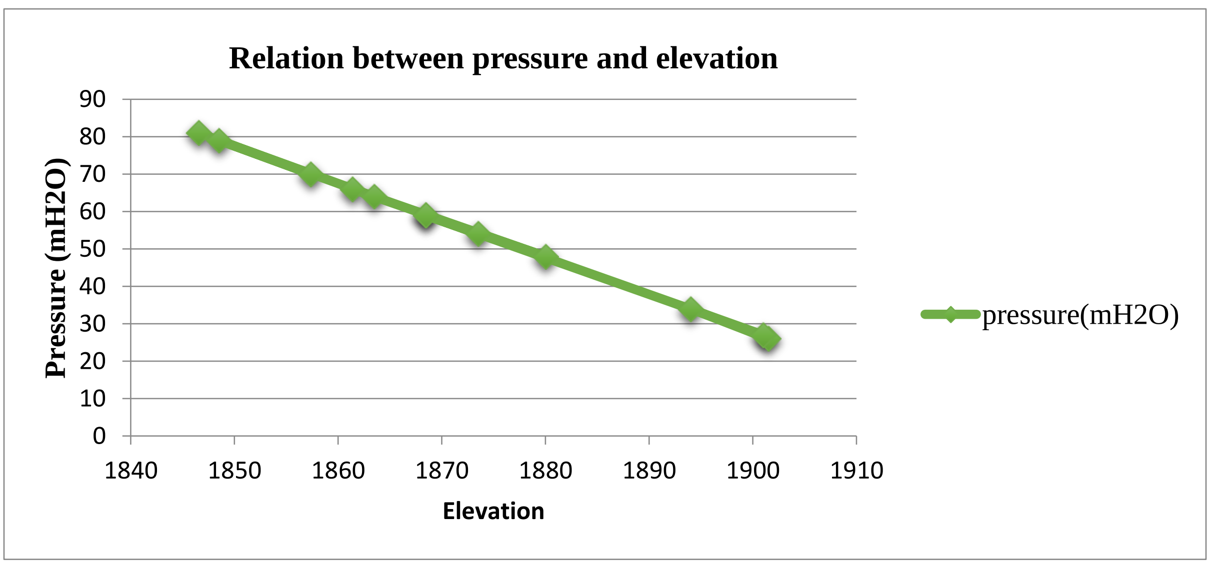

Figure 4.3 the relationship between pressure and elevation.

During hydraulic modeling of water pressure of Finote-Selam town has 179 nodes and 269 pipes were identified. With regard to current simulation the result of pressure at peak consumption was summarized in table (4.15) and detailed in appendix

Table 4.15 Distribution of pressure at peak hour consumption

Pressure (m of H2O)	Number of nodes	Percentage
<=15	35	19.55%
<=25	22	12.29%
<=35	57	31.84%
<=45	32	17.88%
<=55	26	14.52%
<=65	2	1.12%
<=70	1	0.56%
Above	4	2.24%
Total	179	100%

After hydraulic analysis using BenetlyWaterCadV8i as shown in table (4.15), 19.55% of the nodes are under desirable minimum pressure and 2.24% of the nodes are exceeding maximum allowable pressure during peak hour consumption. Specifically junctions 20, 84,22,9,75,19,74 and 18 were negative pressure at peak time consumption. Thus, only 78.21% of nodes have pressure within the recommended limit (15m to 70m). Therefore, from the above table result, 21.79% should be improved in the distribution system to attain the permissible pressure. 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.

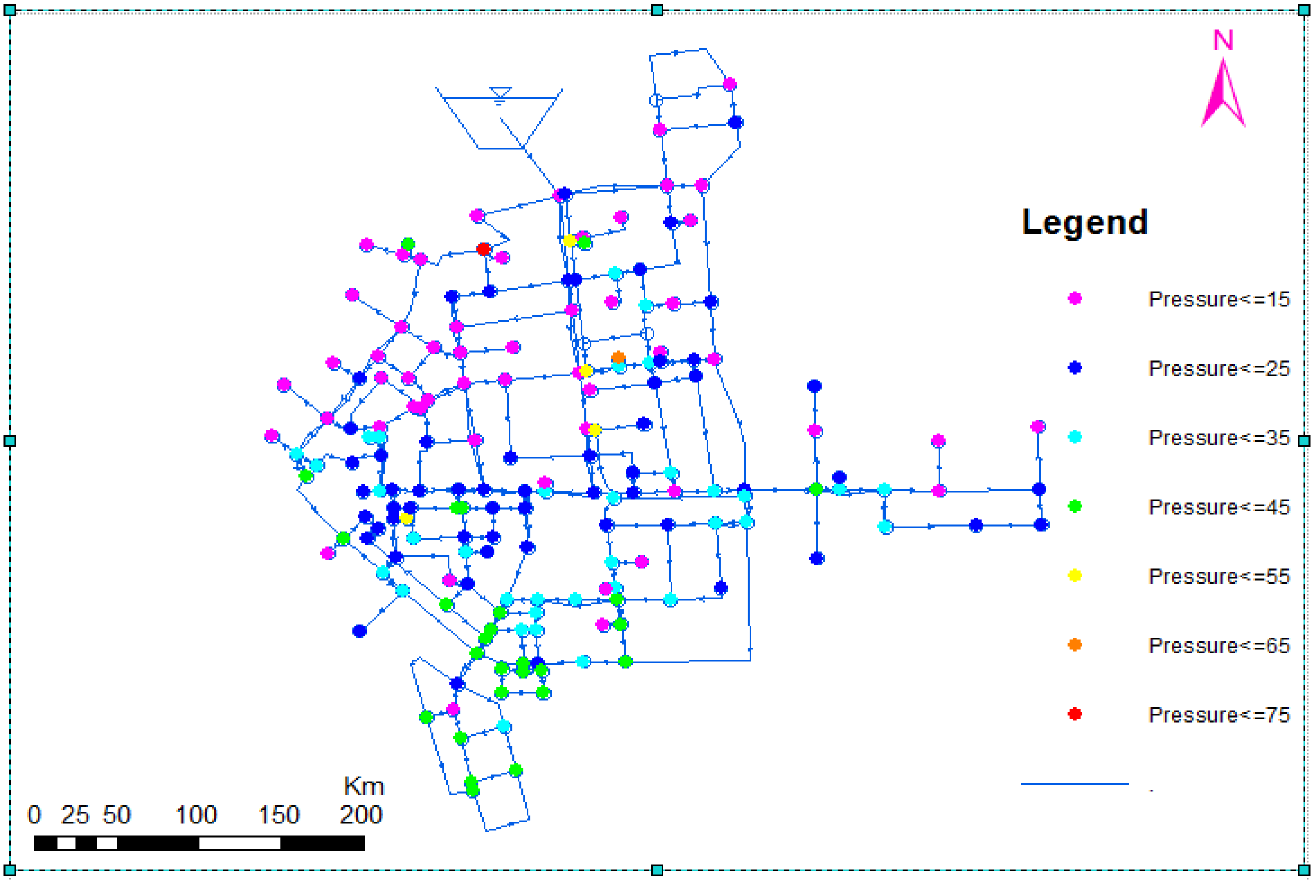

Figure 4.4 Pressure contour map of Finote-Selam town at peak hour consumption

Table 4.16 Distribution of pressure at minimum consumption time

Pressure (m of H2O)	Number of nodes	Percentage
<=15	4	2.23%
<=25	9	5.03%
<=35	17	9.50%
<=45	14	7.82%
<=55	20	11.17%
<=65	18	10.06%
<=70	16	8.94%
Above	81	46.02%
Total	179	100%

As shown the table (4.16), 2.23% of the nodes are under desirable minimum pressure and 46.02% of the nodes are exceeding maximum allowable pressure during minimum hour consumption. There is no negative pressure during a minimum consumption time, while, 52.52% of the nodes are in the permissible pressure range of minimum 15 m and maximum 70m pressure. However, 46.02% of the nodes were getting water above standard pressure (>70m) due to low consumption at midnight when most of the consumers are sleeping and not using water. Higher pressure may cause pipe burst.

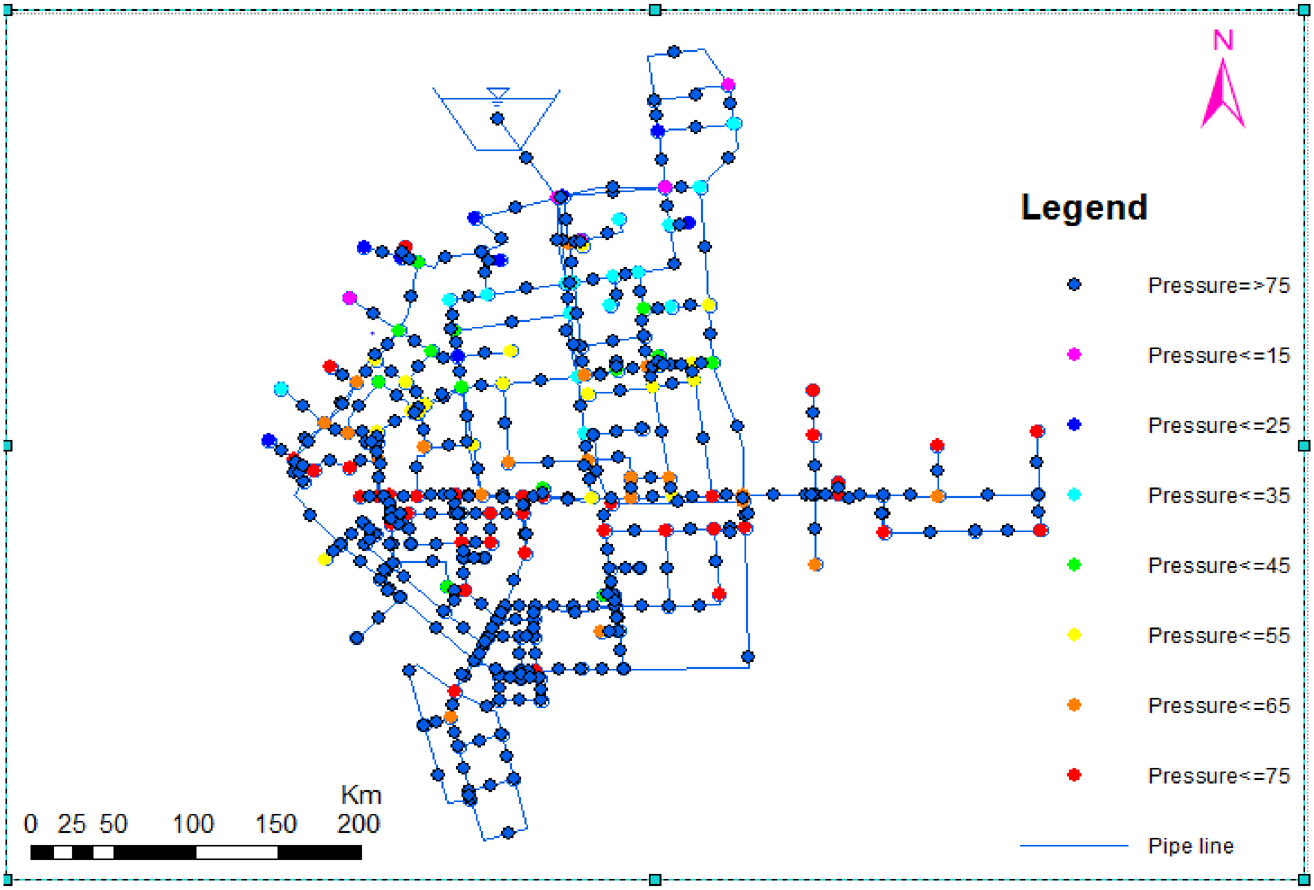

Figure 4.5 Pressure contour map of Finote-Selam town at minimum hour consumption

In the case of Finote-Selam town, the main cause of water supply interruption was shortage of water from the source, lack of maintenance, improper function of pump and interruption of electric power in pumped pressure system. In conclusion, in order to achieve a 15m minimum and 70m maximum pressure, it is necessary to provide pressure control valve, establishing boosting station and replacing the old pipes with the new one that has a diameter required size.

4.4.2. Velocity analysis

The velocity of water flow in a pipe is also one of the important parameters to evaluate hydraulic performance of a water supply distribution system. 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 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 (4.16) and (4.17) below.

Table 4.17 Velocity for water supply distribution system during peak hour consumption

Velocity (m/s)	Number of pipes	Percentage	Effect
0-0.1	19	7.06%	Water stagnation happens
0.1-0.6	102	37.92%	Sedimentation happens
0.6-2	137	50.93%	An acceptable level
>2	11	4.09%	Head loss and water hammer
Total	269	100%	

As indicated table (4.17), 7.06% of the pipes are below desirable minimum velocity and 4.09% of the pipe velocity is exceeding maximum allowable velocity during peak hour consumption. While 50.93% of the pipes are in the recommended velocity range of minimum 0.6 m/s and maximum 2 m/s velocities. In this study area, 49.07% of velocity is not in suitable range based on Ethiopia urban water supply design guideline criteria.

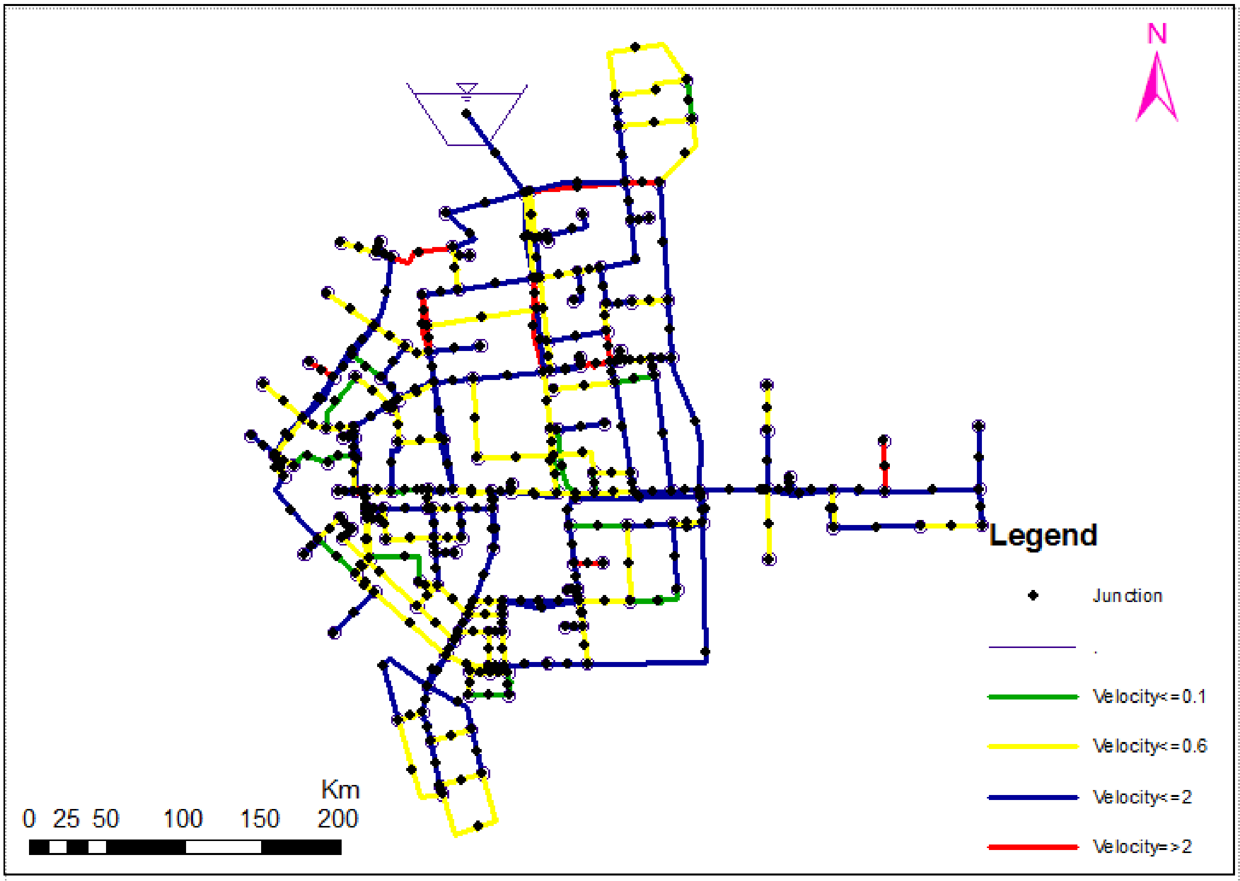

Figure 4.6 Velocity for water supply distribution network during peak hour consumption

Table 4.18 Velocities for water supply distribution system during low consumption time

Velocity (m/s)	Number of pipes	Percentage	Effect
0-0.1	119	44.24%	Water stagnation happens
0.1-0.6	98	36.43%	Sedimentation happens
0.6-2	52	19.33%	An acceptable level
>2	0	0%	Head loss and water hammer
Total	269	100%	

As shown the table (4.18), 44.24% of the pipe was below desirable minimum velocity and there is no pipe velocity is exceeding maximum allowable velocity during low consumption time. While 19.33% of the pipes is in the recommended velocity range of minimum 0.6 m/s and maximum 2 m/s velocities. In this study area, 80.67% of velocity is not in suitable range based on Ethiopia urban water supply design guideline criteria. There is no head loss and water hammer in this study area during the minimum consumption time.

