JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HYDAULIC ENGINEERIG MASTERS OF SCIENCE PROGRAM

ASSESSMENT OF URBAN WATER SUPPLY CHALLENGES AND PERFORMANCE MEASUREMENT OF WATER DISTRIBUTION SYSTEM: CASE STUDY OF METU TOWN

A THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES; JIMMA UNIVERSITY; IN PARTIAL FULFILLMENT FOR THE REQUIREMENT FOR DEGREE OF MASTERS OF HYDRAULIC ENGINEERING

BY: GEMECHU FIKADU OBSO

February, 2017

Jimma, Ethiopia

JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HYDAULIC ENGINEERIG MASTERS OF SCIENCE PROGRAM

ASSESSMENT OF URBAN WATER SUPPLY CHALLENGES AND PERFORMANCE MEASUREMENT OF WATER DISTRIBUTION SYSTEM: CASE STUDY OF METU TOWN

A THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES; JIMMA UNIVERSITY; IN PARTIAL FULFILLMENT FOR THE REQUIREMENT FOR DEGREE OF MASTERS OF HYDRAULIC ENGINEERING

BY: GEMECHU FIKADU OBSO

ADVISOR: Prof. Dr. Ing. ESAYAS ALEMAYEHU

CO-ADVISOR: MR.MEGERSA KEBEDE (MSC)

February, 2017

Jimma, Ethiopia

APPROVAL FORM

This thesis entitled with assessment of urban water supply challenges and performance measurement of water distribution system has been approved by the following advisor department head and director of graduate studies in partial fulfillment of the requirements of degree masters of science in Hydraulic Engineering.

Submitted by:

Gemechu Fikadu _____ _____ _____

Student Signature Date

Approved By:

1. Prof.Dr.IngEsayasAlemayew_____ _____
   Advisor Signature Date
2. Mr. MegersaKebede _____ _____
   Co-advisor Signature Date
3. _____ _____ _____
   External Examiner Signature Date
4. _____ _____ _____
   Internal Examiner Signature Date
5. _____ _____ _____
   Chairperson of department Signature Date
   Graduate Committee

ABSTRACT

Water is one of the main important components of the environment that life cannot sustain without. Therefore an activity that disturbs the provision and supply of water tends to disturb the very survival of humanity.

However this century water supply of cities and towns facing challenges due to inadequacy and poor performance of water distribution system that in turn was affecting the life styles of urban society. As the result of poor and inadequacy of drinking water, the population of Metu Town is suffering from scarce water supply infrastructures and this hinders the day to day life of the society.

The overall situation of drinking water supply system of the town facing challenges due to, rapid increase in population and poor performance of existing water distribution system. These reduce the quantity of drinking water.

The general objective of this paper is to assess the challenges that are hindering water supply service and to measure the performance of the old water supply system

For the analysis of this research, GPS, camera, GIS, water CAD heastad method version 6.5 and SPSS version 22 were used and questionnaire and interview were also done to know status of water supply, cost and performance of water supply.

Based on the analysis, the major causes of water supply scarcities are, electricity outrage covering 70% of respondents idea followed by frequent brake down of pipe lines as 68% of the respondents opinion. Scarcity of water in Metu town causes impacts on life of households. The major impacts are, slowing down of commercial and domestic activities as 99% of the respondents replied and to the 2nd place it causes Risk in drinking of untreated water from open wells or surface waters. Those with this opinion counts to 97% of the household interviewed. The performance of the system based on the pressure and velocity shows that the system fails to perform good since 94.7% of the pipes falls below the allowable velocity range and the sedimentation problem occurred in the system

Therefore improving service system and adequate follow up will be the best mechanic to solve water supply problem of the town.

Key words: water, distribution system, water scarcity, Metu town.

ACKNOWLEDGMENTS

First of all without count my deepest gratitude is forwarded to the almighty God who is always with me. I would like to say thanks to my advisor, **ProfessorDr. Ing.**Esayas Alemayehu and my Co-advisor Megersa Kebede (Msc) for their unlimited support during my paper work.

Sutuma Lemma I have no word to express your support financially and the motivation you gave me from the first class to the end of this journey, this all respect and proud goes to you and May God Bless you all. Solomon, Tariku, Temesgen and all my friends thank you for all your continuous support for the completion of this paper.

My family you have also another chance to see your fruit. I am proud of you and I pray to God for him to Give you long live. I would like to thank very gratefully to Jimma University for its financial support to undertake this research.

Contents

List of figures

List of Tables

Acronyms

ADB	Asian Development Bank
AMCOW	African Ministers' Council on Water
CSA	Central Statistical Authority
GPS	Geographical Positioning System
GIS	Geographical Information System
IWA	International Water Association
MDG	Millennium Development Goal
MTWSSA	Metu Town Water Supply and Sewerage Authority
PI	Performance Indicator
SPSS	Software Packages for Social Sciences
TPI	Technical Performance Indicator
WDS	Water Distribution System
WHO	World Health Organisation

1.1. INTRODUCTION

1.2. Background

Water is one of the main important components of the environment. Without water, life on earth would not exist. Water occurs 97.2 percent in ocean as salt water, 2.09 percent in icecaps and glaciers, 0.6 percent ground water, 0.11 percent runoff and surface water. It is difficult to imagine clean and sanitary environment without water.

Water mainly used for drinking, cooking and preparation of food, bathing, cleaning, washing and personal hygiene, watering in gardens, and water for livestock, sanitation. Various problems may occur due to inadequacy and poor quality of water supply. All peoples, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs"(UN, 1977). Water is the most important of all public services. It is the most essential necessity of life after oxygen. Anything that disturbs the provision and supply of water therefore tends to disturb the very survival of humanity.

Although water covers about 70 percent of the Earth's surface, only 1 percent of it is available to us as a source of drinking. It is understood that our body is made up of about 70 percent water and that it controls virtually every aspect of our whole day life. The importance of water is not only attached to the drinking but also to cooking, bathing, washing and other activities. Where provisions for water and sanitation are inadequate, the diseases that arise from contaminated food, water and hands are among the world's leading causes of premature death and serious illness (http://www.epa.gov/docs/owmitnet/water-efficiency/pubs/supply.htm).

The available water sources throughout the world are becoming depleted and this problem is aggravated by the rate at which populations are increasing, especially in developing countries. Currently, some 30 countries are considered to be water stressed, of which 20 are absolutely water scarce. It is predicted that by 2020, the number of water scarce countries will likely approach 35 (Rosegrant, 2002). It has been estimated that, one-third of the population of the developing world will face severe water shortages by 2025 (Seckler*et al.*, 1998)

In the Africa, 12 countries will be considered to be in a "Water Stress" situation by next year. A total of 1.1 billion people or two thirds of Africa's population will be affected(Dzikus, 2001). Despite its poor and largely rural population, and despite a historic legacy of low investment in infrastructure, Ethiopia has been making substantial progress in increasing water supply coverage. While achievement of the ambitious plan for universal access will be a challenge, reaching the water supply Millennium Development Goal (MDG) target looks achievable, irrespective of data source used(AMCOW, 2011).

Urban water concentrates on sustaining economic growth in cities through investments in water supply, sanitation and wastewater management, and environmental improvement. Water may be distributed through (i) household connections, utility standpipes, and utility tanker supply; (ii) private water carriers; (iii) privately managed standpipes and kiosk networks; and (iv) community managed organizations, among others was explained(ADB, 2010).

Water Supply and water distribution system are non separable terms since water supply for any city passes through network. The distribution of drinking water in distribution networks is technical challenge both in quantitative and qualitative terms. Water Distribution Networks (WDNs) serve many purposes in addition to the provision of water for human consumption, which often accounts for less than 2% of the total volume supplied(Mehta et al.).

Over two million years, people are using water distribution network for their daily water consumption even if they are not publically noticed important with exception of construction and maintenance period(Zhang, 2006).

All population growth and urbanization of cities are becoming challenges for many countries government to meet adequate and safe water, since urban population will reach 60%. Along with this challenges performance of water distribution system is another problem facing water supply industry(Nair, 2010).

The challenges facing many countries in the world today in their struggle for economic and social development is increasingly related to water. One of the international goals set for the

year 2015 in the United Nations Millennium Declaration and in the plan of implementation of the world summit on sustainable development is reducing the proportion of people without adequate access to water and basic sanitation by one-half. While access to sufficient and clean drinking water may be taken for granted in the developed world, problems with access are most severe in the developing world, where more than 5 million people perish every year from water-related diseases, and more than 1 billion people suffer without access to water for their basic needs.(http://www.geotimes.org/may05/feature_worldwater.html)

Africa has the lowest water supply and sanitation coverage of any region in the world. More than 30% of Africans residing in urban areas currently lack access to adequate water services and facilities. In the year 2000, World Health Organisation (WHO) estimated that Africa contains 28% of the world's population without water access to improved water supplies, and 13% of the world's population without access to improved sanitation. Only 62% of the people in African countries have access to improved water supplies, and only 60% have access to improved sanitation(WHO, **2000**)

Therefore, this thesis was designed to assess challenges of the existing drinking water system of the Metu town. The main objective of this research paper addressed the main cause of water supply scarcity related to challenges of drinking water from 'Sor River' and the way to improve adequate water supply of the town and produce a safe environment.

1.3. Statements of the problems

Water quantity and quality are the risk to scarce and poor performance concerns in many developing countries like Ethiopia. The population of the Metu town is mainly suffering from scarce water supply for commercial, drinking and other purposes.

Even though water is as much important for human being even cities in developed countries facing many challenges in water supply and this will bring crisis on sustainability of water supply schemes. In order to improve such condition it is important to assess the challenges and performance of water distribution system.

The overall situation of water supply system of Metu town and its surrounding villages indicate poor sewerage system, rapid increase in population and poor performance of existing water distribution system.As the result of poor and inadequacy of drinking water, the population of the town is mainly suffering from scarce water which in turn hinders the day to day life of the dwellers.

1.4. Objectives of the study

1.4.1. General objective

The overall objective of this study is to assess the challenges facing water supply of Metu town and measure the performance of water distribution system.

1.4.2. Specific objectives

- To identify the major challenges of frequent water shortage at Metu Town
- To assess the socio-economic impacts associated with the water supply shortages.
- To evaluate the performance of water distribution system

1.5. Research questions

These questions are rise to answer the objective of this paper

a. What are the major challenges of Metu town water supply?
b. What impact water supply problem should bring on the socioeconomic activities of Metu town societies?
c. How is the system working in order to meet the demand of the town?

1.6. Significance of the Study

This study is expected to increase the knowledge and up to date information on urban water supply system and its adverse impacts on the urban poor. It may show water problem and related impacts that needs to be addressed to come up with solution. The study will further

serve as benchmark data for any further investigation, as a useful material for academic purposes, and as an added literature to the existing knowledge.

1.7. Scope

Even though water related studies were very wide and extensive, the scope of this work was bounded to the assessment of challenges facing Metu town water supply and measuring performance of the existing distribution system.

1.8. Limitation

Every research has limitations and this particular one is no exception. There has also been no in-depth previous research on water in the community and so it might be very difficult to do a comparative study or to either improve upon or deal with another side of the previous study.

1.9. Structure of the Thesis

This thesis has been structured to five chapters. The first chapter consists of introduction on water supply and related problems, statement of the problem, objectives research question and significance of the study

The reviews of literature were discussed in the second chapter and the third chapter discusses about the description of study area, methodology conducted to come up with result and materials used for the work.

The discussion of the result has been addressed in the fourth chapter while conclusion and recommendation were consisted in the final chapter.

2. LITERATURE REVIEW

2.1. Introduction

Fresh water is a limited resource that is increasingly in demand by population and industry. Rapid urbanisation processes together with the potential impact of climate change is one of the main challenges society needs to confront now and in the future (Kit et al., 2015).

Due to its limitation water scarcity occurred all over the world especially in sub-Saharan Africa, because they are poor enough to overcome the problem. Before entering into more about water scarcity, it should be defined in clear way.

According to Earth clips (2015) water crisis is the deficiency of adequate water resources that can meet the water demands for a particular region. Whenever there is a lack of access to potable and fresh water for drinking and sanitation, the situation means that the water is scarce. Water scarcity thus pertains to a situation where there is water shortage, water crisis, and the lack of access to quality water.

The concept of water scarcity may also refer to the difficulty in obtaining fresh water sources and the deterioration and depletion of the available water sources. Some of the contributing factors to water scarcity are climate change, water overuse, and increased pollution. Many areas around the globe are affected by this phenomenon, and about 2.7 billion people experience water scarcity each and every year

According to the United Nations(UN, 2013) on *water for life*, more than people lack access to clean drinking water. As more people put ever increasing demand on existing water resources, the cost and effort to build or even maintain access to water will increase. With the current consumption rate, two-thirds of the world's population may face water shortages by 2025.

Cities all over the world are facing a range of dynamic global and regional pressures ((see Figure 2.1, (Kelay, 2006, Segrave, 2007, Zuleeg, 2006)). They are facing difficulty in efficiently and transparently managing ever scarcer water resources, delivering water supply and sanitation services. There are equal challenges on disposing of wastewater and minimizing negative

impacts to the environment. In order to develop solutions to manage urban water more effectively, these global and regional pressures must be recognized and used to drive the design and management processes of urban water systems.

