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ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

**EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA**

A Thesis Submitted And Presented To The School Of Graduate Studies Of Addis Ababa
University In Partial Fulfillment Of The Degree Of Master Of Science In Civil
Engineering. (Major In Water Supply And Environmental Engineering)

By

Geatachew Welay

Advisor: -

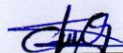


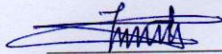
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This Thesis Entitled With “**Effect Of New Demand Centers In Water Supply Distribution System The Case Of Condominium Houses In Lideta Sub City Of Addis Ababa**” Is Approved By Advisor, Examiners, Chairman And School Of Civil And Environmental Engineering Of Addis Ababa University For Partial Fulfillment Of The Requirement For The Degree Of Master Of Science In Water Supply And Environmental Engineering At Addis Ababa Institute Of Technology University, Addis Ababa, Ethiopia.

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Declaration

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Dedication

I dedicate this work to:

The Almighty of GOD and for all my family.

Abstract

Problems in providing satisfactory water supply to the rapidly growing population especially that of the developing countries is increasing from time to time. The objective of this research was to assess the problem of Addis Ababa Lideta sub city water supply and distribution network system. This study assessed the hydraulic performance of Lideta sub city water supply distribution network system based on main performance indicators namely high-water loss, inadequate water supply coverage, satisfaction of customers and low operation and maintenance. Intermittent water distribution is the key problem of many water authorities in developing countries including Ethiopia. Hence, this research was conducted to carry out the hydraulic modeling of the lideta sub city water distribution system which is located in the center of Addis Ababa city of Ethiopia. The objectives of this research were to evaluate the hydraulic performance of the water supply distribution system by assessing the situation of the existing water supply distribution system. Water GEMS V8i software was used as a tool to model the water distribution system. The model can be used to identify the high pressure and low pressure in the junctions and the magnitude of velocity through pipes was used as a base to evaluate the hydraulic performance. Modeling results showed a violation of maximum and minimum pressure and low-velocity requirements. High pressures in the system occurred both during low demand and peak demand have to be identified. The simulation result of the existing system about 88.78% of the junctions was failed to satisfy the allowable pressure and the velocity of about 40.36% was failed out of range during the peak consumption hour. The model performance measures were checked based on the coefficient of determination. In general, it was concluded that the existing water distribution network systems of lideta sub city categorized under satisfactory hydraulic performance situation and were not supply adequate water to various demand categories of the town. In the modified system, the network runs hydraulic parameters are radically improved using the Pressure Reducer Valve added in the system to reduce high-pressure impacts as well as added new water sources wells around the area on water distribution system. The results of the simulation show that the hydraulic simulation about 53.4% of pipes of diameter from the total water distribution system pipe diameters needed to be upgraded.

Key words: New Water Demand Centers, Water Supply Distribution Network, Water GEMS V8i Model, Population Densification, Condominium Houses & Hydraulic Performance.

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Abbreviation Word

AA = Addis Ababa

AABFED = Addis Ababa Bureau of Finance and Economic Develop

AAWSA = Addis Ababa Water and Sewerage Authority

ADD = Average Daily Demand

AGR = Average Growth Rate

BWG = Bentley Water Gems

CAD = Computer Aided Design

CSA = Central Statistical Agency

DCI = Ductile Iron

Dia. = Diameter

DWD = domestic Water Demand

E.C = Ethiopian Calander

EPS = Extended Period Simulation

ETB = Ethiopian Birr

G.C = Gregorian Calander

GI = Galvanized Iron

GIS = Geographical Information System

GM = Global Map

GPS = Geographical Position System

GUIS = Geographical User Inter Faces

GV = Gate Valve

GW = Ground Water

IHDP = International Housing Development Prograded

IWA = International Water Association

L/S = Liter Per Second

LPCD = Liter Per Capita Demand

LSC = Lideta Sub City

LUM = Land Use Map
M/S = Meter Per Second
 M^3/D = Meter Cubic Per Day
MDD = Maximum Daily Demand
MM = Milli Meter
NMA = National Meteorological Agency
NRW = Non-Revenue Water
NWD = Non-Domestic Water Demand
PHD = Peak Hourly Demand
Pr. = Pressure
PRV = Pressure Reducing Valve
PVC = Polyvinyl Chloride
Rel.Hum = Relative Humidity
RF = Rain Fall
SI = System International
Sq. Km = Square Killo Meter
SSS = Steady State Simulation
UTC+3 = East Africa Time
W = Woreda
WDM = Water Distribution Model
WDN = Water Distribution Network
WHO = World Health Organization
WS = Water Supply
WSEE = Water Supply and Environmental Engineering
Yrs. = Years

CHAPTER ONE

1 INTRODUCTION

1.1 Back Ground

Densification, that is building the city inwardly, is then seen as a strategy for building housing while combatting the tendency for cities to spread out and claim valuable land. Increased density is said to lead to reduced emissions through shorter travel routes and opportunities to provide good public transport, which thus promotes sustainable development. Urban densification is one of a sustainable expansion of urban policy. A compact city policy in contrast should be regeneration and densification of the urban area create the opposite, thus contributing to a more sustainable development in its broadest sense, social, economic and environmental (Vaglio 2019a). This paper explores the implications of urban densification in lideta sub city in the case of water supply distribution system. The Integrated Housing Development Programmed (IHDP) in 2006 to minimize housing backlog, slums, and to provide decent shelter to middle- and low-income groups. (AAHDA, 2015)

Lideta is one of ten sub cities of Addis Ababa. It has a total population of 201,713 (CSA 2012). It is situated at the center of Addis Ababa and bounded by Addis Ketema sub city in the North, Nifas Silk-Lafto sub city in the South, Kirkos sub city in the East and Kolfe Keranio sub city in the West (TSION GETACHEW, 2016). Lideta condominium site is the first inner-city relocation project in Addis Ababa. It is the first of the five occupied sites to be re-developed by the IHDP program. It is, therefore, a pilot project for inner city redevelopment based on the resettlement of a significant proportion of the population. On such a central site as Lideta it was deemed important to maximize the value of the land and therefore condominium blocks had to be at least seven floor high (UN-habitat, 2011). Currently large number of condominium housing units have been constructed and transferred to beneficiaries in Addis Ababa city alone (Nigist Goytom, 2015). According to Addis Ababa housing construction project office, it has launched around 182,277 grand low-cost condominium housing projects yet at different sites of the city. In Lideta sub city specifically in the study area there are 65 condominium blocks constructed since 2003 E.C until now. The topology of the condominium houses constructed at the site are G^{+4} G^{+7} and G^{+12} . (TSION GETACHEW, 2016).

Most of the people living in the city's numerous condominium housing developments are experiencing similar problems. Residents, particularly those living on the above of the third floors do not have regular access of water, and sometimes they have to wait for as long as two weeks for water to come. Residents in these condominiums have an improved lifestyle that requires access to uninterrupted water supply every day. Lideta rehabilitation condominium site is differing from the other condominium site of Addis Ababa because it is the inner site of the city. So, because of this Addis Ababa water and sewerage authority cannot be study properly the water demand of in such case in the water supply distribution system(Dechassa 2015).

Provision of adequate water supply and sewerage service to the people of Addis Ababa is the responsibility of Addis Ababa Water and Sewerage Authority (AAWSA). The Addis Ababa Water & Sewerage Authority has established water supply flow rate criteria per capita per day. The domestic water demand for new housing developments is considered under the category House connections so, AAWSA is utilized 110 l/c/day including losses as standard to satisfy the needs of its customers. (AAWSA-PO, 2014)Therefore, this study analysis the water demand before, current and after the rehabilitation of condominium in Lideta and simulate a water supply distribution network on all cases.

1.2 Statement of problems

Water managers in large cities in developing countries experience great difficulties in providing proper water supply and sanitation services in a context of rapidly growing population with changing water use patterns, structural lack of capacity and resources. The results show that the Urbanization effect on changing land use rapidly and increases water consumption. The trend of the water consumption rate in lideta sub city increases at a high rate. Hence at this rate to get adequate water supply with enough pressure to the above G⁺³ floor is difficult.

Projections of water demand in Addis Ababa under various future scenarios have shown that there will be growing mismatch between water demand and water supply of due to densification. Despite the attempt of attaining safe water coverage, water cuts, lack of adequate water supplies have forced many people to complain in water shortage or demand fluctuation

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in most areas of Addis Ababa, particularly on those newly allocated condominium housings Lideta sub city is one of them. Residents, particularly those living on the above of the third floors do not have regular adequate access of water, and sometimes they have been to wait for as long as two weeks for water to come.

This problem is due to the low supplying of water, low pressure head, low velocity, variety of size of pipes and high amount of water losses. But they are expected to have an improved lifestyle that requires access to uninterrupted water supply every day at the condominium houses area.

In general, the gap between water demand and water supply in these new demand centers are widening instead of coming close due to several factors while infrastructures for condominium housing development are not effectively considered with that of basic service such as the provision of drinking water supply. As we showing in the figure bellow the difference before urbanize and now in Lideta sub city is like to.



Figure 1: 1 Representing of Urbanization in Lideta Sub City, Addis Ababa

1.3 Objective of the research

1.3.1 Main Objective

This study aims to follow Assessment approaches that investigate the gap between before and after densification regarding to effects new demand centers of water in the case of Lideta rehabilitation condominium and address possible mitigation measures.

1.3.2 Specific Objectives

To come up with the main objective, the project in parallel will satisfy the following specific objectives:

- Detail investigation of water demand, water pressure and distribution network before and after densification.
- Investigate how the addition of new demand centers affects water pressure and velocity in the distribution system, particularly in densely populated areas.
- Estimate future water demand generated by new urban developments and demand centers due to densification. And identify the Key changed parameters for both cases.
- Utilize the Water GEMS modeling software to simulate the existing water supply distribution system and evaluate its performance under different scenarios of urban densification and the introduction of new demand centers.

1.3.3 Research Questions

In order to achieve the above-mentioned research objectives and seek answers for the stated Problems, the following major research questions will be designed.

- What was changed due to densification regarding provision of water supply in Lideta sub city?
- How can water pressure and velocity measurements assist in diagnosing issues in a plumbing system?
- What key parameters should be identified to simulate the change in water demand in pre/post densification?
- How much is the total water demand requirement of Lideta sub city before and after development of condominium houses?

- What are the mitigation measures to improve the water supply service for new water demand centers?
- Which model is suitable to improve the existing water distribution network system for the case study area of Lideta sub city?
- In a water supply system how can low water pressure impact the delivery of water to consumers?

1.4 Scope of the Study

The scope of the research is limited in space and theme. Spatially, the research was conducted to review the main effect of new demand centers in water supply distribution system spatially the case of condominium houses in Lideta sub city. The study is to carry out the detailed water demand assessment of rehabilitation condominium house and hydraulic performance analysis at Lideta sub city and compare to the water supplied by the water administration of AAWSA. Beside to this develop modeling scenario for the cases of before, current and after condominium houses built using water GEMS V8i model.

1.5 Limitation of the Study

Certain limitations were encountered in the course of this study. One of the greatest challenges the researcher encountered in this study relates to access to and collection of data due to extreme data gaps and paucity. In particular, obtaining water meter at the junction points of the distribution network and miss data on the distribution network of auto CAD file as well as the total amount of water used at each junction.

Obtaining information from housing administration was also a challenge due to suspicion and low level of understanding; this was however overcome by clarity of explanations given by the researcher and research assistants who all had a good grasp of the subject of study. The researcher was therefore able to acquire the relevant data, which helped compile this study report.

1.6 Significance of the Study

The study area lideta sub city has been facing water shortage problems that need to be addressed and solved. In general, for expansion work of water supply scheme and to solve the

current and future water shortage problems water demand modeling and forecasting is very crucial. Therefore, the importance of the study can be for:

- Estimation of the gap between water demand and water supply amount, water pressure and distribution network for the existing and future condition which is very important for planning and implementation of the recommended measures to solve the problems in lideta.
- The selected model, which characterizes the study area, helps for easily integrated with Arc GIS and Auto CAD files and build the distribution network to analysis pre, current and future scenario of water demand. Can be used by the decision makers.
- As a reference or a clue for future study at the town and in the mean while for researchers of other areas in similar cases.

1.7 Thesis Structure

The thesis is categorized into five chapters, Chapter One presents the introduction and covers the aims, objectives of the research and review of existing water supply situation. Chapter Two is the literature review. Chapter Three is focuses on the description of study area, research methodology, data preparation, estimation and analysis. Chapter Four the findings of the research are discussed with appropriate conclusion and recommendations drawn in chapter Five.

The general activity thesis work is summarized in figure bellow (Figure 1.1) the first activity of thesis work is literature reading and data collection. The raw data collected prepared into the compatible data format needed by the models of water GEMS V8i daily per capita water demand, estimate total daily water demand and demand area ratio calculation to each junction. After data input to water GEMS V8i model process achieved, scenario development and management options then to result and discussion.

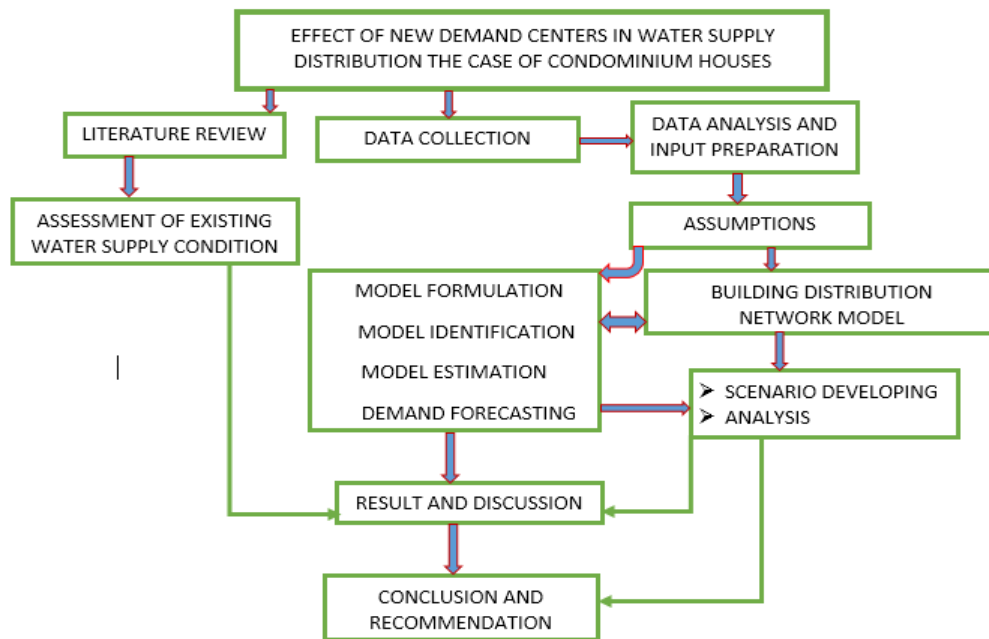


Figure 1: 2 Diagram Of The Thesis Structure Line Out

CHAPTER TWO

2 LITRATURE REVIEW

2.1 Urbanization And Water

Addis Ababa water infrastructure was constructed mostly during the 1950s. Later extensions of the piped water supplies have, however, rendered the distribution system completely incapable of servicing the population, with wide locational difference. Problems affecting governance and organization have also caused the Addis Ababa Water Supply and Sewerage Authority (AAWSA) to be constantly underfinanced. In fact, by the early 90s, half of the domestic water users were illegally connected and access to water for most households was gained indirectly by collection water at a fee from those households who have a piped connection. The urban dwellers suffering the most from these problems are the urban poor. They often live in slums or informal settlements following rapid urban growth, lacking many basic services such safe drinking water, adequate sanitation and durable housing. Ironically, the poor often pay far

more for a liter of water than their richer neighbors, since they often lack access to the water supply system and rely on water provision from private vendors (Kasa et al., n.d.).

Problems in providing satisfactory water supply to the rapidly growing population especially that of the developing countries is increasing from time to time. Water supply system in urban areas is often unable to meet existing demands and are not available to everyone rather some consumers take disproportionate amounts of water and the poor is the first victim develop and expand water supply projects and one of the difficulties among two other is managing and reducing losses of water at all levels of a distribution system. As a result of the overall shortage of water many cities are faced a problem in distributing the available water impartially among the residents. Besides the poor management of existing infrastructure as it increases the level of water losses in water supply. As this research deals with the effect of new demand centers on the distribution water supply system due to case of condominium houses. (Bhatta 2010)

2.1.1 Condominium Houses in Ethiopia

Design considerations remain significant in low-cost housing projects in both developed and developing countries; which are currently faced by challenges of shelter provision for everyone including the urban poor; due to unprecedented increase in rates of urban migration and urbanization. Ethiopia, particularly Addis Ababa city has not been spared. The city administration launched grand low-cost housing projects through the Integrated Housing Development Programmed (IHDP) in 2006 (Nepravishta, n.d.). This study sought to unveil the significance of design considerations in low-cost housing provision thorough the IHDP and the extent to which the Addis Ababa Administration had considered this relevant. The research made use of detailed case analysis of condominium housing on 103 sites of Addis Ababa City using primary and secondary data sources such as questionnaires, interviews, the Delphi technique and document analysis. Qualitative and quantitative data were produced. This research revealed that although the city administration has made great strides in low-cost housing provision, there were omissions in the implementation of housing designs considerations with regards technical issues, people's culture, the needs and interests of the urban poor. As such the research recommends that the city administration should strengthen participation of beneficiaries in projects that affect them directly; and that building codes and

policies in housing be enforced and monitored for sustainable housing provisioning; and prosperity of the poor living in cities(Mohammed and Sahabo, n.d.-a).

2.2 Water Supply and Water Demands

Water is essential to human life and to many industries. While by far the largest body of water on Earth is the saltwater of the oceans, freshwater is required for most human activities. However, most freshwater is locked up in glaciers and polar ice caps. Water supplies are drawn mainly from rivers, lakes, and groundwater. The hydrologic or water cycle renews water supplies by moving water from the oceans, as freshwater, to land.(Owolabi Ayeni, n.d.)

Water consumption varies widely from place to place, but is increasing everywhere as global population rises. Sometimes supply cannot meet local demand, which creates conflict. Climatic factors, such as drought and global warming, water management practices, and over-exploitation place pressure upon water supplies. Diversion of water resources to increase water supplies often has an adverse impact on water quality and the local ecology. Water conservation measures and water management based on sound scientific principles are needed to avert a global water crisis.

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2.2.1 Analysis On Water Supply and Water Demand

In water distribution system, the reliability of water with a constant flow rate should be available to customers throughout the design time. If water is not available in sufficient quantities it should be pumped for a short period of time and at high flow rate, to meet the various demand of customers. Accordingly, service reservoir/storage tanks usually provided in order to store water when the pumping rate is higher than the demand at low/night times. But this can be also used in the case that the pumping rate is below the needed demand, since to equalize the pressure in the network (Sarkar 2017). In developing countries; many water authorities are facing the challenges in providing adequate water supply to the rapidly growing populations.

Water utilities are facing the high level of water loss in their distribution networks. ‘For many utilities, reducing loss should be the first option to pursue when addressing low service coverage

levels and increased demand for piped water supply.

While, ‘the failures, location, size and capacity of pumps in water distribution are the major impacts for low flow or negative pressure raised in the system, and this can lead to intermittent water supply in the distribution system’ (Sofia Ferreira Cabral et al. 2014). There are many reasons and factors why a pump is not performing well in a certain situation of water distribution system. But, as per Marta & Rudolf, 1987; the important and possible reasons to less performing of pumps were identified as below; When the pump is of poor design and quality, If it is not suitable for the given situation and does not work in its optimal range, If the pump is not being used properly and maintained regularly (cleaning, greasing, etc.), If the pump is excessively exposed to sun, rain, dust, etc., If it is overused and was not repaired properly after a break-down and If supply of spare parts is difficult.