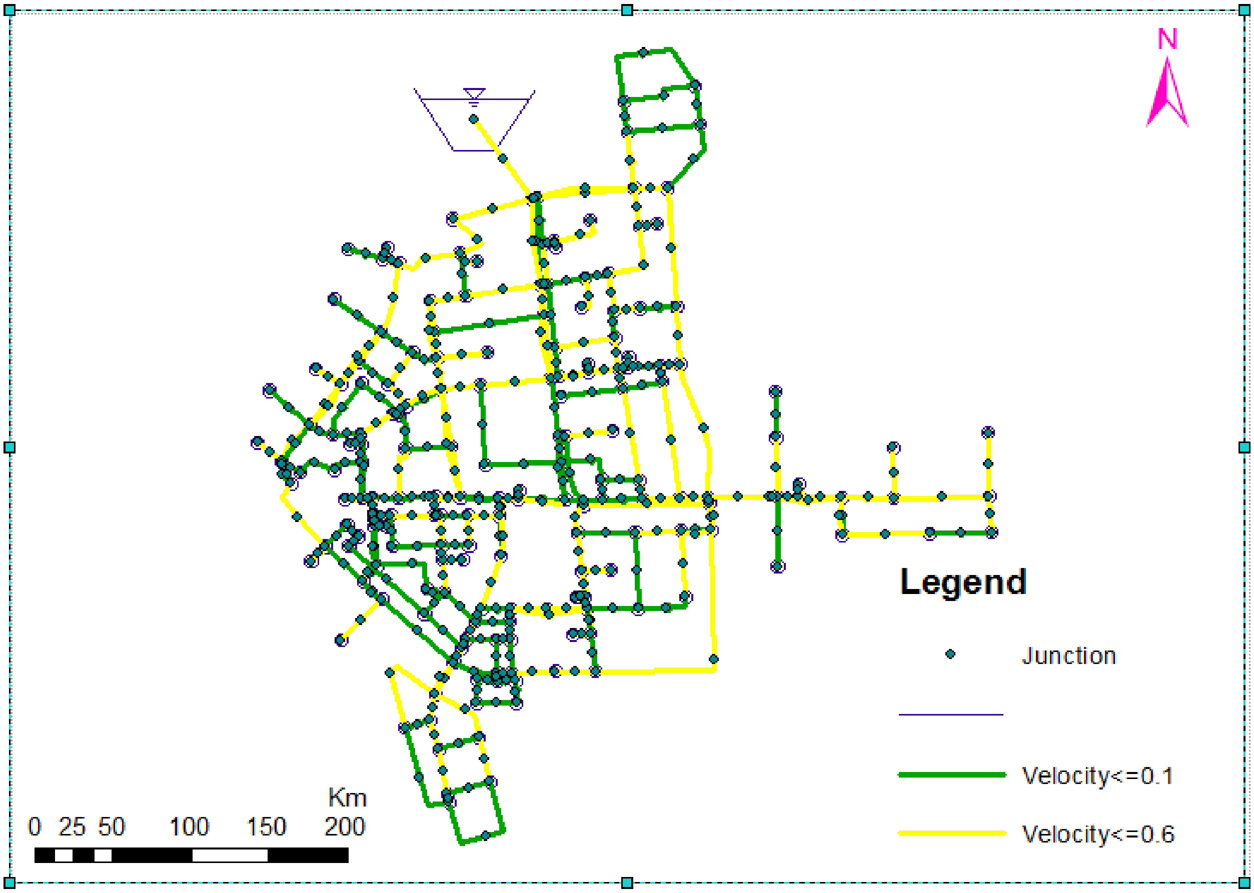

Figure 4.7 Velocity for water supply distribution network during minimum consumption time

Generally, the town water distribution system the velocity in the pipes was in inadequate since velocity in major pipe parts was below 0.6m/s during the minimum consumption time and above 0.6m/s during peak hour consumption as shown figure (4.6) and (4.7). Therefore control of the flow velocity in water distribution networks should be maintained in order to avoid pipe break, water hammer, water stagnation which causes sediment deposition in the pipe and head loss.

4.4.3 Relation between pressure and pipe burst

Burst and their frequency have been collected from Finote-Selam water utility office. The rate of leakage from bursting pipes or faulty joints was increase with the rise of pressure. However, pressure reduction can reduce the rate at which pipe bursts occurred. According to observation and discussion with water utility worker, mostly bursting pipe which is collected by utility was PVC pipe with smaller diameter in the area of bus station, hospital, market center, kidane-mihret church. The cause of pipe burst in Finote-Selam town water distribution system was the combination of age, size and material of pipe, high pressure at different area.

The amount of pipe bursts and leakages from January 2018 to June 2018 were manually counted from the municipality's bookkeeping. The amount of pipe bursts in Finote-Selam is presented in table 4.20

Table 4.20number of pipe burst in the distribution system

Burst location	January	February	March	April	may	June	Cause of burst
Water supply office	6	4	3	1	5	3	Pipe age
Bus station	7	6	6	0	8	10	Traffic load
Hospital	3	2	4	9	4	1	Water pressure
Market center	2	6	5	6	3	5	Pipe age
Prison area	2	1	3	2	4	1	Water pressure
Kidane-mihret church	4	1	0	1	2	5	Water pressure and soil type
Total	24	20	21	19	26	25	

(Source: Finote-Selam water service office, 2018)

There were a total of 137 pipe bursts in 6 months. It means there were 23pipe bursts a month on average. It's evident that bus station suffers the most from pipe bursts.

4.5. Calibration Model Result

Calibration is an iterative procedure of parameter evaluation and adjustment by comparing simulated and observed values. The pressured field measured data at J-157, J-145,J-177,J-88 and J-41 were used for calibration of the model. As the model gives automatically C value for PVC and HDPE pipes are 150, for DCI pipes 120 and for GI pipes are 130. Since the existing pipe is old the roughness coefficient of pipes are less than the model values. Therefore, this standard value of C values used to adjust the model value until closed to the measured value.

Table 4.21 Typical range of C values for different pipes

Type of Pipe material	C value for new pipe	C value for Existing pipe	Age of existing pipe
PVC	150	100-120	26
HDPE	150	130-140	10
GI	130	100-110	26
DCI	120	90-100	26

(Source: Finote-Selam water utility office)

Calibration can be carried out on the base scenarios within the acceptable level. The simulated pressure value of simulated scenarios, the peak demand and low demand time was calibrated until the result was approximately equal to the measured pressure value.

For calibration of a water distribution system, pipe roughness was considered as the primary calibration parameter in this study. In addition, nodal demand was also adjusted for model calibration. Models were simulated considering the starting roughness coefficient (C) value of 90 and it has be changed at an interval of 5 up to 150.Extended period simulation has be performed and compared with the values at eight observed points.

After analyzing, it has been observed that model data and observed data have matched with reasonable extent for C value of 120 as per the AWWA guideline (2005). Therefore, the calibrated C value is selected as 120.

The model output and observed data (from eight observation points) matched within a reasonable extent for C value of 120 for given pipes.