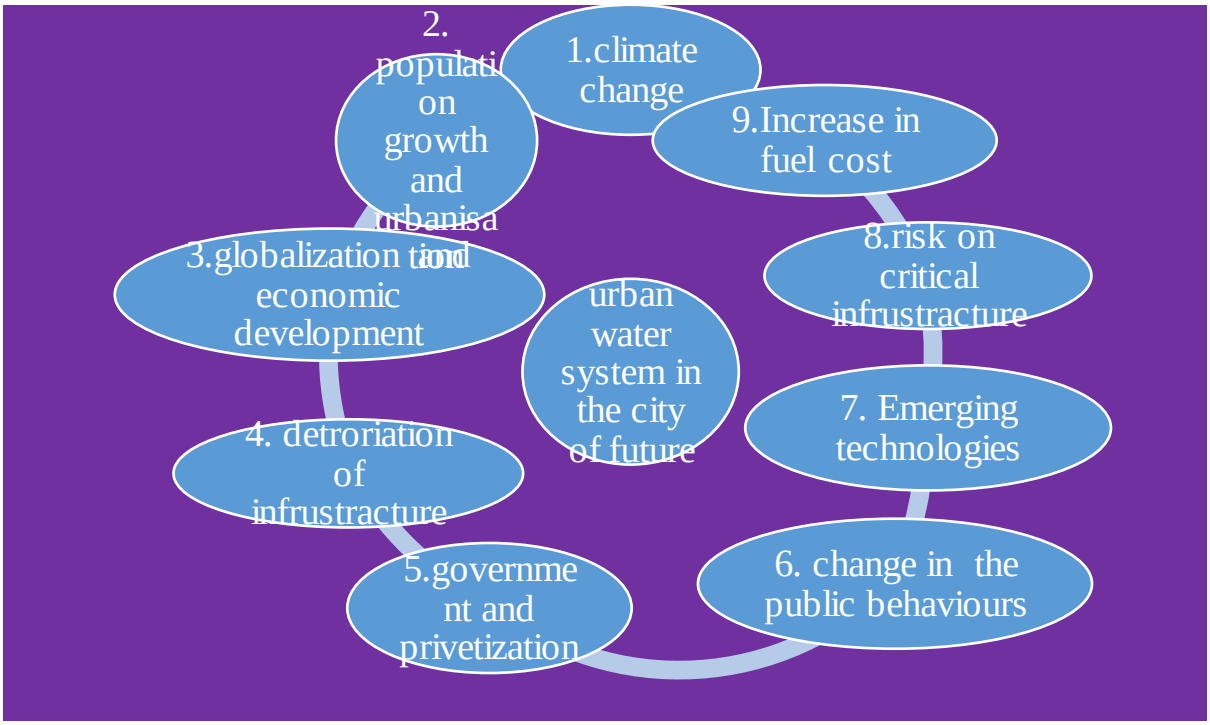

Figure 2-1: Global change drivers in the city of the future

In Ethiopia, the water supply service level, in terms of coverage quantity and quality, is very low due to factors like topography, sources of water reserve, distribution systems, treatment plants, and community health centers(Shanmugham and Bekele, 2011).

Over half the world's populations have no choice but to collect dirty water from unsafe sources. Ethiopia is in the Horn of Africa, where an extended period of droughts, famines and conflicts has had a *serious impact on health and life expectancy*. Many children die before the age of five. Most people in Ethiopia make a living through farming. Without water they cannot grow the crops they need to feed and support their families. Many communities lack such basics as a safe water source and simple toilets. Poor roads make it difficult to reach remote villages and low water tables present additional challenges. According to water 4solution in Ethiopia 43.4M people in Ethiopia don't have access to safe water. This is over half of the population. Over 67 million people don't have access to adequate sanitation in

Ethiopia, almost four-fifths of the population.(https://www.water4.org/what-we-do/our-crisis/m.stories/432/view/28).

The Ethiopian government was responsible for identification, planning, and implementation of WSS improvements. Consistent with the policy of decentralization, most of the responsibilities shifted to regional and local governments under the National Water Resources Management Policy and Strategy (NWRMPS). Implementation of these policies and strategies has ultimately fallen on the local service providers with support from the regional offices of Ministry of Environment (MoE) and the Ministry of Health (MoH). Due to the dual nature of the two ministries involvement and also the national and regional directions, the governments made everyone sign a memorandum of understanding water and health functions in 2006.

2.2. International view of water supply

"Access to good, safe and reliable drinking water is one of the most basic needs of human society and as such requires integrated approach, close cooperation and partnership between all stake holders". Research has shown that access to good, reliable and sufficient water supply increases the health status of people. However, it is unfortunate that many people in the world today are lacking such quantity and quality of water needed(IWA, 2004).

Worldwide water consumption is estimated to be around 914,546 billion liters/year. Agriculture accounts for 70% of all water consumption, industrial usage accounts for 20%, and domestic usage is 10%. In highly industrialized countries, however, manufacturing consumes more than half of the available water. This shows that there is low available water for domestic purpose. Worldwide, per capita water supplies decreased by a third between 1970 and 1990, and there is little doubt that population growth has been and will continue to be one of the main drivers of changes to patterns of water resource use(WPI, 2006)

Water supply system (WSS) is a complex system that integrates several spatial features. Therefore, it is needed to use multi- support information system to have capability of storing; managing and analyzing the large data set. Design of surface water supply system concerns the

locations and capacities of diversion works and storage, as well as the operations of these to meet multiple purposes and objectives. Therefore in order to ensure the availability of sufficient quantity of good quality of water, it becomes almost imperative in a modern society, to plan and build suitable water supply schemes. This may provide potable water to the various section of the community in accordance with their demand and requirements(Khadri and Pande, 2014).But of Lack of energy services and infrastructure (water supply systems) limits women's productive and community development activities: they are generally responsible for gathering fuel and performing household duties involving energy use, such as cooking. Women often have to spend a great deal of time and physical energy searching for fuel and water far from home and hauling it back over long distances. Girls are likely to be kept home from school to help with household chores when women are overburdened, which contributes to the perpetuation of female poverty.(WPI, 2006)

2.3. Water supply policies and strategies

The terms 'policy' and strategy' are often used interchangeably. For the purposes of this work the following definitions are used:'

Policy' is a specific statement that guides or directs decision-making; and

Strategy' refers to an elaborate and systematic plan of action.

As Harvey and Reed (2004) recommend that for government to play very important role in providing, supporting and regulating service based nature of water supply it is must to develop national policies and strategies. There is a range of institutional frameworks and models that can be used for service delivery, and respective governments should be free from external pressure to select the most appropriate options for them. Appropriate legislative and regulatory frameworks that are compatible with government policy must also be developed.

2.3.1. General water resource policy

According to Ethiopian Water Resources Management Policy(MOWR)the survival and well being of a nation depends upon sustainable development and for this, water supply and sanitation which are ingredients of a healthy and productive life are essential requirements.

1. Recognize that the basic minimum requirement, as the reserve (basic human and livestock needs, as well as environment reserve) has the highest priority in any water allocation plan.
2. Ensure that water allocation gives highest priority to water supply and sanitation while apportioning the rest for uses and users that result in highest socio-economic benefits.
3. Enhance and encourage water allocation that is based on efficient use of water resources that harmonizes greater economic and social benefits.
4. Ensure that water allocation shall be based on the basin, sub-basin and other hydrological boundaries and take into consideration the needs of drought prone areas.
5. Adopt the principle that water allocation shall not be made on permanent basis, but rather on an agreed time horizon that fits best with the socioeconomic development plans, especially pertinent to water resources, subjected to appraisals and revisions in light of new developments.

2.3.2. Water Supply policy

Since potable water supply is scare all over the world without regarding of Economic status, time and place it is important to formulate policy regarding water supply. Thus the Ethiopian federal ministry of water, irrigation and energy formulate the following points to regulate the water supply sectors and concerned bodies.

1. Recognize that water supply is an integral part of the overall water resources management and incorporate water supply planning in the domain of comprehensive water resources management undertakings.
2. Promote the development of water supply on participation driven and responsive approaches without compromising social-equity norms.

3. Integrate and co-ordinate the development of water supply with other sector development objectives including irrigation and hydro-power
4. Create and promote a sense of awareness in communities of the ownership and their responsibilities for operation and maintenance of water supply systems and develop participatory management practices.
5. . Enhance the development of different indigenous water sources being used by communities to improve rural water supply.
6. Ensure that rural drinking water and livestock water supply undertakings shall be integral part of the overall socio-economic development, centered on self-reliance, community participation and management.

2.4. Water distribution systems

Water distribution systems serve the community and help power the economy by delivering water from source(s) to its consumers. WDS are comprised of three primary components; water source, treatment, and distribution network. Water sources can be reservoirs, rivers, and groundwater wells. Water treatment facilities disinfect the water to drinking water quality standards prior to delivering it to its consumers. The distribution network is responsible for delivering water from the source or treatment facilities to its consumers at serviceable pressures and mainly consists of pipes, pumps, junctions (nodes), valves, fittings, and storage tanks.

2.5. Performance evaluation of water distribution system

According to(Muranho et al., 2014) performance assessment is *"any approach that allows for the evaluation of the efficiency or the effectiveness of a process or activity through the production of performance measures"* and also key to sustainability. In addition to this using IWA International Water Association methodology (Alegre et al., 2000) defines performance indicators as a "*quantitative measure of a particular aspect of the water undertaking's performance or standard of service*".

There are essentially two main types of performance evaluation tools available to water and wastewater utility managers(Cardoso et al., 2004): systems of performance indicators and technical performance assessment tools.

In hydraulic simulation modeling a distribution network is considered to be one in which all elements are connected to each other, every element is influenced by its neighbors, and each element is consistent with the condition of all other elements. These conditions are mainly controlled by two laws: Law of Conservation of Mass and Law of Conservation of Energy. "Thus the total mass of water entering the system should be equal to the total mass of water leaving the system, and the sum of the flows at any given node should be equal to zero. The principle of conservation of energy is mainly dictated by the Bernoulli's equation, which states that the difference in the energy between any two points should be the same regardless of the path taken" (Haestad Methods, 2003).

A typical network in hydraulic model consists of the following components:

- Nodes linking the pipes
- Pipes
- Storage tanks
- Reservoirs
- Pumps
- Additional appurtenances like valves (Haestad Methods, 2003, Rossman, 2000).

3. MATERIAL AND METHODOLOGY

3.1. Study area

The study were conducted At Metu Town which was located in South Western Oromia Regional State having latitude $8^0$18'N/$35^0$135'E , longitude 8.300^0 N35.583^{0}E and elevation of 1605m above sea level and 600km far away from Addis Ababa. The climate of the area comes under the influence of the Inter-Tropical Convergence Zone (ITCZ). The seasonal rainfall distribution within the study area results from the annual migration of the ITCZ. Two rainy seasons has been experienced. The main rainy season often extends from middle of May through end of October and the small rainy season from March to end of April, the rest of the months are generally dry. The mean daily temperature also varies between 18.7^{0}C and 21.6^{0}c.

3.2. Physio-graphic climate and vegetation

Metu Town is located in the South western part of the northwestern plateau of the Ethiopia physio graphic subdivision. As can be seen the physiographic map and observed during site visit, Metu and Its close surroundings are characterized by a rolling plateau landscape type. The mean annual rainfall distribution of the region shows considerable spatial variation, due to the great range in elevation across the Baro River Sub Basin. The mean annual rainfall is varies from 600mm to as high as 1887mm, while over the high land areas, at elevations over 2400m a.s.l. it reaches as high as 1900mm

3.3. Description of existing water supply

As per the information obtained from the Metu town Water Service office during a visit to the town, the existing water supply has been designed by German Water Engineering and constructed by Berta Construction Company some 30 years ago. The source is from Sor river, from which the water is collected into a wet well via 250mm DCI inlet pipe. From the wet well the raw water is pumped to a roughing filter, used as preliminary treatment unit. The water after passing through the roughing filter is lead to slow sand treatment plant. Treated water from the under drainage system of the slow sand filter is drained into clear water reservoir. From the clear water tank after disinfection the water is pumped to 400m^3 RC reservoir from which it is fed to

the consumers by gravity. The pipeline network consists of looped and branched system catering the water through public fountain and yard connections. The system consists of the following units.

- River side Intake with raw water pumping station
- Slow sand filtration unit,
- Chlorination system,
- Clear water pumping unit,
- 400m^3 Reinforced Concrete service reservoir

Generally, the data from Water Supply Service Office shows the majority of households in Metu are partially supplied with water from the town's water supply system. Householders collect part of their total water needs from the town's water supply system fed directly through private connections or public taps. However, there is insufficient water to meet all demands and the deficit is made up from other sources including hand dug wells and water vendors.

3.4. Population

3.4.1. Source population

The Town consists of four kebeles and now reduced to three and the area was covered 16.32 square kilometer. The population size of the town shows difference according to various sources. Based on the CSA census result (2007), the total population of Metu Town is 29,627 that are 14,795 male and 14,832 female and 8,216 households. But now the total population of the town about 53,906 from which 26,473 are male and 27,469 are females according to administrative municipal data.