Rising water demand as a result of population growth and urbanization has an effect on the availability and reliability of existing water distribution system. Therefore, ‘water demands need

to be assessed on the basis of considering the year and date supplying water through the distribution system. The primary objective is to make sure that the community is being

serviced
adequately.

The first question in the design and operation of WDN is: How much water is needed? the answer to this question is difficult because the required water is a function of various factors. While, some of the factors are completely independent and time varying. Therefore, water demand modeling is one of the most important challenges in the design of WDN, since it reflects the changes in population, climate, land use, the number of service connections and customer life style (Jalal, 2018).

2.3 Population And Housing Units Projection

2.3.1 Design Period

Design period is the number of years in which the design of water works has been working correctly. The economic design period of the components of a water supply depends on their life, initial cost, rate of interest on loan, the ease with which they can be expanded of the likelihood that they will be rendered absolute by technological advances. In order to design the parts of water system, the flow at the end of design period must be estimated. The design period, however, should neither too long or too short. Mostly water supply projects are designed for a design period of 20-30 years which is fairly a good period. The different elements of the water supply systems may approximately be designed for different flow criteria as shown in the table below. (Mandefro and Habtamu 2017)

Table 2:1 Design Period Various Units of Water Supply System

S No.	Name Of Units	Design Period (Yrs.)
1	Wells For Under Ground Source	5 Years
2	Impounding Reservoir	30years
3	Water Pumping Stations	10years
4	Pipe Line from Source to Town	20years
5	Water Treatment Plant	10years

To fix the design period for any water supply scheme the following points should be considered.

- Funds available for the completion of the project
- Life span of materials that are used in the water supply system

- Rate of interest on the loans taken to complete the project
- Operation and maintenance cost
- Anticipated expansion of the town

So, in our case Lideta sub city water supply and sanitation project by considering the above factors we adopted a design period of 23 years and this period from 2009 E.C till the year of 2032 E.C.

2.3.2 Factor Affecting Population Forecasting

The population of a city depends up on the following factors. These factors affect considerably the estimated population.

- Economic factor: - Such as development of new industries, discovery of oil or other minerals in the vicinity of the city.
- Development programs: - Development of projects of national importance such as river valley projects etc.
- Social facilities: - Educational, medical, recreational and other social facilities
- Communication links: - Connection of the town with other big cities, and also to transport of agricultural products
- Tourism: - Tourist facilities, religious places, historical buildings.
- Community Life: - Living habits, social customs, and general education in the community.
- Unforeseen factors: - Earthquakes, floods, epidemics, frequent famines etc.

2.3.3 Methods of Population Forecasting

When the design period is fixed the next step is determining the population of a Town or city depends upon the factors like births, deaths, migration and annexation. The knowledge of population forecasting is important for design of any water supply and distribution system scheme. The design is done on the bases of projected population at design period. Ethiopian statistic authority Method Among the different methods of population projection such as arithmetic, geometric, logistic curve, ratio relation, master plan and etc. we have selected the CSA method.(Sayeed et al., n.d.-a)

Table 2: 2 Base population and its growth rate data of Lideta sub city based on CSA

year	population
------	------------

**EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA**

2007	147319
2009	156428
2023	259822
2032	340357

CSA has produced regional growth rate for different periods for medium growth rate. As we can see from the above table the growth rate is reducing and this may be expected to reduce the birth rate due to excessive family planning practice, wide spread of education and development of extra recreation facilities for the people.

The equation for CSA method is given by:

$$p = p_0 * e^{kn}$$

where P_n = population at n years

n = number of years k = growth rate P_0 = population at present

2.3.4 Per Capita Domestic Water Demand

Per capita demand is the quantity of water consumed by a single person in a day. It is expressed as liter per capita per day (lpcd). It is affected by size of city climatic condition, standard of living industries, quality of water, system of sanitation, cost of water, use of water meter and system of supply. Due to the above considerations AAWSA used 110 lpcd for the Addis Ababa living people so I consider this at my research for my study area Lideta sub city.

2.4 Water Distribution System

Water distribution systems are water utilities that deliver water of the required quantity to individual customers under sufficient pressure through a distribution network (Darshan et al., 2017). The hydraulic infrastructure of the Water distribution system includes elements such as pipes, tanks, reservoirs, pumps, meters valves, etc. The integration of all those elements is needed for efficient and effective water delivery to the required area. Hence, the primary task of water utilities is to deliver water of the required quantity to individual customers under sufficient pressure through a distribution network. The concept of a network is fundamental to a water distribution model. The network contains all of the various components of the system and defines how those elements are interconnected. Networks are comprised of nodes, which represent features at specific locations within the system, and links, which define relationships

between nodes. Water distribution models have many types of nodal elements, including junction nodes where pipes connect, storage tank and reservoir nodes, pump nodes, and control valve nodes (Mahdi and Jalal, n.d.). Models use link elements to describe the pipes connecting these nodes. In addition, elements such as valves and pumps are sometimes classified as links rather than nodes. Intelligent use of element labeling can make it much easier for users to query tabular displays of model data with filtering and sorting commands.

2.4.1 Distribution System Appurtenances

Water systems typically have three classifications of pipe used to transport to demand points throughout a community. These are identified as follows:

- A. Primary feeders: These are large pipes, usually with diameters ranging from 12 to 36 inches, based on the size of the population served. Primary feeders transport water from the water treatment plant to corporation line of the community and/or to major water storage locations within the community.
- B. Secondary feeders: These are connected to the primary feeders to transport water along the major streets of the community. Secondary feeders need to be in place to supply all commercial property, public buildings, and private sector buildings that have a needed fire flow over 1,000 gpm. Secondary feeders typically are 10 to 16 inches in diameter.
- C. Distributor mains: These are used to transport water from the secondary feeders to individual streets in the areas of the community that have small businesses like convenience stores and gas stations but, more importantly, along residential streets. The minimum pipe size should be 6 inches and, based on the system design, a possible dead-end pipe may need to be 8 or even 10 inches.

2.5 Water Demand

Water demand is defined as the volume of water requested by users to satisfy their needs. In a simplified way it is often considered equal to water consumption, although conceptually the two terms do not have the same meaning (Sayeed et al., n.d.-b). In most developing countries, that theoretical water demand considerably exceeds the actual consumptive water use. In many African cities urban water demands are often homogeneous owing to a range of levels of services occurring within the same urban area. Levels of service can vary from household

connections to standpipes or to no service at all (Babel, n.d.). Amount of water required for the user mainly 7 affected by climate, geographic location, population size, economic condition of the community, extent of industrialization, cost of water and etc.

2.5.1 Type Of Water Demand

The produced water from the treatment plant delivers to different type of demand/ purpose. Water demand is will be categorized in different category for easy allocation of water.

2.5.1.1 Domestic Water Demand

The quantity of water required in the houses for drinking, bathing, cooking, washing etc.is called domestic water demand and mainly depends upon the habits, social status, climatic conditions and customs of the people (Gebreegziabher and Tadesse 2011). Domestic water consumption varies according to the mode of services, climatic conditions, socio-economic condition and other related factors.

2.5.1.2 Non-Domestic Water Demand

The non-domestic water demand includes, water demand other than for domestic purpose. These includes; institutions, commercials, industrial, public use and fire demand. Institution and commercial demand refer to the water demand for universities, schools' hospital and etc. Whereas commercial demand includes demand for commercial buildings like; commercial centers, office buildings, warehouses, stores, hotels, shopping centers, health centers, schools, temple, cinema houses, railway and bus stations etc. (Rathnayaka, Malano, and Arora 2016).

Industrial water demand is the water required in the industries which is mainly depends on the type of industries. The water required by factories, paper mills, cloth mills, cotton mills, breweries, sugar refineries etc. comes under industrial use. The quantity of water demand for industrial purpose is around 20 to 25% of the total demand of the city (Rao, 2015). Public water demand is a quantity of water required for public utility purposes such as for washing and sprinkling on roads, cleaning of sewers, watering of public parks, gardens, public fountains etc. comes under public demand. To meet the water demand for public use, provision of 5% of the total consumption is made designing the water works for a city (Asgedom 2012a). Fire may take place due to faulty electric wires by short circuiting, fire catching materials, explosions, bad intension of criminal people or any other unforeseen miss-happenings. If fires are not properly controlled and extinguished in the minimum possible time, they lead to serious

damage and may burn cities (Rao, 2005). Hence, demand for fire-fighting should be included during the design of the distribution system. In the cities, fire hydrants are provided on the water mains at 100 to 150 m apart for fire demand. The quantity of water required for firefighting is generally calculated by using different empirical formulae. Water demand for firefighting purposes shall be assessed on a town-by-town basis, depending on the existence of equipment and the capacity of any firefighting service. Fire hydrants shall be installed at public and municipality interest such as schools, shops, hospitals, fuel stations and at salient points of the distribution network. This demand is taken off by increasing the volume of the storage tanks by 10 % (Vaglio 2019b).

2.5.2 Deterministic Water Demand Estimation

In this approach, the actual water demand for all users is estimated based on predicted water consumption over the service time. One simple approach for deterministic water demand is estimating individual needs based on type of customers and their activities and finally adding this lead to get total water demand. For example, the water demand can be estimated on the basis of per capita demand in small urban areas (Mohammed and Sahabo, n.d.-b).

2.5.3 Stochastic Demand Forecasting

This method mostly considers and adopt the uncertain fluctuations on demand over time and location spans. Risks and sensitivity of forecasts such as the consequence of total loss of supply and the effect of variations in rates income should be considered and included.

Hence, Demand estimation based on historical consumption per user category (domestic, industrial/commercial) and expected changes (increasing or decreasing) in user category over the forecasting period is good example of stochastic demand forecasting (Lee et al. 2017).

The per capita demand of a particular town is the average consumption of water for a year.

Water demand varies from season to season. In dry season the water demand is maximum, because the people will use more water for bathing, cooling, lawn watering and street sprinkling.

The most common method of allocating baseline demands is a simple unit loading method.

This

method involves counting the number of customers (hectares of a given land use, number of fixture units, or number of equivalent dwelling units) that contribute to the demand at a certain

node, and then multiplying that number by the unit demand (for instance, number of gallons/liters per capita per day) for the applicable load classification' (Tomas, et al., 2013).

Therefore, average day demand was used to estimate the baseline demand and other demand in the water distribution system including unaccounted-for water. Hence, most modelers determine the water demand analysis of a given town by applying baseline demand to a variety of peaking factors and demand multipliers (Bhadbhade, 2019).

Water losses occur in all water distribution networks, even new one and it is only the volume that varies. Thereby, the volume of this losses reflects the capacity of water authorities to manage their distribution networks (Dighade, et al., 2014). In general, 'water losses consist of real and apparent losses. And to most water utilities, the level of Non-Revenue Water (NRW) is a key performance indicator of efficiency.

Infrastructure asset management is one of a key topic towards compliance with the performance requirements in water supply and distribution networks. Systems that fully adopt infrastructure asset management principal can achieve many of benefits' (Asgedom 2012b).

To minimize leakage, customer service-level targets are set through consultation and maintenance strategy. Further, the targets are reviewed occasionally or imposed through regulation' (WUAM, 2013).

2.6 Water loss in the distribution system

The term "water loss" is generally adopted to indicate the difference between the overall amount of water supplied in the network and the sum of the water volumes corresponding to the customer consumption recorded by the flow meters (Olivera and Butenko 2016). Water losses occur in all water distribution networks, even new one and it is only the volume that varies. Thereby, the volume of this loss reflects the capacity of water authorities to manage their distribution networks (Kabeto Advisor Yilma Sileshi 2011).

Causes of water loss Produced and delivered water to the distribution system is intend to be sold to the customer without loss or siphon from the distribution system. Not long ago, water companies sell water at a flat rate without metering. As water has become more valuable and

metering technology has improved, more and more water system in the U.S. meters their customers. Although all customers may be meter in a given utility, a fairly sizable portion of the water most utilities produce does not pass through customer meters. Unmetered water includes unauthorized users, including losses from accounting errors, malfunctioning distribution system controls, thefts, inaccurate meters, or leaks (Ahiablame, Engel, and Venort 2012).

Leakage is usually the major component of water loss in developing countries, but this is not the only case in developing or partially developed countries, where illegal connections and meter error are often more significant (Mutikanga, 2019

2.6.1 Sources of Water Loss

International Water Associations (IWA) Water Audit/ balance, defined the components of water losses in a supply network in order to set internationally recognized and consistent standards. This makes it possible to accurately compare performance across national boundaries. The IWA has defined three key water loss components within water supply networks. According to (Ahiablame, Engel, and Venort 2012), the major source of water loss is categorizing as; un authorized consumption, apparent losses and real losses.

2.6.1.1 Real Loss Physical (Real) Losses

Real loss Physical (real) losses are losses that are caused by large damages that may have occurred to the network pipes or by the deterioration of the pipe junctions or the hydraulic devices. Such losses 11 comprise leakage from all parts of the system and overflows at the utility's reservoirs. They are caused by poor operations and maintenance, the lack of active leakage control, and poor quality of underground assets(Kleiner, n.d.).

2.6.1.2 Apparent Loss

Apparent loss The Commercial (apparent) losses, which consist of water volumes actually consumed but not accounted. Such losses are caused by customer meter under registration, data handling errors, and theft of water in various forms.

2.6.1.3 Unbilled Authorized Loss

Unbilled authorized consumption Includes water used by the utility for operational purposes, water used for firefighting, and water provided for free to certain consumer groups

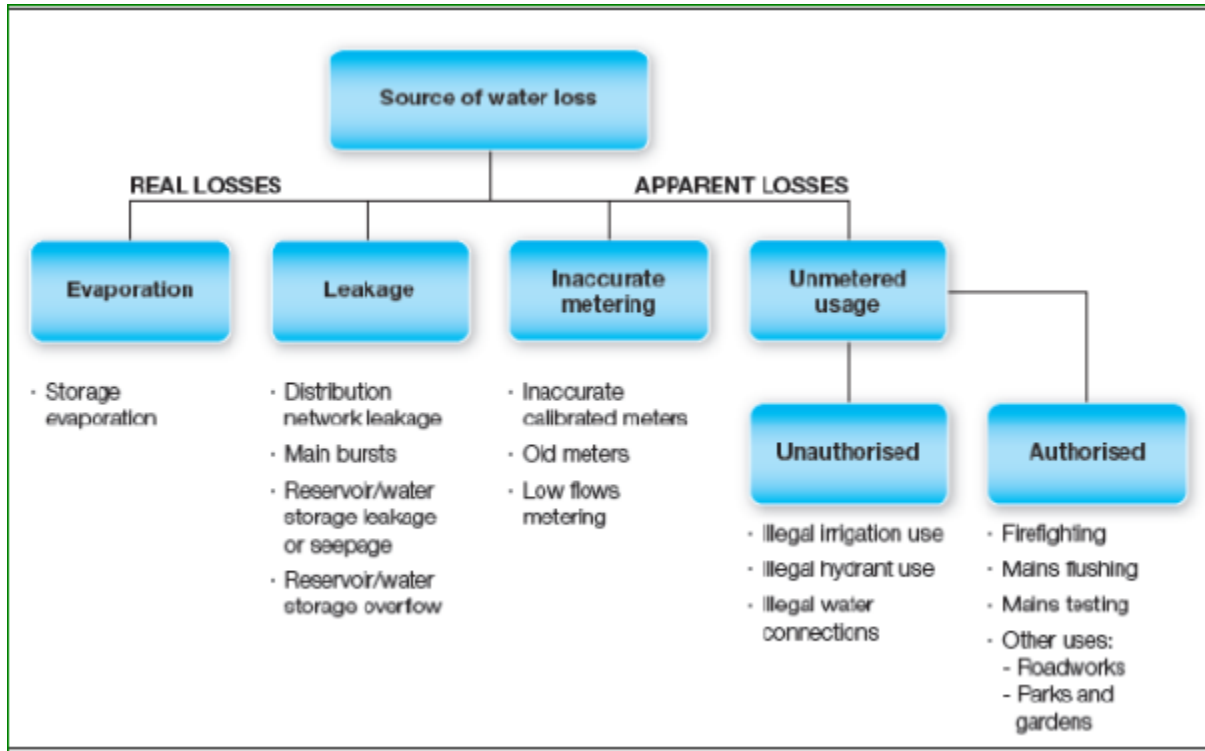


Figure 2: 1 Sources of water loss international water associations (iwa) water audit/ balance

2.7 Review of WDS Models and Analysis software's

There are quite a number of software which models and analyze WDSs. We have the open source which are free to download and use by individuals and organization while there are some which are practically closed from public use and others are commercially available to individuals and organization that may need them either for research, analyzing development of new water distribution systems or managing existing WDSs. The software each have their different aspect of forte and specialty which can denoted in the review below.

- A. **Water GEMS** is a robust, comprehensive and easy to use water modeling and analysis software with the advancements in system optimization, platform interoperability and model building. Water GEMS is a super-set of Water CAD. Water GEMS is an efficient and versatile modeling software which helps to improve comprehension of system behavior, system reaction to operational strategies and system ability to meet future demands. Its flexible multi-platform workspace allows fire flow and water quality simulation, pipe flow and pressure analysis and energy cost analysis. Water GEMS capabilities include intelligent

system management and planning for system reliability, optimization of operation (pumping strategies, system shutdowns and preventive maintenance to minimize disruptions) for efficiency of system and asset renewal or renovation support to ensure sustainability. Its features include prefixed model building, integration with multiple platforms, design and other operations. The unique aspect of Water GEMS is the data presentation mode which is highly appealing and comprehensible. Its versatility also allows presentation with variety of graphical tools. Water GEMS is not an open-source software but is commercially available. Water GEMS software was built with a strong design algorithm to meet the criteria of precision in modelling, analysis and design of WDSs

B. **Water CAD** is a sub-set of Water GEMS. It is a user-friendly WDS modeling management and analysis software that has a range of functions which helps to improve design productivity. These functions include prefixed model building, data archiving and bespoke graphical data presentation, assessment of water demand, WDS configuration, design and operational scenarios and lastly CAD interoperability i.e. ability to model in any familiar platform of choice. Water CAD was built with certain features and capabilities which differentiates it from other modelling software. These features include but not limited to ability to access fire flow capacity, analyze pipe and valve criticality, build and manage hydraulic models, design WDSs, development of maintenance, flushing and management plans, identify water leakages and manage energy use. Water CAD is quite easy to use and is generally considered a flexible and resourceful WDS modeling software

C. **EPANET** is an open-source hydraulic analysis software for WDSs. It performs extensive simulation of hydraulic and water behavior within pressurized WDSs. It was built to aid our comprehension of how water travels in WDSs. EPANET is a very strong and versatile application which provides workspace for hydraulic analysis of systems of any size by editing system input data, running hydraulic and water quality simulation and viewing the result in different choice platforms. It is mostly used as a research tool but can also be used to restore and develop existing and new WDSs respectively. EPANET is an innovation of the United States Environmental Protection Agency

D. **Hydraulic CAD** is water system design, hydraulic analysis and water modeling software integrated in AutoCAD using industry standard EPANET simulation and modelling engine. It

is an open-source software and it is incredibly easy to use with unlimited application support. It was built as an AutoCAD extension software and consequently operates with advantages of AutoCAD including flexibility and familiarity. HydraulCAD was developed to calculate pipe pressure, flow, pressure loss and other variables in WDSs. This software has an inbuilt pipe elements archive which contains detailed information about pipe materials, types and sizes which are used in modelling WDSs and also used for fire-flow analysis. HydraulCAD is designed to be powerful, fast and intuitive

E. **HYDROFLO3** is an updated HYDROFLO series version. It is a strong, flexible and ready to use WDS analysis software. It can model systems with up to 10 sources, 9 branches and approximately 1000 elements. This means that virtually any WDS can be described using the wide range of WDSs elements and components available in its archive. The ease of unit conversions between Metric and SI units is one advantage of using HYDROFLO3, other advantages include calibration and validation of existing WDSs, easy manipulation of hydraulic parameters for all WDSs. HYDROFLO3 permits a peculiar feature as Pump base used for the calculation and analysis of pump hydraulic characteristics which is a requirement in forced flow systems. HYDROFLO3 is also useful in industrial applications, simulation of treatment plants, fire-flow analysis etc. It is robust software used to design WDSs with strong data management capacity.