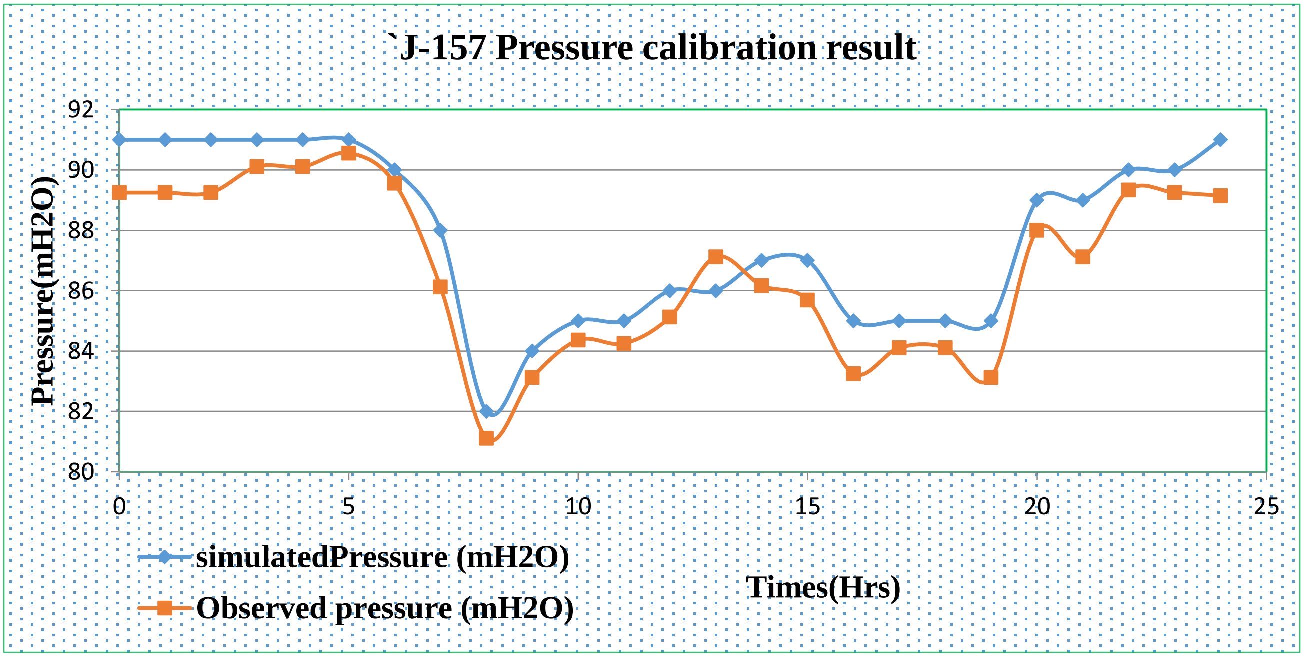

Figure 4.8 J-157 Pressure calibration result

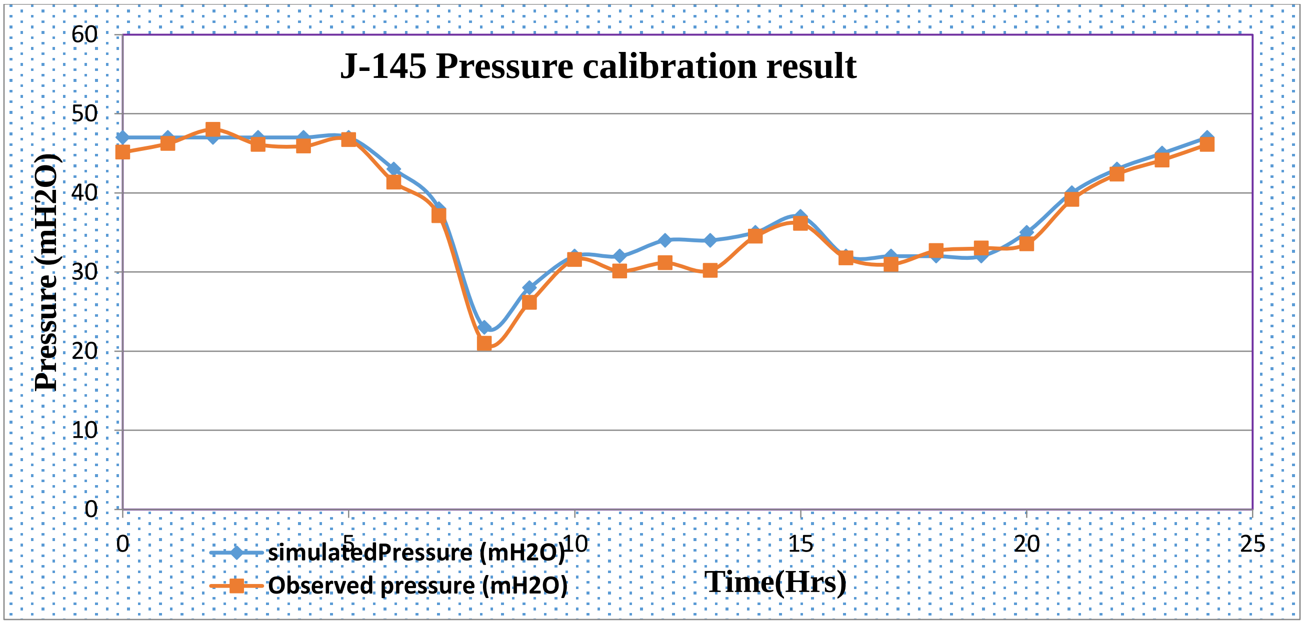

Figure 4.9 J-145 Pressure calibration result

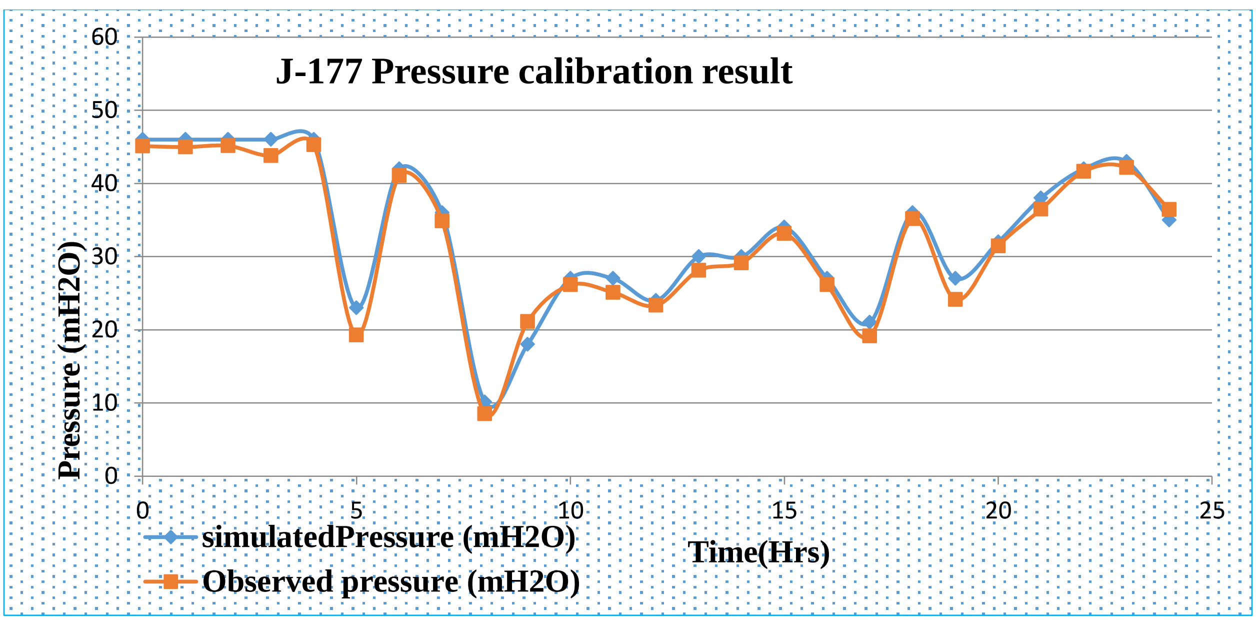

Figure 4.10 J-177 Pressure calibration result

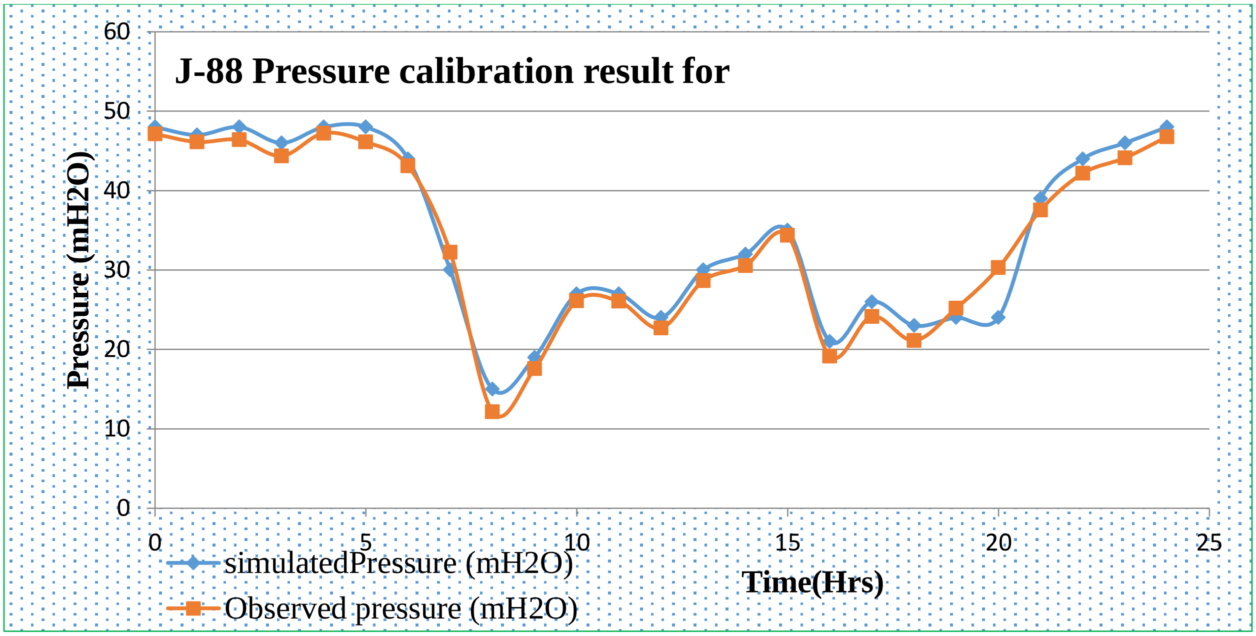

Figure 4.11 J-88 Pressure calibration result

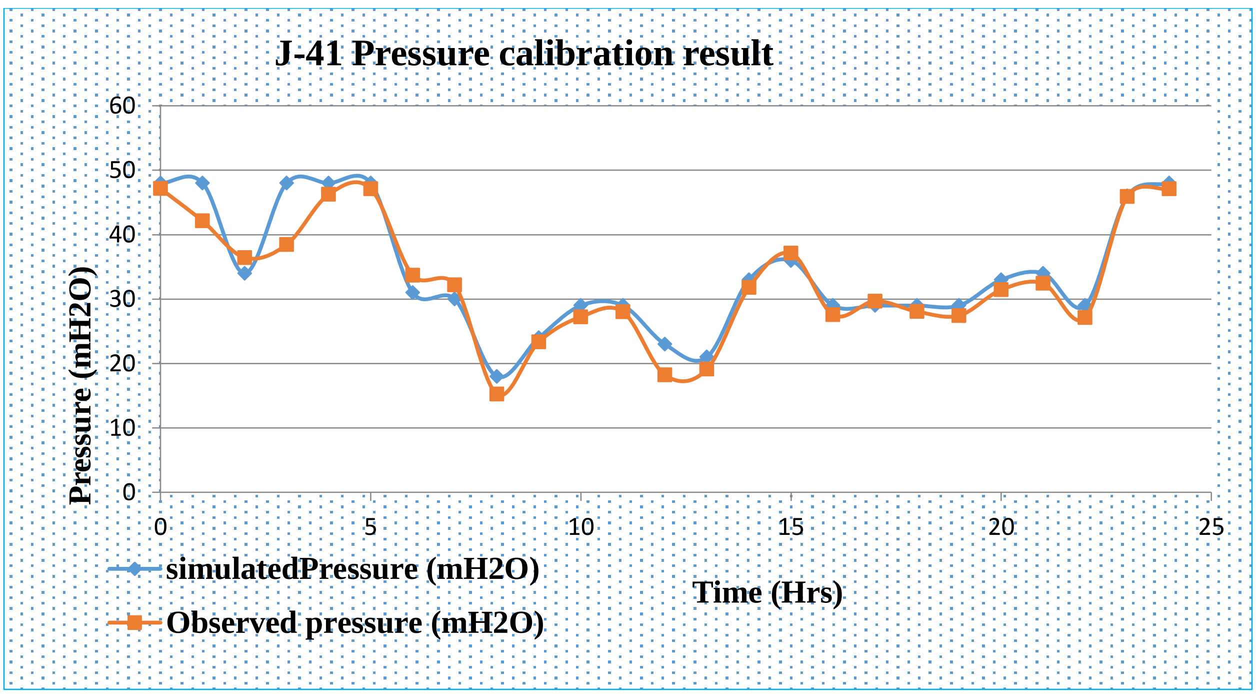

Figure 4.12 J-41 Pressure calibration result

The degree of accuracy varies depending on the size of the system and the amount of field data and testing available to the modeler.

Table4.22 junction pressure calibration based on difference pressure errors

Time (hrs.)	junction	Observed pressure(m H2O)	Simulated pressure(m H2O)	Differences pressure error (m H2O)
6:00AM	J-157	90	92.91	2.91
	J-145	43	44.05	1.05
	J-177	42	44.32	2.32
	J-88	44	44.64	0.64
	J-137	67	70.18	3.18
	J-154	64	65.54	1.54
	J-41	44	45.47	1.47
	J-159	6	8.51	2.51
8:00AM	J-157	82	83.59	1.59
	J-145	30	31.06	1.06
	J-177	16	13.88	-2.12
	J-88	15	15.12	0.12
	J-137	38	40.45	2.45
	J-154	32	34.32	2.32
	J-41	18	14.59	-3.41
	J-159	35	36.98	1.98
10:00AM	J-157	85	86.18	1.18
	J-145	32	32.97	0.97
	J-177	27	29.49	2.49
	J-88	27	27.53	0.53
	J-137	50	52.77	2.77
	J-154	46	46.51	0.51
	J-41	29	31.24	2.24
	J-159	48	48.45	0.45
12:00PM	J-157	86	87.38	1.38
	J-145	34	35.42	1.42
	J-177	30	31.36	1.36
	J-88	30	31.78	1.78
	J-137	53	55.25	2.25
	J-154	48	49.23	1.23
	J-41	31	33.18	2.18
	J-159	50	53.32	3.32
2:00PM	J-157	87	89.86	2.86
	J-145	35	40.01	5.01
	J-177	32	32.67	0.67
	J-88	32	30.63	-1.37
	J-137	56	56.44	0.44
	J-154	51	55.12	4.12
	J-41	33	33.21	0.21
	J-159	53	54.15	1.15
Average				1.469

As shown in table 4.23 the computed pressure values with in an average error of 1.469m pressure from simulated to observed values. Hence the model is acceptable calibrated which is satisfied the criteria pressure calibration under average level (average ±1. 5m to maximum ±5m).

4.6. Model Validation

Methods used to obtain unbiased estimates of future performance of statistical prediction models and classifiers include data splitting and resampling. Model validation is a means of assessing the applicability of a given model with respect to field measured data. The pressured field measured value at J-157, J-154 and J-137 were used for validation of the model. The model validation work was taken manually using the correlation coefficient equation (R^2) method and the graph figure presented 4.4 and 4.5 below.

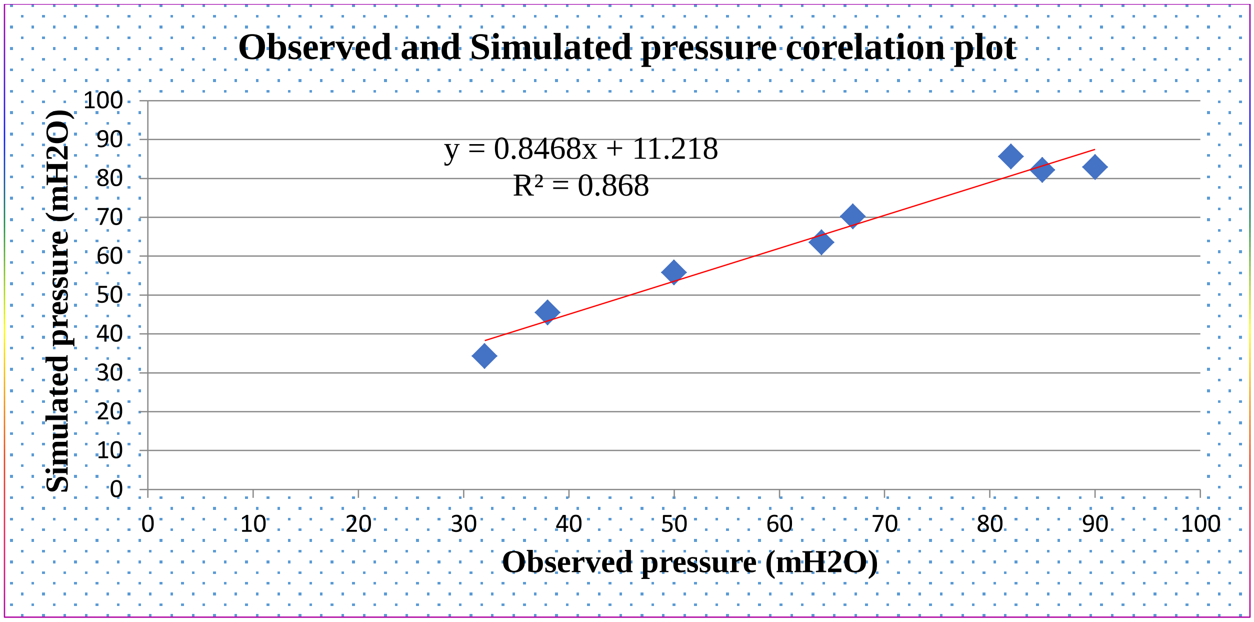

Figure 4.13 the relations between field measured and simulated pressure during low demand time

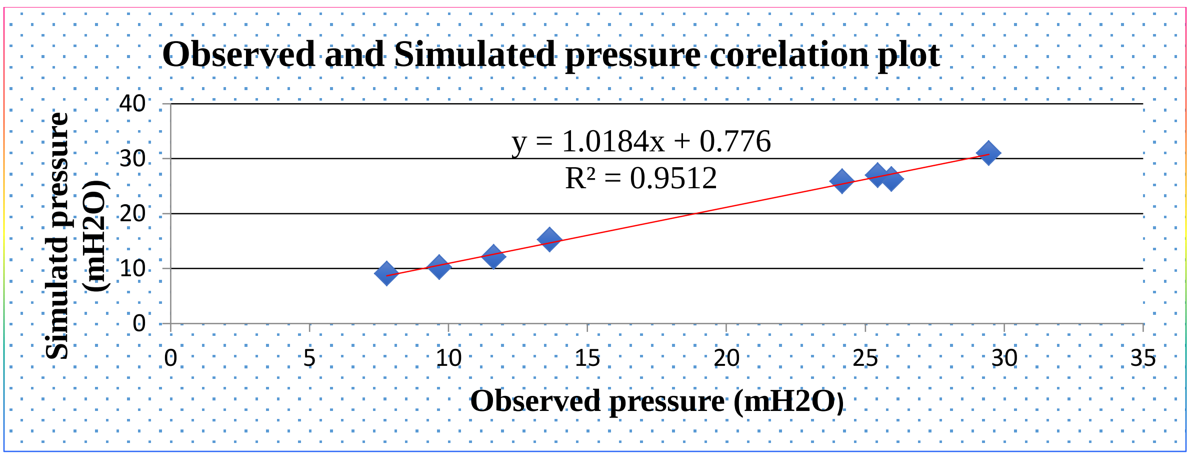

Figure4.14, relation between field measured and simulated pressure during peak demand time

From the above figure 4.4 and 4.5, the correlation (R^2) value for peak demand and low demand time was 0.9512 and 0.9964 respectively. Since the value of R^2 approaches 1 for both scenarios, that indicates there is a good correlation between fields measured pressure and simulated pressure. R2 shows how much of the variance in the dependent variable would be accounted for if the model was derived from which the sample was taken.

4.7. Hydraulic network improvement

In designing or improving a system there are sets of design criterion to be considered these are: pressure, residual chlorine and velocity. The design criteria used in the design of water supply distribution system components, nodal pressure during the period of peak demand, and optimum velocities of the transfer and distribution mains .Modification to the problems is made by creating new alternatives and scenario, trial and error procedure until a solution appeared to meet the design criteria.

4.7.1. Adding pressure reducing valve in the network

The best operational practice to optimize the operation of water distribution system was controlling the pressure in the network. This management of pressure has been reflected in the aspect of reducing excessive pressure by installing pressure reduced valve. By controlling the pressure it is possible to reduce the amount of water loss from the system, the occurrence of internal damage and power consumption related to high pressure.at minimum hour demand pressure was high at lower elevation area. Installing pressure reduced valve at links which have maximum pressure was used to reducing excessive pressure to the desired allowable value seen blow the table.

Table 4.23excessive pressure in the improved system at minimum consumption hour

S.no	Junction	Elevation (m)	Pressure(mH2O) before adding PRV	Pressure(mH2O) after adding PRV
1	J-64	1850.00	77	55
2	J-203	1848.25	79	50
3	J-151	1847.56	80	53
4	J-139	1846.26	81	54
5	J-164	1845.36	82	54
6	J-140	1843.36	84	55
7	J-97	1842.03	85	55
8	J-163	1841.12	86	61
9	J-90	1840.00	87	57
10	J-141	1838.68	88	66
11	J-160	1837.69	89	59
12	J-161	1837.45	90	62
13	J-156	1837.47	91	59
14	J-173	1835.00	92	86
15	J-172	1833.14	94	67
16	J-153	1831.45	95	69
17	J-58	1829.5	98	49
18	J-152	1826.25	101	65
19	J-82	1823.23	104	54
20	J-80	1823.12	105	57
21	J-81	1820.43	106	57

Table 4.24 Improved system nodes with pressure at minimum consumption hour.

Pressure (m of H2O)	Number of nodes	Percentage
<15	5	2.80%
15-75	165	92.18%
≥75	9	5.02%
Total	179	100%

After modifying the existing water distribution system by adding pressure reduced valve, 92.18% of the junctions are in the recommended pressure range of minimum 15m of H2Oand maximum 75m of H2Oand only 7.82 %of the junctions are not in the recommended pressure range.

4.7.2. Improving pipe size

Increasing in the diameter of the pipe in water distribution model results in a corresponding decrease in velocity and increase in pressure. At peak hour consumption the velocities out of the design range are modified by resizing pipes diameter. The pipe which does not satisfied the allowable minimum and maximum velocity was selected for modification to improve the water distribution system.

Table 4.25Modified pipe size in main distribution system

S.no	Label	Existing pipe size(mm)		Modified pipe size(mm)	
		Diameter (mm)	Velocity(m/s)	Diameter(mm)	Velocity(m/s)
1	p-8	80	3.09	110	2.97
2	p-254	80	2.52	110	0.23
3	P-246	80	2.47	110	1.70
4	P-131	80	2.38	110	1.50
5	p-148	25	2.22	63	0.35
6	p-58	50	2.33	100	0.91
7	p-77	80	2.27	110	1.41
8	p-292	50	2.50	80	1.01
9	p-165	150	0.25	50	0.84
10	p-133	80	0.23	50	0.65
11	p-140	150	0.20	80	0.8
12	p-7	150	0.17	80	0.85
13	p-290	200	0.16	110	0.51
14	p-129	200	0.04	110	0.17
15	p-99	200	2.17	250	1.19
16	p-317	80	0.02	50	0.73
17	p-326	100	0.07	50	0.22
18	p-320	80	0.10	50	0.24
19	p-5	200	0.14	110	0.36

20	p-192	150	0.32	100	0.78
21	p-289	200	0.37	150	1.03
22	p-280	150	0.43	80	1.57
23	p-247	50	2.03	110	0.39
24	p-114	80	0.04	50	0.33
25	p-74	80	0.49	50	1.90
26	p-41	80	0.50	50	1.57
27	p-309	100	0.51	50	0.92
28	p-364	150	0.57	80	1.56
29	p-325	100	0.30	50	0.81
30	p-32	50	2.09	80	1.26

Table4.26 improved system velocity in distribution system at peak hour consumption

Velocity (m/s)	Number of pipes	Percentage	Effect
0-0.1	5	1.86%	Water stagnation happens
0.1-0.6	58	21.56%	Sedimentation happens
0.6-2	203	75.46%	An acceptable level
>2	3	1.12%	Head loss and water hammer
Total	269	100%	

After modifying the pipe sizes in the existing distribution system as shown table 75.46% of the pipes are in the recommended velocity range of minimum 0.6 m/s and maximum 2 m/s and only 24.54 %of the pipes are not in the recommended velocity range.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study was conducted to analyze the water distribution network of Finote-Selam town. The total population of the Finote-Selam town was estimated 42,689 in year 2018 and 65,558at the end of design period (2030). The current maximum day water demand and the maximum day water demand at the end of design period (2030) for Finote-Selam town was2, 826.68m3/day and 7,981 m3 / day respectively.

The finding of this study revealed that the water supply coverage of the town was 82.4 % and average per capital domestic water consumption of the town in 2018 was 37.9 l/person/day. 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 was 280,885 m^3 /year that account 32.18% 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 67,863.12m^3year which covers 24.16% 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 213,020.88m^3/year which covers 75.84% from the total losses.Real losses are the dominant component of water losses in Finote-Selam water distribution system. High levels of water losses have a serious impact on Finote-Selam water service finance as well as on available water resources in water scarce environments.

During hydraulic modeling of water pressure of the town has 179 nodes and 269 pipes were identified. During calibration the model is acceptable calibrated which is satisfied the criteria pressure calibration under average level (average ±1. 5m to maximum ±5m). There is a good correlation between fields measured pressure and simulated pressure since, value of R^2 approaches 1 for both scenarios.

At peak hour consumption, 19.55% of the nodes are under desirable minimum pressure, 2.24% of the nodes are exceeding maximum allowable pressure, junctions 20, 84,22,9,75,19,74 and 18were negative pressure and 78.21% of nodes have pressure within the recommended limit.

During minimum time consumption 2.23% of the nodes are below desirable minimum pressure, 46.02% of the nodes are were getting water above standard pressure and52.52% of nodes are in permissible pressure range.

For peak hour consumption 7.06% of the pipes are below desirable minimum velocity and 4.09% of the pipes velocity is exceeding maximum allowable velocity and 50.93% of pipes are in recommended velocity range. During low consumption time, 44.24% of the pipes velocity is below desirable minimum velocity and 9.33% of pipes are in recommended velocity range.

After modifying the existing water distribution system, 92.18% of the junctions are in the recommended pressure range of minimum 15m of H2Oand maximum 75m of H2O and only 7.82 %of the junctions are not in the recommended pressure range.Also75.46% of the pipes are in the recommended velocity range of minimum 0.6 m/s and maximum 2 m/s and only 24.54 %of the pipes are not in the recommended velocity range.