Table 3-1 Population by household

Village(Kebele)	Male Households	Female Households	Total
01	2250	758	3008
02	1715	1900	3615
03	4284	5160	9444
Total	8249	7818	16067

Source: Metu Town Municipality June 9, 2016

Table 3-2Households connected to pipe with former administration division

Village(Kebele)	Households
01	1491
02	891
03	783
04	852
Total	**4017**

Source: Metu town water supply and sewerage Authority June 8, 2016

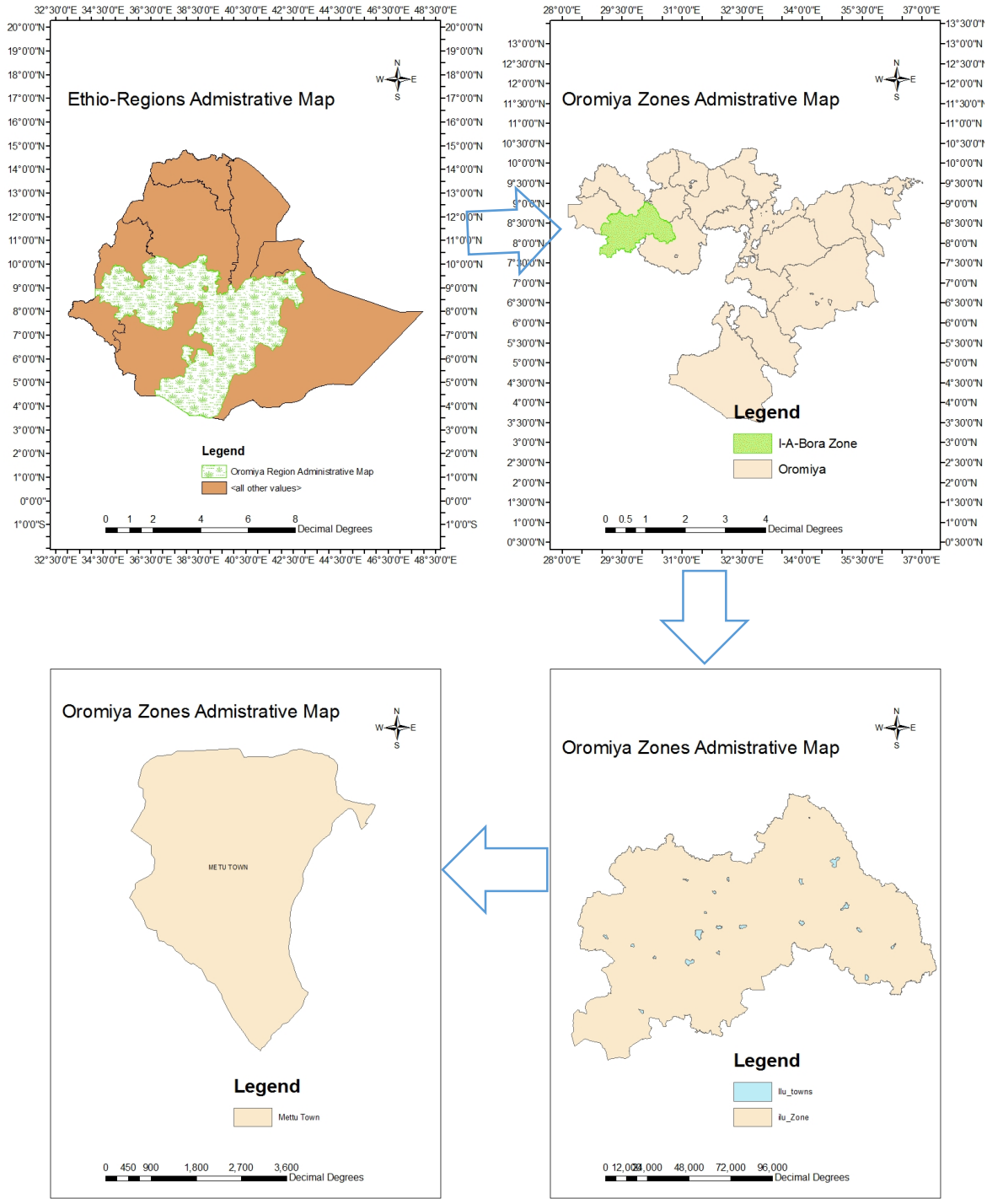

Figure3-1Map of study area

3.5. Study population

Study population was all systematically selected households from the source of population.

3.5.Sampling size and sampling technique

Sampling size were determined purposely based on the will of the researcher and a total number of 100 house hold were selected to survey the problem of water supply scarcity and its impact on socioeconomic style of the society. Even though this figure is not enough to get full information about the problem, based on the uniformity of the life style and status of scarcity, the researcher forced to select the mentioned number. The other reason for why the researcher select small number of sample was that the time supposed to complete this paper was not enough to assess all the population and needs more budget. Since this is very difficult within this period the researcher proposed to select only 100 house hold with respective of village population ratio. Based on population ration 52 household from 03 kebele 27 from 01 kebele and 21 from 02kebele were selected to accomplish the survey, questionnaire and interview.

3.6.Data collection

Data was collected by using a structure and pre-tested questionnaire to perform interview for the selected households to identify major challenges of water supply and socioeconomic impacts of water shortage and GPS was used to collect data for performance measurement of existing water distribution system. The questionnaire was collected by three trained data collectors and the GPS data was collected by professionals. The respondent of the data was any adult family member. The data collector use the next house if respondent were absent from the selected household.

3.7.Data analysis and interpretation

3.7.1. Method of Data Analysis

Software modeling data was gathered through each tool was organized, analyzed and interpreted to meet the objectives of the study. The quantitative data were collected through household

survey/questionnaire/ was organized and analyzed in a way that first the responses for the close ended questions was edited, coded and feed to computer by applying appropriate software (SPSS version 22).Then descriptive statistics mainly frequency, percentage, cross tabulation and mean values was computed for analysis purpose.

On the other hand, the qualitative data was collected using open ended questions of the survey questionnaire; interviews with technical staff members of Metu town water supply and sewerage authority officials and water committees and using informal discussions with the user communities was organized and analyzed through content analysis.

All the information used to analysis the data were produced by Afan Oromo and the translated to English. Then, by reading through all of the qualitative data, it was reviewed and organized to develop a general understanding of the data set and short memos was prepared which was best help in organizing and categorizing the data in to concepts either by question or by case. Then, through narrative description the results of the entire qualitative data was, analyzed and interpreted. Then, the analysis and interpretation of data were integrated to handle the research problem.

Lastly water CAD software was used to investigate the hydraulic performance of the system. In this section the performance of the system were analysed based on the velocity and pressure of the distribution system by using ministry of water resource urban water design criteria (MOWR, 2006)

3.7.2. WaterCAD and hydraulic modeling theory

WaterCAD is an easy-to-use hydraulic and water quality modeling application for water distribution systems. Utilities, municipalities, and engineering firms trust Water CAD as a reliable, resource- saving, decision-support tool for their water infrastructure.

A Model is representing the real world. For explanation and prediction of physical events a computer model uses mathematical equations. Modeling of water distribution system can allow to determine system pressure and flow rates under a variety of different conditions without having go out and physically monitor your system(Dawe, 2000).

In order to effectively utilize the capabilities of WDN simulation softwares, it is must to understand the mathematical principles involved and the principles of hydraulics related to fluid properties. Specific weight, fluid viscosity and compressibility are the most important fluid properties to be considered in WDN Simulations

As thoroughly discussed by different references like (AWWA, 2004) and(Paula, 2000), Models essentially use three types of relations to calculate flows in a complex pipe network system. These relations are;

Conservation of Mass: it is equivalent to conservation of volume and with the assumption that water is an incompressible fluid; this principle requires that the sum of mass flows of all pipes entering a junction must be equal to the sum of mass flows of all pipes leaving that junction.

Conservation of Energy: in water distribution systems, energy is referred to as 'head' and there are three forms of energy of the fluid transported through the pipes; elevation head which is equivalent to potential energy/energy due to elevation difference/energy due to gravity/, velocity head which is equivalent to kinetic energy due to the movement of the fluid, and pressure head which is equivalent to pressure energy/energy imparted by pressure/work done on the fluid/.Bernoulli equation which is an energy balance equation, best expresses the relation between these heads and it applies to all points on the stream line of the flow.

$$\frac{P}{\gamma} + \frac{V^2}{2g} + Z = H \quad \text{(2-1)}$$

Where $\frac{P}{\gamma} = Pressurehead$,$\frac{V^2}{2g} = Velocityhead$,Z= elevation head,$H = thetotalhead$

Hydraulic Grade Line/HGL/: is the sum of elevation and pressure heads. In open water sources, the HGL is the water surface, but for piped pressurized flow condition, the HGL is the height to which water will rise in a piezometer or stand pipe if tapping is made.

Hydraulic Gradient: is the slope of the HGL and fluid flows normally occur from high pressure points to low pressure points in the direction of the hydraulic gradient. Any pipe

lying above the HGL will cause negative pressure and this adverse pressure gradient result pushing the fluid back, against the direction of flow.

Pipe friction head losses: in WDN, energy losses are called head losses and these head losses are mainly due to pipe frictions. The ability to calculate these friction head losses is the key factor in evaluating the flow through pipe networks. The three common empirical equations, Darcy-Weisbach, Hazen-Williams and Manning's equations relate head losses and pipe friction to the fluid velocity, pipe diameter, pipe length and pipe roughness coefficients to calculate the head losses in a pipe network. Manning's equation is generally used for open channel flows, Hazen William equation is for piped flow and Darcy-Weisbach equation is general purpose. However, the difference between the use of Darcy-Weisbach and Hazen-William equations is insignificant. Even though Darcy-Weisbach equation is theoretically thorough and general, it is more complex than the Hazen-Williams equation.

1. **Pressure**

According to (MOWR, 2006) the allowable operating pressure in the distribution system were described as follows.

Table 3-3The operating pressures in the distribution network shall be as follows:

Status	Normal Conditions	`Exceptional Conditions	Remark
Minimum	15 m water head	10 m water head	X
`Maximum	60 m water head	70 m water head	Xx

x Envisaged where distribution pipes are close to reservoirs in terms of perhaps both location and elevation, and in small sections of the distribution system that would require PRV or BPTor otherwise mean raising pressures generally to achieve a 15 m minimum pressure.

xx Envisaged in small section(s) of the distribution system which would otherwise require separate pressure zone(s)

2. Velocity

The acceptable range of the water distribution system Water velocities shall be maintained at less than 2 m/sec, except in short sections. Velocities in small diameter pipes (<DN100) may need even lower limiting velocities.

A minimum velocity of 0.6 m/sec can be taken, but for looped systems there will be pipelines with sections of zero velocity

Table 3-4 velocity range and effect in distribution system

Velocity range (m/s)	Effect
<0.5	Sedimentation problem
0.5-2	Normal
>2	High head loss occurred

3.8.Pre-test

The actual data collectors together with the principal investigator were tested the questionnaire on randomly chosen 3% residential houses of the source of population, which was not be included in the sample. This was helping the investigator to check the research instruments, reaction of respondents, and moods of the population according to his/her religion/ culture and the time required for the data collection.

4. RESULT AND DISCUSSION

4.1. Demography of the respondents

The general objective of this paper is to assess the challenges facing water supply of Metu town and measure the performance of water distribution system. Thus the following table shows the demography of respondents in order to meet the goal. Based on the findings of the survey, socio-economic impact of water supply scarcity, cause of water scarcity, proposed from the referenced literature were presented in chapter two. Finally, there is a brief discussion on data analysis and suggestions for future work.

Table 4-1Demography of Respondents

Variables	Name	Frequency	percent
Sex	Male	57	57
	Female	43	43
	Total	100	100
Educational level	Primary	8	8
	Secondary	15	15
	Diploma	14	14
	BA/BSC	54	54
	MA/MSC	9	9
	Total	100	100
occupational statuses of the house hold	Governmental employee	80	80
	Self-employee	9	9
	Merchant	4	4
	Student	7	7
	Total	100	100
Family size	1 up to 3	25	25
	4 up to 6	71	71
	Above 6	4	4
	Total	100	100

According to table 4.1 above 57% are male and 43% are female respondents. Even if this survey got more percentage of male respondents but females are those who are more responsible for water collection and usage at house hold level. Regarding the educational

level of the respondents, 8% are primary educated 15% are secondary level, 14% Diploma level,54% degree level and 9% are Masters level. From this result the majority of the respondents are degree level and also it gives chance to get the best suggestion since they can understand all the information needed. Out of all the respondents 80% are government employee, 9% self-employee, 4% are merchants and 7% are students. The highest number was covered with government employee. Most of the respondent's family size count to 71 %(4-6 family numbers), followed by 25% with family number o 1-3 and the rest 4% own above 6 family numbers.

4.2.Status of water supply and water cost

Regularity and adequacy of water supply are the factors which govern the availability of water in the study area. Based on the field survey about 93% of the respondents are connected to pipe while 7% of them did not and shown as table below.

Table 4-2 Pipe connected to Homes

S.No	Pipe connected to Home	Percent
1	Yes	93
2	No	7
	Total	100

Source: Metu Town Field survey June, 2016

This implies the majority of the households in the town have pipe connected to their home. Even though the highest number of households have pipe connected to their home they are facing water scarcity problem. Metu town water supply were constructed some 30 years ago and now finished its design period and the new project is under construction since 2011 but even no pipe layout and test were done until this survey was done.

The other is the frequency of water flow which regards the availability of water supply. This is the major concern for Metu town dwellers.

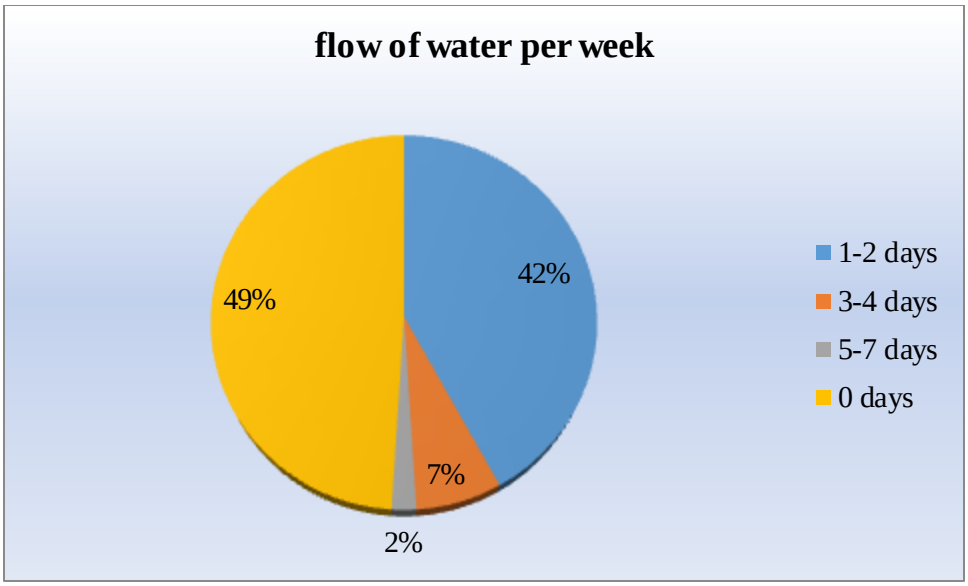

Figure 4-1: flow of water per week

Source: Metu Town Field survey June, 2016

The result from the majority of the respondents shows the water flows mainly none or maximum of one day in a week. From those interviewed, 42% responded that they can get water once in a week and 49% says they never get water within a week even within a month. This is very difficult problem since water is the core of life and societies are suffering such problem. From this it is very simple to understand how the societies of the area fail to fulfill their daily activities due to water shortage and even the time when water comes through pipe is not known and this is another challenge added to water scarcity. Therefore, they are forced to wake up during mid-night if water comes and the neighbor knows it or someone in the house got water while randomly checking the pipe flow.

Since water is scarce and pipe is empty even full of month the dwellers must travel to some distance to fetch water.