There are several other software which are built and developed for modelling, analysis, simulation and optimization of WDSs but have not being included in the review above, some of which are worthy to be mention include WATSYS, InfoWorks, Branch (2014), Eraclito, AFT Fathom 10, Netis, Archimede, Cross, Opti Designer etc.

2.7.1 WATER GEMs V8i Model

Water GEMS was originally developed by the Company Haestad Methods, Inc. based in Watertown, CT (USA). This company was acquired by Bentley Systems in mid-2004, acquisition from which the product began to be known commercially as Bentley WATERGEMS V8i. It is a product whose launch was given early twenty - first century and later software product WATERCAD the same software house launched in the 90s For many experts, WATERGEMS V8i more than an evolution of WATERCAD is essentially a 'super (Which is already included in WATERCAD), adds seamless integration with GIS

environments and includes in a single commercial version all the advanced analysis modules which can only acquire separately in WATERCAD. In this sense, it is software whose target user is the company that operates supplies, regulators and / or important consulting projects (Sonaje and Joshi, n.d.).

WATERGEMS V8i is a hydraulic modeling application for water distribution systems with advanced interoperability, geospatial model building, optimization, and asset management tools.

From fire flow and constituent concentration analyses, to energy consumption and capital cost management, WATERGEMS V8i provides an easy-to-use environment for engineers to analyze, design, and optimize water distribution systems. WATERGEMS V8i is a multi-platform hydraulic and water quality modeling solution for water distribution systems with advanced interoperability, geospatial model-building, optimization, and asset management tools. From fire flow and constituent concentration analyses, to energy consumption and capital cost management, WATERGEMS V8i provides an easy-to-use environment for engineers to analyze, design, and optimize water distribution systems. WATERGEMS V8i is useful for managing the water system data, time-series hydraulic result, current and future scenarios and other core infrastructure data all within the same GIS environment.

2.8 Water Distribution Modeling

A model is a tool that can be used to determine the likely response of a system to a given set of stimuli without having to actually impose those stimuli on the system. Today, water distribution modeling is a critical part of designing and operating water distribution systems that are capable of serving communities reliably, efficiently, and safely, both now and in the future. Demand for drinking water is increasing on continual basis with corresponding increase in population. This ever-increasing demand can be fulfilled by designing efficient water distribution networks based on advance computing systems include modern hydraulic modeling and designing software's. Extensive review has been carried out for software's used in designing water distribution networks and data management of hydraulic properties of networks. Software's for water distribution include public domain software's like EPANET, Branch and Loop as well as commercial software's like Acquis, Water GEMS, Water CAD,

etc. Water distribution system designing software's differ from each another in various aspects include their functionality, compatibility to different computational systems; graphical user interfaces (GUIs), searching and optimizing algorithms, languages and programs used in their developments. The choice of water distribution network software is based on the availability of the data, time, financial implications, resources, applicability and overall purview of the project(Paneria and Bhatt 2017a).

2.8.1 Water Distribution Network Building and Model Setup

The approach to building the model is to first sketch out the system practically on existing topographic maps. The concept of a network is fundamental to a water distribution model. The network contains all of the various components of the system, and defines how those elements are interconnected. Networks are comprised of nodes, which represent features at specific locations within the system, and links, which define relationships between nodes. Water distribution models have many types of nodal elements, including junction nodes where pipes connect, storage tank and reservoir nodes, pump nodes, and control valve nodes. Models use link elements to describe the pipes connecting these nodes. In addition, elements such as valves and pumps are sometimes classified as links rather than nodes. Intelligent use of element labeling can make it much easier for users to query tabular displays of model data with filtering and sorting commands. Rather than starting pipe labeling at a random node, it is best to start from the water source and number outward along each pipeline. In addition, just as pipe elements were not laid randomly, a pipe-labeling scheme should be developed to reflect that(Hussni, Zyouid, and Shaheen 2013).

2.9 Water Distribution Network Simulation

The term simulation generally refers to the process of imitating the behavior of one system through the functions of another. It can be used to predict system responses to events under a wide range of conditions without disrupting the actual system. Using simulations, problems can be anticipated in proposed or existing systems, and can be evaluated before time, money, and materials are invested in a real-world project (Mulatu 2017). As per (Melaku, 2015), in water distribution networks the most basic type of model simulations is either steady-state or extended-period simulations. Steady-state simulations; represent a particular view of a point in

time and are used to determine the operating behavior of a system under static conditions. It computes the hydraulic parameters such as flows, pressures, pump operating characteristics, and others by assuming that demands and boundary conditions were not changed concerning time. In general, this type of analysis was used to determine the short-term effect of demand conditions on the system. Extended period simulations determine the dynamic behavior of a system over some time, and they analyze the system on the assumption that the hydraulic demands and boundary conditions change over time. Therefore, regardless of project size, model-based simulation can provide valuable information to assist an engineer in making well-informed decisions. Water GEMS is a hydraulic modeling application for water distribution systems with advanced interoperability, geospatial model building, optimization, and asset management tools. From fire flow and constituent concentration analyses to energy consumption and capital cost management, Water GEMS provides an easy-to-use environment for engineers to analyze, design, and optimize water distribution systems. This model uses an assortment of data, input, and output files. It is important to understand which essential, temporary holding places for results are and which must be transmitted when sending a model to another user. In general, the model is contained in a file with the wtg.mdb extension. This file contains essentially all of the information needed to run the model. This model gives the choice between performing a steady state analysis of the system and performing an extended-period simulation over any time period (Paneria and Bhatt 2017c).

2.9.1 Hydraulic Performance of Distribution Networks

Hydraulic analysis of flows and pressures in a distribution system has been a standard form of engineering analysis since its development by Hardy Cross in 1936. The demand usually reaches a peak in the morning when people are at home and preparing their Meal and its second peak in the evening Maximum water use and minimum water use, usually related to average water use by multiplication of peaking factors (Ayala 2018). The measurements of the hydraulic performance of the distribution network can be undertake by checking whether (a) can supply safe and wholesome water to the users, whether these constitute a family, a group of families, or a community; (b) can supply water in adequate quantity; and (c) can make water readily available to the users, in order to encourage personal and household hygiene. However, all the above criteria are directly or indirectly affects by the pressure and velocity distribution

in the system. To maintain the system in optimum and safe condition, the pressure and velocity distribution variation should range from 0.3 -2.5 m/s and 15 – 60 m respectively. According to Water pipeline design guideline (2014), the following tables, Table 2.5 shows the recommended values of velocity and pressure in large towns water supply system(Sayeed, Hossain, and Sharmin 2014).

Table 2: 3 Velocity and Pressure Variation with Corresponding Effects

S No	Velocity (m\s)	Status	Pressure(m)	Status
1	<0.3	Sedimentation Will Occurs	<0	No Flow Due to Negative Pressure
2	0.3-2.5	Safe Condition	0-15	Low Pressure to Satisfy the Demand
3	>2.5	Scoring Will Occurs	15-60	Safe Water Pressure
4			>60	Pipe Break Due to High Pressure

2.9.2 Steady State Simulation

A steady-state simulation provides information regarding the equilibrium flows, pressures, and other variables defining the state of the network for a unique set of hydraulic demands and 21 boundary conditions. Steady-state models are generally used to analyze specific worst-case conditions such as peak demand times, fire protection usage, and system component failures in which the effects of time are not particularly significant.

2.9.3 Extended Period Simulation

Extended period simulation tracks a system over time, and it is a serious of linked steady state run. The need to run extended period simulation is because the system operations change over time. This simulation is important as demand varies over the course of the day, pumps and wells go on and off, valves open and close and tanks fill and draw.

CHAPTER THREE

3 MATERIALS AND METHOD

3.1 Introduction

The rapid increasing water demands in many parts of the world cannot be sustained indefinitely and many countries are in a situation of severe and permanent water stress. The urban water sector in many developing countries, there are serious constraints in meeting the challenge to provide adequate water sustainably for all urban residents in Ethiopia.

Provision of water supply and sewerage service to the people of Addis Ababa is the responsibility of Addis Ababa Water and Sewerage Authority (AAWSA). AAWSA is a public authority and organized into eight branch offices, namely: Arada, Addis Ketema, NifaseSilik, Mekanisa, Gulele, Megenagna, Gured Shola and Akaki which provide services to all parts of the city. The Addis Ababa Water & Sewerage Authority has established water supply flow rate criteria per capita per day. The domestic water demand for new housing developments is considered under the category House connections so AAWSA is utilizing 110 l/c/day including losses as standard to satisfy the needs of its customers. The daily average per capita water consumption in urban areas is in between 10 to 20 lcd and in rural area, it is much lower at 3 to 4 lcd. This is far from the united nation recommended minimum daily per capita domestic water of 20 lcd.

Water demand of Addis Ababa is the biggest factor regarding present and future water stress in which Demand for water service far exceeds supply. As such, there is no excess capacity or back-up supply for water or sewerage in the city that would provide redundancy in the system. There are a number of pocket areas that receive water two or three days a week through the piped system. The water and sewerage system in Addis Ababa does not serve all areas of the city or segments of society, and is generally maintained on an ad hoc basis. Especially considering that water scarcity is already a challenge for the city and is expected to worsen due to climate change and increased demand(Ababa 2014).

3.2 Description of the Study Area

3.2.1 Geographic Location

Addis Ababa lies $9^{\circ}1'48''N$ latitude and $38^{\circ}44'24''E$ longitude. The city is located at the heart of the country, at an altitude ranging from 2,100 meters at Akaki in the south to 3,000(9,800 ft) meters at Entoto Hill in the North. This makes Addis Ababa the third highest city in the world, after La Paz and Quito in Latin America. Its time zone is categorized in East Africa Time (UTC+3). The city occupies a total area of 540 Sq. Km. Lideta is one of ten sub cities of Addis Ababa. It has a total population of 201,713 (CSA, 2007). Its geographical area covers 9.18 KM² (Ibid). It is situated at the center of Addis Ababa and bounded by Addis Ketema sub city in the North, Nifas Silk-Lafto sub city in the South, Kirkos sub city in the East and Kolfe Keranio sub city in the West. This study is denoting to the seven woredas of the sub city, except woreda 01, 02 and 10.

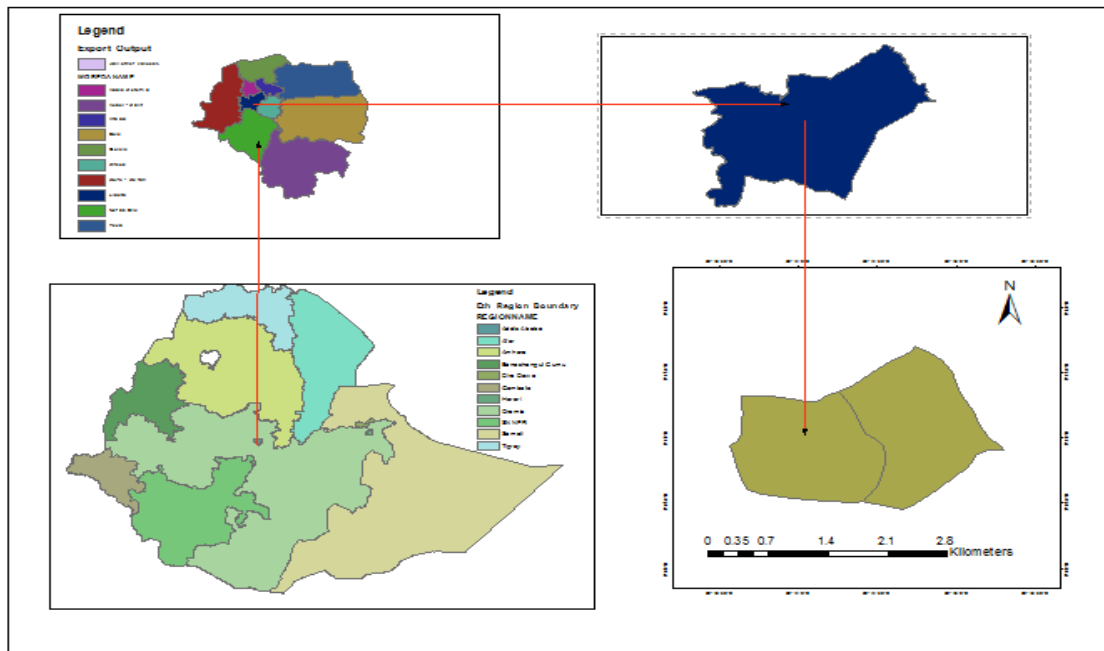


Figure 3: 1 Geographical Location Of The Study Area

3.2.2 Climate Conditions (Temperature and Rain Fall)

Addis Ababa has subtropical highland climate. The city possesses a complex mix of highland Climate zones, with temperature differences of up to 10 °C, depending on elevation and prevailing wind patterns.

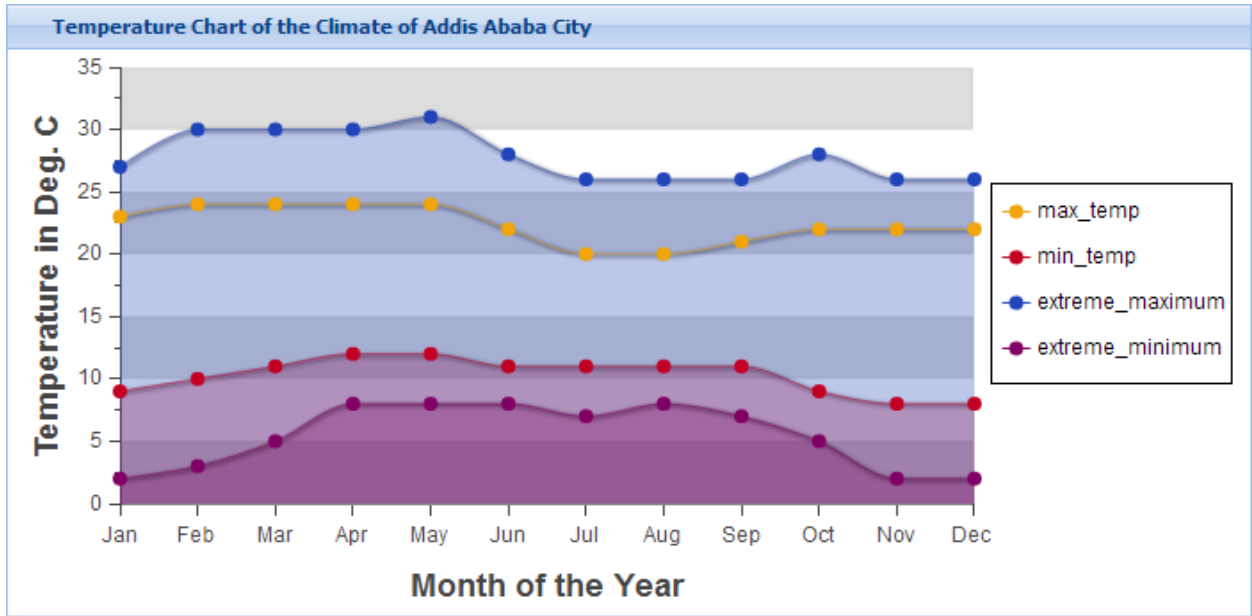


Figure 3: 2 Climate Change Of Addis, Source National Meteorological Agency (NMA)

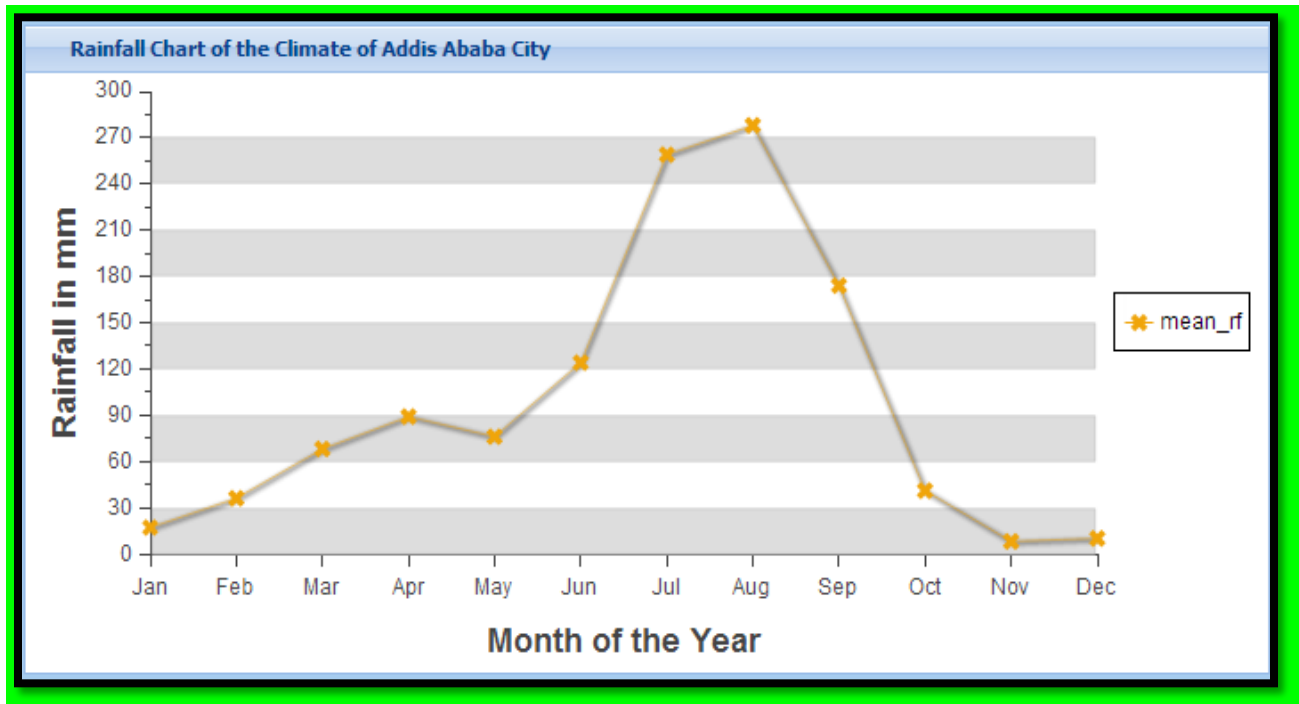


Figure 3: 3 Rainfall Patterns of Addis Ababa City

According to National Meteorological Agency of Ethiopia, mean minimum and maximum temperature of the day varies from season to season; however, the variation is not too large. Mean minimum temperature varies from 7°C to 11°C and mean maximum varies from 21°C to 25°C. For month of December mean minimum temperature is 7°C and mean maximum temperature is 23°C. For month of May mean minimum temperature is 11°C and mean maximum temperature is 25°C. From June to mid-September is main rainy season for city of Addis Ababa. Mid-November to January is a season for occasional rain.