Therefore control of the flow velocity in water distribution networks should be maintained in order to avoid pipe break, water hammer, water stagnation which causes sediment deposition in the pipe and head loss.

The result of the analysis showed that the overall technical performance of existing water distribution 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 velocity and pressure in permissible range.

5.2. Recommendation

Based on the findings, the following recommendations are made:

- To satisfy continuousrising of water demand several measures should be taken and for the existing situation of Finote-Selam town water supply distribution system and the resources take a seriously such as the following.
- 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.
- A planned and scheduled rationing system should be implemented to supply water equally for residents of the town.
- Increasing pumping hour of the pump from 18 hours per day to 21 hours per day to reduce the currently gab between water demand and water production from 435.56 m^3/day to 12.16m^3/day.
- So as to alleviative water scarcity of the town additional borehole should be drilled around Gurge and Aba NigusWanza with the quantity of water 435.56m^3/day to fulfill the current gab between water demand and water supply.
- In order to achieve a 15m minimum and 70m maximum pressure, it is necessary to provide pressure controlling valve, establishing break pressure tank and replacing the old pipe with the new one that has a diameter ofappropriate size.
- Due to variations in topography, pressure zones are established to ensure minimum pressures can be provided to critical areas, particularly to sections of the water distribution grid at higher elevations.
- The water supply system of Finote-Selam will be redesigned as continuous supply depending on fixed and extended pattern, assuming the availability of water sources, and the using of pressure reducing valves to reduce the high pressures in the system if the pressure of the distribution system is above from the permissible limit or if these design parameters may be above the design criteria.
- There is need for replacement of old pipes to avoid the loss of water as real losses are the main contributors to the water losses.

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AppendixA

Junctions (nodal) pressure result; for peak demand time

Label	X (m)	Y (m)	Elevation (m)	Zone	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-1	309,437.12	1,182,051.73	1,917.00	Zone - 1	2.48	1,927.09	10
J-2	309,818.93	1,182,092.56	1,917.20	Zone - 1	0.66	1,918.05	1
J-3	309,836.35	1,181,948.85	1,902.15	Zone - 1	0.59	1,921.89	20
J-4	309,722.84	1,181,773.34	1,897.23	Zone - 1	0.68	1,923.71	26
J-5	309,635.63	1,181,758.61	1,894.12	Zone - 1	0.40	1,923.72	30
J-7	309,492.85	1,181,735.89	1,897.11	Zone - 1	0.31	1,923.74	27
J-8	309,468.05	1,181,732.45	1,901.00	Zone - 1	0.38	1,926.20	25
J-9	309,508.90	1,181,383.49	1,901.50	Zone - 1	0.71	1,898.39	-3
J-10	309,095.79	1,181,340.40	1,885.00	Zone - 1	0.86	1,897.27	12
J-11	308,966.93	1,181,279.30	1,878.02	Zone - 1	1.01	1,896.28	18
J-12	308,796.95	1,181,175.25	1,876.03	Zone - 1	0.47	1,894.64	19
J-13	308,608.27	1,181,210.42	1,871.12	Zone - 1	0.87	1,895.17	24
J-14	308,722.23	1,181,360.03	1,867.50	Zone - 1	0.56	1,897.15	30
J-15	308,790.05	1,181,444.19	1,878.00	Zone - 1	0.72	1,897.82	20
J-16	308,873.64	1,181,556.86	1,885.00	Zone - 1	0.97	1,899.50	14
J-17	308,940.38	1,181,811.40	1,892.15	Zone - 1	0.61	1,908.23	16
J-18	308,880.48	1,181,829.56	1,907.12	Zone - 1	0.36	1,906.64	0
J-19	308,749.01	1,181,867.07	1,909.15	Zone - 1	0.97	1,905.86	-3
J-20	309,082.34	1,181,458.20	1,910.00	Zone - 1	0.86	1,899.85	-10
J-21	309,054.64	1,181,671.85	1,901.02	Zone - 1	1.05	1,921.47	20
J-22	309,535.33	1,181,167.40	1,901.00	Zone - 1	0.39	1,897.67	-3
J-23	309,559.81	1,180,927.36	1,873.50	Zone - 1	0.78	1,897.44	24
J-24	309,386.42	1,180,931.85	1,861.51	Zone - 1	0.34	1,896.46	35
J-25	309,312.94	1,180,934.43	1,861.50	Zone - 1	0.38	1,891.96	30
J-26	309,169.67	1,180,938.80	1,862.00	Zone - 1	0.63	1,892.11	30
J-28	308,841.92	1,180,936.68	1,861.00	Zone - 1	0.58	1,890.29	29
J-29	308,798.76	1,180,934.44	1,856.50	Zone - 1	0.52	1,893.74	37
J-31	308,846.44	1,180,828.88	1,856.12	Zone - 1	0.39	1,887.39	31
J-32	308,855.14	1,180,681.59	1,851.00	Zone - 1	0.52	1,887.03	36
J-33	308,806.66	1,180,622.95	1,842.23	Zone - 1	0.57	1,886.53	44
J-34	308,665.89	1,180,754.24	1,837.50	Zone - 1	0.69	1,886.52	49
J-35	308,535.76	1,180,988.45	1,846.18	Zone - 1	1.47	1,893.23	47
J-37	308,797.38	1,181,136.45	1,851.50	Zone - 1	0.91	1,894.51	43
J-38	309,534.46	1,181,388.67	1,867.25	Zone - 1	0.41	1,923.56	56
J-39	309,648.58	1,181,405.30	1,884.35	Zone - 1	0.38	1,918.73	34
J-40	309,759.47	1,181,417.10	1,866.00	Zone - 1	0.54	1,906.07	40
J-41	309,848.88	1,180,931.32	1,880.00	Zone - 1	1.13	1,898.17	18
J-42	310,093.67	1,180,937.97	1,863.45	Zone - 1	0.59	1,899.94	36
J-46	310,433.63	1,180,942.71	1,857.36	Zone - 1	0.84	1,896.27	39
J-47	310,593.49	1,180,937.64	1,846.56	Zone - 1	0.95	1,893.84	47

J-48	310,596.71	1,180,798.62	1,852.24	Zone - 1	2.32	1,893.05	41
J-49	310,921.18	1,180,803.72	1,847.38	Zone - 1	2.17	1,886.32	39
J-50	311,152.44	1,180,808.10	1,852.67	Zone - 1	1.08	1,886.45	34
J-51	311,144.17	1,180,941.82	1,851.45	Zone - 1	1.40	1,887.75	36
J-52	311,140.25	1,181,177.81	1,856.00	Zone - 1	1.54	1,884.60	29
J-53	310,788.34	1,180,935.87	1,864.18	Zone - 1	1.37	1,890.89	27
J-54	310,785.72	1,181,124.20	1,856.50	Zone - 1	4.57	1,871.97	15
J-55	310,347.64	1,181,161.43	1,861.24	Zone - 1	1.84	1,890.39	29
J-56	310,345.01	1,181,332.24	1,853.21	Zone - 1	0.72	1,889.84	37
J-57	309,073.83	1,180,200.11	1,856.00	Zone - 1	1.03	1,884.96	29
J-58	309,143.21	1,180,319.24	1,829.50	Zone - 1	1.10	1,886.21	57
J-59	309,224.51	1,180,473.42	1,835.27	Zone - 1	0.60	1,887.52	52
J-60	309,247.70	1,180,521.13	1,842.03	Zone - 1	0.80	1,887.73	46
J-62	309,641.79	1,180,522.71	1,836.70	Zone - 1	0.35	1,891.44	55
J-63	309,634.61	1,180,567.56	1,848.00	Zone - 1	0.16	1,891.76	44
J-64	309,622.95	1,180,662.64	1,850.00	Zone - 1	0.78	1,892.47	42
J-67	309,630.51	1,180,908.00	1,853.25	Zone - 1	0.91	1,894.96	42
J-68	310,098.10	1,180,915.15	1,862.23	Zone - 1	0.91	1,899.44	37
J-69	310,104.95	1,180,815.66	1,857.35	Zone - 1	0.64	1,897.60	40
J-70	309,992.43	1,180,814.61	1,855.00	Zone - 1	1.92	1,896.97	42
J-71	310,009.52	1,180,566.98	1,857.23	Zone - 1	1.71	1,891.04	34
J-72	309,167.24	1,181,851.98	1,851.00	Zone - 1	0.55	1,922.41	71
J-73	309,142.85	1,181,976.95	1,912.12	Zone - 1	0.68	1,924.28	12
J-74	308,697.30	1,181,678.67	1,917.75	Zone - 1	0.27	1,899.38	-18
J-75	308,455.56	1,181,337.03	1,897.26	Zone - 1	0.66	1,894.62	-3
J-78	309,055.90	1,180,105.82	1,871.38	Zone - 1	0.87	1,878.84	7
J-79	308,962.61	1,180,076.40	1,823.15	Zone - 1	1.59	1,877.91	55
J-80	309,280.26	1,179,876.16	1,821.23	Zone - 1	2.25	1,874.04	53
J-81	309,119.33	1,179,828.64	1,820.45	Zone - 1	0.88	1,874.47	54
J-82	309,127.42	1,179,798.88	1,823.12	Zone - 1	0.59	1,874.48	51
J-83	309,780.26	1,182,416.99	1,822.35	Zone - 1	2.41	1,915.80	93
J-84	310,044.01	1,182,475.86	1,922.16	Zone - 1	0.68	1,915.68	-6
J-85	309,943.30	1,182,091.96	1,900.00	Zone - 1	4.56	1,915.87	16
J-86	309,988.59	1,181,434.67	1,891.28	Zone - 1	1.21	1,906.10	15
J-87	309,975.70	1,181,650.62	1,878.13	Zone - 1	3.46	1,909.08	31
J-88	309,135.74	1,181,128.16	1,879.31	Zone - 1	0.63	1,894.28	15
J-89	310,354.38	1,180,678.05	1,869.00	Zone - 1	0.48	1,897.40	28
J-90	309,093.36	1,180,870.54	1,840.00	Zone - 1	0.28	1,890.19	50
J-91	309,314.80	1,180,869.42	1,856.26	Zone - 1	0.46	1,891.54	35
J-92	309,321.98	1,180,720.08	1,857.12	Zone - 1	1.07	1,890.05	33
J-93	309,109.04	1,180,583.39	1,853.26	Zone - 1	0.45	1,887.51	34
J-94	309,071.70	1,180,871.21	1,843.35	Zone - 1	0.66	1,890.20	47
J-95	309,358.59	1,180,281.81	1,856.24	Zone - 1	2.24	1,887.20	31
J-96	309,672.10	1,180,289.25	1,838.12	Zone - 1	3.93	1,890.22	52
J-97	309,653.43	1,180,428.26	1,842.16	Zone - 1	0.68	1,890.81	49

J-98	308,875.92	1,180,558.00	1,846.15	Zone - 1	0.90	1,886.17	40
J-99	309,561.27	1,181,164.64	1,835.00	Zone - 1	0.60	1,894.96	60
J-100	309,476.93	1,181,884.17	1,873.16	Zone - 1	0.59	1,926.58	53
J-101	309,456.53	1,182,058.96	1,908.12	Zone - 1	1.72	1,926.65	18
J-102	309,519.22	1,181,895.66	1,917.45	Zone - 1	0.23	1,926.30	9
PF-11	308,411.43	1,181,142.23	1,906.64	Zone - 1	0.41	1,887.79	-19
PF-10	308,630.76	1,181,418.00	1,856.12	Zone - 1	1.09	1,863.26	7
PF-4	309,525.76	1,181,874.00	1,882.50	Zone - 1	0.26	1,925.81	43
PF-8	309,655.10	1,181,972.23	1,897.94	Zone - 1	0.54	1,909.38	11
PF-17	309,622.59	1,181,649.91	1,900.15	Zone - 1	0.47	1,914.47	14
NPF19	309,840.53	1,181,644.30	1,893.12	Zone - 1	0.83	1,907.74	15
PF-14	309,796.86	1,181,460.46	1,884.12	Zone - 1	0.62	1,901.83	18
PF-2	309,271.22	1,181,478.51	1,878.24	Zone - 1	0.88	1,859.66	-19
NPF23	309,042.72	1,180,596.54	1,886.12	Zone - 1	0.47	1,887.37	1
NPF20	309,736.67	1,181,187.08	1,840.24	Zone - 1	0.73	1,868.72	28
PF-12	308,611.82	1,180,697.01	1,872.45	Zone - 1	0.41	1,882.44	10
PF-13	308,723.15	1,180,404.02	1,841.21	Zone - 1	0.47	1,871.90	31
PF-5	308,894.25	1,180,830.78	1,825.49	Zone - 1	0.53	1,883.50	58
NPF24	308,737.59	1,180,932.75	1,852.14	Zone - 1	0.63	1,886.82	35
PF-16	308,895.75	1,181,870.78	1,854.35	Zone - 1	0.86	1,897.83	43
PF-3	309,232.03	1,181,819.96	1,912.14	Zone - 1	0.37	1,918.98	7
PF-18	309,902.98	1,181,959.93	1,907.56	Zone - 1	0.71	1,912.30	5
PF-6	309,600.25	1,180,563.59	1,889.04	Zone - 1	0.47	1,889.48	0
NPF21	309,729.69	1,180,666.50	1,849.17	Zone - 1	1.16	1,855.23	6
PF-15	310,432.28	1,180,985.09	1,853.14	Zone - 1	0.81	1,888.59	35
PF-7	309,644.96	1,181,437.46	1,848.25	Zone - 1	0.45	1,916.79	68
PF-1	309,388.07	1,180,963.81	1,883.45	Zone - 1	0.66	1,892.50	9
NPF22	309,591.00	1,180,425.72	1,866.78	Zone - 1	0.89	1,877.51	11
J-130	309,102.28	1,180,703.17	1,846.36	Zone - 1	0.46	1,887.99	42
NPF25	309,178.52	1,180,704.39	1,848.56	Zone - 1	0.50	1,882.40	34
PF-9	308,757.81	1,181,137.39	1,851.24	Zone - 1	0.45	1,892.10	41
J-136	308,845.36	1,180,870.72	1,852.25	Zone - 1	0.59	1,887.57	35
J-137	308,500.63	1,181,072.08	1,855.45	Zone - 1	0.68	1,893.66	38
J-139	309,357.26	1,180,521.12	1,846.26	Zone - 1	0.40	1,888.09	42
J-140	309,355.07	1,180,407.16	1,843.36	Zone - 1	0.31	1,887.51	44
J-141	309,189.97	1,180,407.89	1,838.68	Zone - 1	0.38	1,887.06	48
J-142	309,070.58	1,181,556.96	1,892.36	Zone - 1	0.44	1,910.13	18
J-143	309,482.94	1,181,619.75	1,894.00	Zone - 1	0.39	1,912.77	19
J-145	309,544.81	1,181,316.92	1,881.25	Zone - 1	0.44	1,904.32	23
J-146	309,774.79	1,181,345.42	1,874.50	Zone - 1	0.47	1,904.72	30
J-147	310,350.75	1,180,941.01	1,848.50	Zone - 1	0.58	1,897.94	49
J-148	309,988.69	1,180,935.18	1,861.36	Zone - 1	0.56	1,901.34	40
J-149	309,913.35	1,181,430.59	1,876.45	Zone - 1	0.43	1,905.58	29
J-150	309,522.16	1,180,287.44	1,842.15	Zone - 1	0.40	1,888.71	46
J-151	309,491.11	1,180,522.13	1,847.56	Zone - 1	0.61	1,889.47	42