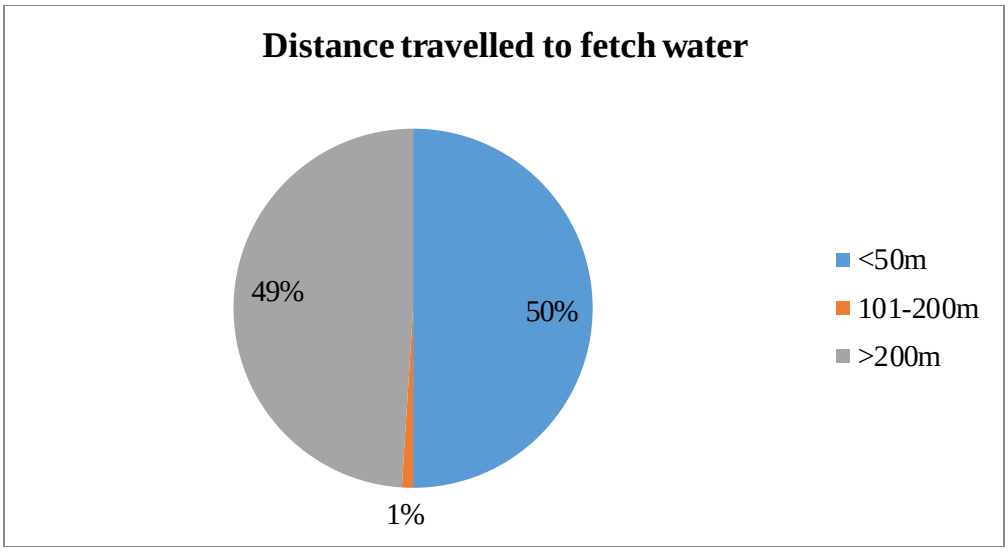

Figure 4-2: Distance traveled to fetch water

Source: Metu town field survey June, 2016

From the figure 50% of the respondents said that they were travelled <50m and 49% of them says they travel greater than 200m and 1% travel 101-200m. This shows all the respondents must walk from their house for finding water at least twice or more within a week. This distance if all travel up to 200m it takes up to 30minutes.Eventhough this distance is within the range of 0.5km and acceptable for urban water supply coverage, it is not logical in urban areas since water must be in the house of people.

Below table shows the water consumption per day of house hold. This consumption depends on the number of house hold size and the largest number of respondents meaning 75% of them use three to four jar equivalent to 60 to 80 liters, 13% needed one to two jar or 20 to 40 liters 10% used five to six jar equivalent to 100-120 liters and 2% responds that they needed seven to eight jar which is equal to 140-160 liters. The majority of interviewed means 71% have house hold of between 4 and 6 on average of 5 members per household which is acceptable in urban today. In order to feet this all needs the society must invest large amount of capital to buy water from vendor and this brings great impact on the dwellers.

Table 4-3: Water consumption (Number of jar 20litres of household per day)

Number of jar needed	Equivalent in liters	% of house hold
1-2	20-40	13
3-4	60-80	75
5-6	100-120	10
7-8	140-160	2

Source: Metu Town Field survey June, 2016

Based on water used per day the households were asked about the sufficiency of water and the response of the household was recorded by the following figure, 87% says they did not fulfill their requirements while 13% of the respondents clarify the sufficiency of water they get per day. This implies large number of society needs extra water per a day, and they have large problem of water scarcity exist in the town which lasts for more than five years.

Table 4-4 Sufficiency of water for house hold

Sufficiency of water for house hold	**Percentage of Respondents**
Yes	13
No	87

Source: Metu Town Field survey June, 2016

Any water supply and delivery service have water bill every month. Therefore, the entire household who have pipe connected to their home regularly should pay water tariff. But there is no constant amount of money they pay monthly for amount (liters) of water they were used. Such irregularity occurs due to two things according to the response from house hold. First, irregularities from month to month occurs from frequency of pipe flow and secondly, from topography of the area ,meaning some areas may get water within a week while other even do not get within a month and pay only for water meter. The water bill from respondents is recorded in the table below.

Table 4-5: water bill per month of water meter owners

S.No	Amount of water bill in Birr	% Households	**S.No**	Amount of water bill in birr	% Households	Total (%)
1	Not connected	7	**6**	30	10	
2	12	2	**7**	35	3	
3	15	4	**8**	40	27	
4	20	37	**9**	60	1	
5	25	8	**10**	80	1	
	Total	**58**		**Total**	**42**	**100**

Source: Metu town field survey June, 2016

The result shows large numbers of respondents, 37% pay an average of 20 birr followed by 27% pay 40 birr, 10% pay 30 birr, and 8% pay 25 birr per month. Those who were not connected to pipe covering 7% of the household have no water bill per month. They use jar equivalent to 20 liters of water to buy water for their needs.

The official tariff of one jar established by Metu town water supply authority is 0.5 cents which is not sufficient to maintain, operate, energy and replacement activities of water supply system and this is one of the challenges for the improvement of the service and delivery.

Based on the level of scarcity and demand of water by the people from those who buy from small trucks since there are no tank and reservoir owners, the amount that the household pays of one jar varies from place to place and week to week. In the following table the amount paid for one jar recorded during field survey.

Table4-6: Amount paid and preferred amount of a jar of water

S.No	Amount paid	%household	Preferred amount	%household
1	1	4	1	78
2	2	3	2	6
3	5	79	3	15
4	6	2	5	1
5	7	9		
6	>8	3		
`Total	**`Total**	**100**	**Total**	**100**

Source: Metu Town Field survey June, 2016

In the table above the majority of the societies are paying 5 birr to buy a jar of water covering 79% and followed by 9% paying 7 birr. According to the respondents idea this amount is costly and they preferred other amount. Based on the field survey, 78% of the households preferred 1birr whilst 6% preferred 2 birr and 15% says paying 3 birr is fair. From this the majority preferred that the amount that should be paid for 20litres of water must be 1 birr, even though it is greater than what is mentioned by Metu town water supply authority.

When users buy water from water suppliers they always pay 5 birr for a jar of water and the profit analysis of water supplier is estimated as follows if the official cost of one jar is estimated at 0.5 cents, supplier who sells his water at 5 birr gain a huge profit of 900% without including fuel and transport cost where they transport by three wheel car called bajaj.

Table4-7: profit analysis of water suppliers for households

S.No	Cost of water per jar (20liters)	Selling price	Business profit	% business profit
1	0.5	1	0.5	100
2	0.5	2	1.5	300
3	0.5	5	4.5	900
4	0.5	6	5.5	1100
5	0.5	7	6.5	1300
6	0.5	>8	7.5	1500

Source: Metu Town Field survey June, 2016

As the society preferred to pay 1 birr for 20liters if water the profit for water suppliers is 100% without including all hidden cost. But this is very difficult to overcome since water demand is higher and higher than water supply of the town.

Cost of water to buy $1m^3$ of water which is equivalent to 1001itres when supplied by bajaj owners is about 250 birr. This is very difficult for those who are working on construction industries since this sector need much water. However they use this way since they have no choice to solve the problem. During ceremony and other events societies are forced to buy water from suppliers by bajaj and they are suffering from loosing much money and time as well as unprotected water diseases because those who bring water for societies also buy water from

distant place and mix with river water that have no quality to reduce their cost and maximize their profit.

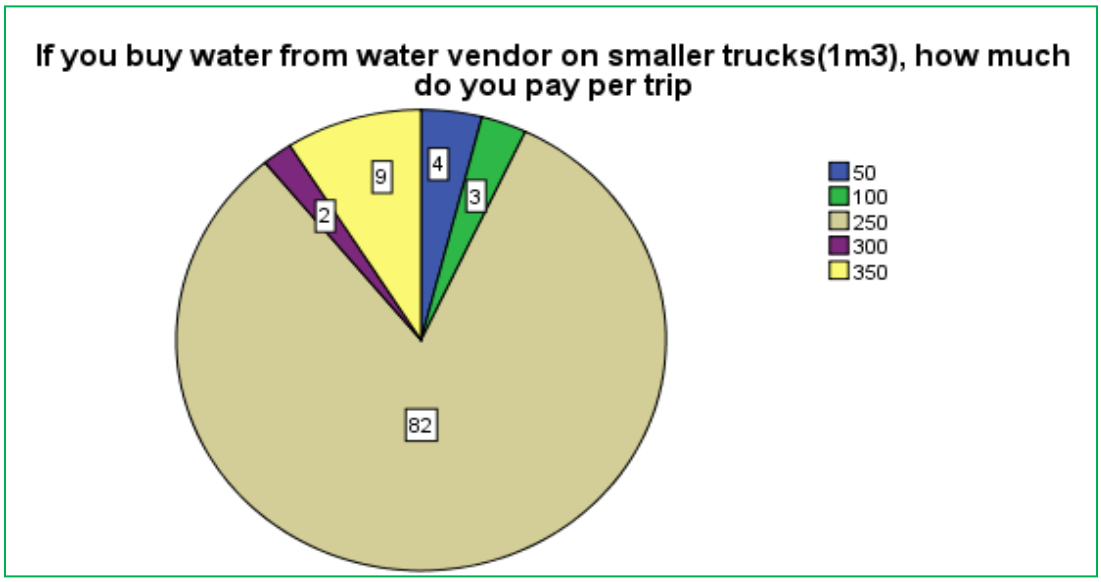

Figure 4-3: cost of 1m3 of water from water vendor by bajaj

Source: Metu town field survey June, 2016

From fig 4.5 from all respondent 82% of them says the expense 250 birr to buy a cubic meter of water from suppliers, followed by 9% those pays 350 birr to buy the same quantity of water. Thus, on average 250 birr was paid in order to buy $1m^3$ of water. From this it is easy to understand how much societies are in huge crisis of water and economy at the same time even without getting enough water quality and quantity.

Based on the cost above during the survey time respondents were asked whether the cost of water from vendors is expensive to afford. The records were as described below in Table.

Table 4-8Affordability of Water Cost from Vendors

Water cost	Percent of respondent
Expensive	92
Affordable	8
Total	100

Source: Metu town field survey June, 2016

As seen from table almost all of them say that water from vendors is very expensive. To the opposite side only 8% of them declare it is affordable. This response is from those who can get

water at their home at least twice in a week and buy water from nearby. This result describes all the societies in Metu town are exposed to pay much since water is life and all the daily process whether in the home or commercial cannot be done without water. Since the cost of one jar of water is 5 birr and $1m^3$ of water equivalent to 20 jar is the same (there is no difference between buying from others and water vendors). But households used to buy how much jar they want rather than buy one meter cube since they have no tankers or reservoir at their home.

4.3.Causes of water problem and its Impacts

In the study area both households and water supply officials strongly agree that the societies are facing water supply problem at large scale. It appears from the following figure 99% of the respondents says there is problem concerning water supply service and delivery system and 1% says no problem.

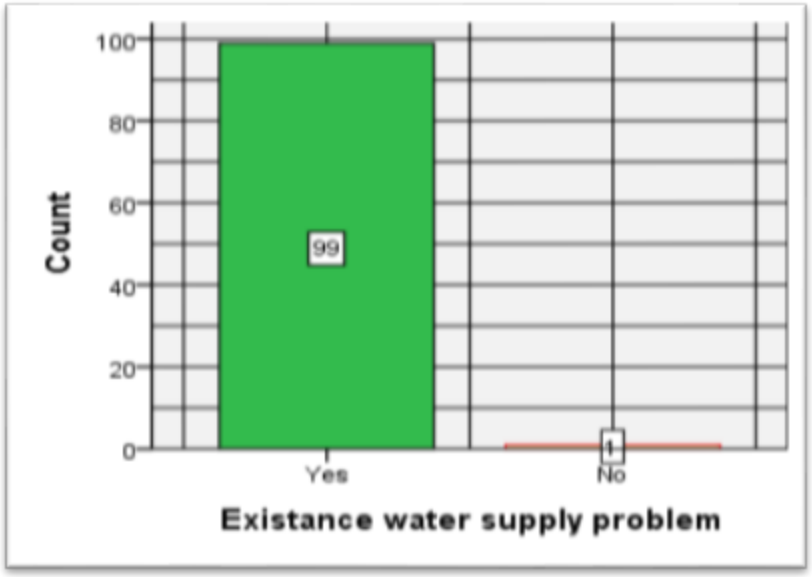

Figure 4-4: Existence of water supply problem

Source:Metu town field survey June, 2016

According to household's idea, there are many problems related to water supply and delivery system. Based on the rank of problem, respondents were asked to rank water problems in terms of major, minor, no cause and don't know or cannot tell about problem stated. This

result as listed in following table 70% of the respondents have an opinion of electric power outrage is the major cause of water shortage. Even though the response from many household is that the major cause of water problem is power problem, but this is not a problem as officials of Metu town water supply and sewerage authorities. According to the respondents idea the major cause for water problem in the study area is the frequent broke down of pipe lines. Those who have this opinion cover 68% and also this idea was gathered from officials the breakdown of pipe lines occurred due to design period of the old system. From the result 39% of the respondents also assume that the major problem is town expansion, while 32% of them say lack of technical expertise were the major cause of water problem. On the other hand, 21% of the household have an opinion of illegal connection were a problem, while 15% thinks unplanned community development project is the cause of water problem in the area.

Table4-9: Possible cause of water problems

Causes of water problems	Major cause (%)	Minor cause (%)	Not a cause (%)	Don't Know (%)	Total (%)
(1) Illegal connections	21	15	29	35	100
(2)MTWSSA lack technical expertise to handle the pumps	32	27	17	24	100
(3) Tanker owners arranged with the MTWSSA to limit water supply	17	22	21	40	100
(4) Frequent broken down of pipe lines	68	15	8	9	100
(5) Few pipe lines cannot support fast expansion of township	39	29	10	22	100
(6) Land owners do not want new pipe lines to pass their lands	11	47	28	14	100
(7) Unplanned township/community	15	18	32	35	100
(8) Electricity power outrage problems	70	22	1	7	100
(9) Other (Specify)					

Source: Metu town field survey June, 2016

During the field survey, households were asked to rank the impacts followed by water problem and they have tried to present in the following table 4.10. the rank according to respondents thinking 99% of them think that sever impact of water scarcity is that the slowing down of commercial and domestic activities were happened. Without water nothing is done and life is not expected. This show the societies were suffering highly from scarce water. The severe impact according to the response was risk of drinking untreated water from open wells, surface water. Those who have this opinion count to 97% of the households. As ranking continues, 90% think high water price to buy from water vendors occurred as water scarcity occurs while 88% responded water problem can bring heavy load of works in home to women to get water in addition to home work. According to the result from the survey the other impact of water problem was wasting of time to fetch water. This group covers 78% while those thinking long queues in fetching water which result in quarrels were 48% of the household.