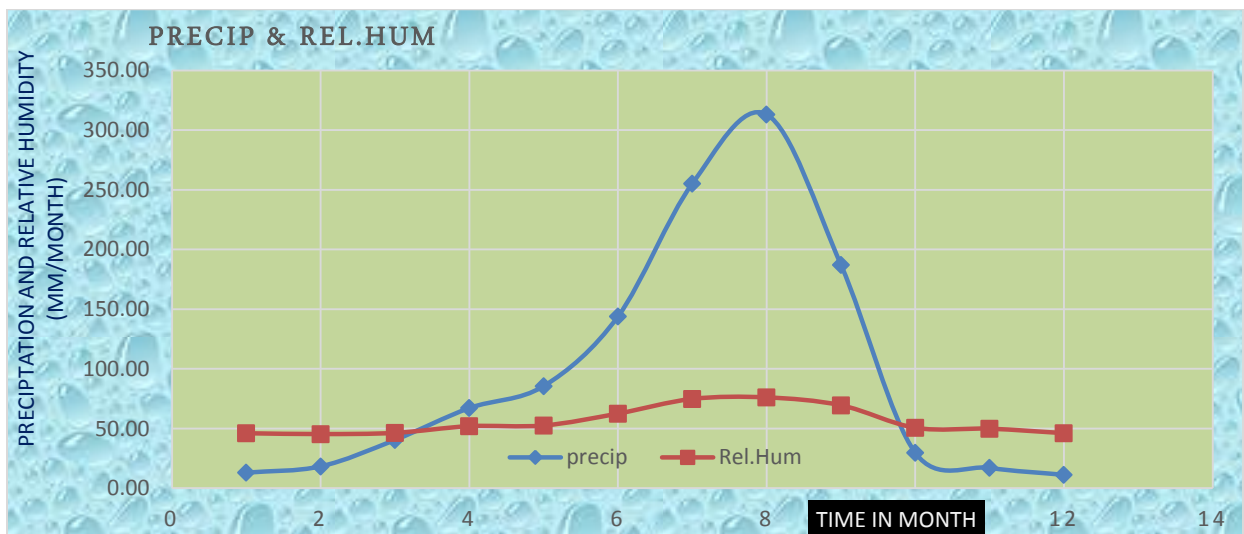


Figure 3: 4 Graph Of Precipitation And Relative Humidity

3.2.3 Socio-Economic Situation

Lideta Sub-City is one of the ten sub-cities of Addis Ababa, characterized by a diverse population, including low-income households, middle-class residents, and some affluent neighborhoods. As urbanization increases, the population density in Lideta has grown, which exacerbates challenges related to resource distribution, including water supply. The economy in Lideta is mixed, with informal sectors contributing significantly alongside formal businesses. Many residents engage in trade, small-scale manufacturing, and services. Economic disparities exist, with some areas showing signs of development and others suffering from poverty and lack of access to basic services.

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The socio-economic situation in Lideta Sub-City is deeply interconnected with the state of water supply and distribution. Improving access to clean and reliable water is essential not only for health outcomes but also for enhancing the economic prospects and overall quality of life for residents. Continued investment in water infrastructure, community engagement, and sustainable management practices will be crucial in addressing these challenges moving forward.

3.2.4 Land use map of the study area

Lideta sub city has covered a total area of 9.18km². The Local Development Plan for Lideta was launched on 6 May 2009 and proposed the following site allocation: 1 ha of land was specifically allocated to green space for residents; 2 ha of land were assigned for social services; 3 ha of land were provided for allocation to private homeowners whose houses had to be demolished; an area of 5 ha was designated to multi-use facilities; 2 ha were designated to the building of infrastructure; 4 ha were set aside for commercial purposes; and 8 ha were allocated to condominium development.

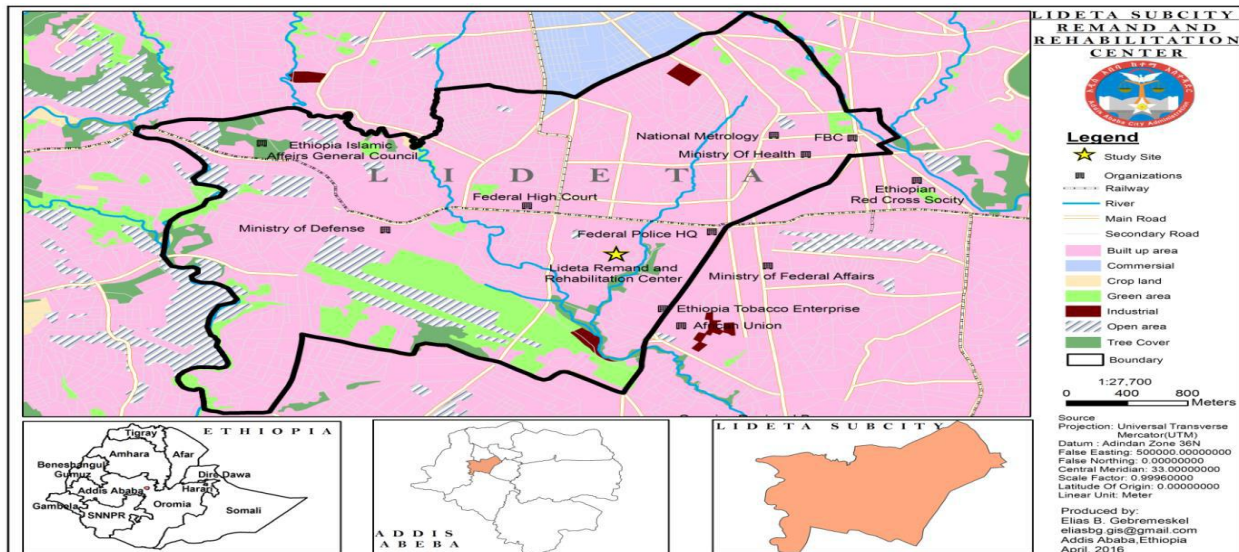


Figure 3: 5 Location and Land Use Map of Lideta Sub City

- Materials which are used in this research are described as follows;
 - ❖ GPS was used for describing and finding the location of the study area
 - ❖ Arc GIS 10.3 was used for map delineation, land use mapping and extracting of elevation

- ❖ Google earth software was used for magnification of study area and check readings are correct on land
- ❖ Water gemsV8 was used for estimation of water distribution network and amount
- ❖ AutoCAD was used for describing water distribution network line layout

3.3 Data Gathering Instruments

3.3.1 Questionnaire

This study uses closed and open questionnaires to examine existing and currently water distribution system methods in household consumers, hospitals, schools and businesses. The questionnaire was first written in English and then translated into Amharic to make it easier for respondents to understand. Then send the questionnaire to the respondent.

3.3.2 Interview

To secure additional information, unstructured interview question was conducted for the employee and consumers. Raw data on existing water supply and currently distribution system interviews with AAWSA workers and woredas administration offices, workers, consumers about the current and existing water supply distribution system and also when it come and how long is waiting. Therefore, an interview schedule was prepared because of its advantages like the chance of obtaining in-depth data related to the problems.

3.3.3 Observation

In order to make the research actual on site observation technique were carried out at some of the components of the distribution network system like reservoir, pump stations, tanks and etc. The researchers also used field observation as a key data collection method for this study. therefore, the method is performed through face-to-face on-site observation, a checklist was created to obtain data on the status of the study area and to assess the water supply distribution network system in the study area.

3.3.4 Data Collection

According to the work plan indicated in the proposal primary and secondary data were collected

from the town water supply service and at the land in situ (field) testing was carried out. Some supplementary information was also collected from other respective offices, supportive

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qualitative information through discussion with local experts of water supply service was also important. The study applied mostly secondary data with the use of quantitative research method in the analysis and interpretation of data. The major land use types of residential, commercial, industrial, and open space are combined into three categories. The objective is to explore the regression relationship between the possible influential factors and total water usage or water consumption.

3.3.4.1 Data Sources

Information were collected in three major categories: water use, land use, census data, and climate data. All collected secondary data sources and their respective organizations are summarized below in the Table 3:1

Table 3: 1 List of data sources collected offices

Name of the Office	Data type
Addis Ababa water and sewerage authority	<ul style="list-style-type: none"> ➤ Rate Of Per Capita ➤ Water Supply Distribution Network System in Auto Cad Form ➤ Source Of Water and Its Capacity ➤ Length And Type of Pipe Used ➤ Monthly Billed Water Consumption ➤ Etc.
Ethiopian Metrological Agency	Metrological dada <ul style="list-style-type: none"> ❖ <i>Temperature</i> ❖ <i>Rainfall</i> ❖ <i>Relative humidity</i> ❖ <i>Sunshine hours</i>
Addis Ababa housing development office	Condominium building in Addis Ababa and in each sub city sites
Lideta housing administration	<ul style="list-style-type: none"> ➤ Land use ➤ <i>Population</i> ➤ <i>population density</i> ➤ housing units, housing density ➤ <i>condominium sites and its numbers</i>
Ethiopian statistical agency	<ul style="list-style-type: none"> ➤ Number of populations, ➤ Addis Ababa growth rate ratio

3.4 Data Analysis

The collected data were analyzed and interpreted in accordance with qualitative research approach method. In data analysis AutoCAD 2016, ArcGIS 10.3, Water GEMS model v8i, Global Mapper, Excel and other modeling software stand alone or integrated to each other were used.

Water GEMS model is a hydraulic modeling application, for water distribution systems with Advanced Interoperability, geospatial model building, optimization, and asset management tools. From fire flow and constituent concentration analyses, to energy consumption and capital cost management, Water GEMS provides an easy-to-use environment for engineers to analyze, design, and optimize water distribution systems. In this paper, Water GEMS model is used for Modelling of water distribution systems specifically for determining system pressure and flowing rate under a variety of different conditions. Hydraulic analysis is an essential prerequisite for any project involving the implementation of works in a source. Much analysis of hydraulics for the purpose of design can be carried out by applying basic theory rather than resorting to numerical or physical modelling techniques Regarding the Lideta sub city digital mapping and network data for water distribution network in Auto CAD format incorporating material types and size was mainly collected from the Arada branch office of AAWSA. Updating, isolation of valves, checking and transforming network data to the Water GEMS model software and integration with other user interference programs like ArcGIS were performed to get an information on the selected study area is based on the current actual state and for enabling different scenarios and alternatives in to the model by isolating the selected study form other region, also branching and looping skeletonization process is also performed.in addition Arc GIS used for the generate elevation as well as developing contour lines for the specified area.

- ✚ In general Water gems model capabilities
 - Assess fire flow capacity
 - Analyze pipe and valve criticality
 - Build and manage hydraulic models
 - Design water distribution systems

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- Develop flushing plans
- Identify water loss
- Manage energy use

3.4.1 Methods Of Population Forecasting, Changing Of Population In Lideta Sub City

The base population for the study area was taken for census data which is conducted in 2007 by Ethiopian Statistical Agency. There are 10 woredas in the Lideta sub city, however only seven of them aside from woredas one, two, and ten are covered in the research. The estimated total population of the study area is shown in table 3:2 which estimated based on the growth rate of 3% found from Addis Ababa city before the development of condominiums.

Table 3: 2 Population forecast of the Study Area before development

Year	Woreda's List							Total people
	W03	W04	W05	W06	W07	W08	W09	
2007	27944	29355	27500	13931	18185	15081	15323	147319
2008	28795	30249	28338	14356	18739	15540	15789	151805
2009	29671	31170	29201	14793	19310	16013	16270	156428
2010	30575	32119	30090	15243	19898	16501	16766	161192
2011	31506	33098	31006	15708	20504	17003	17276	166101
2012	32466	34105	31950	16186	21129	17521	17802	171160
2013	33455	35744	32923	16679	22657	30430	18344	190232
2014	34473	36833	33926	17187	23347	31357	18903	196026
2015	35523	37954	34959	17710	24058	32311	19479	201996
2016	36605	39110	36024	18250	24791	33296	22532	210607
2017	37720	40301	37121	18806	25546	34310	23218	217021
2018	38869	41529	38252	19378	26324	35354	23925	223631
2019	40052	42794	39417	19968	27125	36431	24654	230441
2020	41272	44097	40617	20576	27951	37541	25405	237459
2021	42529	45440	41854	21203	28803	38684	26179	244691
2022	43824	46824	43129	21849	29680	39862	26976	252143
2023	45159	48250	44442	22514	30584	41076	27797	259822
2024	46534	49719	45796	23200	31515	42327	28644	267734
2025	47951	51233	47190	23906	32475	43616	29516	275888
2026	49412	52793	48627	24635	33464	44944	30415	284290
2027	50916	54401	50108	25385	34483	46313	31341	292948
2028	52467	56058	51634	26158	35533	47723	32296	301870
2029	54065	57765	53207	26954	36615	49177	33279	311063
2030	55712	59524	54827	27775	37730	50675	34293	320536
2031	57408	61337	56497	28621	38880	52218	35337	330298
2032	59157	63205	58218	29493	40064	53808	36413	340357

The population estimate that was produced using the CSA technique took into consideration for dwellers of the newly developed condominiums. After then, continue estimating the research area's population as shown in table 3-3 and Figure 3: 6 Population increases of the for specific newly built condominium sites (after densification)

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. The population of the condominiums was calculated using the Ethiopian average of five people per room, which is the number of individuals living in a single room. The total number of blocks, rooms per block, and estimated population residing in condominiums inside each woreda and the research area are all included in the number of structures constructed in the area.

Table 3: 3 Population forecasted of the of the study area (before and after densification)

year		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
W 3	Population	27944	28481	29083	29705	30368	31072	31677	32605	33401	34207	35044
	Area in hectare	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4
	Density/hectare	478.8	488	498.34	509	520.4	532.4	542.8	558.7	572.3	586.14	600.5
W 4	Population	29355	29919	30552	31205	31902	32641	33276	34252	35088	35935	36814
	Area in hectare	88	88	88	88	88	88	88	88	88	88	88
	Density/hectare	334	340	348	355	363	371	379	390	399	409	419
W 5	Population	27500	28029	28621	29234	29886	30579	31174	32088	32871	33664	34488
	Area in hectare	13.64	13.64	13.64	13.64	13.64	13.64	13.64	13.64	13.64	13.64	13.64
	Density/hectare	2016	2055	2098	2143	2191	2242	2285	2352	2410	2468	2528
W 6	Population	14199	14500	14810	15140	15491	15793	16255	16652	17054	17471	17471
	Area in hectare	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91	6.91
	Density/hectare	2055	2098	2143	2191	2242	2285	2352	2410	2468	2528	2528
W 7	Population	18185	18535	18927	19332	19763	20222	20615	21219	21737	22262	22806
	Area in hectare	49	49	49	49	49	49	49	49	49	49	49
	Density/hectare	374	381	389	398	407	416	424	437	447	458	469
W 8	Population	15323	15617	19278	19690	20130	20596	40027	41197	42400	43640	44914
	Area in hectare	84	84	84	84	84	84	84	84	84	84	84
	Density/hectare	182	185	228	233	239	244	474	488	502	517	532
W9	Population	15081	15371	15696	16031	16389	16769	17095	17596	18026	18461	18913
	Area in hectare	76	76	76	76	76	76	76	76	76	76	76
	Density/hectare	199	202	207	211	216	221	225	232	237	243	249
Total Population (for Woreda 3,4, 5, 6, 7, 8 and 9)		147587	150452	156967	160338	163930	167672	190120	195609	200577	205640	210450

Finally, the total population, area, density horizon and density per hectare. and km² respectively of each woreda is as the table showing bellow.

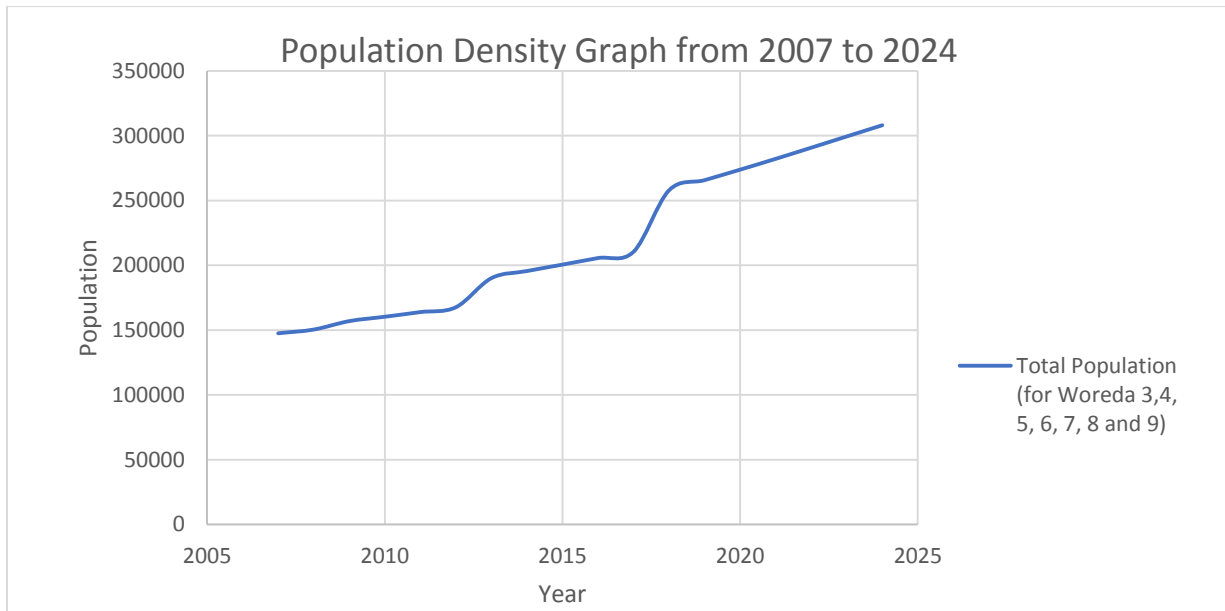


Figure 3: 6 Population increases of the for specific newly built condominium sites (after densification)

3.4.2 Water Demand Forecasting

Determining demands is not a straightforward process like collecting data on the physical characteristics of a system. Some data, such as billing and production records, can be collected directly from the utility but are usually not in a form that can be directly entered into the model. For example, metering data are not grouped by node. Once this information has been collected, establishing consumption rates is a process requiring study of past and present usage trends and, in some cases, the projection of future ones.

The first stage, explanatory variables analysis, consists of the description and analysis of the explanatory variables that are used to construct the demand scenarios (Sofia, 2014). The context data can be categorized as follows: clients and billed consumption, infrastructure, hydraulic operation, socio-demographic, consumption habits, characteristics of facilities and climate.

The method used for water demand forecasting is simple water demand forecasting system by taken the currently high per capita used by AAWSA offices to Addis Ababa water supply distribution system. According the AAWSA water supply documents the currently high per capita in Addis Ababa is used 110 l/c/d this is to estimate domestic water demand and for the

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commercial and institutional centers used 35% of the domestic water demand and the same to the industrial water demand and fire water demand 25% and 5% respectively. The water loss from 40% currently water loss amount to 20% till the design period 23-year 2032. After forecasted the total water demand as average daily water demand, maximum daily water demand and peak hourly water demand, the peak hourly water demand for the water supply distribution system used to develop three scenarios for the old, present and future water distribution network system for the base year of 2009, 2023 and 2032 respectively.