J-152	309,086.65	1,179,996.66	1,826.25	Zone - 1	0.36	1,876.84	50
J-153	309,238.25	1,180,041.25	1,831.45	Zone - 1	0.40	1,876.90	45
J-154	309,076.25	1,180,939.66	1,858.25	Zone - 1	0.58	1,890.29	32
J-155	309,795.41	1,181,423.82	1,879.00	Zone - 1	0.39	1,905.87	27
J-156	309,521.61	1,181,495.90	1,837.45	Zone - 1	0.47	1,923.58	86
J-157	309,745.16	1,181,534.62	1,837.25	Zone - 1	0.49	1,919.64	82
J-158	309,744.87	1,181,635.88	1,888.46	Zone - 1	0.34	1,919.60	31
J-159	309,605.57	1,180,805.36	1,858.36	Zone - 1	0.38	1,893.78	35
J-160	309,034.74	1,180,502.36	1,837.69	Zone - 1	0.63	1,887.27	49
J-161	309,172.82	1,180,374.51	1,837.45	Zone - 1	0.58	1,886.74	49
J-162	309,305.85	1,180,280.02	1,837.45	Zone - 1	0.42	1,886.90	49
J-163	309,302.93	1,180,407.14	1,841.12	Zone - 1	0.39	1,887.16	46
J-164	309,354.06	1,180,474.35	1,845.36	Zone - 1	0.52	1,887.74	42
J-165	308,753.13	1,180,757.12	1,847.68	Zone - 1	0.57	1,885.82	38
J-166	308,789.66	1,180,792.50	1,848.26	Zone - 1	0.48	1,885.81	37
J-167	308,746.28	1,180,835.88	1,848.56	Zone - 1	0.73	1,885.84	37
J-168	309,921.84	1,181,371.25	1,874.12	Zone - 1	0.48	1,904.78	31
J-169	309,307.23	1,180,250.96	1,836.25	Zone - 1	0.47	1,886.78	50
J-170	309,374.44	1,180,253.88	1,838.15	Zone - 1	0.60	1,886.72	48
J-171	309,378.83	1,180,169.13	1,836.45	Zone - 1	0.80	1,886.70	50
J-172	309,229.79	1,180,169.86	1,833.14	Zone - 1	0.32	1,886.72	53
J-173	309,231.25	1,180,258.99	1,835.00	Zone - 1	0.17	1,886.75	52
J-174	308,692.52	1,181,172.31	1,868.02	Zone - 1	0.41	1,895.07	27
J-175	308,800.96	1,181,364.08	1,882.15	Zone - 1	0.91	1,895.09	13
J-176	308,919.67	1,181,252.22	1,874.15	Zone - 1	0.91	1,895.29	21
J-177	309,242.99	1,181,356.18	1,881.15	Zone - 1	0.64	1,897.63	16
J-178	309,261.54	1,181,059.39	1,867.50	Zone - 1	0.67	1,897.25	30
J-179	309,545.49	1,181,066.53	1,868.42	Zone - 1	0.61	1,897.44	29
J-183	309,836.19	1,181,001.83	1,864.00	Zone - 1	0.55	1,898.80	35
J-184	309,697.50	1,181,003.26	1,866.00	Zone - 1	0.68	1,897.73	32
J-186	309,699.21	1,180,928.98	1,868.46	Zone - 1	0.69	1,897.73	29
J-187	309,197.50	1,180,869.86	1,857.46	Zone - 1	0.46	1,889.99	32
J-188	309,201.15	1,180,758.81	1,854.00	Zone - 1	0.87	1,888.59	35
J-189	309,098.87	1,180,758.08	1,852.26	Zone - 1	0.48	1,888.49	36
J-190	308,907.19	1,180,871.00	1,853.23	Zone - 1	0.75	1,888.14	35
J-191	308,915.96	1,180,755.87	1,847.56	Zone - 1	0.46	1,888.38	41
J-192	308,942.22	1,181,245.26	1,873.24	Zone - 1	0.59	1,895.23	22
J-193	308,964.20	1,181,121.82	1,867.36	Zone - 1	0.34	1,894.45	27
J-194	308,898.59	1,181,360.77	1,882.11	Zone - 1	0.38	1,897.77	16
J-195	308,989.91	1,181,479.12	1,887.14	Zone - 1	0.63	1,899.58	12
J-196	309,792.34	1,182,301.42	1,912.31	Zone - 1	0.06	1,916.43	4
J-197	310,063.56	1,182,330.65	1,895.12	Zone - 1	0.42	1,915.78	21
J-198	308,572.02	1,181,030.89	1,855.15	Zone - 1	0.39	1,893.66	38
J-199	308,698.73	1,181,041.16	1,860.00	Zone - 1	0.52	1,893.66	34
J-200	308,799.18	1,181,068.56	1,863.28	Zone - 1	0.57	1,893.71	30

J-201	308,938.44	1,180,936.15	1,857.50	Zone - 1	0.69	1,890.29	33
J-202	309,822.68	1,180,807.84	1,858.15	Zone - 1	0.71	1,891.75	34
J-203	309,832.67	1,180,522.47	1,848.25	Zone - 1	0.91	1,891.05	43
J-204	309,188.74	1,181,691.31	1,901.00	Zone - 1	0.41	1,922.54	21

AppendixB

Junctions (nodal) pressure result; for night flow/ low consumption time

Label	X (m)	Y (m)	Elevation (m)	Zone	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-1	309,437.12	1,182,051.73	1,917.00	Zone - 1	0.39	1,928.65	12
J-2	309,818.93	1,182,092.56	1,917.20	Zone - 1	0.10	1,928.35	11
J-3	309,836.35	1,181,948.85	1,902.15	Zone - 1	0.09	1,928.47	26
J-4	309,722.84	1,181,773.34	1,897.23	Zone - 1	0.11	1,928.54	31
J-5	309,635.63	1,181,758.61	1,894.12	Zone - 1	0.06	1,928.54	34
J-7	309,492.85	1,181,735.89	1,897.11	Zone - 1	0.05	1,928.54	31
J-8	309,468.05	1,181,732.45	1,901.00	Zone - 1	0.06	1,928.62	28
J-9	309,508.90	1,181,383.49	1,901.50	Zone - 1	0.11	1,927.66	26
J-10	309,095.79	1,181,340.40	1,885.00	Zone - 1	0.14	1,927.62	43
J-11	308,966.93	1,181,279.30	1,878.02	Zone - 1	0.16	1,927.58	49
J-12	308,796.95	1,181,175.25	1,876.03	Zone - 1	0.07	1,927.52	51
J-13	308,608.27	1,181,210.42	1,871.12	Zone - 1	0.14	1,927.53	56
J-14	308,722.23	1,181,360.03	1,867.50	Zone - 1	0.09	1,927.61	60
J-15	308,790.05	1,181,444.19	1,878.00	Zone - 1	0.11	1,927.63	50
J-16	308,873.64	1,181,556.86	1,885.00	Zone - 1	0.15	1,927.69	43
J-17	308,940.38	1,181,811.40	1,892.15	Zone - 1	0.10	1,928.00	36
J-18	308,880.48	1,181,829.56	1,907.12	Zone - 1	0.06	1,927.95	21
J-19	308,749.01	1,181,867.07	1,909.15	Zone - 1	0.15	1,927.92	19
J-20	309,082.34	1,181,458.20	1,910.00	Zone - 1	0.14	1,927.71	18
J-21	309,054.64	1,181,671.85	1,901.02	Zone - 1	0.17	1,928.46	27
J-22	309,535.33	1,181,167.40	1,901.00	Zone - 1	0.06	1,927.64	27
J-23	309,559.81	1,180,927.36	1,873.50	Zone - 1	0.12	1,927.64	54
J-24	309,386.42	1,180,931.85	1,861.51	Zone - 1	0.05	1,927.60	66
J-25	309,312.94	1,180,934.43	1,861.50	Zone - 1	0.06	1,927.45	66
J-26	309,169.67	1,180,938.80	1,862.00	Zone - 1	0.10	1,927.45	65
J-28	308,841.92	1,180,936.68	1,861.00	Zone - 1	0.09	1,927.39	66
J-29	308,798.76	1,180,934.44	1,856.50	Zone - 1	0.08	1,927.49	71
J-31	308,846.44	1,180,828.88	1,856.12	Zone - 1	0.06	1,927.30	71
J-32	308,855.14	1,180,681.59	1,851.00	Zone - 1	0.08	1,927.29	76
J-33	308,806.66	1,180,622.95	1,842.23	Zone - 1	0.09	1,927.28	85
J-34	308,665.89	1,180,754.24	1,837.50	Zone - 1	0.11	1,927.27	90
J-35	308,535.76	1,180,988.45	1,846.18	Zone - 1	0.23	1,927.47	81
J-37	308,797.38	1,181,136.45	1,851.50	Zone - 1	0.14	1,927.51	76
J-38	309,534.46	1,181,388.67	1,867.25	Zone - 1	0.07	1,928.53	61
J-39	309,648.58	1,181,405.30	1,884.35	Zone - 1	0.06	1,928.37	44

J-40	309,759.47	1,181,417.10	1,866.00	Zone - 1	0.08	1,927.94	62
J-41	309,848.88	1,180,931.32	1,880.00	Zone - 1	0.18	1,927.66	48
J-42	310,093.67	1,180,937.97	1,863.45	Zone - 1	0.09	1,927.74	64
J-46	310,433.63	1,180,942.71	1,857.36	Zone - 1	0.13	1,927.62	70
J-47	310,593.49	1,180,937.64	1,846.56	Zone - 1	0.15	1,927.54	81
J-48	310,596.71	1,180,798.62	1,852.24	Zone - 1	0.37	1,927.51	75
J-49	310,921.18	1,180,803.72	1,847.38	Zone - 1	0.34	1,927.29	80
J-50	311,152.44	1,180,808.10	1,852.67	Zone - 1	0.17	1,927.30	74
J-51	311,144.17	1,180,941.82	1,851.45	Zone - 1	0.22	1,927.34	76
J-52	311,140.25	1,181,177.81	1,856.00	Zone - 1	0.24	1,927.24	71
J-53	310,788.34	1,180,935.87	1,864.18	Zone - 1	0.22	1,927.44	63
J-54	310,785.72	1,181,124.20	1,856.50	Zone - 1	0.72	1,926.82	70
J-55	310,347.64	1,181,161.43	1,861.24	Zone - 1	0.29	1,927.43	66
J-56	310,345.01	1,181,332.24	1,853.21	Zone - 1	0.11	1,927.41	74
J-57	309,073.83	1,180,200.11	1,856.00	Zone - 1	0.16	1,927.23	71
J-58	309,143.21	1,180,319.24	1,829.50	Zone - 1	0.17	1,927.27	98
J-59	309,224.51	1,180,473.42	1,835.27	Zone - 1	0.09	1,927.31	92
J-60	309,247.70	1,180,521.13	1,842.03	Zone - 1	0.13	1,927.32	85
J-62	309,641.79	1,180,522.71	1,836.70	Zone - 1	0.05	1,927.45	91
J-63	309,634.61	1,180,567.56	1,848.00	Zone - 1	0.03	1,927.46	79
J-64	309,622.95	1,180,662.64	1,850.00	Zone - 1	0.12	1,927.49	77
J-67	309,630.51	1,180,908.00	1,853.25	Zone - 1	0.14	1,927.57	74
J-68	310,098.10	1,180,915.15	1,862.23	Zone - 1	0.14	1,927.72	65
J-69	310,104.95	1,180,815.66	1,857.35	Zone - 1	0.10	1,927.66	70
J-70	309,992.43	1,180,814.61	1,855.00	Zone - 1	0.30	1,927.64	72
J-71	310,009.52	1,180,566.98	1,857.23	Zone - 1	0.27	1,927.44	70
J-72	309,167.24	1,181,851.98	1,851.00	Zone - 1	0.09	1,928.49	77
J-73	309,142.85	1,181,976.95	1,912.12	Zone - 1	0.11	1,928.55	16
J-74	308,697.30	1,181,678.67	1,917.75	Zone - 1	0.04	1,927.69	10
J-75	308,455.56	1,181,337.03	1,897.26	Zone - 1	0.10	1,927.52	30
J-78	309,055.90	1,180,105.82	1,871.38	Zone - 1	0.14	1,927.03	56
J-79	308,962.61	1,180,076.40	1,823.15	Zone - 1	0.25	1,927.00	104
J-80	309,280.26	1,179,876.16	1,821.23	Zone - 1	0.36	1,926.87	105
J-81	309,119.33	1,179,828.64	1,820.45	Zone - 1	0.14	1,926.89	106
J-82	309,127.42	1,179,798.88	1,823.12	Zone - 1	0.09	1,926.89	104
J-83	309,780.26	1,182,416.99	1,822.35	Zone - 1	0.38	1,928.27	106
J-84	310,044.01	1,182,475.86	1,922.16	Zone - 1	0.11	1,928.27	6
J-85	309,943.30	1,182,091.96	1,900.00	Zone - 1	0.72	1,928.27	28
J-86	309,988.59	1,181,434.67	1,891.28	Zone - 1	0.19	1,927.95	37
J-87	309,975.70	1,181,650.62	1,878.13	Zone - 1	0.55	1,928.05	50
J-88	309,135.74	1,181,128.16	1,879.31	Zone - 1	0.10	1,927.52	48
J-89	310,354.38	1,180,678.05	1,869.00	Zone - 1	0.08	1,927.66	59
J-90	309,093.36	1,180,870.54	1,840.00	Zone - 1	0.05	1,927.39	87
J-91	309,314.80	1,180,869.42	1,856.26	Zone - 1	0.07	1,927.43	71
J-92	309,321.98	1,180,720.08	1,857.12	Zone - 1	0.17	1,927.39	70

J-93	309,109.04	1,180,583.39	1,853.26	Zone - 1	0.07	1,927.31	74
J-94	309,071.70	1,180,871.21	1,843.35	Zone - 1	0.10	1,927.39	84
J-95	309,358.59	1,180,281.81	1,856.24	Zone - 1	0.35	1,927.31	71
J-96	309,672.10	1,180,289.25	1,838.12	Zone - 1	0.62	1,927.41	89
J-97	309,653.43	1,180,428.26	1,842.16	Zone - 1	0.11	1,927.43	85
J-98	308,875.92	1,180,558.00	1,846.15	Zone - 1	0.14	1,927.27	81
J-99	309,561.27	1,181,164.64	1,835.00	Zone - 1	0.09	1,927.57	92
J-100	309,476.93	1,181,884.17	1,873.16	Zone - 1	0.09	1,928.63	55
J-101	309,456.53	1,182,058.96	1,908.12	Zone - 1	0.27	1,928.63	20
J-102	309,519.22	1,181,895.66	1,917.45	Zone - 1	0.04	1,928.62	11
PF-11	308,411.43	1,181,142.23	1,906.64	Zone - 1	0.07	1,927.29	21
PF-10	308,630.76	1,181,418.00	1,856.12	Zone - 1	0.17	1,926.50	70
PF-4	309,525.76	1,181,874.00	1,882.50	Zone - 1	0.04	1,928.61	46
PF-8	309,655.10	1,181,972.23	1,897.94	Zone - 1	0.09	1,928.07	30
PF-17	309,622.59	1,181,649.91	1,900.15	Zone - 1	0.07	1,928.23	28
NPF-19	309,840.53	1,181,644.30	1,893.12	Zone - 1	0.13	1,928.00	35
PF-14	309,796.86	1,181,460.46	1,884.12	Zone - 1	0.10	1,927.80	44
PF-2	309,271.22	1,181,478.51	1,878.24	Zone - 1	0.14	1,926.39	48
NPF-23	309,042.72	1,180,596.54	1,886.12	Zone - 1	0.07	1,927.31	41
NPF-20	309,736.67	1,181,187.08	1,840.24	Zone - 1	0.12	1,926.71	86
PF-12	308,611.82	1,180,697.01	1,872.45	Zone - 1	0.07	1,927.14	55
PF-13	308,723.15	1,180,404.02	1,841.21	Zone - 1	0.07	1,926.80	85
PF-5	308,894.25	1,180,830.78	1,825.49	Zone - 1	0.08	1,927.17	101
NPF-24	308,737.59	1,180,932.75	1,852.14	Zone - 1	0.10	1,927.26	75
PF-16	308,895.75	1,181,870.78	1,854.35	Zone - 1	0.14	1,927.66	73
PF-3	309,232.03	1,181,819.96	1,912.14	Zone - 1	0.06	1,928.38	16
PF-18	309,902.98	1,181,959.93	1,907.56	Zone - 1	0.11	1,928.16	21
PF-6	309,600.25	1,180,563.59	1,889.04	Zone - 1	0.07	1,927.39	38
NPF-21	309,729.69	1,180,666.50	1,849.17	Zone - 1	0.18	1,926.27	77
PF-15	310,432.28	1,180,985.09	1,853.14	Zone - 1	0.13	1,927.37	74
PF-7	309,644.96	1,181,437.46	1,848.25	Zone - 1	0.07	1,928.31	80
PF-1	309,388.07	1,180,963.81	1,883.45	Zone - 1	0.10	1,927.47	44
NPF-22	309,591.00	1,180,425.72	1,866.78	Zone - 1	0.14	1,927.00	60
J-130	309,102.28	1,180,703.17	1,846.36	Zone - 1	0.07	1,927.33	81
NPF-25	309,178.52	1,180,704.39	1,848.56	Zone - 1	0.08	1,927.14	78
PF-9	308,757.81	1,181,137.39	1,851.24	Zone - 1	0.07	1,927.44	76
J-136	308,845.36	1,180,870.72	1,852.25	Zone - 1	0.09	1,927.31	75
J-137	308,500.63	1,181,072.08	1,855.45	Zone - 1	0.11	1,927.49	72
J-139	309,357.26	1,180,521.12	1,846.26	Zone - 1	0.06	1,927.33	81
J-140	309,355.07	1,180,407.16	1,843.36	Zone - 1	0.05	1,927.32	84
J-141	309,189.97	1,180,407.89	1,838.68	Zone - 1	0.06	1,927.30	88
J-142	309,070.58	1,181,556.96	1,892.36	Zone - 1	0.07	1,928.06	36
J-143	309,482.94	1,181,619.75	1,894.00	Zone - 1	0.06	1,928.16	34
J-145	309,544.81	1,181,316.92	1,881.25	Zone - 1	0.07	1,927.88	47
J-146	309,774.79	1,181,345.42	1,874.50	Zone - 1	0.07	1,927.90	53