The respondents were also asked about the quality of water used from the system and 68% of them replied, the water has some particles inside while 26% says it have color.

Table4-10: Possible impacts of water problems

Water Issue	Severe Impact (%)	Minor Impact (%)	Not aImpact (%)	Don't Know (%)	Total (%)
(1) Slowing down of domestic & commercial activities	99	1	0	0	100
(2) High water prices from water vendors	90	2	8	0	100
(3) Too much time is wasted in search of water	74	24	2	0	100
(4) Long queues in fetching water, resulting in quarrels	48	47	5	0	100
(5) Children usually are either late to or absent from school	28	48	19	5	100
(6) Children risk their lives crossing roads in search of water	37	45	16	2	100
(7) Prices of food items increase due to shortage of water	26	55	11	8	100
(8) Risk in drinking of untreated water from	97	3	0	0	100

open wells or surface waters					
(9) Work load of women in the households becomes very heavy	88	12	0	0	100
(10) Other (specify)					

Source: Metu town field survey June, 2016

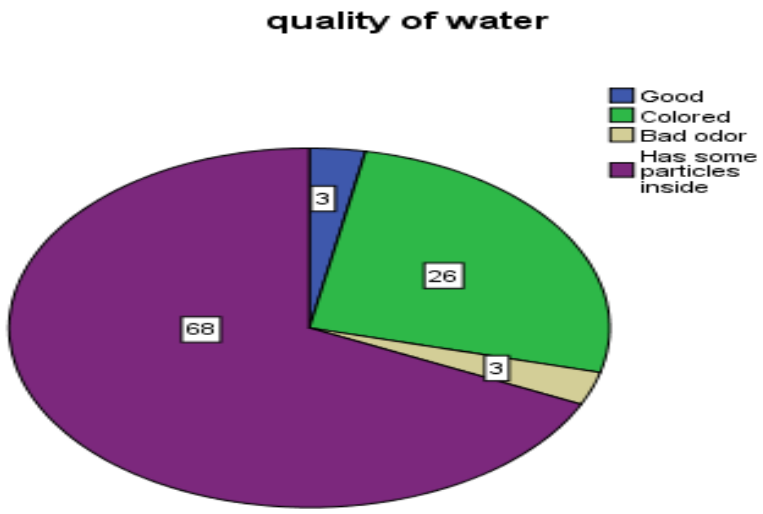

Figure 4-5: views on quality of drinking water

Source: Metu town field survey June, 2016

4.4.Public participation and system performance analysis.

Public participation is the key effort to solve any developmental program regarding its size and capital. This process creates the ownership sense within the society and keep the project functional and reduce the impact of problem since the societies assumes the program as their own property. Based on the use of public involvement, households were asked to speak about the knowledge they have about public participation regarding any development program especially water supply and service program. From the respondent's idea, 16% of them answered that Metu town water supply and sewerage authorities call elders, chiefs and communities to discuss on water supply and delivery system problem while 33% replied they are sure that there is no discussion among stakeholders. On the other side, 51% of them did

not know whether there were discussions or not concerning water problem. From 16% who were sure about the discussion were asked to describe the number of meeting held within two years and 4% of them says it was held eight times while 4% of them says two, 3% equal replied five and three times . The rest 84% have no idea to share because they have no information about the meeting. This implies how big the gap of public participation is identified.The knowledge of household about the meeting participation on water problem was explained in the following figure 4.9

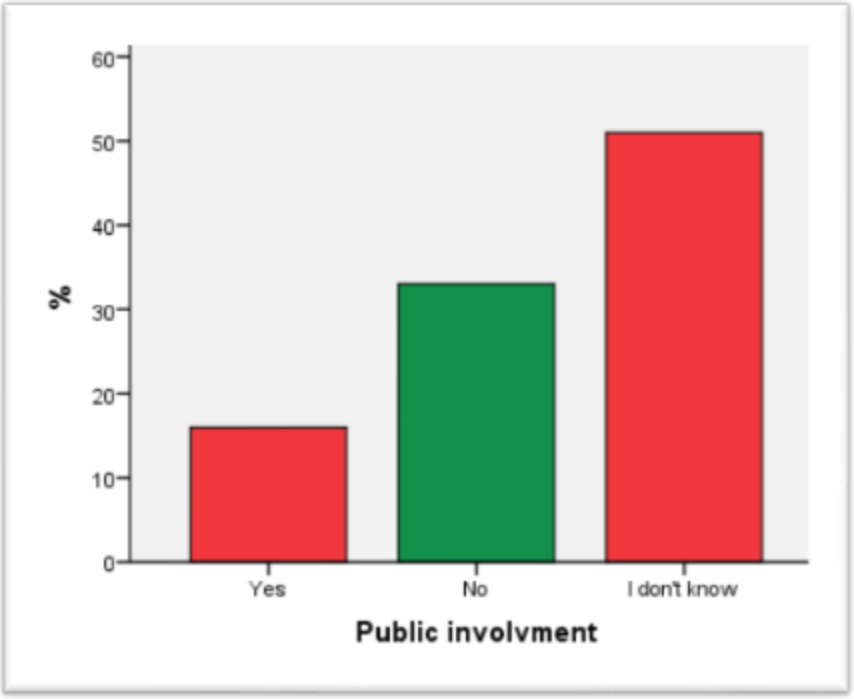

Figure 4-6public participation knowledge of household

Source: Metu town field survey June, 2016

The respondents were also asked if public participation in any developmental program or project including water supply were useful to solve problem concerning the program or project before and after implementation. The result from the households shows if there were discussions among communities and officials as well as all concerned bodies, it was important to solve water supply and delivery system problem. Those who have this opinion are 79% of the house hold interviewed. On the other hand 15% of them say it has no impact on solving

problem. This idea is the idea of those have knowledge of public participation and there was no problem solved as they have addressed it to concerned bodies. That is why they refuse to say public participation is important. The rest of the respondents (6%) have no knowledge of public involvement importance and they cannot tell whether it is useful to solve problems. The following table 4.11 describes the response from households on the importance public involvement in decision making of solving water supply and delivery system problem.

Table 4-11: Importance of public participation in solving water problem

Does public participation is important to solve water problem.	Yes (%)	No (%)	I don't know (%)	**Total (%)**
	79	15	6	**100**

Source: Metu town field survey June, 2016

All the results stated above were based on the first two objective of this paper. The first objective of this research paper is to identify the major challenges of frequent water shortage at Metu Town and the second one were to assess the socio-economic impacts associated with the water supply shortages. Based on this objective the field survey and interview were held and the finding was achieved. Even though it is not supported by officials the major cause of water problem is the shortage of electric power as respondents' opinion. The response from officials shows the shortage is due to the phase out of the old project and unsupported expansion of pipe line. This one was also supported to some extent by households. The old project cannot serve the current population since it was designed to serve about 15000 population 30 years ago. Currently the population is growing more and more and know reached to about 54000. This is huge number and the project designed to serve the former population know serve about one third of the population if it normally functional at this time. Following power shortage, the majority of the societies responded that the shortage of water in the town is caused by frequent breakdown of pipe line and this is also supported by officials to large extent. Based on the second objective, slowing down of commercial and domestic activities were the major impacts of water shortage followed by risky of drinking polluted water which causes health problem and expose the society to expense money to regain their health. This was not only impacts which affect the socioeconomic activities of the society. High water price which was caused by water shortage is

the major headache to the households in addition to finding of water that were not enough for household requirement.

If the finding based on the above two objective looks like those listed before, what performance of the system might actually tested by water CAD heastad method version 6.5 based on flow and pressure whether the existing system failed to serve the society as the officials and household said. Actually the existing system is out of date and need to be updated or rehabilitated as seen during field visit.

4.5. Hydraulic Performance evaluation of old or existing water distribution system

Performance of existing water distribution system was evaluated using water CAD heastad method version 6.5. Even though there are different performance indicators, for the aim of this research, velocity and pressure of the system were used to evaluate the performance.

Water CAD setting was done before proceeds to analysis the performance of the water distribution system. The standard setting were described as follow

1. Friction method-Hazen-Williams formula
2. Liquid- water at20°c(68F)
3. Input modes-coordinate x-y; setting-pressure; Tank level-level

After setting all the needed unit and procedure, junction data collected from site using GPS were synchronized to water CAD and the analysis of the system were done. Based on the software result the system layout map the distribution system performance considering velocity range and pressure were analsyed and discussed.

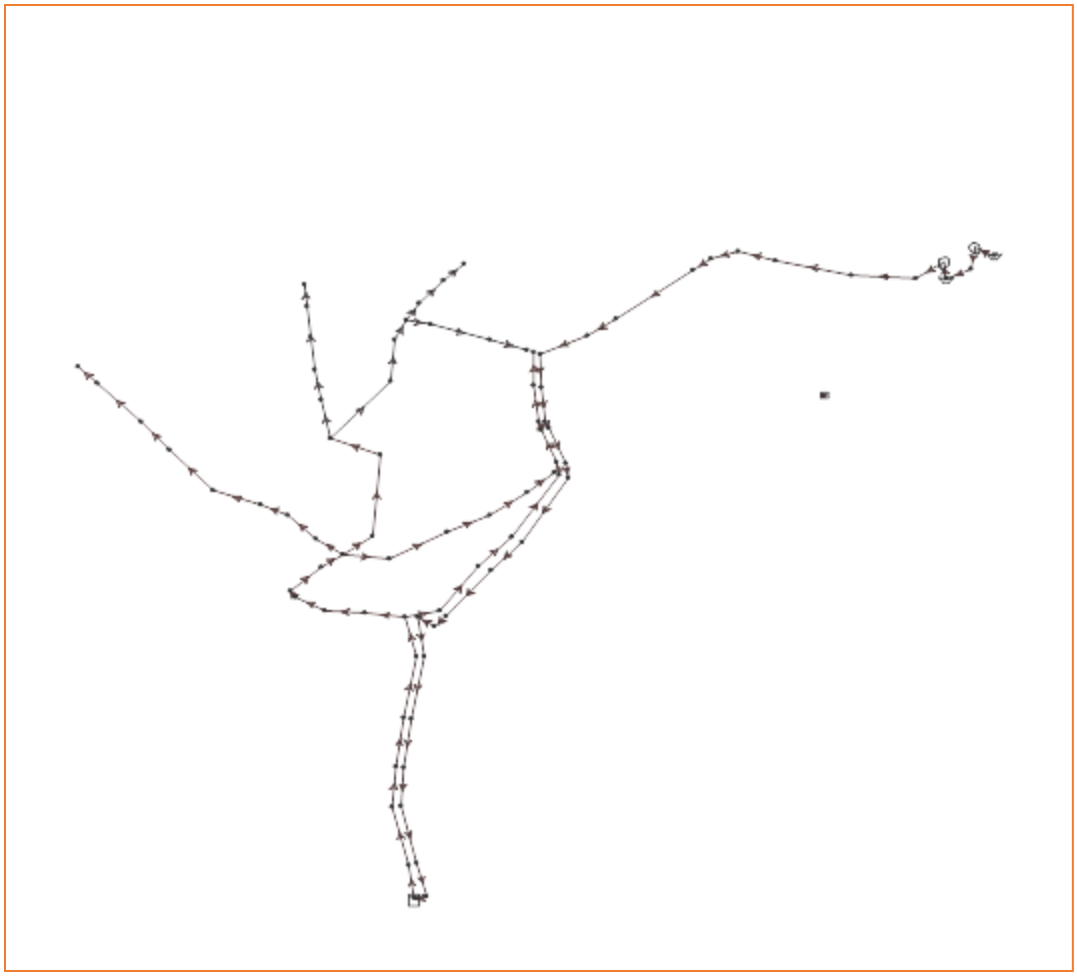

Figure 4-7: distribution system of Metu town water supply

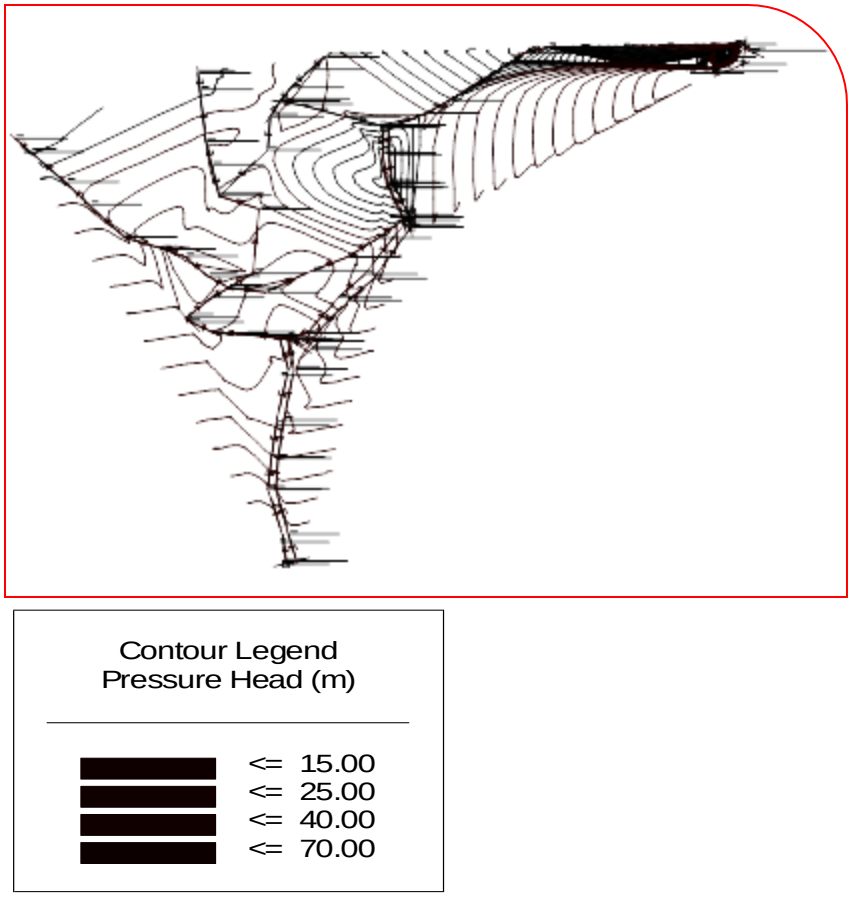

Figure 4-8: system pressure distributions

Table 4-12 pipe materials and size

Diameter(mm)	50	65	80	150	200	**Total**
DCI					4490.61	**4490.61**
uPVC				1204.57		**1204.57**
GI	1969.63	2694.1	2004.65			**6668.38**
Total length						**12363.6**
Percentage of pipe coverage	15.93	21.79	16.21	9.74	36.32	**100**

The analysis from the software shows the following range of velocities and pressure of water distribution system of the existing Metu town water supply.