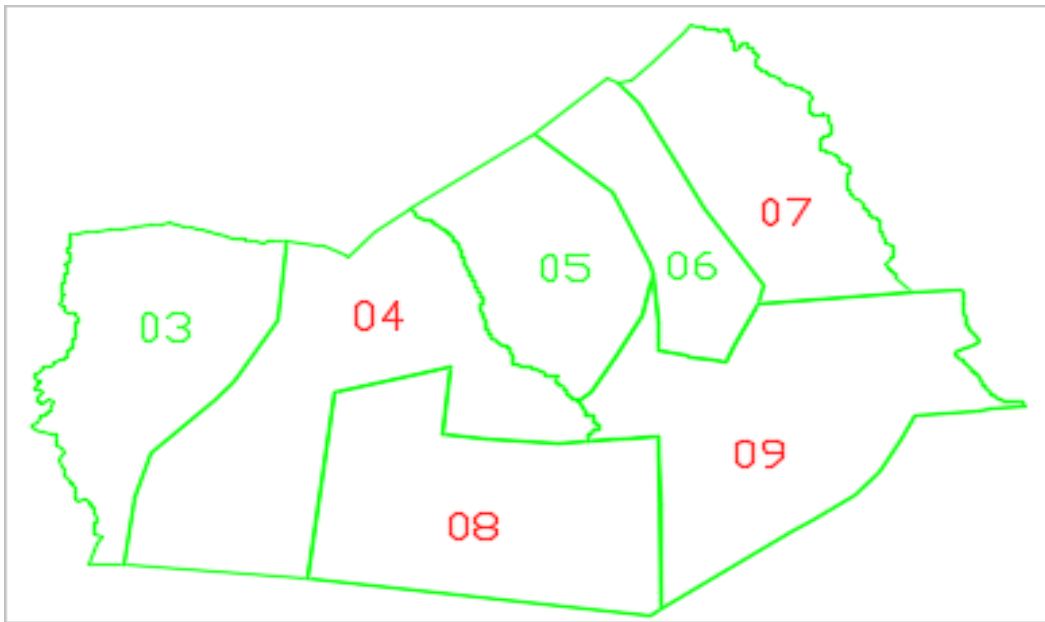
Table 3: 4 Total water demand estimation method in m³/day based on data found from AWSAA

description	population	domestic demand	ind. Deman	industrial dem	fire demand	(total demand)	total demand m ³ /d	water loss %	water loss amount m ³ /d	average daily demand	max.daily dem	peak hourly dem
demand l/c.d		110	35%	25%	5%							
2009	156428	17207112	6022489.31	4301778.08	860355.62	28391735	28391.74	40%	11356.69	39748.43	47698.12	67572.33
2010	161192	17731147	6205901.41	4432786.72	886557.34	29256392	29256.39	40%	11702.56	40958.95	49150.74	69630.21
2011	166101	18271141	6394899.25	4567785.18	913557.04	30147382	30147.38	40%	12058.95	42206.34	50647.60	71750.77
2012	171160	18827580	6589652.93	4706894.95	941378.99	31065507	31065.51	40%	12426.20	43491.71	52190.05	73935.91
2013	190232	20925565	7323947.73	5231391.24	1046278.25	34527182	34527.18	40%	13810.87	48338.06	58005.67	82174.69
2014	196026	21562843	7546995.15	5390710.82	1078142.16	35578691	35578.69	40%	14231.48	49810.17	59772.20	84677.29
2015	201996	22219530	7776835.37	5554882.41	1110976.48	36662224	36662.22	40%	14664.89	51327.11	61592.54	87256.09
2016	210607	23166815	8108385.27	5791703.76	1158340.75	38225245	38225.24	40%	15290.10	53515.34	64218.41	90976.08
2017	217021	23872350	8355322.36	5968087.40	1193617.48	39389377	39389.38	40%	15755.75	55145.13	66174.15	93746.72
2018	223631	24599371	8609779.81	6149842.72	1229968.54	40588962	40588.96	30%	12176.69	52765.65	63318.78	89701.61
2019	230441	25348533	8871986.64	6337133.32	1267426.66	41825080	41825.08	30%	12547.52	54372.60	65247.12	92433.43
2020	237459	26120511	9142178.86	6530127.76	1306025.55	43098843	43098.84	30%	12929.65	56028.50	67234.20	95248.44
2021	244691	26915999	9420599.66	6728999.75	1345799.95	44411398	44411.40	30%	13323.42	57734.82	69281.78	98149.19
2022	252143	27735713	9707499.63	6933928.31	1386785.66	45763927	45763.93	30%	13729.18	59493.10	71391.73	101138.28
2023	259822	28580391	10003137.01	7145097.86	1429019.57	47157646	47157.65	30%	14147.29	61304.94	73565.93	104218.40
2024	267734	29450794	10307777.88	7362698.49	1472539.70	48593810	48593.81	30%	14578.14	63171.95	75806.34	107392.32
2025	275888	30347704	10621696.45	7586926.04	1517385.21	50073712	50073.71	30%	15022.11	65095.83	78114.99	110662.90
2026	284290	31271929	10945175.27	7817982.33	1563596.47	51598683	51598.68	20%	10319.74	61918.42	74302.10	105261.31
2027	292948	32224301	11278505.48	8056075.34	1611215.07	53170097	53170.10	20%	10634.02	63804.12	76564.94	108467.00
2028	301870	33205677	11621987.11	8301419.36	1660283.87	54789368	54789.37	20%	10957.87	65747.24	78896.69	111770.31
2029	311063	34216941	11975929.31	8554235.22	1710847.04	56457952	56457.95	20%	11291.59	67749.54	81299.45	115174.22
2030	320536	35259002	12340650.65	8814750.47	1762950.09	58177353	58177.35	20%	11635.47	69812.82	83775.39	118681.80
2031	330298	36332798	12716479.42	9083199.58	1816639.92	59949117	59949.12	20%	11989.82	71938.94	86326.73	122296.20
2032	340357	37439297	13103753.87	9359824.19	1871964.84	61774840	61774.84	20%	12354.97	74129.81	88955.77	126020.67

SOURCE: AAWSA (2008-2012) GTP2 final report 2015 E.C

3.4.3 The Analysis of The Pattern of Urban Rehabilitation Lideta Sub City

From this study of the changing use of land and settlement, it is found that the urban rehabilitation pattern of Addis Ababa City has finally changed from ground settlement to new multi-story (up to 12 floors) buildings, even if the largest part of the city is still occupied with old settlement.



NB. The blue color represents condominium sites of the study area and the green one is boundary line of the study area

Figure 3: 7 Condominium Sites of the Rehabilitated Area The the Study Area

3.5 Distribution System Analysis

3.5.1 Water Distribution System Modeling

Planning, designing, operation and maintenance of WDSs have become more and more important as cities are growing and demanding more infrastructure components to provide service. The WDS modeling (i.e. computer modeling) is used to observe the behavior of water networks which could be steady-state models, dynamic or water quality models. There are a number of commercial (i.e. Water GEMS, H2ONET, Info Works etc.) and open software (i.e. EPANET) that enable computer simulations to model water networks (Savic et al. 2011). A

water distribution system (WDS) design deals with achieving the desired network performance. WDS design can involve new and existing network redesigns in order to keep up with the required service performance. Very often, WDS design is expensive, which encourages cost effectiveness in the required investments. Urbanization that takes into account factors such as demographics (population ageing, household occupancy rates, etc.) and other activities are associated with water demand changes. In addition to the aforementioned issues, the challenge of meeting the required hydraulic performance of WDSs is worsened by the uncertainties that are associated with WDS parameters (the present and future water demand). With all the factors mentioned here, mitigation and adaptive measures are considered essential to improve WDS performance in the long-term planning horizon.

Scenario planning is a useful approach to deal with high levels of uncertainty when planning, developing, and managing water distribution systems. Scenarios should highlight many possible alternatives in the future and each alternative future is not equally likely. Probabilistic scenarios are proposed. An example is given to demonstrate the process to generate the scenarios with probabilities, which indicates a promising new insight the technique may provide. Scenarios are able to inform the decision-making process, conversely, be applied to test the robustness of strategies (Dong & Giesen, 2012).



Figure 3: 8 Developing water distribution network of the study area overlapping

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Figure 3: 9 Water Gems V8i Model Building Distribution Network System Scenario

Table 3: 5 Scenario development for the new water demand center

scenarios	Scenario description	Input data
Scenarios 1	<ul style="list-style-type: none"> ❖ Analysis of old distribution system before rehabilitation (in 2009) <ul style="list-style-type: none"> ➤ old water demand ➤ hydraulic parameter 	<ul style="list-style-type: none"> ✓ Junction (demand, elevation) ✓ Pipe (length, type, diameter-fact.) ✓ Pump(head,) ✓ Reservoir(elevation) ✓ Tank(diameter)
Scenarios 2	<ul style="list-style-type: none"> ❖ Analysis of the new distribution system with rehabilitation (in 2023) <ul style="list-style-type: none"> ➤ new water demand centers ➤ analysis of the change in hydraulic parameter 	<ul style="list-style-type: none"> ✓ Junction (demand, elevation) ✓ Pipe (length, type, diameter-fact.) ✓ Pump(head,) ✓ Reservoir(elevation) ✓ Tank(diameter)
Scenarios 3	<ul style="list-style-type: none"> ❖ Development of new distribution system in the new demand center area (in 2032) <ul style="list-style-type: none"> ➤ new water demand centers ➤ analysis of the change in hydraulic parameter 	<ul style="list-style-type: none"> ✓ Junction (demand, elevation) ✓ Pipe (length, type, diameter-fact.) ✓ Pump(head,) ✓ Reservoir(elevation) ✓ Tank(diameter)

3.5.2 Allocating Base Water Demand To Each Node

To assign base demand to each service node, it is necessary to determine the houses around each supply node. It is a multi-step procedure to allocate water demand to the node, which is as follows:

A. Area demand system

The water distribution system is classified into supply areas according to land use, such as residential, commercial, and industrial area, and public service. The map of the town was taken from the municipality of lideta sub city in AutoCAD file format prepared in ArcMap to change urban land use. Identify the number of the house around each supply node The urban land uses the town-based AutoCAD format was obtained from the administration of lideta city and water supply distribution networks from AAWSA. Then the urban land use was prepared in ArcMap. The land use map and the town WDN, which is display in Water GEMS. The number of houses in each census block was physically counted, and assigned to the nearest supply node. An Excel sheet was created for demand allocation. Area served to each node by creating Thiessen polygon at the water GEMS Model and read its sub area in GIS software. To allocate demand at each node total demand multiply by each Thiessen polygon areas divided to the total area of the study area.

3.6 Calibration And Validation Of Model

The credibility of analysis is merely evident if analysis of result precisely reflects observed field values. Thus, to have a confidence on analysis result it needs to calibrate a system. An effort to perform hydraulic network calibration and validation for this case study is presented as follows. Calibration is the process of comparing the analysis results to field observations and, if necessary, adjusting the data describing the system until system predicted performance reasonably agrees with measured system performance over a wide range of operating conditions.

Even though the required data have been collected from AAWSA and entered into a hydraulic simulation software package, the system cannot assume that the analysis is an accurate mathematical representation of the system. The hydraulic simulation software simply solves the equations of continuity and energy using the supplied data; thus, the quality of the data will

dictate the quality of the results. The accuracy of a hydraulic network depends on how well it has been calibrated, so a calibration analysis should always be performed before a system is used for decision making purposes. The sample of junction nodes used for the calibration and validation are the following selected points from the distribution network as we shown in the figure 3.4 bellow.

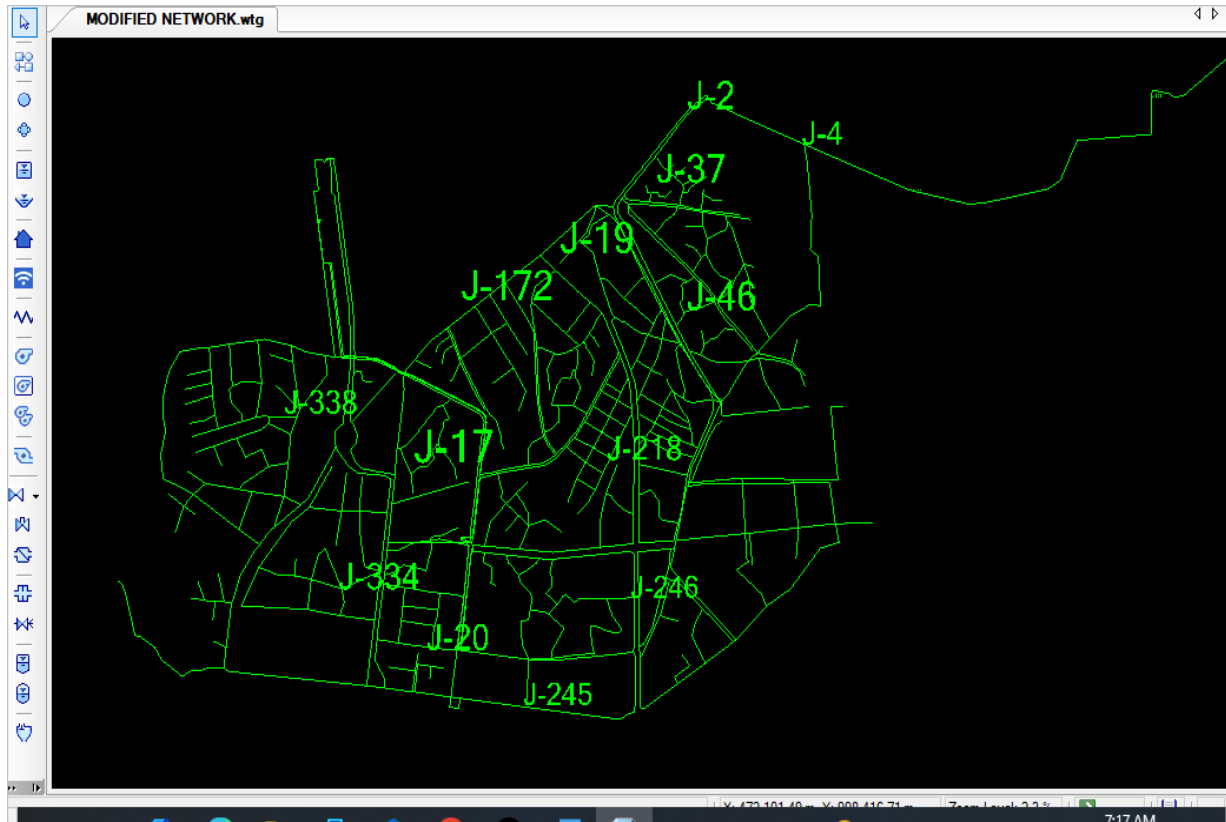


Figure 3: 10 Observed Sample Of Junction Nodes From Distribution Network

CHAPTER FOUR

4 RESULT AND DISCUSSION

4.1 Water Demand and Population Forecasting before and after densification

The average number of people in a single room in Ethiopia was used to estimate the total population of woreda eight (the rehabilitated), assuming five people per room. As categorized in the table below, the number of buildings constructed in the together with the total number of blocks, rooms per block, and total number of rooms in each identical building. Thus, following rehabilitation, the population of woreda eight rose by 19,030. However, prior to the condominium's development beginning in 2002, over 1,365 people were living there. This means the population surge from 1,365 to 19,030 that is increase by about 1294.14% of the population before densification.

Table 4: 1 Condominium At Woreda 8 Site And Its Capacity

Topology	No of blocks	No of Room	Total Room	5 person /room aver.
G+4 resident	36	30	1080	5400
G+4shop &resident	5	30	150	750
G+7 resident	5	144	720	3600
G+7 shop & resident	6	144	864	4320
G+12 shop &resident	4	248	992	4960
TOTAL			3806	19030

Source: Lideta sub city administration office

This shows the population surge of woredas that were rehabilitated area in Lideta sub city with base population taken from 2007 census data and population projection till the time of 2017 year by using the average growth rate of Addis Ababa 3%. The significant effect shows in woreda 8 as shown in the graph below.

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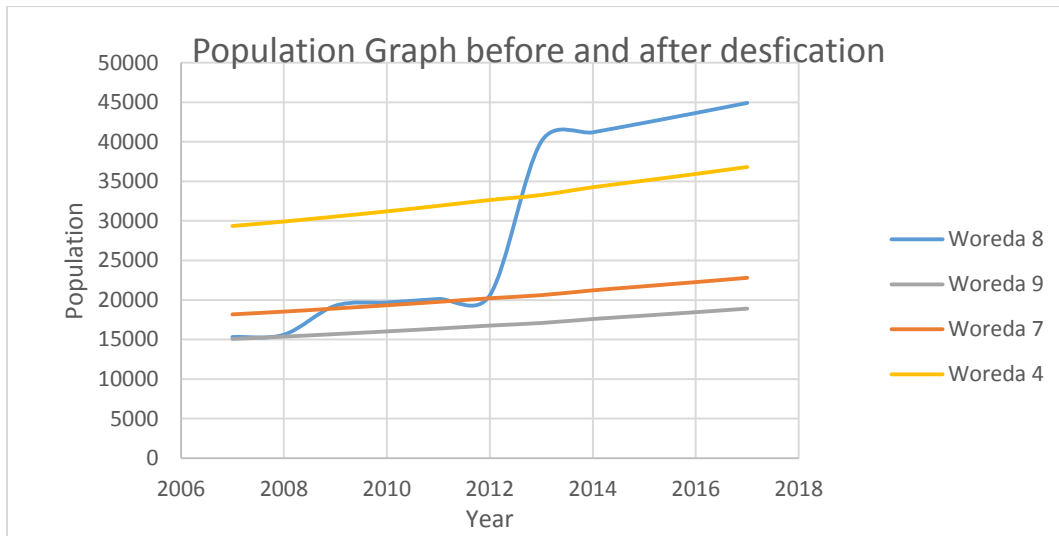


Figure 4: 1 Population Surge Before And After Densification

The population and water demand forecasting are very crucial for adjusting the required water activities or projects before shortage of water is exhibited in the sub city. The resettlement starts in 2009. Just after this year up to 2013 the population increase very rapidly. The population and total water demand of Lideta Sub city in 2009 was obtained as 214080 and 54397.7m³/day respectively. As shown in 2013 the water demand was forecasted considering and without considering the densification and the result was obtained as 28807.9m³/day and 61333.3m³/day and difference was about 8.5%. in the present year 2024 the gap of the demand is increase by about 17.8% by considering both cases. That is why models are helpful for forecasting water demands of the future. At the end of the design period the demand difference will be 27.7% hence, additional sources and revising of the water distribution system is very critical. This increased demand may require upgrades or expansions to the water supply system to ensure an adequate and reliable water supply.

Table 4: 2 Forecasted Population And Domestic Water Without Considering And Considering Densification

Year	Without considering densification			Considering densification			Percentage increase due densification
	Forecasted Population	Forecasted domestic water demand (m ³ /day)	Forecasted Total water demand (Domestic + non-	Forecasted population	Forecasted domestic water demand (m ³ /day)	Forecasted Total water demand (Domestic + non-	

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			Domestic) (m ³ /day)			Domestic) (m ³ /day)	
2009	214080	23548.8	54397.7	214080	23548.8	54397.7	
2013	241375	26551.2	61333.3	261890	28807.9	66546.1	8.5%
2023	325822	35840.4	76877.6	356549	39220.4	90599.1	17.8%
2024	335744	36931.9	79218.9	367407	40414.8	93358.2	17.8%
2032	426815	46949.6	92960.2	467066	51377.3	118681.5	27.7%

4.2 Key changes parameters of the water supply distribution system due to densification

Densification, which refers to an increase in population density within a given area, can have several key impacts on the parameters of a water supply distribution system. There will be more consumers in a given area leading to higher demand for water. This increased demand may require upgrades or expansions to the water supply system to ensure an adequate and reliable water supply. The higher population density can result in fluctuations in water pressure within the distribution system. This can lead to issues such as low pressure in some areas and high pressure in others, affecting the overall efficiency and performance of the system. As population density increases, there may be a greater risk of contamination from sources such as industrial runoff, agricultural activities, or improper waste disposal. This can impact the quality of the water supply and necessitates additional treatment measures to maintain water safety.

4.3 The Impact of New Demand Centers on Water Supply Distribution System

The water demand analysis focus on major factor that is caused due to the increase of total water demand due to new condominium development in Lideta sub city caused increase of number of populations. The new water demand centers on a water supply are a critical aspect of that affects the water distribution system. When new demand centers emerge since 2013 the population increases by about 10% similarly the total water demand increases similarly as shown in figure 4.2 and table 4.2. Increasing the total discharge causes change in the hydraulic performances such as velocity and pressure head.

The population increases leads to inadequate of the existing water distribution system experiencing significant water loss, pressure, and flow velocity (Yitbarek , 2022). As each

community may be significantly different from the others in scale and water use, the WDSs have spatially variable demand patterns. Hence, there might be considerable variability of real flow patterns for different parts of the system. To quantify the impacts, WDSs' performances under both uniform and spatial distributed patterns are compared based on case studies. Consequently, the system operation might not reach the expected performance determined during the design stage, since all corresponding facilities are commonly tailor-made to serve the design flow scenario instead of the real situation (Kegong, et al., 2019).