J-147	310,350.75	1,180,941.01	1,848.50	Zone - 1	0.09	1,927.67	79
J-148	309,988.69	1,180,935.18	1,861.36	Zone - 1	0.09	1,927.78	66
J-149	309,913.35	1,181,430.59	1,876.45	Zone - 1	0.07	1,927.93	51
J-150	309,522.16	1,180,287.44	1,842.15	Zone - 1	0.06	1,927.36	85
J-151	309,491.11	1,180,522.13	1,847.56	Zone - 1	0.10	1,927.38	80
J-152	309,086.65	1,179,996.66	1,826.25	Zone - 1	0.06	1,926.97	101
J-153	309,238.25	1,180,041.25	1,831.45	Zone - 1	0.06	1,926.97	95
J-154	309,076.25	1,180,939.66	1,858.25	Zone - 1	0.09	1,927.39	69
J-155	309,795.41	1,181,423.82	1,879.00	Zone - 1	0.06	1,927.94	49
J-156	309,521.61	1,181,495.90	1,837.45	Zone - 1	0.07	1,928.53	91
J-157	309,745.16	1,181,534.62	1,837.25	Zone - 1	0.08	1,928.40	91
J-158	309,744.87	1,181,635.88	1,888.46	Zone - 1	0.05	1,928.40	40
J-159	309,605.57	1,180,805.36	1,858.36	Zone - 1	0.06	1,927.53	69
J-160	309,034.74	1,180,502.36	1,837.69	Zone - 1	0.10	1,927.31	89
J-161	309,172.82	1,180,374.51	1,837.45	Zone - 1	0.09	1,927.29	90
J-162	309,305.85	1,180,280.02	1,837.45	Zone - 1	0.07	1,927.30	90
J-163	309,302.93	1,180,407.14	1,841.12	Zone - 1	0.06	1,927.30	86
J-164	309,354.06	1,180,474.35	1,845.36	Zone - 1	0.08	1,927.32	82
J-165	308,753.13	1,180,757.12	1,847.68	Zone - 1	0.09	1,927.25	79
J-166	308,789.66	1,180,792.50	1,848.26	Zone - 1	0.08	1,927.25	79
J-167	308,746.28	1,180,835.88	1,848.56	Zone - 1	0.12	1,927.25	79
J-168	309,921.84	1,181,371.25	1,874.12	Zone - 1	0.08	1,927.90	54
J-169	309,307.23	1,180,250.96	1,836.25	Zone - 1	0.07	1,927.29	91
J-170	309,374.44	1,180,253.88	1,838.15	Zone - 1	0.09	1,927.29	89
J-171	309,378.83	1,180,169.13	1,836.45	Zone - 1	0.13	1,927.29	91
J-172	309,229.79	1,180,169.86	1,833.14	Zone - 1	0.05	1,927.29	94
J-173	309,231.25	1,180,258.99	1,835.00	Zone - 1	0.03	1,927.29	92
J-174	308,692.52	1,181,172.31	1,868.02	Zone - 1	0.41	1,927.53	59
J-175	308,800.96	1,181,364.08	1,882.15	Zone - 1	0.14	1,927.53	45
J-176	308,919.67	1,181,252.22	1,874.15	Zone - 1	0.14	1,927.54	53
J-177	309,242.99	1,181,356.18	1,881.15	Zone - 1	0.10	1,927.63	46
J-178	309,261.54	1,181,059.39	1,867.50	Zone - 1	0.11	1,927.62	60
J-179	309,545.49	1,181,066.53	1,868.42	Zone - 1	0.10	1,927.63	59
J-183	309,836.19	1,181,001.83	1,864.00	Zone - 1	0.09	1,927.69	64
J-184	309,697.50	1,181,003.26	1,866.00	Zone - 1	0.11	1,927.65	62
J-186	309,699.21	1,180,928.98	1,868.46	Zone - 1	0.11	1,927.65	59
J-187	309,197.50	1,180,869.86	1,857.46	Zone - 1	0.07	1,927.38	70
J-188	309,201.15	1,180,758.81	1,854.00	Zone - 1	0.14	1,927.34	73
J-189	309,098.87	1,180,758.08	1,852.26	Zone - 1	0.08	1,927.34	75
J-190	308,907.19	1,180,871.00	1,853.23	Zone - 1	0.12	1,927.33	74
J-191	308,915.96	1,180,755.87	1,847.56	Zone - 1	0.07	1,927.34	80
J-192	308,942.22	1,181,245.26	1,873.24	Zone - 1	0.09	1,927.54	54
J-193	308,964.20	1,181,121.82	1,867.36	Zone - 1	0.05	1,927.52	60
J-194	308,898.59	1,181,360.77	1,882.11	Zone - 1	0.06	1,927.63	45
J-195	308,989.91	1,181,479.12	1,887.14	Zone - 1	0.10	1,927.70	40

J-196	309,792.34	1,182,301.42	1,912.31	Zone - 1	0.01	1,928.29	16
J-197	310,063.56	1,182,330.65	1,895.12	Zone - 1	0.07	1,928.27	33
J-198	308,572.02	1,181,030.89	1,855.15	Zone - 1	0.06	1,927.49	72
J-199	308,698.73	1,181,041.16	1,860.00	Zone - 1	0.08	1,927.49	67
J-200	308,799.18	1,181,068.56	1,863.28	Zone - 1	0.09	1,927.49	64
J-201	308,938.44	1,180,936.15	1,857.50	Zone - 1	0.11	1,927.39	70
J-202	309,822.68	1,180,807.84	1,858.15	Zone - 1	0.11	1,927.46	69
J-203	309,832.67	1,180,522.47	1,848.25	Zone - 1	0.14	1,927.44	79
J-204	309,188.74	1,181,691.31	1,901.00	Zone - 1	0.07	1,928.49	27

AppendixC

Pipe result; during peak demand time

Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)	HLG (m/km)	remark
P-1	367	350	PVC	150	141.1	1.47	4.402	Existing line
P-3	145	50	PVC	150	-2.23	1.13	26.521	Existing line
P-4	289	80	PVC	150	-3.53	0.70	6.294	Existing line
P-5	88	200	PVC	150	-4.52	0.14	0.114	Existing line
P-7	145	200	PVC	150	-5.38	0.17	0.159	Existing line
P-8	25	80	PVC	150	-15.55	3.09	98.138	Existing line
P-11	143	50	PVC	150	1.08	0.55	6.910	Existing line
P-14	188	80	PVC	150	-4.66	0.93	10.538	Existing line
P-15	108	80	PVC	150	-3.50	0.70	6.215	Existing line
P-16	140	80	PVC	150	-4.98	0.99	11.926	Existing line
P-17	265	80	PVC	150	-8.62	1.71	32.897	Existing line
P-18	63	50	PVC	150	2.18	1.11	25.476	Existing line
P-19	137	50	PVC	150	0.97	0.49	5.643	Existing line
P-20	119	80	GI	120	-5.51	1.10	21.757	Existing line
P-25	218	80	GI	120	1.99	0.40	3.302	Existing line
P-27	173	50	PVC	150	0.97	0.49	5.686	Existing line
P-28	74	50	GI	120	2.80	1.42	61.124	Existing line
P-29	143	50	GI	120	-0.31	0.16	1.019	Existing line
P-32	43	50	HDPE	130	-3.50	1.78	79.694	Expansion line
P-35	148	50	PVC	150	0.61	0.31	2.397	Existing line
P-36	76	50	PVC	150	1.05	0.53	6.586	Existing line
P-37	192	50	PVC	150	0.09	0.04	0.064	Existing line
P-38	305	50	PVC	150	-2.01	1.02	21.966	Existing line
P-41	39	80	PVC	150	2.51	0.50	3.344	Existing line
P-43	115	50	GI	120	2.28	1.16	41.872	Existing line
P-44	112	50	GI	120	3.91	1.99	113.580	Existing line
P-51	160	100	PVC	150	10.22	1.30	15.209	Existing line
P-52	139	50	PVC	150	0.97	0.49	5.632	Existing line
P-53	325	50	PVC	150	1.95	0.99	20.749	Existing line
P-54	231	50	GI	120	-0.22	0.11	0.539	Existing line

P-55	134	50	PVC	150	-1.30	0.66	9.744	Existing line
P-56	236	50	PVC	150	1.54	0.78	13.366	Existing line
P-57	356	80	PVC	150	-4.24	0.84	8.832	Existing line
P-58	188	50	PVC	150	4.57	2.33	100.495	Existing line
P-59	195	100	PVC	150	-10.18	1.30	15.105	Existing line
P-61	171	50	PVC	150	0.72	0.36	3.234	Existing line
P-62	138	80	PVC	150	-4.30	0.85	9.064	Existing line
P-64	53	80	PVC	150	-2.77	0.55	4.026	Existing line
P-67	45	150	DCI	130	-16.92	0.96	6.999	Existing line
P-68	96	150	DCI	130	-17.55	0.99	7.493	Existing line
P-72	468	150	PVC	150	-23.12	1.31	9.580	Existing line
P-73	100	50	PVC	150	1.84	0.93	18.517	Existing line
P-74	113	50	PVC	150	0.96	0.49	5.608	Existing line
P-75	248	50	GI	120	1.68	0.86	23.856	Existing line
P-77	256	80	PVC	150	-11.40	2.27	55.282	Existing line
P-78	239	100	PVC	150	-7.13	0.91	7.817	Existing line
P-79	304	100	PVC	150	-7.81	0.99	9.244	Existing line
P-80	321	150	DCI	130	10.25	0.58	2.768	Existing line
P-82	214	50	PVC	150	0.27	0.14	0.535	Existing line
P-83	198	50	PVC	150	0.66	0.33	2.751	Existing line
P-86	96	50	PVC	150	3.58	1.82	63.764	Existing line
P-87	98	50	PVC	150	1.28	0.65	9.497	Existing line
P-88	425	50	GI	120	-1.38	0.70	16.599	Expansion line
P-90	168	50	HDPE	130	-0.55	0.28	2.588	Expansion line
P-92	31	50	HDPE	130	-0.17	0.09	0.299	Expansion line
P-93	510	50	HDPE	130	0.31	0.16	0.870	Expansion line
P-94	385	50	HDPE	130	-1.07	0.55	8.896	Expansion line
P-96	531	50	PVC	150	0.17	0.09	0.234	Existing line
P-97	299	50	PVC	150	-0.24	0.12	0.416	Existing line
P-99	124	200	PVC	150	-68.30	2.17	17.537	Existing line
P-101	216	200	PVC	150	-59.94	1.91	13.770	Existing line
P-102	443	200	PVC	150	-63.57	2.02	15.353	Existing line
P-103	216	80	GI	120	4.32	0.86	13.851	Existing line
P-104	192	80	PVC	150	4.84	0.96	11.287	Existing line
P-107	141	80	PVC	150	3.30	0.66	5.572	Existing line
P-108	516	200	PVC	150	-55.53	1.77	11.952	Existing line
P-109	218	50	PVC	150	4.54	2.31	99.007	Existing line
P-110	250	100	HDPE	130	-6.82	0.87	9.378	Expansion line
P-112	150	50	GI	120	1.05	0.53	9.916	Existing line
P-113	212	50	GI	120	1.10	0.56	10.933	Existing line
P-114	159	80	HDPE	130	0.20	0.04	0.041	Expansion line
P-120	140	100	PVC	150	-5.08	0.65	4.173	Existing line
P-121	97	100	HDPE	130	-5.59	0.71	6.494	Expansion line
P-123	358	50	GI	120	0.09	0.04	0.098	Existing line
P-124	95	50	GI	120	-0.62	0.32	3.784	Existing line

P-125	98	50	HDPE	130	0.66	0.34	3.675	Expansion line
P-126	967	100	PVC	150	-7.04	0.90	7.624	Existing line
P-129	283	200	PVC	150	1.33	0.04	0.012	Existing line
P-131	354	80	HDPE	130	-11.95	2.38	78.586	Expansion line
P-132	410	80	HDPE	130	4.45	0.88	12.604	Expansion line
P-133	144	80	HDPE	130	1.14	0.23	1.010	Expansion line
P-134	69	80	HDPE	130	3.02	0.60	6.164	Expansion line
P-135	65	50	GI	120	-0.84	0.43	6.513	Existing line
P-136	151	50	HDPE	130	1.13	0.57	9.805	Expansion line
P-137	243	80	HDPE	130	1.09	0.22	0.940	Expansion line
P-138	181	80	HDPE	130	-2.83	0.56	5.438	Expansion line
P-139	149	50	PVC	150	-1.86	0.95	19.066	Existing line
P-140	176	150	DCI	130	-3.49	0.20	0.376	Existing line
P-141	364	150	PVC	150	37.64	2.13	23.623	Existing line
P-142	44	50	PVC	150	1.03	0.53	6.371	Existing line
P-143	322	250	PVC	150	45.22	0.92	2.756	Existing line
P-148	108	25	GI	120	1.09	2.22	312.957	Existing line
P-149	23	25	GI	120	0.26	0.53	21.859	Existing line
P-150	198	25	GI	120	0.54	1.10	85.438	Existing line
P-151	141	25	GI	120	0.47	0.96	65.793	Existing line
P-155	135	25	GI	120	-0.17	0.34	9.863	Existing line
P-159	190	25	GI	120	0.88	1.80	211.544	Existing line
P-160	144	100	HDPE	130	-5.77	0.73	6.875	Expansion line
P-161	79	50	PVC	150	0.52	0.27	1.818	Existing line
P-162	283	25	GI	120	0.05	0.11	1.185	Existing line
P-163	177	25	GI	120	0.73	1.49	148.409	Existing line
P-165	79	25	GI	120	0.41	0.84	51.790	Existing line
P-166	217	25	GI	120	0.47	0.96	65.793	Existing line
P-167	48	25	GI	120	0.53	1.07	81.322	Existing line
P-168	150	80	HDPE	130	1.80	0.36	2.360	Expansion line
P-169	79	50	HDPE	130	-0.89	0.45	6.362	Expansion line
P-170	61	25	GI	120	0.63	1.28	113.035	Existing line
P-171	44	25	GI	120	0.86	1.75	200.313	Existing line
P-172	81	25	GI	120	0.37	0.75	42.306	Existing line
P-173	68	25	GI	120	0.71	1.45	142.029	Existing line
P-174	35	25	GI	120	0.47	0.96	65.792	Existing line
P-175	107	25	GI	120	1.16	2.36	348.649	Existing line
P-176	42	25	GI	120	0.81	1.65	181.038	Existing line
P-177	117	50	HDPE	130	2.45	1.25	41.286	Expansion line
P-178	32	25	GI	120	0.45	0.91	60.007	Existing line
P-179	32	25	GI	120	0.66	1.35	123.672	Existing line
P-180	190	80	HDPE	130	-4.01	0.80	10.407	Expansion line
P-181	62	25	GI	120	0.89	1.81	212.809	Existing line
P-182	120	80	PVC	150	-2.76	0.55	3.997	Existing line
P-184	76	25	GI	120	0.50	1.02	73.369	Existing line

P-185	40	25	GI	120	0.45	0.92	60.716	Existing line
P-190	367	150	DCI	130	32.49	1.84	23.448	Existing line
P-191	23	150	PVC	150	35.50	2.01	21.194	Existing line
P-192	22	150	PVC	150	5.62	0.32	0.700	Existing line
P-193	142	80	HDPE	130	-3.66	0.73	8.804	Expansion line
P-194	116	80	HDPE	130	-2.83	0.56	5.451	Expansion line
P-195	104	100	HDPE	130	-9.63	1.23	17.782	Expansion line
P-196	243	100	PVC	150	-4.77	0.61	3.709	Existing line
P-197	21	200	PVC	150	75.34	2.40	21.032	Existing line
P-217	95	50	PVC	150	1.05	0.54	6.596	Existing line
P-225	44	80	HDPE	130	2.47	0.49	4.254	Expansion line
P-226	54	50	PVC	150	2.82	1.44	41.116	Existing line
P-227	12	50	PVC	150	2.82	1.44	41.115	Existing line
P-228	113	25	GI	120	-0.41	0.84	51.790	Existing line
P-229	179	80	HDPE	130	-3.58	0.71	8.441	Expansion line
P-230	175	50	PVC	150	1.21	0.62	8.599	Existing line
P-232	98	50	PVC	150	-0.85	0.43	4.418	Existing line
P-234	19	80	HDPE	130	2.63	0.52	4.772	Expansion line
P-235	72	80	HDPE	130	2.63	0.52	4.773	Expansion line
P-236	110	80	PVC	150	-2.47	0.49	3.241	Existing line
P-238	289	80	HDPE	130	4.25	0.85	11.605	Expansion line
P-241	125	50	HDPE	130	0.53	0.27	2.426	Expansion line
P-243	74	80	PVC	150	-3.48	0.69	6.149	Existing line
P-245	99	80	GI	120	-12.79	2.54	103.365	Existing line
P-246	116	80	GI	120	-12.41	2.47	97.780	Existing line
P-247	114	50	GI	120	3.99	2.03	118.104	Existing line
P-248	238	50	GI	120	2.78	1.42	60.513	Existing line
P-249	417	50	GI	120	-0.82	0.42	6.332	Expansion line
P-252	73	80	HDPE	130	5.45	1.08	18.369	Expansion line
P-254	232	50	HDPE	130	-0.44	0.23	1.747	Expansion line
P-255	263	50	HDPE	130	-0.48	0.25	2.027	Expansion line
P-256	83	100	PVC	150	11.87	1.51	20.087	Existing line
P-257	245	80	HDPE	130	-5.18	1.03	16.693	Expansion line
P-258	220	50	PVC	150	2.56	1.30	34.212	Existing line
P-260	228	150	PVC	150	20.67	1.17	7.782	Existing line
P-261	29	150	PVC	150	20.67	1.17	7.781	Existing line
P-262	140	50	GI	120	-1.64	0.83	22.698	Existing line
P-263	105	50	GI	120	1.23	0.63	13.375	Existing line
P-265	75	80	HDPE	130	-3.20	0.64	6.852	Expansion line
P-267	164	100	PVC	150	-7.79	0.99	9.203	Existing line
P-268	150	100	PVC	150	-8.19	1.04	10.100	Existing line
P-269	134	80	PVC	150	-4.62	0.92	10.361	Existing line
P-270	151	80	PVC	150	-5.22	1.04	13.024	Existing line
P-272	171	50	GI	120	-1.25	0.64	13.844	Existing line
P-273	113	50	GI	120	-1.43	0.73	17.613	Existing line