1. **Pressure**

Table 4-13 The allowable operating pressures in the distribution network

Pressure range values	Number of junction	percent
<15mH_2O	4	5
15-16 mH_2O	31	41
>60 mH_2O	41	54
Total	76	100

From the above table 5 % of the junction or nodes in the distribution system fail below the minimum requirement of pressure. This was happen due to large elevation difference and distance from the source.

2. **Velocities**

Table 4-14 Velocity range in pipe network

Velocity range (m/s)	Count	%	Effect
<0.5	72	**94.7**	Sedimentation problem
0.5-2	4	**5.3**	Normal
>2			High head loss occurred

As seen from the above table; only 5.3 % satisfies the requirement of allowable velocities. The rest 94.7 % of the pipe in the distribution system fails below the recommended velocity range. This implies the majority of the pipes in the distribution system have the problem of sedimentation. When the flow is moving very slow in pipes the very tinny materials remains on the inner wall of the pipes and causes water quality problems. Therefore, the cause for the low velocity occurrence may be the diameters of pipes since the system were nearly free of pressure problem.

4.6. Interventional works

An intervention has been done in order to solve problem related to water and water supply infrastructure. Metu town got potable water in 1975 treated from Sor River. There is only one water reservoir in Metu located at elevation of 1730 meters with maximum discharge of the

town is 100m3/day with the capacity of 14 liters per second. To observe trend of water production in Metu town, water production, consumption and loss values of water from 1998 to 2002 are shown in the table below.

Table 4-15Water production, consumption & loss values of water in Metu, 2006-2010

Fiscal Year (June - July)	Production in m^3	Consumption in m^3	Loss in M^3	Percent
2006	242,720	210100.15	32,620	86.56
2007	252,720	223100.24	29,620	88.28
2008	267,120	233379.96	33,740	87.36
2009	307,520	251317.11	56,203	81.72
2010	317,520	272326.13	45,194	85.76

Source: Water office of Metu town, February 2011

As it is shown table 4.15, Water loss of Metu town from 2006 to 2010 is less than 20% with irregular variation from year to year. Water consumption in Metu town is greater than 80% of the total water produced.

There are 49 spatially distributed water points in Metu town. They are used to distribute water for those who do not have private water distribution lines. The major problems related47to water service delivery to Metu include shortage of water supply system, manual water filtration process by sand, high population growth compared to the existing water coverage, high concentration of iron ground water and damage created to water distribution lines. The town does not have any alternative source of water for different uses and investment activities. This will particularly create serious shortage of water with the opening of Metu University, which is expected to consume huge amount of water by sharing water with the existing population, social services (Hospital and Teacher's Training College) and investment activities of the town.

Table 4-16 Water coverage of Metu town at the end of the planning period, 2010

Year		2010	2020
Population size		40,120	60,938
Domestic water	Actual consumption in m3	272326.13	-

demand	Demand on the basis of 35Lit/d/person	512,884.05	779016.16
	Coverage of the actual water compared to 35Lit/d/person demand in percent	53.1	-

Assumption: DWD=30L/p/day; PD= 30% of DWD; Loss= 15% of DWD; IWD=55% of DWD

Source: -Metu town socioeconomic and spatial study report

As it is shown in table 4.16, the total population of the town in 2010 was 40,120 on the basis of population projection. The total amount of water provided for the population of the town in 2010 was 272326.13m^3 but the total amount of water required for the population of the town on the basis of water demand for individuals in 2020, i.e. 35Liters/person/day, is 512,884.05m^3. The relation between actual water consumed and the amount required according to the standard is 53.1%. This water coverage is small and hence concerned bodies and stakeholders should work hard to minimize the gap between actual water coverage and demand of the town. Additionally, investment activities like coffee processing requires huge amount of water and hence alternative methods should be designed for such investment activities to minimize their impacts of water sharing with residents.

Figure 4-9:Metu town water supply under construction

In order to solve water supply problem of Metu town, government take measure to construct new water supply project which were proposed to serve the town for the next 30 years with full capacity. For the construction of new project government invested 180million birr for civil work and 50 million birr for electro mechanical work. Totally the investment was about 230 million Ethiopian birr. This is huge amount but it is must for the government in order to solve water supply scarcity and deteriorated quality of water. This cost rises from 85 million birr because

there was delay of time during the construction, problem of material supply like pipes and cost variation over the period when it was estimated at the beginning.

The newly under construction project were proposed to serve the current and the future growing population, for the next thirty years.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Water crisis and its impact in Metu town is the result of lack of cooperation during proposal of developmental program with all concerned bodies and public participation after and before implementation.

Useful information about water crisis, impacts of water shortage, water costs and extent of public participation have been addressed in this paper to provide information to improve water supply and delivery service for official as well as societies.

The major cause of water crisis or shortage in the area are power shortage, frequent breakdown of pipe lines un supported expansion due to the nature of environment and capacity of old water supply system as determined from field survey. This all problems cause major impacts on Metu town societies. This impact includes the slowdown of daily domestic and commercial activities which in turn decline the economy of the societies. The others are work load on women in home, and expose societies to pay more money to buy water outside.

Performance of the existing system is highly reduced because of low velocity profile which causes sedimentation, showing 94.7 % of the pipes do not satisfies the minimum required velocity of 0.6m/s. When the flow is moving very slow in pipes the very tinny materials remains on the inner wall of the pipes and causes water quality problems. Since the system was almost free of pressure problem this may happen due to the diameter of the pipe. Regarding pressure 5 % of the nodes falls below the minimum requirement due to high elevation difference.

5.2. Recommendation

Since water is the most essential component that has the power to change the life style of human being, it should be important to take best measures in order to solve problem pertaining to water and water sectors. Thus this paper tries to recommend the following recommendation that is important to solve water problem and performance analysis of Metu town.

1. Since life cannot exist without water every concerned body of the society should take care for the system thus the continuity of water supply schemes and sufficiency of water demand is met, which improves the life of the society and reduces burden especially on women's.
2. In order to reduce the impact of water supply problem on society government and society should work together.
3. It is better to teach the society about the consequence of drinking unprotected water and advise them to treat water as much as possible. This duty must be held by zonal health office and Metu Town water supply and sewerage authority cooperatively.
4. The under construction project that were delayed for more than five (5) years must be completed within few months and the problem of water supply will be solved with greater extent since the capacity of the project was designed to serve the societies for the next 30 years.
5. Society involvement is the very important system to solve not only water supply but also for all developmental project since it was supposed to serve the society.
6. Cooperation works with funding organization is also the best way to improve the quality and quantity of water supply, and to create smooth relationships between the society and the government.
7. Improving billing system and service system, on time maintenance, consequent supervision, problem identification, active response to grievance from society specially the poor urban dwellers is the key point to solve water scarcity problem and to reduce the impact of water supply shortage

8. To improve the performance of the system, proper follow up and supervision must be accomplished.
9. Private sector participation may also be the important point to solve water supply problem and regulation of water supply system must carefully be adopted.

.

REFERENCES

ADB (2010) Urban water supply sector risk assessment. Mandaluyong City, Philippines:.

ALEGRE, H., HIRNER, W., BAPTISTA, J. M. & PARENA, R. (2000) Performance Indicators for Water Supply Services. *Manual of Best Practice Series*. IWA Publishing, London, UK.

AMCOW (2011) An AMCOW Country status overview: water supply and sanitation in Ethiopia,Turning Finance in to services for 2015 and Beyond.

AWWA (2004) Computer Modelling of Water Distribution systems.

CARDOSO, M. A., COELHO, S. T., MATOS, R. & ALEGRE, H. (2004) Performance assessment of water supply and waste water systems. *Urban Water Journal*, 1**,** 55-67.

DAWE, P. (2000) Workshop on hydraulic modeling with waterCAD. SOPAC Water Resource Unit, sopac miscellaneous report 395 2000

DZIKUS, A. (2001) "*Managing Water for African Cities: An Introduction to Urban Water Demand", . Regional Conference on the Reform of the Water Supply and Sanitation Sector in Africa - Enhancing Public-Private Partnership in the Context of the Africa Vision for Water (2025)* Kampala, Uganda.

EARTHCILPS (2015) water scarcity.

HAESTAD METHODS, W., T.M, CHASE, D.V, SAVIC, D.A, GRAYMAN, W, BECKWITH, S, AND KOELLE, E . (2003) *Advanced Water Distribution Modeling and Management*. 1ed,Haestad press.

HARVEY, P. A. & REED, R. A. (2004) *Rural Water Supply in Africa: Building Blocks for Handpump Sustainability*. WEDC, Loughborough University, UK.

HTTP://WWW.EPA.GOV/DOCS/OWMITNET/WATER-EFFICIENCY/PUBS/SUPPLY.HTM (Retrived 25 june, 2016).

HTTP://WWW.GEOTIMES.ORG/MAY05/FEATURE_WORLDWATER.HTML (Retrived 25june,2016).

HTTPS://WWW.WATER4.ORG/WHAT-WE-DO/OUR-CRISIS/M.STORIES/432/VIEW/28 (Retrived August 19,2016).

IWA (2004) Integrated Water Resources Management: A Reassessment A Water Forum Contribution. *Water International,*, 29**,** 248-256.

KELAY, T., CHENOWETH, J. & FIFE-SCHWA, C. (2006) *Trend Report on Consumer Trends, Cross-cutting issues across Europe* TECHNEAU,.

KHADRI, S. F. R. & PANDE, C. (2014) Urban Water Supply Systems - A Case Study On Water Network Distribution in Chalisgaon City in Dhule District Maharashtra Using Remote Sensing & GIS Techniques *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)***,** 1-12.

KIT, O., PÉREZ, M. G. & THOMAS SCHILLER (2015) **MACS Water Smart. The new web-based hydraulic and financial water distribution network assessment tool** *2nd New Development In IT & Water Conference*

MEHTA, D., LAKHANI, K., PATEL, D. & PATEL, G. STUDY OF WATER DISTRIBUTION NETWORK USING EPANET *International journal of Advanced Research in Engineering, Science and Management***,** 1-9.

MOWR Ethiopian Water Resource Management policy.

MOWR (2006) Urban Water Supply Design Criteria. IN DEPARTMENT, W. R. A. U. W. S. A. S. (Ed.).

MURANHO, J., FERREIRAD, A., SOUSA, J., GOMES, A. & MARQUES, A. S. (2014) Technical performance evaluation of water distribution networks based on EPANET. *12th International Conference on Computing and Control for the Water Industry, .* Elsevier Ltd.

NAIR, S. (2010) Challenges in urban water management in a changing environment case study from a growing tropical city. Kerala, Nansen Environmental Research Centre, India.

PAULA, D. (2000) Workshop on Hydraulic Network Modelling Using WaterCAD.

ROSEGRANT, M. W., CAI, X., CLINE, S.A. (2002) "*Averting an Impending Crisis*", Global Water Outlook to 2025, Food Policy Report, . *International Water Management Institute(IWMI), Colombo, Sri Lanka.*

ROSSMAN, L. A. (2000) *EPAnet Users Manual. Environmental Protection Agency, EPA/600/R-00/057.* Cincinnati.

SEGRAVE, A. J. (2007) *Report on trends in the Netherlands*: TECHNEAU,.

SHANMUGHAM, S. & BEKELE, S. (2011) AN ASSESSMENT ON THE STATUS OF WATER SUPPLY AND SANITATION IN ETHIOPIA:A CASE OF AMBO TOWN. *Journal of Sustainable Development in Africa* 13.

UN (1977) Report of United Nation water conference. Mar del plata,Argentina.

UN (2013) water for life.

WHO (2000) Global Water Supply and Sanitation Assessment Report.

WPI (2006) Water Facts.

ZHANG, T. (2006) The Application of GIS and CARE-W on Water Distribution Networks in Skärholmen Pressure Zone, Stockholm, Sweden. Stockholm, Royal Institute of Technology (KTH).

ZULEEG, S. (2006) *Trends in Central Europe (GERMANY / SWITZERLAND)*: TECHNEAU.

APPENDIXES

Master program in Hydraulic Engineering, Jimma Institute of Technology (JiT), Jimma, Ethiopia

Master Thesis Topic: Assessing the challenges of urban water supply and performance measurement of water distribution system: case of Metu Town

All information provided will be treated as strictly confidential and for academic purpose only.

HouseholdsQuestionnaire (Questionnaire for Water Consumers)

Respondent Number: ……

Section A:

Q1. Sex: (1) Male (2) Female

Q2. Age: (1) 15 – 19 (2) 20 – 29 (3) 30 – 39 (4) 40– 49 (5) 50 – 59 (6) 60+

Q3. Marital Status: (1) Married (2) Single (3) Divorced/Separated (4) widowed

Q4. What is your household size? (How many are you in your household?):

(1)1 (2) 2 (3) 3 (4) 4 (5) 5 (6) 6 (7) 7 (8) 8 (9) 9 +

Q5. What is your highest level of education? (1) Illiterate (2) Primary (3) secondary

(4) Certificate (5) diploma (6) BA/BSC (7) MA/MSC (8) PhD

Q6. What do you do for a living? (Occupation)……

Q7. Which part of Metu do you stay? (Your area of residence in Metu): (1) 01 (2) 02 (3)03

Section B:

Q8. Do you have pipe connected to your home? (1) Yes (2) No

Q9. If yes, how many days does your tap flow in a week? (1) 1-2 (2) 3-4 (3) 5-7

Q10. If not, how far (in meters or kilometers) does it take you to walk to where you draw / fetch water? (1) < 50 m (2)50 - 100 m (3) 100 -200 m (4) over 200m

Q11. On the average how many jars of water do you need for your household per day? (1)1 (2) 2 (3) 3 (4) 4 (5) 5 (6) 6 (7) 7 (8) 8 (9) 9 +

Q12. Is the water you fetch sufficient to meet your household requirements? (1) Yes (2) No

Q13. If you have pipe connected to your home, how much do you pay (on the average) as water bill per month? birr.....