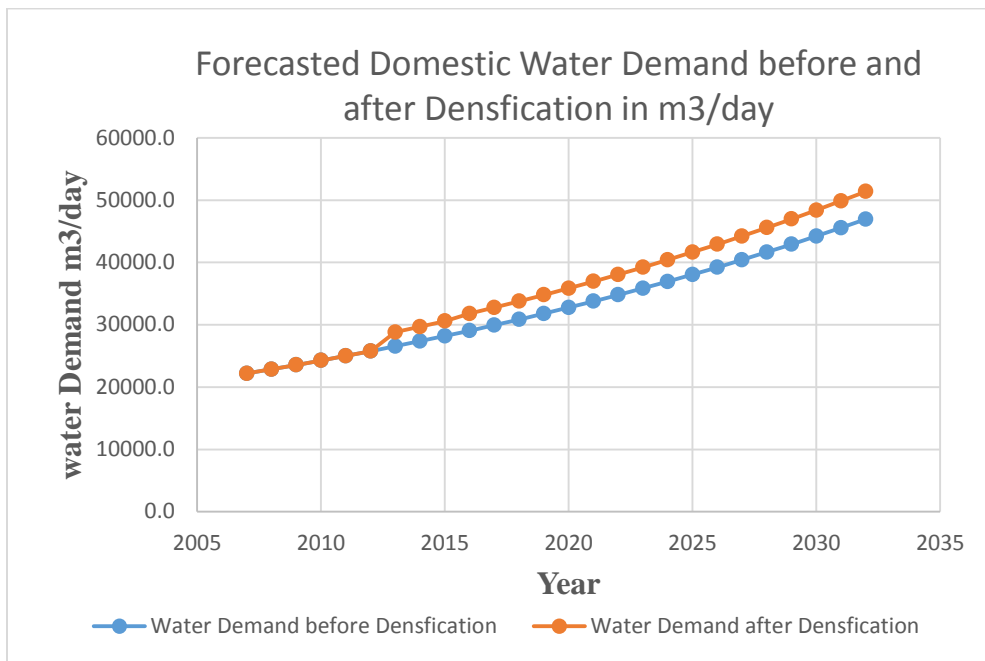


Figure 4: 2 Forecasted Domestic Water Demand After Densification

4.4 Hydraulic Performance of Increasing New Demand Centers on The Water Supply Distribution System

The hydraulic performance of increasing new water demand centers on the water supply distribution system is a critical concern for managing the delivery of water to these areas. When additional demand centers are introduced, the hydraulic performance of the distribution system can be affected in several ways. The increased demand for water may necessitate higher flow rates through the distribution system. This could lead to challenges such as increased pressure drop along the pipelines and the potential for inadequate flow in certain areas. The addition of new water demand centers can alter the pressure dynamics within the distribution

system. Higher demand may require adjustments to maintain appropriate pressure levels, especially at peak usage times. The existing infrastructure may face limitations in meeting the increased demand. Evaluating the capacity of reservoirs, pumping stations, and pipelines is crucial to ensuring that the system can handle the additional water requirements without compromising performance.

Assessing the network layout and configuration becomes important to ensure that water can be distributed efficiently to the new demand centers. This may involve evaluating pipeline sizes, routing, and the need for additional infrastructure. Changes in flow patterns and pressure levels can impact water quality within the distribution system. Maintaining adequate water circulation and addressing potential stagnation points is vital to preserving water quality. To address these concerns and maintain the hydraulic performance of the water supply distribution system, hydraulic modeling, simulation, and analysis can be employed. These tools help assess the impact of new demand centers on the system's performance and inform decision-making regarding infrastructure upgrades, operational adjustments, and system optimization.

Overall, managing the hydraulic performance of the water supply distribution system involves a comprehensive understanding of the impact of increasing demand centers and proactive planning to address potential challenges.

4.5 Model Out Put Result

4.5.1 Calibration And Validation Of Model

Calibration and validation are critical steps in the modeling process for hydraulic models like **WaterGEMS** (which is a software used for water distribution modeling). These steps ensure that the model's predictions are accurate and reliable for real-world applications. Calibration is the process of adjusting the parameters of a model so that its outputs match observed data as closely as possible. It is done using available water pressure of at sample junction nodes J-17, J-172, J-19, J-2, J-20, J-218, J-245, J-246, J-334, J-37, J-4 and J-46 field data or measurements collected from AAWSA show in the table below. Validation is the process of assessing whether the calibrated model can reliably predict system behavior under different nodes where no data was used for calibration. It serves to check the model's predictive accuracy and generalization

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beyond the calibration dataset. Run simulations using the calibrated model with the validation data and compare the predicted results to the actual observed values. This helps to identify whether the model's behavior is consistent across the sample of junction's water pressure.

Table 4:3 Observed And Simulated Pressure At Sample Junction Over A time

Time (hr.)	Pressure junction	Maximum Observed Pressure (m)	Simulated Pressure
2:00 AM	J-17	-0.4	-2.0
	J-172	-0.2	-0.4
	J-19	-0.2	-0.4
	J-2	6.0	3.5
	J-20	13.0	10.0
	J-218	4.8	2.2
	J-245	-0.2	-2.0
	J-246	2.5	1.2
	J-334	5.8	3.1
	J-37	-4	-11.0
	J-4	-0.2	-0.4
	J-46	3.8	2.0
8:00 pm	J-17	-0.2	-1.0
	J-172	-0.2	-0.3
	J-19	-0.3	-0.4
	J-2	4.5	2.1
	J-20	11.0	7.5
	J-218	-0.3	-0.5
	J-245	-0.5	-3.5
	J-246	-0.4	-0.2
	J-334	-0.2	-0.1
	J-37	-0.1	-0.6

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	J-4	-0.6	-1.2
	J-46	5.5	3.0

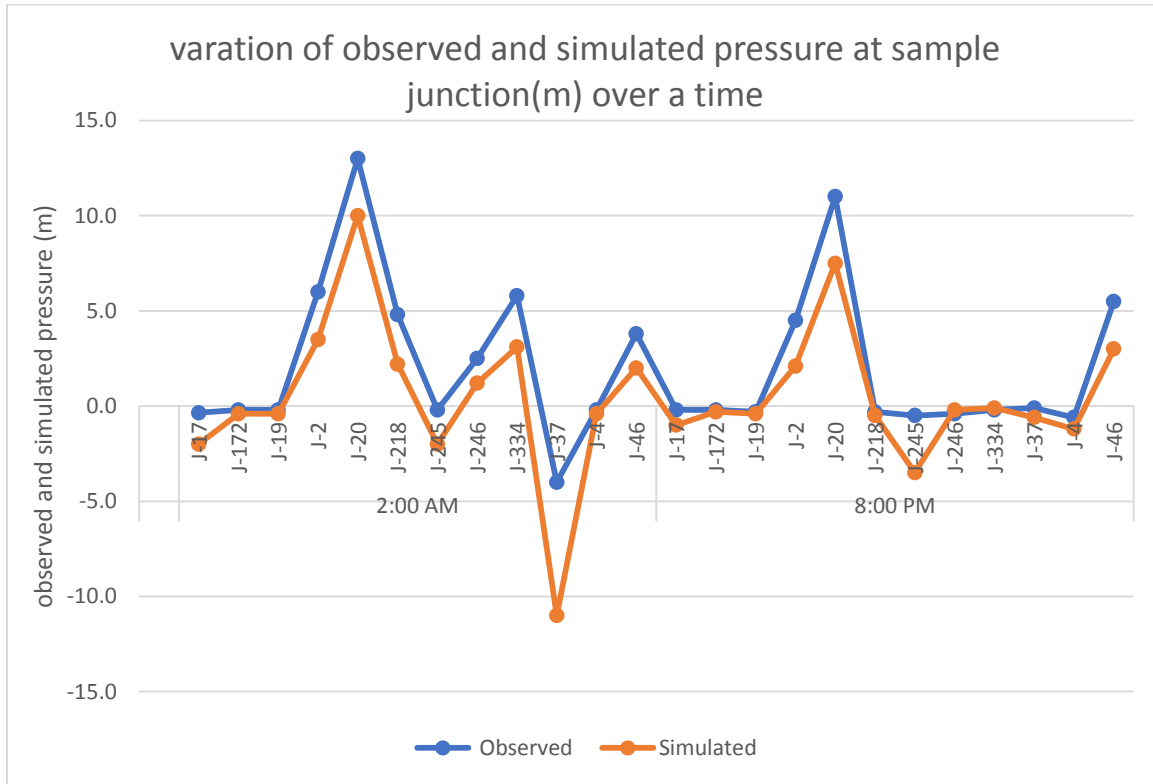


Figure 4: 3 Observed And Simulated Pressure At Sample Junction Over A Time

Pressures were measured in the field in order to compare with the results of the distribution system. The measurements covered a wide range of subsystems and branch to get a representative sample. Figure 4:1 is a comparison plot of observed pressures versus calculated pressures at various taps throughout the system. The diagonal line on the plot represents the line of perfect correlation in Figure 3:11 below here. Ideally all the points should align themselves on this line; meaning that all observed pressures would be equal to the computed pressures, giving a correlation coefficient of 1 that is the best correlation between observed and simulated. The linear correlation coefficient (R) of observed versus computed pressures is calculated by Equation 3-10 value is at 0.8554. The coefficient of determination (R²) value was 0.8554, it indicates that observed and simulated relation is strongly as values tend to 1.

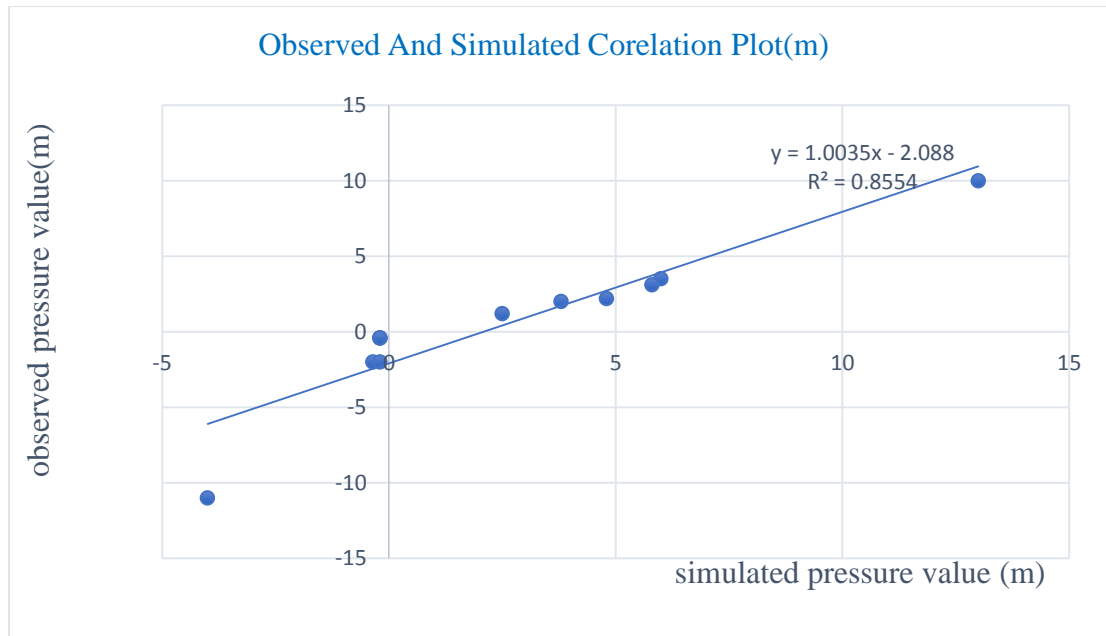


Figure 4:4 Observed And Simulated Correlation Plot

4.5.2 Calibration Based on Difference Error

The degree of accuracy varies depending on the size of the system and the amount of field data and testing available to the modeler. States that the average difference of $\pm 1.5\text{m}$ to a maximum of $\pm 5.0\text{m}$ for a good data set and ± 3.0 to $\pm 10\text{m}$ for a bad data set would be a reasonable target. this is in terms of comparing the observed versus the calculated pressure and heads in the system.

Table 4: 4 The Accuracy Of Observed And Simulated Data Error

Time (hr.)	Pressure junction	Maximum Observed Pressure (m)	Simulated Pressure(m)	Difference pressure Error(m)
2:00 AM	J-17	-0.4	-2.0	1.7
	J-172	-0.2	-0.4	0.2
	J-19	-0.2	-0.4	0.2
	J-2	6.0	3.5	2.5
	J-20	13.0	10.0	3.0
	J-218	4.8	2.2	2.6

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	J-245	-0.2	-2.0	1.8
	J-246	2.5	1.2	1.3
	J-334	5.8	3.1	2.7
	J-37	-4	-11.0	7.0
	J-4	-0.2	-0.4	0.2
	J-46	3.8	2.0	1.8
Average Error				2.1

As shown in Table 3:7 computed values are within an average error of 2.1m pressure simulated to observed values. Hence, the model is acceptable calibrated which is satisfied the setting pressure calibration and validation criteria under average level (average +1.5m to the maximum +5m).

4.5.3 Pressure

The minimum and maximum operating pressure in the water supply distribution system network in Ethiopia was 15 m and 80 m respectively (MOWR, 2006). Pressure influences the water supply capacity of the distribution system. In order to achieve a 15 m minimum and 80 m maximum operating pressure, it is necessary to provide pressure controlling valve establishing boosting station and replacing the old pipe with the new one. According 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 decrease as elevation increase and vice versa. Plot graph

The WDN of Lideta sub city was classified using a contour browser, which area is high, medium, and small-pressure parts. With concerning current simulation, the result for pressure using the estimated average daily demand during peak hour consumption is summarized in Table 4.3.

As described in Table 4.3, 88% below recommended pressure, 0 % above the recommended pressure and 88% of junctions are within the recommended pressure ranges of minimum 15 m and maximum 80 m 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.

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Table 4: 5 Pressure Difference Between Each Scenario

Pressure range	Percentage Of Pressure In The Year		
	2009	2023	2032
<=0	72.72	88.78	92.51
0 - 20	18.59	9.98	7.24
20 - 80	4.62	1.00	0.00
>= 80	0.00	0.00	0.00

4.5.4 Velocity

Velocity of water flow in a pipe is also one of the important parameters in hydraulic modeling performance evaluation of the efficiency of water supply distribution and transmission line. Velocity distribution is also varying with demand pattern changes. There are specific standards for velocity. The result of velocity of Gudo Bahir is not desirable or adequate with response to urban water supply design criteria. These types of hydraulic indicators are as if a pressure unfortunate as the result of the strategy description. At the peak hour demand the values are different as compare to minimum consumption hour. The water supply system network velocity during peak hour demand is summarized in the Table 4.4 below.

Table 4: 6 Velocity Difference Between Each Scenario

Velocity In (m/sec)	Percentage Of Velocities In The Year		
	2009	2023	2032
<= 0.6	29.91	40.36	35.75
0.6 -3.00	56.46	38.88	34.10
>= 3.00	13.45	20.76	30.81

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. The velocity of flow in the pipe below 0.6 m/s causes“ water stagnation and bacteriological growth in the pipe, on the other hand velocity of flow in the pipe above 2 m/s causes a water hammer problem. Velocity in water distribution system was varied with the demand pattern change.

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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.

4.5.5 Diameter Size

Table 4: 7 Diameter Size Difference Between Each Scenario

Diameter size (mm)/year	2009 Diam. Used	2023 Diam. Used
Dia.50	227	232
Dia.60	130	150
Dia.63	107	9
Dia.90	130	32
Dia.100	26	27
Dia.110	35	37
Dia.150	27	29
Dia.200	39	41
Dia.250	17	22
Dia.300	6	6
Dia.350	3	3
Dia.>=400	7	7

As we shown in the table above or graph below the diameter size used before and after even if till the current time what size and the update due to the increasing number of population or the water demand at the study area. When we see at the year of 2009 around 227 pipes used 50 mm dia. Size but after densification that means at the year of 2023 232 pipes used the size of 50 mm dia. The difference between these years they updated 5 pipes only. generally, no more change at the diameter size of the distribution system.

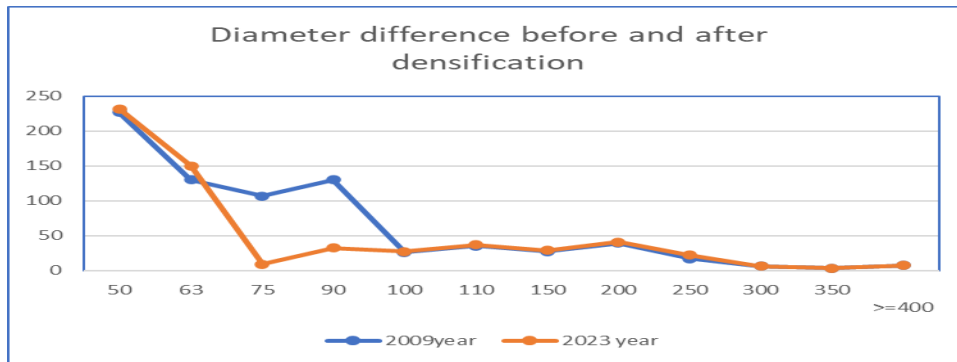


Figure 4: 5 Diameter Difference Before And After Densification

CHAPTER FIVE

5 CONCLUSION AND RECCOMENDATION

5.1 Conclusion

Due to the case of densification or rehabilitation In this study area I concluded such as, the existing WDS is simulated through the construct of a model using Bentley Water GEMS V8i. The actual system was evaluated for the existing design, operation, and maintenance of the network, especially in various abnormal situations. The result evaluated the design, operation and maintenance facilities were poor due to the wrong model result implementation without modifying and due to the poor technician. Finally, we can conclude that there is no clear operation and maintenance system for the WDS in Lideta sub city as well as Addis Ababa, which ensures the needed for establishing an effective operation and maintenance system for lideta sub city Most of these problems are created in the condominium area sites woreda 8, woreda 7, woreda 4 and woreda 9. The study comes about confirmed the Water GEMS modeling procedure than the conventional trial and error simulation approach by water CAD V8i. After computing the existing system, about 88.78% of junctions are failed to satisfy desirable minimum pressure during steady state simulation and 1.0 % of junctions are failed due to extremely high pressure during the steady state simulation.in addition due to low and high velocity rate also 40.36 % and 20.76% failed respectively. Generally, the condition or a situation of actual water distribution system of the study area is inadequacies. In the modified system, the network runs for the Darwin designer tool for the changed of the system hydraulic parameters are radically improved using the entered data designed average daily demand.

5.2 Recommendation

This study has found out the very critical findings, which are very important for the overall modeling and operation of lideta sub city water distribution and water loss system. Finally, the researcher has serious to recommend some of the very important issues to improve the hydraulic modeling of the water system. The universal peak factors, which are used in the design of water distribution systems, should be modified and adjusted in the design of new water systems in lideta sub city according to the local conditions of operating and managing the distribution networks. Hydraulic Analysis: Conduct hydraulic modeling to understand how increasing water demand in condominiums affects pressure levels, flow rates, and overall system performance within the distribution network.

Water Usage Patterns: How do the water usage patterns of residents in condominiums with new demand centers differ from those without? What are the implications for water supply and distribution systems?

Demand Forecasting: Develop predictive models to forecast future water demand trends in condominiums and assess how these projections can inform system planning and design.

Pumping and Storage: Investigate the capacity of pumping stations and storage reservoirs to meet rising demand from condominiums, and assess the need for upgrades or modifications.

Infrastructure Capacity: What is the capacity of existing water supply infrastructure in condominium complexes to accommodate increased demand? Are there potential bottlenecks or areas of concern?