P-274	252	50	GI	120	1.97	1.00	31.982	Existing line
P-275	170	50	GI	120	1.39	0.71	16.819	Existing line
P-276	158	50	GI	120	-0.18	0.09	0.388	Existing line
P-278	93	50	HDPE	130	-1.64	0.83	19.487	Expansion line
P-279	95	80	HDPE	130	5.58	1.11	19.155	Expansion line
P-280	69	150	PVC	150	7.56	0.43	1.208	Existing line
P-282	41	150	PVC	150	0.92	0.05	0.022	Existing line
P-283	42	50	PVC	150	0.85	0.43	4.462	Existing line
P-284	37	80	HDPE	130	2.83	0.56	5.470	Expansion line
P-286	37	25	GI	120	0.62	1.27	110.207	Existing line
P-287	43	80	HDPE	130	1.83	0.36	2.420	Expansion line
P-288	75	80	HDPE	130	1.83	0.36	2.422	Expansion line
P-289	242	200	PVC	150	11.71	0.37	0.669	Existing line
P-290	108	200	PVC	150	5.15	0.16	0.146	Existing line
P-291	227	80	PVC	150	6.10	1.21	17.340	Existing line
P-292	118	50	PVC	150	4.91	2.50	114.678	Existing line
P-293	139	25	GI	120	0.30	0.62	29.471	Existing line
P-294	96	25	GI	120	0.66	1.35	123.461	Existing line
P-295	115	80	HDPE	130	-0.69	0.14	0.401	Expansion line
P-296	144	150	DCI	130	-19.49	1.10	9.096	Existing line
P-297	114	150	DCI	130	-20.89	1.18	10.343	Existing line
P-299	110	80	PVC	150	1.99	0.40	2.171	Existing line
P-300	63	80	PVC	150	-4.15	0.83	8.519	Existing line
P-301	38	80	PVC	150	-4.16	0.83	8.552	Existing line
P-302	188	50	HDPE	130	0.58	0.29	2.823	Expansion line
P-303	170	100	PVC	150	-4.99	0.64	4.038	Existing line
P-304	53	100	PVC	150	-6.08	0.77	5.812	Existing line
P-305	52	80	HDPE	130	3.14	0.62	6.601	Expansion line
P-306	113	80	HDPE	130	1.06	0.21	0.881	Expansion line
P-307	127	80	HDPE	130	-1.69	0.34	2.098	Expansion line
P-308	47	100	HDPE	130	6.01	0.77	7.419	Expansion line
P-309	67	100	HDPE	130	3.98	0.51	3.462	Expansion line
P-310	130	80	HDPE	130	-1.51	0.30	1.705	Expansion line
P-311	380	50	PVC	150	0.78	0.40	3.821	Existing line
P-312	51	50	PVC	150	0.21	0.11	0.342	Existing line
P-313	61	50	PVC	150	-0.26	0.13	0.507	Existing line
P-314	115	50	PVC	150	-1.00	0.51	5.967	Existing line
P-315	441	80	HDPE	130	-3.43	0.68	7.796	Expansion line
P-316	60	80	HDPE	130	-4.59	0.91	13.371	Expansion line
P-317	149	80	HDPE	130	-0.68	0.14	0.395	Expansion line
P-318	29	80	HDPE	130	2.35	0.47	3.867	Expansion line
P-319	67	80	HDPE	130	1.09	0.22	0.936	Expansion line
P-320	85	80	HDPE	130	0.50	0.10	0.217	Expansion line
P-321	149	80	HDPE	130	-0.30	0.06	0.087	Expansion line
P-322	89	80	HDPE	130	-0.62	0.12	0.329	Expansion line

P-323	76	80	HDPE	130	-0.79	0.16	0.512	Expansion line
P-324	105	80	HDPE	130	-2.46	0.49	4.202	Expansion line
P-325	95	100	PVC	150	-2.35	0.30	1.002	Existing line
P-326	230	100	PVC	150	-0.52	0.07	0.060	Existing line
P-327	55	100	PVC	150	11.22	1.43	18.091	Existing line
P-328	145	100	PVC	150	5.29	0.67	4.492	Existing line
P-329	168	80	PVC	150	-1.43	0.28	1.178	Existing line
P-330	267	150	PVC	150	12.03	0.68	2.855	Existing line
P-331	148	150	PVC	150	10.96	0.62	2.404	Existing line
P-332	297	50	PVC	150	0.43	0.22	1.254	Existing line
P-333	101	50	GI	130	0.51	0.26	2.252	Existing line
P-334	140	50	GI	120	0.00	0.00	0.000	Existing line
P-335	284	50	GI	120	-0.24	0.12	0.665	Existing line
P-341	349	80	HDPE	130	5.22	1.04	16.960	Expansion line
P-342	72	80	HDPE	130	3.68	0.73	8.866	Expansion line
P-343	139	50	HDPE	130	0.99	0.51	7.740	Expansion line
P-344	223	50	GI	120	0.35	0.18	1.287	Existing line
P-346	150	100	PVC	150	4.19	0.53	2.921	Existing line
P-347	139	100	PVC	150	3.47	0.44	2.064	Existing line
P-348	74	50	GI	120	-0.03	0.02	0.014	Existing line
P-349	104	50	GI	120	0.43	0.22	1.928	Existing line
P-350	117	50	GI	120	-1.22	0.62	13.211	Existing line
P-351	111	50	GI	120	1.19	0.61	12.581	Existing line
P-352	55	80	HDPE	130	-3.72	0.74	9.067	Expansion line
P-353	113	80	HDPE	130	-4.90	0.97	15.073	Expansion line
P-354	102	50	HDPE	130	0.32	0.16	0.963	Expansion line
P-355	62	50	HDPE	130	-1.09	0.56	9.195	Expansion line
P-356	165	50	HDPE	130	-1.29	0.66	12.525	Expansion line
P-357	115	50	PVC	150	-0.55	0.28	2.017	Existing line
P-358	183	80	PVC	150	-1.02	0.20	0.631	Existing line
P-359	24	100	PVC	150	3.60	0.46	2.201	Existing line
P-360	128	80	HDPE	130	3.00	0.60	6.085	Expansion line
P-361	172	80	HDPE	130	1.14	0.23	1.016	Expansion line
P-362	108	80	PVC	150	-5.39	1.07	13.799	Existing line
P-363	137	80	PVC	150	-0.76	0.15	0.365	Existing line
P-364	101	150	DCI	130	10.07	0.57	2.678	Existing line
P-365	140	150	DCI	130	4.43	0.25	0.585	Existing line
P-366	149	80	PVC	150	-5.02	1.00	12.075	Existing line
P-367	211	80	HDPE	130	3.41	0.68	7.686	Expansion line
P-368	116	80	HDPE	130	2.82	0.56	5.430	Expansion line
P-369	147	50	HDPE	130	-0.27	0.14	0.718	Expansion line
P-370	292	50	HDPE	130	-0.17	0.09	0.298	Expansion line
P-371	273	50	HDPE	130	0.53	0.27	2.382	Expansion line
P-372	82	80	HDPE	130	0.22	0.04	0.047	Expansion line
P-373	155	80	HDPE	130	-0.17	0.03	0.031	Expansion line

P-374	68	50	GI	120	1.14	0.58	11.676	Existing line
P-375	134	50	GI	120	-0.12	0.06	0.170	Existing line
P-376	122	80	HDPE	130	-0.69	0.14	0.402	Expansion line
P-377	97	80	HDPE	130	0.09	0.02	0.009	Expansion line
P-378	97	150	PVC	150	0.92	0.05	0.024	Existing line
P-379	210	50	GI	120	1.52	0.78	19.846	Existing line
P-380	170	50	GI	120	0.19	0.10	30.683	Existing line
P-381	217	50	GI	120	-1.01	0.52	9.339	Existing line
P-382	216	50	GI	120	-0.03	0.02	0.013	Existing line
P-383	191	50	GI	120	-0.45	0.23	2.044	Existing line
P-384	286	50	GI	120	0.49	0.25	2.472	Existing line
P-385	136	150	DCI	130	-18.00	1.02	7.852	Existing line
P-386	282	150	DCI	130	-23.60	1.34	12.973	Existing line
P-387	162	150	DCI	130	-5.19	0.29	0.786	Existing line

AppendixD

Pipe result; during low demand time/night flow

Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)	HLG (m/km)	remark
P-1	367	350	PVC	150	22.62	0.24	0.148	Existing line
P-3	145	50	PVC	150	-0.36	0.18	0.887	Existing line
P-4	289	80	PVC	150	-0.56	0.11	0.209	Existing line
P-5	88	200	PVC	150	-0.72	0.02	0.005	Existing line
P-7	145	200	PVC	150	-0.85	0.03	0.005	Existing line
P-8	25	80	PVC	150	-2.48	0.49	3.263	Existing line
P-11	143	50	PVC	150	0.19	0.10	0.271	Existing line
P-14	188	80	PVC	150	-0.79	0.16	0.397	Existing line
P-15	108	80	PVC	150	-0.60	0.12	0.237	Existing line
P-16	140	80	PVC	150	-0.82	0.16	0.423	Existing line
P-17	265	80	PVC	150	-1.41	0.28	1.153	Existing line
P-18	63	50	PVC	150	0.34	0.18	0.835	Existing line
P-19	137	50	PVC	150	0.15	0.08	0.184	Existing line
P-20	119	80	GI	120	-0.88	0.17	0.726	Existing line
P-25	218	80	GI	120	0.28	0.06	0.088	Existing line
P-27	173	50	PVC	150	0.16	0.08	0.193	Existing line
P-28	74	50	GI	120	0.45	0.23	2.093	Existing line
P-29	143	50	GI	120	-0.04	0.02	0.027	Existing line
P-32	43	50	HDPE	130	-0.51	0.26	2.269	Expansion line
P-35	148	50	PVC	150	0.09	0.05	0.075	Existing line
P-36	76	50	PVC	150	0.16	0.08	0.205	Existing line
P-37	192	50	PVC	150	0.02	0.01	0.006	Existing line
P-38	305	50	PVC	150	-0.30	0.15	0.652	Existing line
P-41	39	80	PVC	150	0.39	0.08	0.111	Existing line
P-43	115	50	GI	120	0.36	0.19	1.402	Existing line

P-44	112	50	GI	120	0.63	0.32	3.821	Existing line
P-51	160	100	PVC	150	1.61	0.21	0.498	Existing line
P-52	139	50	PVC	150	0.15	0.08	0.185	Existing line
P-53	325	50	PVC	150	0.31	0.16	0.680	Existing line
P-54	231	50	GI	120	-0.03	0.02	0.018	Existing line
P-55	134	50	PVC	150	-0.20	0.10	0.319	Existing line
P-56	236	50	PVC	150	0.24	0.12	0.438	Existing line
P-57	356	80	PVC	150	-0.67	0.13	0.289	Existing line
P-58	188	50	PVC	150	0.72	0.37	3.293	Existing line
P-59	195	100	PVC	150	-1.61	0.20	0.495	Existing line
P-61	171	50	PVC	150	0.11	0.06	0.106	Existing line
P-62	138	80	PVC	150	-0.68	0.13	0.297	Existing line
P-64	53	80	PVC	150	-0.45	0.09	0.140	Existing line
P-67	45	150	DCI	130	-2.73	0.15	0.239	Existing line
P-68	96	150	DCI	130	-2.83	0.16	0.255	Existing line
P-72	468	150	PVC	150	-3.71	0.21	0.324	Existing line
P-73	100	50	PVC	150	0.29	0.15	0.624	Existing line
P-74	113	50	PVC	150	0.15	0.08	0.185	Existing line
P-75	248	50	GI	120	0.27	0.14	0.803	Existing line
P-77	256	80	PVC	150	-1.85	0.37	1.906	Existing line
P-78	239	100	PVC	150	-1.16	0.15	0.269	Existing line
P-79	304	100	PVC	150	-1.26	0.16	0.317	Existing line
P-80	321	150	DCI	130	1.65	0.09	0.095	Existing line
P-82	214	50	PVC	150	0.04	0.02	0.017	Existing line
P-83	198	50	PVC	150	0.10	0.05	0.090	Existing line
P-86	96	50	PVC	150	0.56	0.29	2.090	Existing line
P-87	98	50	PVC	150	0.20	0.10	0.310	Existing line
P-88	425	50	GI	120	-0.22	0.11	0.544	Expansion line
P-90	168	50	HDPE	130	-0.09	0.04	0.084	Expansion line
P-92	31	50	HDPE	130	-0.03	0.01	0.010	Expansion line
P-93	510	50	HDPE	130	0.05	0.02	0.028	Expansion line
P-94	385	50	HDPE	130	-0.17	0.09	0.292	Expansion line
P-96	531	50	PVC	150	0.03	0.01	0.008	Existing line
P-97	299	50	PVC	150	-0.04	0.02	0.014	Existing line
P-99	124	200	PVC	150	-10.91	0.35	0.586	Existing line
P-101	216	200	PVC	150	-9.59	0.31	0.462	Existing line
P-102	443	200	PVC	150	-10.16	0.32	0.515	Existing line
P-103	216	80	GI	120	0.70	0.14	0.470	Existing line
P-104	192	80	PVC	150	0.73	0.15	0.344	Existing line
P-107	141	80	PVC	150	0.52	0.10	0.183	Existing line
P-108	516	200	PVC	150	-8.86	0.28	0.400	Existing line
P-109	218	50	PVC	150	0.74	0.38	3.433	Existing line
P-110	250	100	HDPE	130	-1.14	0.14	0.340	Expansion line
P-112	150	50	GI	120	0.16	0.08	0.306	Existing line
P-113	212	50	GI	120	0.16	0.08	0.317	Existing line

P-114	159	80	HDPE	130	0.08	0.02	0.008	Expansion line
P-120	140	100	PVC	150	-0.82	0.10	0.142	Existing line
P-121	97	100	HDPE	130	-0.90	0.11	0.219	Expansion line
P-123	358	50	GI	120	0.03	0.02	0.017	Existing line
P-124	95	50	GI	120	-0.09	0.05	0.102	Existing line
P-125	98	50	HDPE	130	0.09	0.05	0.099	Expansion line
P-126	967	100	PVC	150	-1.13	0.14	0.259	Existing line
P-129	283	200	PVC	150	0.21	0.01	0.000	Existing line
P-131	354	80	HDPE	130	-1.94	0.39	2.707	Expansion line
P-132	410	80	HDPE	130	0.70	0.14	0.409	Expansion line
P-133	144	80	HDPE	130	0.16	0.03	0.027	Expansion line
P-134	69	80	HDPE	130	0.47	0.09	0.195	Expansion line
P-135	65	50	GI	120	-0.13	0.07	0.206	Existing line
P-136	151	50	HDPE	130	0.17	0.09	0.302	Expansion line
P-137	243	80	HDPE	130	0.15	0.03	0.023	Expansion line
P-138	181	80	HDPE	130	-0.45	0.09	0.185	Expansion line
P-139	149	50	PVC	150	-0.30	0.15	0.639	Existing line
P-140	176	150	DCI	130	-0.55	0.03	0.013	Existing line
P-141	364	150	PVC	150	6.01	0.34	0.790	Existing line
P-142	44	50	PVC	150	0.16	0.08	0.207	Existing line
P-143	322	250	PVC	150	7.30	0.15	0.094	Existing line
P-148	108	25	GI	120	0.17	0.35	10.254	Existing line
P-149	23	25	GI	120	0.04	0.08	0.717	Existing line
P-150	198	25	GI	120	0.09	0.17	2.800	Existing line
P-151	141	25	GI	120	0.07	0.15	2.156	Existing line
P-155	135	25	GI	120	-0.03	0.05	0.307	Existing line
P-159	190	25	GI	120	0.14	0.28	6.931	Existing line
P-160	144	100	HDPE	130	-1.00	0.13	0.269	Expansion line
P-161	79	50	PVC	150	0.08	0.04	0.062	Existing line
P-162	283	25	GI	120	0.01	0.02	0.059	Existing line
P-163	177	25	GI	120	0.12	0.23	4.863	Existing line
P-165	79	25	GI	120	0.07	0.13	1.696	Existing line
P-166	217	25	GI	120	0.07	0.15	2.156	Existing line
P-167	48	25	GI	120	0.08	0.17	2.666	Existing line
P-168	150	80	HDPE	130	0.28	0.05	0.073	Expansion line
P-169	79	50	HDPE	130	-0.14	0.07	0.198	Expansion line
P-170	61	25	GI	120	0.10	0.20	3.702	Existing line
P-171	44	25	GI	120	0.14	0.28	6.561	Existing line
P-172	81	25	GI	120	0.06	0.12	1.387	Existing line
P-173	68	25	GI	120	0.11	0.23	4.653	Existing line
P-174	35	25	GI	120	0.07	0.15	2.156	Existing line
P-175	107	25	GI	120	0.18	0.37	11.422	Existing line
P-176	42	25	GI	120	0.13	0.26	5.929	Existing line
P-177	117	50	HDPE	130	0.39	0.20	1.382	Expansion line
P-178	32	25	GI	120	0.07	0.14	1.968	Existing line