Q14. If you buy water outside your house, how much do you pay (on the average) for one jar cane (20liter) of water? (1) 1birr (2) 2birr (3) 3 birr (4) 4 birr (5) 5 birr (6) 6 birr (7) 7 birr (8) other

Q15. How much do you think an average urban dweller in Metu should pay for one jar cane (20 liters) of water? (1) 1 birr (2) 2 birr (3) 3 birr (4) 4 birr (5) 5 birr (6) 6 birr (7) 7 birr (8) 8 birr (9) other

Q16. If you buy water from water vendor on smaller trucks ($1m^3$), how much do you pay per trip? Birr.....

Q17. Do you think water price per trip is expensive or affordable to you? (1) Expensive (2) affordable (3) don't know

Q18. Do you think there are problems with water supply and delivery in your area?(1)Yes, problems (2) No, no problems (3) Don't Know

Q19. What will you say about the following issues of water supply in your area? Tick (√) as appropriate in the columns under: Severe problem, Minor problem, Not a problem and Don't know, in the table below.

Water Issue	Severe problem	Minor problem	Not a problem	Don't Know
(1) Slowing down of domestic & commercial activities				
(2) High water prices from water vendors				
(3) Too much time is wasted in search of water				
(4) Long queues in fetching water, resulting in quarrels				
(5) Children usually are either late to or absent from school				
(6) Children risk their lives crossing roads in search of water				
(7) Prices of food items increase due to shortage of water				
(8) Risk in drinking of untreated water from open wells or surface waters				
(9) Work load of women in the households becomes very heavy				
(10) Other (specify)				

Q20. What will you say about the quality of the water that you drink? (1) Good (2) Salty (3) Colored (4) bad odor (5) Has some particles inside (6) other (specify)

Q21. What do you think are the possible causes of the water problems in your area? Tick (√) as appropriate in the columns under: Major cause, Minor cause, Not a cause and Don't know in the table below.

Causes of water problems	Major cause	Minor cause	Not a cause	Don't Know
(1) Illegal connections				
(2)MTWSSA lack technical expertise to handle the pumps				
(3) Tanker owners arranged with the MTWSSA to limit water supply				
(4) Frequent broken down of pipe lines				
(5) Few pipe lines cannot support fast expansion of township				
(6) Land owners do not want new pipe lines to pass their lands				
(7) Unplanned township/community				
(8) Electricity power outage problems				
(9) Other (Specify)				

Q22. Do you know if the MTWSSA has ever involved chiefs & elders or the residents association in your area in discussing water supply and delivery issues? (1) Yes (2) No (3) Don't Know

Q23. If yes, how many meetings have been held since the last 2 years? (1)1 (2) 2 (3) 3 (4) 4 (5) 5 (6) 6 (7) 7 (8) 8 (9) 9 +

Q24. Do you think involving the Chiefs & Elders or the residents association by the MTWSSA will be helpful in solving some of your water supply problems? (1) Yes (2) No (3) Don't Know

Q25. Do you think water bills should be increased in order to improve water supply and delivery services? (1) Yes (2) No (3) Don't Know

Q26. Do you accept that water supply and delivery should be handled by a private company? (1) Yes (2) No (3) Don't Know

Q27. What do you think can be done to improve water supply and delivery services in Your area ? ……..

THANK YOU FOR YOUR ASSISTANCE AND VALUABLE TIME.

AFAAN OROMOO VERSION

Jimmaa Universitiitti Inistitiyutii Teknooloojii Jimmaatti Sagantaa Barnoota Digirii 2ffaa Muummee Hydraulic Engineering

Mata duree Qorannochaa: - **Assessing the challenges of urban water supply and performance measurement of water distribution system: case of Metu Town**

- Odeeffannoon kun icciitiin isaa gutumma aguutuutti kan eegameef dhimma akkaadaamii ykn barnootaa qofaa fkan ooludha.

Gaaffii AbbaaWarraaf (itti fayyadamtoota bishaaniif)

Maqaa Gaafatamaa ykn Lakkoofsa gaafatamaa_____

Kutaa A

G1. Saala: (1) Dhiira (2) Dhalaa

G2. Umurii: (1) 15 – 19 (2) 20 – 29 (3) 30 – 39 (4) 40– 49 (5) 50 – 59 (6) 60+

G3. Haala fuudhaaf heerumaa: (1) fuudheera (2) hinfuune (3) hiikeera (4) kan irraa du'e

G4. Lakkoofsa Maatii: (1)1 (2) 2 (3) 3 (4) 4 (5) 5 (6) 6 (7) 7 (8) 8 (9) 9 +

G5. Sadarkaa barnootaa (1) barnoota hinqabu (2)sad 1ffaa (3)sad 2ffaa (4) teekinika (5) digrii (6) digirii 2ffaa (7) digirii 3ffaa (Phd)

G6.Hojii (ogummaa)_____

G7. Mattuukeessaaiddookamjiraatta?(maqaanaannoosanaayknganda)

Kutaa B

G8. Sararribishaaniiyknboombaanmanakeessanittigaleejiraa (1) eeyyee (2) lakkii

G9. Yooeeyyeeta'ebishaantorbanittiyeroomeeqaargattuyknisiniifdhufa?(1) 1-2 (2) 3-4 (3) 5-7

G10.Yoo lakkii jettan bishaan waraabbachuuf fageenya hammamii isinitti fudhata?

(1) < 50 m (2)50 - 100 m (3) 100 -200 m (4) 200m ol

G11. Giddu galeessaan guyyaatti maatii keessaniif bishaan huuroo(jaarkaanii) litira 20 meeqa fayyadamtu? 1)1 (2) 2 (3) 3 (4) 4 (5) 5 (6) 6 (7) 7 (8) 8 (9) 9 +

G12. Bishaan isin waraabbattan maatii keessaniif gahaadhaa? (1) eeyyee(2) lakkii

G13.Yoo ujummoon bishaanii mana keessaniif galeera ta'e Taarifa bishaanii ji'aan qarshii hangam kaffaltu?_____

G14. Yoo bishaan bakkeetii bittu ta'e giddugaleessaan jaarkaanii abbaa liitira 20 tokko qarshii meeqaan bittu? (1) 1birr (2) 2birr (3) 3 birr (4) 4 birr (5) 5 birr (6) 6 birr (7) 7 birr (8) kanbiraa

G15. Jiraataan Magaalaa mattuu bishaan jarkaanii abbaa liitira 20 tokko bituuf qarshii hangamii kaffaluu qabajettani iyaaddu? (1) 1 birr (2) 2 birr (3) 3 birr (4) 4 birr (5) 5 birr (6) 6 birr (7) 7 birr (8) 8 birr (9) kan biraa

G16. Namoota baajaajii dhaan bishaan dhiyeessanii gurguranirraa meetir kuubii tokko(1m3) bituuf qarshii meeqa kanfaltu?_____

G17. Gatiin namoota dhiyeessan kana irraa bishaan ittiin bitamu akkamittiin ibsitu (1) madaalawaadha (2) madaalawaamiti (3) beekuuhindandeenye

G18. Naannoo keetti dhiyeessii fi raabsa bishaanii irratti rakkoon jira jettanii yaadduu? (1) eeyyee (2) lakkii (3) hinbeeku

G19. Haala naannoo keessanii wajjin walqabsiisuun rakkinoota dhiiyeessaa fi raabsa bishaanii irratti mula'atan gabatee armaan gadii keessatti mallattoo(√) kaa'uun agarsiisaa

RakkooBishaanirrattiMul'atu	Rakkoobaay'eehammaataa	Rakkoo salphaa	Rakko onhinjiru	Hin beeku
(1)haala sochii hojii mana keessaa fi daldaalaa harkifachiisa				
(2) namoota bishaan dhiyeessan irraa gatii guddaan bituu				
(3) Bishaan waraabuuf yeroo baay'eetu gubata				
(4) bishaan waraabuuf hiriira dheeraa mul'atuun waldhabdeen ni uumam				
(5) Ijoolleen mana barumsaa akka booda hafan ykn tasuma hafan godha				
(6) jireenya daa'immaan daandii qaxxamuranii bishaan barbaadaniif balaa qaba				
(7) gatiinnyaataasababahanqinabishaaniifdabaluu				
(8) Miidhaa sababii bishaan hin qulleeffamne bollaa fi lagaa waraabuun dhufu				
(9) hojiin mana keessaa dubartootatti akka ulfaatu gochuu				
(10) kan biraan yoo jiraate ibsaa?				

G20. Qulqullina bishaan dhugdanii irratti yaada maalii qabdu? (1) gaariidha (2) ashabaawaadha (3) halluu qaba (4) foolii badaa qaba (5) wantoota xixiqqoo of keessaa qaba (6) kan biraa ibsaa

G21. Sababoonni rakkina bishaan dhugaatii naannoo keessanitti mul'atu kam akka ta'e mallattoo (√) kaa'uun agarsiisaa

Sababa rakkoo bishaanii	Saba bagu ddaa	Saba baXi qqaa	Sababa kana miti	Hinb eeku
(1) Sarara seeraan alaa				
(2) Rakkoo dhabiinsa hojjetaa tekinikaa paampii haala gaariin qabuu dhiyeessa bishaan dhugaatii magaalaa Mattuu				
(3) warri taankii bishaanii bishaan akka qusatamuuf dhiyeessa bishaan magaalaatiin ajajamuu				
(4) sararri bishaanii deddeebi'ee cabuu ykn miidhamuu				
(5) sararrri tokko tokko babal'isuu ariifachiisaaf mijatoo ta'uu dhabuu				
(6) abbootiin lafaa sararri haaraan lafa isaaniirra akka hin baane eyyamuu dhabuu				
(7)pilaanii qindaa'e dhabuu Magaalichaa ykn naannichaa				
(8) rakkoo addaan cituu humna ibsaa				
(9) Kan biraa yoo jiraate ibsaa				

G.22.Dhiyeessi bishaan magaalaa Mattuu maanguddootaa fi qondaalota ykn hawaasa naannoo waliin dhimma dhiyeessa fi raabsa bishaanii irratti mari'achuu isaanii waan beektan qabduu?

(1)eeyyee (2) lakkii (3)hinbeeku

G.23.Yoo eeyyee jettan waggoota lamaan 2n darban keessatti yeroo meeqa walgahiin geggeeffame? (1)1 (2) 2 (3) 3 (4) 4 (5) 5 (6) 6 (7) 7 (8) 8 (9) 9 +

G24. Maanguddoota, qondaalotaa fi fayyadamtoota naannoo maree kana irratti hirmaachisuun rakkoo dhiyeessa bishaan dhugaatii hamma tokko furuuf ni fayyada jettanii yaadduu? (1) eeyyee (2) lakkii (3) hinbeeku

G25. Dhiyeessaa fi Raabsa bishaan dhugaatii fooyyessuuf gatii bishaanii dabaluun barbaachisaadha jettanii yaadduu? (1) eeyyee (2) lakkii (3) hinbeeku

G26. Dhiyeessi bishaan dhugaatii harka dhuunfaatiin yoo raawwate ni fudhaattuu ykn gaariidha jettanii yaadduu? (1) eeyyee (2) lakkii (3) hinbeeku

G27. Dhiyyeessaa fi raabsa bishaan dhugaatii naannoo keessanii fooyyessuuf maaltu godhamuu qaba jettanii yaadduu?_____

GARGAARSAA FI YEROO NAAF KENNITANIIF GALATOOMAA!

Annex - I Pipe Flex Table

Label	Start Node		Stop Node	Length (User Defined) (m)	Diameter (mm)	Material	Hazen-Williams C	Velocity (m/s)	Flow (L/s)	Headloss (m)	Pressure Loss (m H2O)
P-1	P-1	P-1	P-2	78.33	200	DCI	130	0.84	26.31	0.31	3.91
P-2	P-2	P-2	P-3	89.92	200	DCI	130	0.84	26.31	0.35	3.91
P-3	P-3	P-3	P-4	98.76	200	DCI	130	0.55	17.31	0.18	1.8
P-4	P-4	P-4	P-5	74.37	200	DCI	130	0.63	19.81	0.17	2.31
P-5	P-5	P-5	P-6	118.26	200	DCI	130	0.63	19.81	0.27	2.31
P-6	P-6	P-6	P-7	219.15	200	DCI	130	0.34	10.81	0.16	0.75
P-7	P-7	P-7	P-8	263.04	200	DCI	130	0.31	9.81	0.17	0.63
P-8	P-8	P-8	P-9	132.89	200	DCI	130	0.31	9.81	0.08	0.63
P-9	P-9	P-9	P-10	92.35	200	DCI	130	0.31	9.81	0.06	0.63
P-10	P-10	P-10	P-11	78.94	200	DCI	130	0.31	9.81	0.05	0.63
P-11	P-11	P-11	P-12	334.98	200	DCI	130	0.31	9.81	0.21	0.63
P-12	P-12	P-12	P-13	116.13	200	DCI	130	0.31	9.81	0.07	0.63
P-13	P-13	P-13	P-14	179.83	200	DCI	150	0.31	9.81	0.09	0.48
P-14	P-14	P-14	P-15	140.21	200	DCI	150	0.31	9.81	0.07	0.48
P-15	P-15	P-15	P-16	147.52	200	DCI	150	0.31	9.81	0.07	0.48
P-16	P-16	P-16	P-17	24.08	200	DCI	150	0.31	9.81	0.01	0.48
P-17	P-17	P-17	P-18	160.32	200	DCI	150	0.31	9.81	0.08	0.48
P-18	P-18	P-18	P-19	64.62	200	DCI	150	0.31	9.81	0.03	0.48
P-19	P-19	P-19	P-20	312.72	200	DCI	150	0.31	9.81	0.15	0.48
P-20	P-20	P-20	P-21	155.75	200	DCI	150	0.31	9.81	0.08	0.48
P-21	P-21	P-21	P-22	245.97	200	DCI	150	0.31	9.81	0.12	0.48
P-22	P-22	P-22	P-23	58.22	200	DCI	150	0.31	9.81	0.03	0.48
P-23	P-23	P-23	P-24	68.58	200	DCI	150	0.31	9.81	0.03	0.48
P-24	P-24	P-24	P-25	166.73	200	DCI	150	0.31	9.81	0.08	0.48
P-25	P-25	P-25	P-26	263.04	200	DCI	150	0.31	9.81	0.13	0.48
P-26	P-26	P-26	P-27	207.26	200	DCI	150	0.31	9.81	0.1	0.48
P-27	P-27	P-27	P-28	163.37	200	DCI	150	0.31	9.81	0.08	0.48
P-28	P-28	P-28	P-29	245.06	200	DCI	150	0.31	9.81	0.12	0.48
P-29	P-29	P-29	P-30	144.48	200	DCI	150	0.31	9.81	0.07	0.48