Installing of pressure reducing valve devices, which decrease pressure is recommend as a solution to control the occurrences of maximum pressures during low consumption hour for

desirable pressure range. Old and corrode pipes should be replaced and faulty water meters need to be maintained or replaced to minimize leaks and errors of water production recording and to control and minimize the risks of water loss customers should be encouraged to report telephonically and the information should be obtained comprehensively seeking all relevant details of accurate and timely communication is the key to efficient action.

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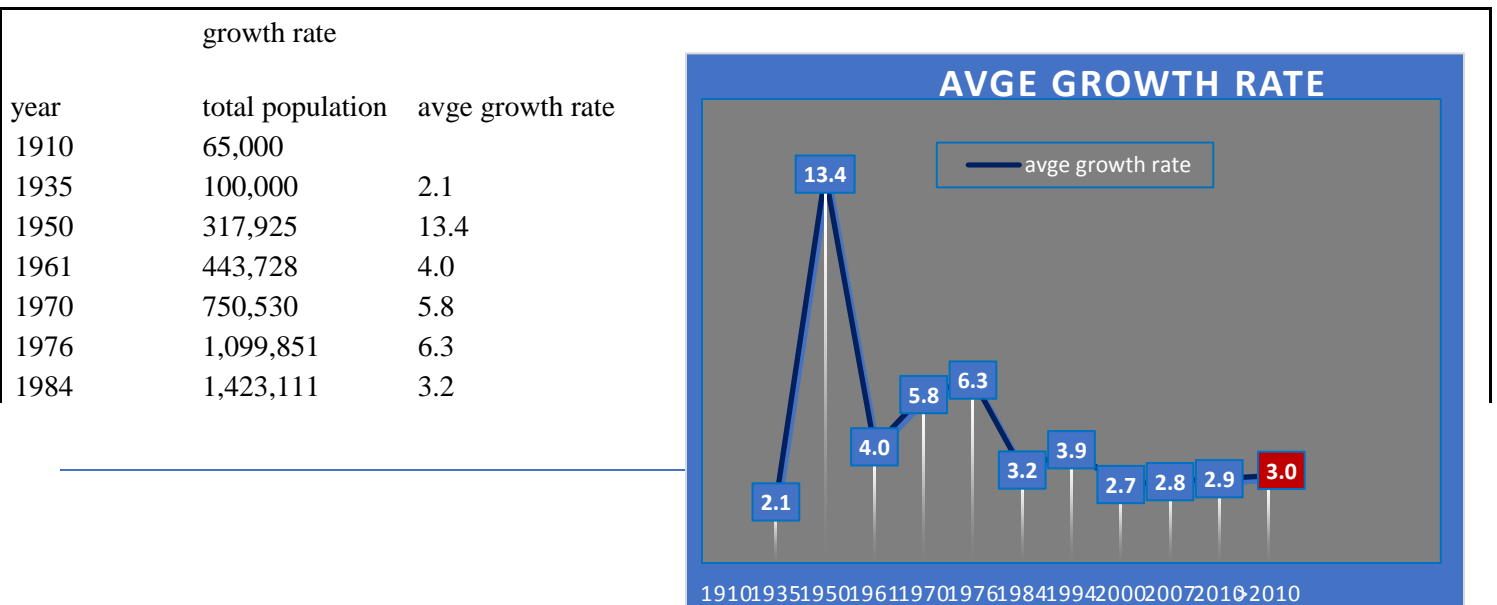
Appendixes

Appendix 1: Population Forecasting Methods Used

A. Condominium built sites and its population number

Woreda Name	Siet Name	No of blocks	No of rooms	Size of peoples/room	Total No of peoples
W03	_____	0	0	0	0
W04	balcha	3	120	5	600
W05	_____	0	0	0	0
W06	_____	0	0	0	0
W07	dekmehari	4	177	5	885
W08	lideta/mehandis	65	2475	5	12375
W09	sengatera 40/60	5	410	6	2460
Total sum					16320

B. Growth rate assumed from Addis Ababa historical growth rate



**EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA**

1994	2,112,737	3.9
2000	2,495,000	2.7
2007	2,738,248	2.8
2010	2,917,295	2.9
>2010		3.0

C. Integrated land information center from Addis Ababa administration

in the year of 2015 lideta sub city						
source :- addis ababa city administration integrated land information center						
woreda	area hect.	total area km2	population	density/hect	building	%of sub city pop
W01	273.73	9.18	21427	78.28	8524	11.08
W02	115.83	9.18	16322	140.91	6017	8.44
W03	58.36	9.18	26810	459.39	6715	13.86
W04	87.88	9.18	28166	320.52	8135	14.56
W05	44.17	9.18	26387	601.52	7419	13.64
W06	30.65	9.18	13365	435.51	4138	6.91
W07	48.61	9.18	17455	357.52	5601	9.02
W08	75.91	9.18	14586	192.12	2323	7.48
W09	84.38	9.18	14585	172.85	2311	7.6
W10	98.94	9.18	14355	145.11	4060	7.42

D. Population forecasting each woredas

year	lideta	%of sub city pop	population	density/hect	density/km2	woreda	area hect.	area in km2	total area km2
2007	201613	11.08	21427	78.28	0.7828	W01	273.73	2.7373	9.18
2008	205491	8.44	16322	140.91	1.4091	W02	115.83	1.1583	9.18
2009	209834	13.86	26810	459.39	4.5939	W03	58.36	0.5836	9.18
2010	214323	14.56	28166	320.52	3.2052	W04	87.88	0.8788	9.18

**EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA**

2011	219107	13.64	26387	601.52	6.0152	W05	44.17	0.4417	9.18	
2012	224186	6.91	13365	435.51	4.3551	W06	30.65	0.3065	9.18	
2013	228547	9.02	17455	357.52	3.5752	W07	48.61	0.4861	9.18	
2014	235246	7.48	14586	192.12	1.9212	W08	75.91	0.7591	9.18	
2015	240989	7.6	14585	172.85	1.7285	W09	84.38	0.8438	9.18	
2016	246805	7.41	14355	145.11	1.4511	W10	98.94	0.9894	9.18	
2017	252842	100			29.0373			9.1846		

year	lideta	woreda	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	sum
		area	273.73	115.83	58.36	87.88	44.17	30.65	48.61	75.91	84.38	98.94	918.46
		%of people	11.08	8.44	13.86	14.56	13.64	6.91	9.02	7.48	7.6	7.41	100
2007	201613		22339	17016	27944	29355	27500	13931	18185	15081	15323	14940	201613.00
2008	205491		22768	17343	28481	29919	28029	14199	18535	15371	15617	15227	205491.00
2009	209834		23250	17710	29083	30552	28621	14500	18927	15696	15947	15549	209834.00
2010	214323		23747	18089	29705	31205	29234	14810	19332	16031	16289	15881	214323.00
2011	219107		24277	18493	30368	31902	29886	15140	19763	16389	16652	16236	219107.00
2012	224186		24840	18921	31072	32641	30579	15491	20222	16769	17038	16612	224186.00
2013	228547		25323	19289	31677	33276	31174	15793	20615	17095	17370	16935	228547.00
2014	235246		26065	19855	32605	34252	32088	16255	21219	17596	17879	17432	235246.00
2015	240989		26702	20339	33401	35088	32871	16652	21737	18026	18315	17857	240989.00
2016	246805		27346	20830	34207	35935	33664	17054	22262	18461	18757	18288	246805.00
2017	252842		28015	21340	35044	36814	34488	17471	22806	18913	19216	18736	252842.00

**EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA**

Year	woreda	W3	W4	W5	W6	W7	W8	W9	Total people			
	Area	58.36	87.88	44.17	30.65	48.61	75.91	84.38	430		Year	Total Populatin
	%of people	13.86	14.56	13.64	6.91	9.02	7.48	7.6	73		2009	153326
2007		27944	29355	27500	13931	18185	15081	15323	147319		2010	156606
2008		28481	29919	28029	14199	18535	15371	15617	150152		2011	160101
2009		29083	30552	28621	14500	18927	15696	15947	153326		2012	163813
2010		29705	31205	29234	14810	19332	16031	16289	156606		2013	166999
2011		30368	31902	29886	15140	19763	16389	16652	160101		2014	171894
2012		31072	32641	30579	15491	20222	16769	17038	163813		2015	176091
2013		31677	33276	31174	15793	20615	17095	17370	166999		2016	180340
2014		32605	34252	32088	16255	21219	17596	17879	171894		2017	184752
2015		33401	35088	32871	16652	21737	18026	18315	176091			
2016		34207	35935	33664	17054	22262	18461	18757	180340			
2017		35044	36814	34488	17471	22806	18913	19216	184752			

E. Total population number of the study area

EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA

	Woreda's List							
Year	W03	W04	W05	W06	W07	W08	W09	Total people
2007	27944	29355	27500	13931	18185	15081	15323	147319
2008	28795	30249	28338	14356	18739	15540	15789	151805
2009	29671	31170	29201	14793	19310	16013	16270	156428
2010	30575	32119	30090	15243	19898	16501	16766	161192
2011	31506	33098	31006	15708	20504	17003	17276	166101
2012	32466	34105	31950	16186	21129	17521	17802	171160
2013	33455	35744	32923	16679	22657	30430	18344	190232
2014	34473	36833	33926	17187	23347	31357	18903	196026
2015	35523	37954	34959	17710	24058	32311	19479	201996
2016	36605	39110	36024	18250	24791	33296	22532	210607
2017	37720	40301	37121	18806	25546	34310	23218	217021
2018	38869	41529	38252	19378	26324	35354	23925	223631
2019	40052	42794	39417	19968	27125	36431	24654	230441
2020	41272	44097	40617	20576	27951	37541	25405	237459
2021	42529	45440	41854	21203	28803	38684	26179	244691
2022	43824	46824	43129	21849	29680	39862	26976	252143
2023	45159	48250	44442	22514	30584	41076	27797	259822
2024	46534	49719	45796	23200	31515	42327	28644	267734
2025	47951	51233	47190	23906	32475	43616	29516	275888
2026	49412	52793	48627	24635	33464	44944	30415	284290
2027	50916	54401	50108	25385	34483	46313	31341	292948
2028	52467	56058	51634	26158	35533	47723	32296	301870
2029	54065	57765	53207	26954	36615	49177	33279	311063
2030	55712	59524	54827	27775	37730	50675	34293	320536
2031	57408	61337	56497	28621	38880	52218	35337	330298
2032	59157	63205	58218	29493	40064	53808	36413	340357

Appendix 2: Water Demand Projection

**EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA**

A. water demand forecasting method

description	population	domestic demand	land inst. Demand	industrial demand	fire demand	total demand l/c.d	total demand m3/d	der loss %	water loss amount m3/d	average daily demand	max.daily demand	peak hourly demand
demand l/c.d		110	35%	25%	5%							
2009	156428	17207112	6022489.31	4301778.08	860355.62	28391735	28391.74	40%	11356.69	39748.43	47698.12	67572.33
2010	161192	17731147	6205901.41	4432786.72	886557.34	29256392	29256.39	40%	11702.56	40958.95	49150.74	69630.21
2011	166101	18271141	6394899.25	4567785.18	913557.04	30147382	30147.38	40%	12058.95	42206.34	50647.60	71750.77
2012	171160	18827580	6589652.93	4706894.95	941378.99	31065507	31065.51	40%	12426.20	43491.71	52190.05	73935.91
2013	190232	20925565	7323947.73	5231391.24	1046278.25	34527182	34527.18	40%	13810.87	48338.06	58005.67	82174.69
2014	196026	21562843	7546995.15	5390710.82	1078142.16	35578691	35578.69	40%	14231.48	49810.17	59772.20	84677.29
2015	201996	22219530	7776835.37	5554882.41	1110976.48	36662224	36662.22	40%	14664.89	51327.11	61592.54	87256.09
2016	210607	23166815	8108385.27	5791703.76	1158340.75	38225245	38225.24	40%	15290.10	53515.34	64218.41	90976.08
2017	217021	23872350	8355322.36	5968087.40	1193617.48	39389377	39389.38	40%	15755.75	55145.13	66174.15	93746.72
2018	223631	24599371	8609779.81	6149842.72	1229968.54	40588962	40588.96	30%	12176.69	52765.65	63318.78	89701.61
2019	230441	25348533	8871986.64	6337133.32	1267426.66	41825080	41825.08	30%	12547.52	54372.60	65247.12	92433.43
2020	237459	26120511	9142178.86	6530127.76	1306025.55	43098843	43098.84	30%	12929.65	56028.50	67234.20	95248.44
2021	244691	26915999	9420599.66	6728999.75	1345799.95	44411398	44411.40	30%	13323.42	57734.82	69281.78	98149.19
2022	252143	27735713	9707499.63	6933928.31	1386785.66	45763927	45763.93	30%	13729.18	59493.10	71391.73	101138.28
2023	259822	28580391	10003137.01	7145097.86	1429019.57	47157646	47157.65	30%	14147.29	61304.94	73565.93	104218.40
2024	267734	29450794	10307777.88	7362698.49	1472539.70	48593810	48593.81	30%	14578.14	63171.95	75806.34	107392.32
2025	275888	30347704	10621696.45	7586926.04	1517385.21	50073712	50073.71	30%	15022.11	65095.83	78114.99	110662.90
2026	284290	31271929	10945175.27	7817982.33	1563596.47	51598683	51598.68	20%	10319.74	61918.42	74302.10	105261.31
2027	292948	32224301	11278505.48	8056075.34	1611215.07	53170097	53170.10	20%	10634.02	63804.12	76564.94	108467.00
2028	301870	33205677	11621987.11	8301419.36	1660283.87	54789368	54789.37	20%	10957.87	65747.24	78896.69	111770.31
2029	311063	34216941	11975929.31	8554235.22	1710847.04	56457952	56457.95	20%	11291.59	67749.54	81299.45	115174.22
2030	320536	35259002	12340650.65	8814750.47	1762950.09	58177353	58177.35	20%	11635.47	69812.82	83775.39	118681.80
2031	330298	36332798	12716479.42	9083199.58	1816639.92	59949117	59949.12	20%	11989.82	71938.94	86326.73	122296.20
2032	340357	37439297	13103753.87	9359824.19	1871964.84	61774840	61774.84	20%	12354.97	74129.81	88955.77	126020.67

B. peak hourly demand used for the water distribution system at the selected year in the design period

EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA

Year	2009	2023	2032
Population	156428	259822	340357
Average daily demand (m3/day)	39748.43	61304.94	74129.81
Max.daily demand (m3/day)	47698.12	73565.93	88955.77
Peak hourly demand (m3/day)	67572.33	104218.40	126020.67
Year	2009	2023	2032
Peak hourly demand (m3/d)	67572.33	104218.4	126020.7

Appendix 3: Data's Which Used For The Model

A. Data Of Reservoir, tank And Pump

Items		Elevation	V(m3)	Q(m3/hr)	Head(m)	power kw	Efficiency	flow des. (l/s)	head desi	pump inle	Pump outlet-D
army rese	R2	2373.5	5000								
			(500+500)								
junmeda r	R1	2467	5000								
Mexico pu	Pmp1,1	2351		700	98	132	71.5	75	98		
Geja pupn	old(1)--pn	2368.5		270	90	132	71.5	75	90	125	100
	new(2)--p	2369.4		162	140	110	75	45	140	200	150
		base	maximum	inactive vol.	volume full	area	diameter				
Geja tank	old(1)-----	2364.5	2368.5	0	250	58.26	rect				
	new(2)----	2369.2	2375	0	1000		14.82m				
kasa Gebr	old(1)-----	2444.4	2449	0	500	108.69	rect				
	new(2)----	2453	2459	292	500		23m				

B. sample of input data to junction J1-J56 but the total junction of the study area are 378 before rehabilitation of the area at 2009 e.c

EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA

Junction	Elevation	Area(hect)	Qm3/day
1	2363.56	1.13	177.90
2	2435.2	0.02	3.14
3	2387.95	0.14	22.29
4	2433.1	0.02	3.14
5	2387.89	1.34	210.50
6	2392.46	0.47	73.44
7	2365.19	1.97	308.93
8	2393.45	1.82	286.39
9	2385.93	4.82	757.62
10	2363.5	3.16	497.12
11	2425.02	0.33	52.28
12	2426.95	1.42	223.71
13	2401.82	0.98	154.55
14	2425.34	1.49	234.66
15	2423.76	0.93	146.09
16	2416.03	2.20	344.94
17	2403.92	0.95	148.84
18	2425.71	1.41	221.26
19	2425.04	1.19	186.89
20	2408.08	1.75	275.36
21	2400.75	0.62	97.66
22	2393.85	0.23	35.97
23	2389	1.10	173.34
24	2423.83	0.21	33.19
25	2422.63	0.75	117.20
26	2390	0.76	119.72
27	2423.36	1.19	186.63
28	2390.65	0.58	91.24
29	2421.23	1.32	207.09
32	2415.8	0.21	32.64
33	2417.73	0.81	126.66
34	2414.54	0.68	106.95
36	2412.85	0.55	86.35
38	2410.59	0.37	57.75
40	2412.46	0.33	52.08
41	2400.53	1.47	230.81
42	2407.4	0.33	52.51
44	2402.81	0.68	106.66
46	2380.98	0.11	16.68
47	2417.81	2.17	341.74
48	2416.53	0.56	88.54
49	2407.34	0.23	36.92
50	2408.61	0.41	64.49
51	2414	0.64	101.23
52	2406.84	0.62	97.70
53	2407.75	0.61	95.25
54	2408.68	0.35	55.69
55	2413.52	1.04	162.68
56	2409.05	0.39	60.76

C. sample of input data to junction J1-J49 but the total junction of the study area are 402 after rehabilitation of the area at the current situation 2023 e.t

EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA

Junction	Elevation	Area(hect)	Q m3/day
1	2363.56	1.14	275.77
2	2435.20	0.02	4.85
3	2387.95	0.15	35.53
4	2433.10	0.02	4.85
5	2387.89	1.34	325.83
6	2392.46	0.47	114.44
7	2365.19	1.97	477.70
8	2393.45	1.83	443.03
9	2385.93	4.83	1169.71
10	2363.50	3.17	768.07
11	2425.02	0.34	81.79
12	2426.95	1.43	346.24
13	2401.82	0.99	239.55
14	2425.34	1.50	363.11
15	2423.76	0.93	226.51
16	2416.03	2.20	533.28
17	2403.92	0.95	230.77
18	2425.71	1.41	342.45
19	2425.04	1.19	289.45
20	2408.08	1.76	425.90
21	2400.75	0.63	151.83
22	2393.85	0.23	56.65
23	2389.00	1.11	268.50
24	2423.83	0.22	52.35
25	2422.63	0.75	181.65
26	2390.00	0.77	185.82
27	2423.36	0.88	212.65
28	2390.65	0.44	106.11
29	2421.23	0.69	166.38
30	2421.33	0.28	66.86
31	2421.72	0.91	220.24
32	2416.05	0.35	84.66
33	2415.80	0.21	50.98
34	2417.73	0.50	122.24
35	2414.54	0.29	70.16
36	2410.70	0.20	48.24
37	2412.85	0.14	33.59
38	2406.53	0.40	97.32
39	2410.59	0.14	34.38
40	2402.46	0.27	64.72
41	2412.46	0.22	52.82
42	2400.53	0.95	231.44
43	2407.40	0.25	59.74
44	2402.31	0.19	45.65
45	2404.27	0.28	68.81
46	2397.10	0.87	211.74
47	2380.98	0.11	26.88
48	2417.81	2.18	528.26
49	2416.53	0.48	116.43

Appendix 4: Input Data's

**EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA**

A.sample of input data to the pipe before rehabilitation of the study area but the total pipes are 565