P-179	32	25	GI	120	0.10	0.21	4.051	Existing line
P-180	190	80	HDPE	130	-0.68	0.14	0.392	Expansion line
P-181	62	25	GI	120	0.14	0.29	6.972	Existing line
P-182	120	80	PVC	150	-0.39	0.08	0.105	Existing line
P-184	76	25	GI	120	0.08	0.16	2.405	Existing line
P-185	40	25	GI	120	0.07	0.14	1.989	Existing line
P-190	367	150	DCI	130	5.19	0.29	0.784	Existing line
P-191	23	150	PVC	150	5.69	0.32	0.711	Existing line
P-192	22	150	PVC	150	0.85	0.05	0.021	Existing line
P-193	142	80	HDPE	130	-0.58	0.12	0.288	Expansion line
P-194	116	80	HDPE	130	-0.45	0.09	0.180	Expansion line
P-195	104	100	HDPE	130	-1.54	0.20	0.599	Expansion line
P-196	243	100	PVC	150	-0.73	0.09	0.114	Existing line
P-197	21	200	PVC	150	12.02	0.38	0.704	Existing line
P-217	95	50	PVC	150	0.17	0.09	0.222	Existing line
P-225	44	80	HDPE	130	0.38	0.08	0.132	Expansion line
P-226	54	50	PVC	150	0.44	0.22	1.287	Existing line
P-227	12	50	PVC	150	0.44	0.22	1.297	Existing line
P-228	113	25	GI	120	-0.07	0.13	1.697	Existing line
P-229	179	80	HDPE	130	-0.54	0.11	0.258	Expansion line
P-230	175	50	PVC	150	0.18	0.09	0.262	Existing line
P-232	98	50	PVC	150	-0.13	0.07	0.137	Existing line
P-234	19	80	HDPE	130	0.40	0.08	0.149	Expansion line
P-235	72	80	HDPE	130	0.40	0.08	0.147	Expansion line
P-236	110	80	PVC	150	-0.42	0.08	0.120	Existing line
P-238	289	80	HDPE	130	0.70	0.14	0.405	Expansion line
P-241	125	50	HDPE	130	0.08	0.04	0.071	Expansion line
P-243	74	80	PVC	150	-0.54	0.11	0.193	Existing line
P-245	99	80	GI	120	-2.08	0.41	3.590	Existing line
P-246	116	80	GI	120	-2.02	0.40	3.385	Existing line
P-247	114	50	GI	120	0.65	0.33	4.068	Existing line
P-248	238	50	GI	120	0.45	0.23	2.085	Existing line
P-249	417	50	GI	120	-0.14	0.07	0.223	Expansion line
P-252	73	80	HDPE	130	0.88	0.18	0.631	Expansion line
P-254	232	50	HDPE	130	-0.07	0.04	0.057	Expansion line
P-255	263	50	HDPE	130	-0.08	0.04	0.066	Expansion line
P-256	83	100	PVC	150	1.87	0.24	0.659	Existing line
P-257	245	80	HDPE	130	-0.82	0.16	0.547	Expansion line
P-258	220	50	PVC	150	0.40	0.21	1.121	Existing line
P-260	228	150	PVC	150	3.26	0.18	0.255	Existing line
P-261	29	150	PVC	150	3.26	0.18	0.253	Existing line
P-262	140	50	GI	120	-0.28	0.14	0.851	Existing line
P-263	105	50	GI	120	0.19	0.09	0.402	Existing line
P-265	75	80	HDPE	130	-0.53	0.11	0.249	Expansion line
P-267	164	100	PVC	150	-1.27	0.16	0.318	Existing line

P-268	150	100	PVC	150	-1.33	0.17	0.348	Existing line
P-269	134	80	PVC	150	-0.76	0.15	0.364	Existing line
P-270	151	80	PVC	150	-0.85	0.17	0.453	Existing line
P-272	171	50	GI	120	-0.20	0.10	0.454	Existing line
P-273	113	50	GI	120	-0.23	0.11	0.576	Existing line
P-274	252	50	GI	120	0.31	0.16	1.048	Existing line
P-275	170	50	GI	120	0.22	0.11	0.550	Existing line
P-276	158	50	GI	120	-0.03	0.01	0.012	Existing line
P-278	93	50	HDPE	130	-0.26	0.13	0.628	Expansion line
P-279	95	80	HDPE	130	0.87	0.17	0.617	Expansion line
P-280	69	150	PVC	150	1.15	0.06	0.037	Existing line
P-282	41	150	PVC	150	0.11	0.01	0.000	Existing line
P-283	42	50	PVC	150	0.13	0.07	0.139	Existing line
P-284	37	80	HDPE	130	0.45	0.09	0.179	Expansion line
P-286	37	25	GI	120	0.10	0.20	3.608	Existing line
P-287	43	80	HDPE	130	0.29	0.06	0.076	Expansion line
P-288	75	80	HDPE	130	0.29	0.06	0.079	Expansion line
P-289	242	200	PVC	150	1.87	0.06	0.023	Existing line
P-290	108	200	PVC	150	0.82	0.03	0.004	Existing line
P-291	227	80	PVC	150	0.97	0.19	0.580	Existing line
P-292	118	50	PVC	150	0.79	0.40	3.857	Existing line
P-293	139	25	GI	120	0.05	0.10	0.986	Existing line
P-294	96	25	GI	120	0.11	0.21	4.098	Existing line
P-295	115	80	HDPE	130	-0.11	0.02	0.014	Expansion line
P-296	144	150	DCI	130	-3.14	0.18	0.310	Existing line
P-297	114	150	DCI	130	-3.36	0.19	0.350	Existing line
P-299	110	80	PVC	150	0.31	0.06	0.070	Existing line
P-300	63	80	PVC	150	-0.65	0.13	0.278	Existing line
P-301	38	80	PVC	150	-0.66	0.13	0.282	Existing line
P-302	188	50	HDPE	130	0.09	0.04	0.084	Expansion line
P-303	170	100	PVC	150	-0.81	0.10	0.139	Existing line
P-304	53	100	PVC	150	-0.99	0.13	0.203	Existing line
P-305	52	80	HDPE	130	0.50	0.10	0.220	Expansion line
P-306	113	80	HDPE	130	0.18	0.04	0.034	Expansion line
P-307	127	80	HDPE	130	-0.26	0.05	0.064	Expansion line
P-308	47	100	HDPE	130	0.97	0.12	0.254	Expansion line
P-309	67	100	HDPE	130	0.63	0.08	0.113	Expansion line
P-310	130	80	HDPE	130	-0.26	0.05	0.067	Expansion line
P-311	380	50	PVC	150	0.13	0.07	0.136	Existing line
P-312	51	50	PVC	150	0.04	0.02	0.015	Existing line
P-313	61	50	PVC	150	-0.04	0.02	0.012	Existing line
P-314	115	50	PVC	150	-0.15	0.08	0.183	Existing line
P-315	441	80	HDPE	130	-0.55	0.11	0.265	Expansion line
P-316	60	80	HDPE	130	-0.75	0.15	0.467	Expansion line
P-317	149	80	HDPE	130	-0.12	0.02	0.017	Expansion line

P-318	29	80	HDPE	130	0.37	0.07	0.128	Expansion line
P-319	67	80	HDPE	130	0.17	0.03	0.031	Expansion line
P-320	85	80	HDPE	130	0.08	0.02	0.007	Expansion line
P-321	149	80	HDPE	130	-0.05	0.01	0.003	Expansion line
P-322	89	80	HDPE	130	-0.10	0.02	0.012	Expansion line
P-323	76	80	HDPE	130	-0.12	0.02	0.016	Expansion line
P-324	105	80	HDPE	130	-0.29	0.06	0.081	Expansion line
P-325	95	100	PVC	150	-0.51	0.06	0.058	Existing line
P-326	230	100	PVC	150	-0.20	0.02	0.010	Existing line
P-327	55	100	PVC	150	1.90	0.24	0.676	Existing line
P-328	145	100	PVC	150	0.90	0.11	0.170	Existing line
P-329	168	80	PVC	150	-0.34	0.07	0.083	Existing line
P-330	267	150	PVC	150	2.00	0.11	0.102	Existing line
P-331	148	150	PVC	150	1.84	0.10	0.088	Existing line
P-332	297	50	PVC	150	0.05	0.03	0.028	Existing line
P-333	101	50	GI	130	0.07	0.04	0.060	Existing line
P-334	140	50	GI	120	-0.01	0.01	0.004	Existing line
P-335	284	50	GI	120	-0.05	0.03	0.037	Existing line
P-341	349	80	HDPE	130	0.86	0.17	0.604	Expansion line
P-342	72	80	HDPE	130	0.61	0.12	0.318	Expansion line
P-343	139	50	HDPE	130	0.17	0.08	0.282	Expansion line
P-344	223	50	GI	120	0.06	0.03	0.052	Existing line
P-346	150	100	PVC	150	0.71	0.09	0.109	Existing line
P-347	139	100	PVC	150	0.60	0.08	0.079	Existing line
P-348	74	50	GI	120	0.00	0.00	0.000	Existing line
P-349	104	50	GI	120	0.06	0.03	0.054	Existing line
P-350	117	50	GI	120	-0.19	0.10	0.426	Existing line
P-351	111	50	GI	120	0.18	0.09	0.384	Existing line
P-352	55	80	HDPE	130	-0.54	0.11	0.252	Expansion line
P-353	113	80	HDPE	130	-0.74	0.15	0.452	Expansion line
P-354	102	50	HDPE	130	0.04	0.02	0.025	Expansion line
P-355	62	50	HDPE	130	-0.17	0.09	0.301	Expansion line
P-356	165	50	HDPE	130	-0.20	0.10	0.389	Expansion line
P-357	115	50	PVC	150	-0.09	0.05	0.075	Existing line
P-358	183	80	PVC	150	-0.17	0.03	0.022	Existing line
P-359	24	100	PVC	150	0.52	0.07	0.063	Existing line
P-360	128	80	HDPE	130	0.42	0.08	0.161	Expansion line
P-361	172	80	HDPE	130	0.14	0.03	0.020	Expansion line
P-362	108	80	PVC	150	-0.87	0.17	0.473	Existing line
P-363	137	80	PVC	150	-0.11	0.02	0.010	Existing line
P-364	101	150	DCI	130	1.67	0.09	0.096	Existing line
P-365	140	150	DCI	130	0.74	0.04	0.022	Existing line
P-366	149	80	PVC	150	-0.83	0.16	0.427	Existing line
P-367	211	80	HDPE	130	0.54	0.11	0.254	Expansion line
P-368	116	80	HDPE	130	0.45	0.09	0.178	Expansion line

P-369	147	50	HDPE	130	-0.04	0.02	0.022	Expansion line
P-370	292	50	HDPE	130	-0.02	0.01	0.008	Expansion line
P-371	273	50	HDPE	130	0.08	0.04	0.080	Expansion line
P-372	82	80	HDPE	130	0.02	0.00	0.000	Expansion line
P-373	155	80	HDPE	130	-0.04	0.01	0.002	Expansion line
P-374	68	50	GI	120	0.18	0.09	0.375	Existing line
P-375	134	50	GI	120	-0.03	0.02	0.016	Existing line
P-376	122	80	HDPE	130	-0.12	0.02	0.016	Expansion line
P-377	97	80	HDPE	130	-0.02	0.00	0.000	Expansion line
P-378	97	150	PVC	150	0.11	0.01	0.000	Existing line
P-379	210	50	GI	120	0.23	0.12	0.611	Existing line
P-380	170	50	GI	12	0.03	0.02	1.034	Existing line
P-381	217	50	GI	120	-0.16	0.08	0.309	Existing line
P-382	216	50	GI	120	0.00	0.00	0.000	Existing line
P-383	191	50	GI	120	-0.07	0.03	0.058	Existing line
P-384	286	50	GI	120	0.08	0.04	0.083	Existing line
P-385	136	150	DCI	130	-2.92	0.17	0.271	Existing line
P-386	282	150	DCI	130	-3.83	0.22	0.447	Existing line
P-387	162	150	DCI	130	-0.84	0.05	0.027	Existing line

Appendix E

Assigned Base Water Demand to Each Supply Node by area proportional method

Label	Area(m2)	Demand(l/s)
J-1	166166	1.95
J-2	163075	1.91
J-3	94568	1.11
J-4	66827	0.78
J-5	89228	1.05
J-7	43791	0.51
J-8	76297	0.90
J-9	53489	0.63
J-10	133878	1.57
J-11	15830	0.19
J-12	24569	0.29
J-13	182221	2.14
J-14	190063	2.23
J-15	80206	0.94
J-16	82133	0.96
J-17	36727	0.43
J-18	114225	1.34
J-19	92766	1.09
J-20	45303	0.53

J-21	49759	0.58
J-22	39819	0.47
J-23	48524	0.57
J-24	19170	0.22
J-25	37712	0.44
J-26	47244	0.55
J-28	28901	0.34
J-29	101770	1.19
J-31	171452	2.01
J-32	161337	1.89
J-33	28887	0.34
J-34	31291	0.37
J-35	93174	1.09
J-37	29337	0.34
J-38	73214	0.86
J-39	3046	0.04
J-40	34857	0.41
J-41	16093	0.19
J-42	177074	2.08
J-46	45501	0.53
J-47	27516	0.32
J-48	17979	0.21
J-49	59374	0.70
J-50	88872	1.04
J-51	107899	1.27
J-52	14382	0.17
J-53	29597	0.35
J-54	44980	0.53
J-55	25187	0.30
J-56	35795	0.42
J-57	100976	1.18
J-58	84384	0.99
J-59	79833	0.94
J-60	39993	0.47
J-62	55228	0.65
J-63	95516	1.12
J-64	35643	0.42
J-67	67623	0.79
J-68	32539	0.38
J-69	21468	0.25
J-70	43841	0.51

J-71	62526	0.73
J-72	30301	0.36
J-73	21871	0.26
J-74	18586	0.22
J-75	35541	0.42
J-78	28901	0.34
J-79	21468	0.25
J-80	40235	0.47
J-81	17213	0.20
J-82	56058	0.66
J-83	23401	0.27
J-84	16596	0.19
J-85	95516	1.12
J-86	35643	0.42
J-87	67623	0.79
J-88	32539	0.38
J-89	21468	0.25
J-90	43841	0.51
J-91	62526	0.73
J-92	30301	0.36
J-93	21871	0.26
J-94	18586	0.22
J-95	35541	0.42
J-96	28901	0.34
J-97	21468	0.25
J-98	40235	0.47
J-99	17213	0.20
J-100	56058	0.66
J-101	23401	0.27
J-102	66827	0.78
PF-11	89228	1.05
PF-10	68813	0.81
PF-4	76297	0.90
PF-8	53489	0.63
PF-17	133878	1.57
NPF-19	15830	0.19
PF-14	24569	0.29
PF-2	182221	2.14
NPF-23	190063	2.23
NPF-20	80206	0.94
PF-12	82133	0.96

PF-13	36727	0.43
PF-5	114225	1.34
NPF-24	92766	1.09
PF-16	45303	0.53
PF-3	177074	2.08
PF-18	45501	0.53
PF-6	27516	0.32
NPF-21	17979	0.21
PF-15	59374	0.70
PF-7	88872	1.04
PF-1	107899	1.27
NPF-22	14382	0.17
J-130	29597	0.35
NPF-25	44980	0.53
PF-9	25187	0.30
J-136	35795	0.42
J-137	100976	1.18
J-139	84384	0.99
J-140	79833	0.94
J-141	39993	0.47
J-142	55228	0.65
J-143	95516	1.12
J-145	144555	1.70
J-146	14785	0.17
J-147	96125	1.13
J-148	85248	1.00
J-149	56285	0.66
J-150	25847	0.30
J-151	241472	2.83
J-152	25896	0.30
J-153	114225	1.34
J-154	92766	1.09
J-155	45303	0.53
J-156	177074	2.08
J-157	45501	0.53
J-158	100976	1.18
J-159	84384	0.99
J-160	79833	0.94
J-161	39993	0.47
J-162	55228	0.65
J-163	166166	1.95

J-164	163075	1.91
J-165	94568	1.11
J-166	66827	0.78
J-167	89228	1.05
J-168	68813	0.81
J-169	76297	0.90
J-170	53489	0.63
J-171	133878	1.57
J-172	15830	0.19
J-173	24569	0.29
J-174	182221	2.14
J-175	190063	2.23
J-176	80206	0.94
J-177	82133	0.96
J-178	36727	0.43
J-179	114225	1.34
J-183	145283	1.70
J-184	147892	1.74
J-186	177074	2.08
J-187	45501	0.53
J-188	27516	0.32
J-189	17979	0.21
J-190	59374	0.70
J-191	88872	1.04
J-192	107899	1.27
J-193	14382	0.17
J-194	29597	0.35
J-195	44980	0.53
J-196	25187	0.30
J-197	35795	0.42
J-198	100976	1.18
J-199	84384	0.99
J-200	79833	0.94
J-201	39993	0.47
J-202	69833	0.82
J-203	25837	0.30
J-204	24980	0.29