Pipe Id	Material Type	Diameter in
1	DCI	200
2	DCI	400
3	DCI	300
4	DCI	150
5	DCI	200
6	DCI	200
7	DCI	150
8	DCI	200
9	DCI	200
10	DCI	150
11	DCI	150
12	DCI	150
13	DCI	200
14	ST	150
15	ST	200
16	DCI	250
17	DCI	250
18	PVC(JIS)	110
19	PVC(JIS)	110
20	PVC(JIS)	110
21	PVC(JIS)	100
22	PVC(JIS)	50
23	PVC(JIS)	110
24	PVC(JIS)	110
25	PVC(JIS)	100
26	PVC(JIS)	100
27	PVC(JIS)	63
28	PVC(JIS)	100
29	PVC(JIS)	100
30	PVC(JIS)	100
31	PVC(JIS)	100
32	GS	100
33	DCI	200
34	HDPE	110
35	HDPE	110
36	HDPE	150
37	DCI	200
38	DCI	200
39	HDPE	110
40	HDPE	110
41	PVC(ISO)	50
42	DCI	350
43	DCI	250
44	DCI	200
45	HDPE	110
46	PVC(JIS)	50
47	PVC(JIS)	50
48	DCI	800
49	PVC(JIS)	50
50	DCI	500

B.sample of input data to the pipe after rehabilitation of the study area but total pipes are 607

EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA

<i>Pipe id</i>	<i>Material Type</i>	<i>Diameter in mm</i>
1	DCI	200
2	DCI	400
3	DCI	300
4	DCI	150
5	DCI	200
6	DCI	200
7	DCI	150
8	DCI	200
9	DCI	200
10	DCI	150
11	DCI	150
12	DCI	150
13	DCI	200
14	ST	150
15	ST	200
16	DCI	250
17	DCI	250
18	PVC(JIS)	110
19	PVC(JIS)	110
20	PVC(JIS)	110
21	PVC(JIS)	100
22	PVC(JIS)	50
23	PVC(JIS)	110
24	PVC(JIS)	110
25	PVC(JIS)	100
26	PVC(JIS)	100
27	PVC(JIS)	63
28	PVC(JIS)	100
29	PVC(JIS)	100
30	PVC(JIS)	100
31	PVC(JIS)	100
32	GS	100
33	DCI	200
34	HDPE	110
35	HDPE	110
36	HDPE	150
37	DCI	200
38	DCI	200
39	HDPE	110
40	HDPE	110
41	PVC(ISO)	63
42	PVC(ISO)	63
43	ISO-PE	50
44	ISO-PE	50
45	HDPE	110
46	PVC(JIS)	50
47	PVC(JIS)	50
48	PVC(JIS)	50
49	PVC(JIS)	50
50	PVC(JIS)	50

Appendix 5: Output Results of Pipe

**EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA**

A. pipe output result before rehabilitation at the year of 2009e.c

Label	Diameter	Material	Flow (L/s)	Velocity (m/s)	Headloss (m)	Length (m)
P-1	200	Ductile Iron	55.7	1.8	0.016	13
P-2	400	Ductile Iron	233.9	1.9	0.008	451
P-3	300	Ductile Iron	122.3	1.7	0.009	8
P-4	150	Ductile Iron	5.6	0.4	0.005	21
P-5	200	Ductile Iron	80	2.6	0.031	8
P-6	200	Ductile Iron	127.4	3.0	0.073	338
P-7	150	Ductile Iron	25.5	1.4	0.015	13
P-8	200	Ductile Iron	96.7	2.8	0.044	15
P-9	200	Ductile Iron	20.7	0.7	0.003	14
P-10	150	Ductile Iron	25.5	1.4	0.015	215
P-11	150	Ductile Iron	6.4	0.4	0.001	695
P-12	150	Ductile Iron	10.2	0.6	0.003	15
P-13	200	Ductile Iron	20.7	0.7	0.003	1,234
P-14	150	Steel	25.2	1.4	0.013	182
P-15	200	Steel	10.2	0.3	0.001	562
P-16	250	Ductile Iron	178.2	3.6	0.046	602
P-17	250	Ductile Iron	78.5	1.6	0.01	892
P-18	110	PVC	99.1	3.0	0.642	75
P-19	110	PVC	11.2	1.2	0.011	10
P-20	110	PVC	11.2	1.2	0.011	145
P-21	100	PVC	1.7	0.2	0.001	123
P-22	50	PVC	1.3	0.7	0.01	165
P-23	110	PVC	18	1.9	0.027	52
P-24	110	PVC	18	1.9	0.027	11
P-25	100	PVC	1.6	0.2	0.001	19
P-26	100	PVC	6.7	0.9	0.007	10
P-27	63	PVC	6.2	2.0	0.057	166
P-28	100	PVC	1.6	0.2	0.001	149
P-29	100	PVC	13.8	1.8	0.027	14
P-30	100	PVC	13.8	1.8	0.027	271
P-31	100	PVC	8.7	1.1	0.011	152
P-32	100	Galvanized iron	0	0.0	0	11
P-33	200	Ductile Iron	11.9	0.4	0.001	65
P-34	110	PVC	28	2.9	0.062	10
P-35	110	PVC	28	3.0	0.062	27
P-36	150	PVC	17.7	1.0	0.006	9
P-37	200	Ductile Iron	55.8	1.8	0.016	508
P-38	200	Ductile Iron	40.2	1.3	0.009	20
P-39	110	PVC	13.4	1.4	0.016	9
P-40	110	PVC	13.4	1.4	0.016	107
P-41	50	PVC	3.1	1.6	0.048	64
P-42	350	Ductile Iron	474.7	3.0	0.054	10
P-43	250	Ductile Iron	306.8	2.6	0.125	4
P-44	200	Ductile Iron	167.9	2.5	0.121	616
P-45	110	PVC	11	1.2	0.011	132
P-46	50	PVC	7.7	2.3	0.263	6
P-47	50	PVC	1.5	0.8	0.012	72
P-48	800	Ductile Iron	356.2	0.7	0.001	1,470
P-49	50	PVC	2.7	1.4	0.038	35
P-50	500	Ductile Iron	356.2	1.8	0.006	1,282

B. pipe output result after rehabilitation at the year of 2023e.c

**EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA**

Label	Diameter	Material	Flow (L/s)	Velocity (m/s)	Headloss (m)	Length (m)
P-1	200	Ductile Irc	100	2.5	0.046	13
P-2	400	Ductile Irc	311	2.5	0.013	451
P-3	300	Ductile Irc	180	2.6	0.019	8
P-4	150	Ductile Irc	23	1.3	0.013	21
P-5	200	Ductile Irc	146	2.8	0.093	8
P-6	200	Ductile Irc	177	3.0	0.134	338
P-7	150	Ductile Irc	35	2.0	0.027	13
P-8	200	Ductile Irc	134	2.8	0.08	15
P-9	200	Ductile Irc	29	0.9	0.005	14
P-10	150	Ductile Irc	35	2.0	0.027	215
P-11	150	Ductile Irc	9	0.5	0.002	695
P-12	150	Ductile Irc	14	0.8	0.005	15
P-13	200	Ductile Irc	29	0.9	0.005	1,234
P-14	150	Steel	35	2.0	0.023	182
P-15	200	Steel	14	0.5	0.001	562
P-16	250	Ductile Irc	210	3.0	0.062	602
P-17	250	Ductile Irc	74	1.5	0.009	892
P-18	110	PVC	135	2.1	1.147	75
P-19	110	PVC	16	1.7	0.022	10
P-20	110	PVC	16	1.7	0.022	145
P-21	100	PVC	2	0.3	0.001	123
P-22	50	PVC	2	1.1	0.024	165
P-23	110	PVC	26	2.7	0.053	52
P-24	110	PVC	26	2.7	0.053	11
P-25	100	PVC	2	0.3	0.001	19
P-26	100	PVC	10	1.3	0.014	10
P-27	63	PVC	9	2.9	0.114	166
P-28	100	PVC	2	0.3	0.001	149
P-29	100	PVC	20	2.6	0.053	14
P-30	100	PVC	20	2.6	0.053	271
P-31	100	PVC	13	1.6	0.023	152
P-32	100	Galvanize	0	0.0	0	11
P-33	200	Ductile Irc	38	1.2	0.008	65
P-34	110	PVC	40	4.2	0.119	10
P-35	110	PVC	40	4.2	0.119	27
P-36	150	PVC	24	1.3	0.01	9
P-37	200	Ductile Irc	100	3.0	0.046	508
P-38	200	Ductile Irc	79	2.5	0.03	20
P-39	110	PVC	19	2.0	0.031	9
P-40	110	PVC	19	2.0	0.031	107
P-41	63	PVC	4	1.3	0.024	5
P-42	63	PVC	4	1.3	0.024	30
P-43	50	PVC	2	1.2	0.028	48
P-44	50	PVC	1	0.5	0.005	114
P-45	110	PVC	14	1.4	0.016	132
P-46	50	PVC	8	3.0	0.277	6
P-47	50	PVC	1	0.7	0.009	72
P-48	50	PVC	1	0.3	0.002	35
P-49	50	PVC	3	1.3	0.033	35
P-50	50	PVC	1	0.5	0.006	65

C.pipe output result after rehabilitation at the year of 2032e.c

**EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA**

Label	Diameter	Material	Flow (L/s)	Velocity (m/s)	Headloss (m)	Length (m)
P-1	200	Ductile Irc	133	2.8	0.078	13
P-2	400	Ductile Irc	410	3.0	0.022	451
P-3	300	Ductile Irc	248	2.3	0.035	8
P-4	150	Ductile Irc	30	1.7	0.02	21
P-5	200	Ductile Irc	199	2.6	0.166	8
P-6	200	Ductile Irc	238	2.3	0.231	338
P-7	150	Ductile Irc	48	2.7	0.048	13
P-8	200	Ductile Irc	181	2.5	0.139	15
P-9	200	Ductile Irc	39	1.2	0.008	14
P-10	150	Ductile Irc	48	2.7	0.048	215
P-11	150	Ductile Irc	12	0.7	0.004	695
P-12	150	Ductile Irc	19	1.1	0.009	15
P-13	200	Ductile Irc	39	1.2	0.008	1,234
P-14	150	Steel	47	2.7	0.041	182
P-15	200	Steel	19	0.6	0.002	562
P-16	250	Ductile Irc	277	1.5	0.103	602
P-17	250	Ductile Irc	96	2.0	0.014	892
P-18	110	PVC	180	1.8	1.945	75
P-19	110	PVC	22	2.3	0.038	10
P-20	110	PVC	22	2.3	0.038	145
P-21	100	PVC	3	0.4	0.002	123
P-22	50	PVC	3	1.5	0.043	165
P-23	110	PVC	35	2.6	0.093	52
P-24	110	PVC	35	2.5	0.093	11
P-25	100	PVC	3	0.4	0.002	19
P-26	100	PVC	13	1.7	0.024	10
P-27	63	PVC	12	2.8	0.198	166
P-28	100	PVC	3	0.4	0.002	149
P-29	100	PVC	27	2.3	0.092	14
P-30	100	PVC	27	2.3	0.092	271
P-31	100	PVC	17	2.2	0.04	152
P-32	100	Galvanize	0	0.0	0	11
P-33	200	Ductile Irc	50	1.6	0.013	65
P-34	110	PVC	53	2.5	0.201	10
P-35	110	PVC	53	2.5	0.201	27
P-36	150	PVC	31	1.8	0.017	9
P-37	200	Ductile Irc	133	2.4	0.078	508
P-38	200	Ductile Irc	104	2.3	0.05	20
P-39	110	PVC	26	2.7	0.053	9
P-40	110	PVC	26	2.7	0.053	107
P-41	63	PVC	5	1.7	0.042	5
P-42	63	PVC	5	1.7	0.042	30
P-43	50	PVC	3	1.6	0.049	48
P-44	50	PVC	1	0.6	0.008	114
P-45	110	PVC	18	1.9	0.028	132
P-46	50	PVC	11	2.6	0.479	6
P-47	50	PVC	2	0.9	0.016	72
P-48	50	PVC	1	0.4	0.003	35
P-49	50	PVC	3	1.7	0.058	35
P-50	50	PVC	1	0.7	0.011	65

Appendix 6: Output Result of Junctions

EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA

A.sample of output result junction at the year of 2009 e.c before rehabilitation

Label	Elevation	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-1	2,363.56	2	2,380.36	1.7
J-2	2,435.20	0	2,447.32	1.2
J-3	2,387.95	0	2,411.02	2.3
J-4	2,433.10	0	2,450.76	1.8
J-5	2,387.89	2	2,411.25	2.3
J-6	2,392.46	1	2,386.46	-6
J-7	2,365.19	4	2,382.25	1.7
J-8	2,393.45	3	2,385.82	-0.8
J-9	2,385.93	9	2,383.06	-0.3
J-10	2,363.50	6	2,382.68	1.9
J-11	2,425.02	1	2,419.91	-0.5
J-12	2,426.95	3	2,371.99	-3.5
J-13	2,401.82	2	2,136.09	-2.5
J-14	2,425.34	3	2,370.24	-5.5
J-15	2,423.76	2	2,370.17	-5.3
J-16	2,416.03	4	2,360.66	-5.1
J-17	2,403.92	2	2,358.94	-4.5
J-18	2,425.71	3	2,370.25	-5.5
J-19	2,425.04	2	2,370.17	-5.4
J-20	2,408.08	3	2,362.65	-4.5
J-21	2,400.75	1	2,360.95	-4
J-22	2,393.85	0	2,360.80	-1.3
J-23	2,389.00	2	2,404.66	1.6
J-24	2,423.83	0	2,426.84	3
J-25	2,422.63	1	2,421.91	-1
J-26	2,390.00	1	2,413.32	2.3
J-27	2,423.36	2	2,427.02	4
J-28	2,390.65	1	2,419.72	2.9
J-29	2,421.23	2	2,421.62	0
J-32	2,415.80	0	2,420.17	4
J-33	2,417.73	1	2,396.12	-2.2
J-34	2,414.54	1	2,397.01	-1.7
J-36	2,412.85	1	2,398.34	-1.4
J-38	2,410.59	1	2,401.36	-0.9
J-40	2,412.46	1	2,404.65	-0.8
J-41	2,400.53	3	2,399.96	-0.1
J-42	2,407.40	1	2,420.08	1.3
J-44	2,404.27	1	2,406.96	0.3
J-46	2,380.98	0	2,419.82	3.9
J-47	2,417.81	4	2,414.84	-0.3
J-48	2,416.53	1	2,416.59	0
J-49	2,407.34	0	2,414.72	0.7
J-50	2,408.61	1	2,407.53	-0.1

B.sample of output result junction at the year of 2023 e.c after rehabilitation

EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA

Label	Elevation	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-1	2,323.56	3	2,330.07	6
J-2	2,435.20	0	2,431.76	3.5
J-3	2,387.95	0	2,386.48	-1
J-4	2,433.10	0	2,437.58	-0.4
J-5	2,387.89	3	2,387.20	-1
J-6	2,392.46	1	2,341.28	-5
J-7	2,365.19	5	2,333.53	-3
J-8	2,393.45	5	2,340.10	-5
J-9	2,385.93	12	2,335.02	-3
J-10	2,363.50	8	2,334.33	-2
J-11	2,425.02	1	2,394.47	-30
J-12	2,426.95	4	2,308.90	-5
J-13	2,401.82	3	1,907.93	-4
J-14	2,425.34	4	2,305.51	-12
J-15	2,423.76	2	2,305.39	11
J-16	2,416.03	6	2,286.53	12
J-17	2,403.92	2	2,282.51	-2
J-18	2,425.71	4	2,305.52	12
J-19	2,425.04	3	2,305.37	-0.4
J-20	2,408.08	4	2,290.39	10
J-21	2,400.75	2	2,286.91	-14
J-22	2,393.85	1	2,286.61	-10
J-23	2,389.00	3	2,375.21	-14
J-24	2,423.83	1	2,406.95	-17
J-25	2,422.63	2	2,402.49	-20
J-26	2,390.00	2	2,388.57	-1
J-27	2,423.36	2	2,407.54	-16
J-28	2,390.65	1	2,401.18	11
J-29	2,421.23	2	2,403.97	-17
J-30	2,421.33	1	2,403.12	-18
J-31	2,421.72	2	2,401.76	-20
J-32	2,416.05	1	2,402.57	-13
J-33	2,415.80	1	2,401.83	-14
J-34	2,417.73	1	2,379.29	-3
J-35	2,414.54	1	2,379.97	-31
J-36	2,410.70	1	2,379.91	-21
J-37	2,412.85	0	2,381.13	-11
J-38	2,406.53	1	2,380.72	-26
J-39	2,410.59	0	2,384.41	-26
J-40	2,402.46	1	2,384.25	-1.8
J-41	2,412.46	1	2,388.46	-24
J-42	2,400.53	2	2,384.59	-16
J-43	2,407.40	1	2,401.57	-6
J-44	2,402.31	0	2,400.36	-2
J-45	2,404.27	1	2,400.37	-4
J-46	2,397.10	2	2,399.59	2
J-47	2,380.98	0	2,405.65	25
J-48	2,417.81	6	2,391.05	-27
J-49	2,416.53	1	2,393.45	-23
J-50	2,407.34	1	2,390.10	-17

C. Sample of output result junction at the year of 2032 e.c after rehabilitation

EFFECT OF NEW DEMAND CENTERS IN WATER SUPPLY DISTRIBUTION SYSTEM THE
CASE OF CONDOMINIUM HOUSES IN LIDETA SUB CITY OF ADDIS ABABA

Label	Elevation	Demand (L/s)	Hydraulic Grade (m)	Pressure (m H2O)
J-1	2,363.56	4	2,234.11	-12
J-2	2,435.20	0	2,406.65	-2
J-3	2,387.95	0	2,331.69	-5
J-4	2,433.10	0	2,416.38	-17
J-5	2,387.89	5	2,332.98	-5
J-6	2,392.46	2	2,253.51	-12
J-7	2,365.19	7	2,240.11	-11
J-8	2,393.45	6	2,251.46	-14
J-9	2,385.93	16	2,242.68	-4
J-10	2,363.50	11	2,241.49	-2
J-11	2,425.02	1	2,344.55	-8
J-12	2,426.95	5	2,199.44	-22
J-13	2,401.82	3	1,530.54	-8
J-14	2,425.34	5	2,193.55	-23
J-15	2,423.76	3	2,193.34	-23
J-16	2,416.03	8	2,160.51	-25
J-17	2,403.92	3	2,153.38	-25
J-18	2,425.71	5	2,193.56	-23
J-19	2,425.04	4	2,193.30	-23
J-20	2,408.08	6	2,167.22	-24
J-21	2,400.75	2	2,161.15	-23
J-22	2,393.85	1	2,160.62	-23
J-23	2,389.00	4	2,312.29	-77
J-24	2,423.83	1	2,364.99	-5
J-25	2,422.63	3	2,357.46	-65
J-26	2,390.00	3	2,333.73	-6
J-27	2,423.36	3	2,365.98	-5
J-28	2,390.65	1	2,354.98	-3
J-29	2,421.23	2	2,359.80	-6
J-30	2,421.33	1	2,358.33	-6
J-31	2,421.72	3	2,355.98	-5
J-32	2,416.05	1	2,357.38	-5
J-33	2,415.80	1	2,356.10	-6
J-34	2,417.73	2	2,317.11	-10
J-35	2,414.54	1	2,318.30	-9
J-36	2,410.70	1	2,318.19	-9
J-37	2,412.85	0	2,320.29	-9
J-38	2,406.53	1	2,319.59	-9
J-39	2,410.59	0	2,325.96	-8
J-40	2,402.46	1	2,325.69	-7
J-41	2,412.46	1	2,332.98	-7
J-42	2,400.53	3	2,326.28	-7
J-43	2,407.40	1	2,355.65	-5
J-44	2,402.31	1	2,353.56	-4
J-45	2,404.27	1	2,353.58	-5
J-46	2,397.10	3	2,352.23	-4
J-47	2,380.98	0	2,366.66	-14
J-48	2,417.81	7	2,338.04	-8
J-49	2,416.53	2	2,342.06	-7
J-50	2,407.34	1	2,336.34	-7