P-30	P-30	P-30	P-31	45.72	200	DCI	150	0.31	9.81	0.02	0.48
P-31	P-31	P-31	P-32	149.05	150	PVC	150	0.23	3.99	0.06	0.37
P-32	P-32	P-32	P-33	250.85	150	PVC	150	0.23	3.99	0.09	0.37
P-33	P-33	P-33	P-34	169.77	150	PVC	150	0.23	3.99	0.06	0.37
P-34	P-34	P-34	P-35	205.74	150	PVC	150	0.23	3.99	0.08	0.37
P-35	P-35	P-35	P-36	261.52	150	PVC	150	0.23	3.99	0.1	0.37
P-36	P-36	P-36	P-37	137.46	80	GI	120	0.53	2.68	0.79	5.74
P-37	P-37	P-37	P-38	115.82	80	GI	120	0.53	2.68	0.66	5.74
P-38	P-38	P-38	P-39	30.78	80	GI	120	0.53	2.68	0.18	5.74
P-39	P-39	P-39	P-40	145.08	80	GI	120	0.53	2.68	0.83	5.74
P-40	P-40	P-40	P-41	91.14	80	GI	120	0.53	2.68	0.52	5.74
P-41	P-41	P-41	P-42	110.34	65	GI	120	0.3	1	0.28	2.53
P-42	P-42	P-42	P-43	138.68	65	GI	120	0.3	1	0.35	2.53
P-43	P-43	P-43	P-44	102.41	65	GI	120	0.3	1	0.26	2.53
P-44	P-44	P-44	P-45	172.82	65	GI	120	0.3	1	0.44	2.53
P-45	P-45	P-45	P-46	224.33	65	GI	120	0.3	1	0.57	2.53
P-46	P-46	P-46	P-47	152.7	65	GI	120	0.3	1	0.39	2.53
P-47	P-47	P-47	P-48	219.46	65	GI	120	0.3	1	0.56	2.53
P-48	P-48	P-48	P-49	94.79	65	GI	120	0.3	1	0.24	2.53
P-49	P-49	P-49	P-50	118.87	65	GI	120	0.03	-0.1	0	0.04
P-50	P-50	P-50	P-51	160.32	65	GI	120	0.03	-0.1	0.01	0.04
P-51	P-51	P-51	P-52	163.37	65	GI	120	0.03	-0.1	0.01	0.04
P-52	P-52	P-52	P-53	226.77	65	GI	120	0.03	-0.1	0.01	0.04
P-53	P-53	P-53	P-54	158.5	65	GI	120	0.03	-0.1	0.01	0.04
P-54	P-54	P-54	P-55	128.32	65	GI	120	0.3	0.99	0.32	2.49
P-55	P-55	P-55	P-56	338.02	65	GI	120	0.3	0.99	0.84	2.49
P-56	P-56	P-56	P-57	184.4	65	GI	120	0.3	0.99	0.46	2.49
P-57	P-57	P-57	P-58	166.42	50	GI	120	0.25	0.5	0.42	2.52
P-58	P-58	P-58	P-59	127.41	50	GI	120	0.25	0.5	0.32	2.52

P-59	P-59	P-59	P-60	269.14	50	GI	120	0.25	0.5	0.68	2.52
P-60	P-60	P-60	P-61	89.31	50	GI	120	0.25	0.5	0.23	2.52
P-61	P-61	P-61	P-62	318.52	50	GI	120	0.25	0.49	0.77	2.43
P-62	P-62	P-62	P-63	174.65	50	GI	120	0.25	0.49	0.42	2.43
P-63	P-63	P-63	P-64	90.53	50	GI	120	0.25	0.49	0.22	2.42
P-64	P-64	P-64	P-65	84.12	50	GI	120	0.2	0.4	0.14	1.67
P-65	P-65	P-65	P-66	128.32	50	GI	120	0.2	0.4	0.21	1.67
P-66	P-66	P-66	P-67	93.27	50	GI	120	0.2	0.4	0.16	1.67
P-67	P-67	P-67	P-68	82.91	50	GI	120	0.05	0.09	0.01	0.11
P-68	P-68	P-68	P-69	213.36	50	GI	120	0.05	0.09	0.02	0.11
P-69	P-69	P-69	P-70	131.67	50	GI	120	0.05	0.09	0.01	0.11
P-70	P-70	P-70	P-71	142.65	80	GI	120	0.53	2.68	0.78	5.74
P-71	P-71	P-71	P-72	170.38	150	PVC	150	0.23	3.99	0.06	0.37
P-72	P-72	P-72	P-73	112.78	80	GI	120	0.06	0.3	0.01	0.1
P-73	P-73	P-73	P-74	226.77	80	GI	120	0.06	0.3	0.02	0.1
P-74	P-74	P-74	P-75	167.03	80	GI	120	0.06	0.3	0.02	0.1
P-75	P-75	P-75	P-76	307.24	80	GI	120	0.06	0.3	0.03	0.1
P-76	P-76	P-76	P-77	53.34	80	GI	120	0.06	0.3	0.01	0.1
P-77	P-77	P-77	P-78	147.22	80	GI	120	0.06	0.3	0.01	0.1
P-78	P-78	P-78	P-79	33.22	80	GI	120	0.06	0.3	0	0.1
P-79	P-79	P-79	P-80	155.45	80	GI	120	0.06	0.3	0.02	0.1
P-80	P-80	P-80	P-80	137.46	80	GI	120	0.06	0.3	0.01	0.1

Annex – 2 Junction Flex Table

Label	X (m)	Y (m)	Elevation (m)	Demand (L/s)	Pressure (m H2O)	Hydraulic Grade (m)	Pressure Head (m)
J-1	784,947.00	918,372.00	1,681.00	0	83.66	1,764.83	84
J-2	785,443.00	919,230.00	1,651.00	0	114.25	1,765.48	114
J-3	784,071.00	919,030.00	1,680.00	0	76.4	1,756.55	76
J-4	783,510.00	918,544.00	1,689.00	0	68.16	1,757.30	68
J-5	784,477.60	916,550.60	1,757.00	0	6.81	1,763.82	7
J-6	785,381.00	919,181.00	1,658.00	0	107.21	1,765.43	107
J-7	784,692.00	918,152.00	1,707.00	0	52.46	1,759.57	52
J-8	783,361.00	918,705.00	1,676.00	0	80.58	1,756.75	81
J-9	784,602.00	919,205.00	1,691.00	0.8	64.91	1,756.04	65
J-10	784,063.00	919,119.00	1,679.00	1	77.17	1,756.32	77
J-11	784,444.00	916,691.00	1,756.00	0	7.88	1,763.89	8
J-12	785,531.00	919,258.00	1,646.00	0	119.3	1,765.54	119
J-13	784,878.00	918,543.00	1,665.00	0	99.72	1,764.92	100
J-14	784,536.00	919,139.00	1,690.00	0	66.06	1,756.20	66
J-15	784,468.72	917,558.15	1,725.00	0	39.24	1,764.32	39
J-16	786,323.49	919,186.52	1,549.00	18	5.17	1,554.18	5
J-17	784,408.69	918,969.55	1,689.00	0	67.42	1,756.55	67
J-18	784,321.00	918,404.00	1,701.00	0	57.31	1,758.43	57
J-19	784,008.00	918,154.00	1,711.00	0	47.86	1,758.95	48
J-20	785,022.00	918,908.00	1,696.00	0	69.01	1,765.15	69
J-21	784,694.00	917,922.00	1,710.00	0	54.47	1,764.58	54
J-22	784,097.00	918,762.00	1,694.00	0	63.1	1,757.23	63
J-23	784,860.00	918,830.00	1,681.00	0	83.89	1,765.06	84
J-24	784,490.00	918,954.00	1,696.00	0	60.42	1,756.54	60
J-25	783,914.00	918,195.00	1,709.00	0	49.6	1,758.70	50
J-26	784,453.00	919,041.00	1,688.00	0	68.27	1,756.41	68
J-27	784,103.00	918,053.00	1,706.00	0	53.2	1,759.31	53
J-28	784,014.00	917,834.00	1,713.00	0	47.84	1,760.94	48
J-29	784,401.00	917,093.00	1,734.00	0	30.03	1,764.09	30
J-30	784,955.00	918,308.00	1,689.00	0	75.65	1,764.80	76
J-31	784,889.64	918,517.06	1,668.00	0	96.71	1,764.91	97
J-32	784,357.00	918,715.00	1,689.00	0	68.06	1,757.19	68
J-33	784,819.00	918,250.00	1,697.00	0	62.43	1,759.56	62
J-34	784,864.00	918,690.00	1,665.00	0	99.79	1,764.99	100
J-35	784,799.00	918,037.00	1,705.00	0	59.53	1,764.65	60

J-36	785,659.00	919,222.00	1,615.00	0	150.32	1,765.62	150
J-37	785,915.00	919,161.00	1,573.00	2	192.4	1,765.79	192
J-38	784,545.00	918,081.00	1,713.00	0	46.48	1,759.57	46
J-39	784,543.38	917,727.41	1,728.00	0	36.38	1,764.46	36
J-40	784,390.00	916,930.00	1,745.00	0	18.97	1,764.01	19
J-41	784,118.00	917,935.00	1,711.00	0	49.01	1,760.11	49
J-42	784,693.00	918,888.00	1,686.00	0	70.38	1,756.52	70
J-43	784,032.00	917,809.00	1,713.00	0	48.02	1,761.12	48
J-44	785,117.00	918,975.00	1,695.00	0	70.08	1,765.22	70
J-45	784,423.00	917,299.00	1,727.00	0	37.11	1,764.19	37
J-46	783,607.00	918,426.00	1,686.00	0	71.54	1,757.69	72
J-47	784,270.16	917,743.48	1,720.00	0	42.49	1,762.57	42
J-48	784,366.76	918,889.31	1,690.00	0	66.64	1,756.77	67
J-49	784,293.00	918,067.00	1,709.00	0	50.17	1,759.27	50
J-50	784,133.00	917,752.00	1,717.00	0	44.69	1,761.78	45
J-51	784,907.00	918,330.00	1,688.00	0.2	71.41	1,759.56	71
J-52	784,504.37	917,684.03	1,729.00	0	35.36	1,764.43	35
J-53	783,752.00	918,255.00	1,692.00	0	66.12	1,758.26	66
J-54	784,349.00	917,967.00	1,717.00	0	42.49	1,759.58	42
J-55	784,150.00	918,473.00	1,695.00	0	62.84	1,757.97	63
J-56	783,296.00	918,774.00	1,674.00	2	82.34	1,756.51	82
J-57	784,121.00	918,637.00	1,688.00	0	69.41	1,757.55	69
J-58	786,133.50	919,145.85	1,559.00	18	206.54	1,765.95	207
J-59	784,192.00	917,988.00	1,712.00	1.19	47.49	1,759.59	47
J-60	784,448.32	917,723.51	1,729.00	0	35.32	1,764.40	35
J-61	784,417.38	916,685.00	1,756.00	0	7.73	1,763.74	8
J-62	784,358.11	916,928.71	1,745.00	0	18.61	1,763.65	19
J-63	784,372.70	917,097.73	1,734.00	0	29.53	1,763.59	30
J-64	784,397.17	917,301.99	1,727.00	0	36.44	1,763.51	36
J-65	784,442.41	917,559.46	1,725.00	0	38.34	1,763.42	38
J-66	784,817.79	918,845.77	1,682.00	0.18	74.36	1,756.51	74
J-67	784,405.25	917,722.79	1,720.00	2	43.27	1,763.36	43
J-68	784,521.75	917,751.98	1,729.00	0	34.27	1,763.34	34
J-69	784,651.43	917,937.99	1,710.00	0	53.21	1,763.32	53
J-70	784,764.08	918,061.13	1,705.00	0	58.19	1,763.30	58
J-71	784,926.51	918,321.80	1,689.00	0	74.12	1,763.27	74

J-72	784,917.34	918,374.20	1,681.00	0	82.1	1,763.27	82
J-73	784,864.95	918,511.74	1,668.00	0	95.06	1,763.25	95
J-74	784,854.47	918,543.18	1,665.00	0	98.05	1,763.25	98
J-75	784,837.44	918,697.75	1,665.00	0	98.04	1,763.24	98
J-76	784,841.37	918,835.29	1,681.00	0.6	82.06	1,763.22	82

Annex – 3 GPS Collected Data

code	X	Y	Z	Remark
1	786310	919238	1548	intake
2	786273	919256	1546	RWP
3	786266	919197	1549	RWL
4	786193	919150	1554	RW
5	786242	919197	1551	SOURCE
6	786136	919155	1559	PL1
7	785915	919161	1573	PL2
8	785659	919222	1615	PL3
9	785531	919258	1646	PL4
10	785443	919230	1651	PL5
11	785381	919181	1658	PL6
12	785117	918975	1695	PL7
13	785022	918908	1696	PL8
14	784864	918690	1665	ductile 200mm
15	784878	918543	1665	to 4kilo 80mm
16	784890	918522	1668	flashing out
17	784947	918372	1681	to 4kilo
18	784955	918308	1689	PL9
19	784799	918037	1705	PL10

20	784694	917922	1710	PL11
21	784531	917736	1728	PL12
22	784456	917716	1729	t cross 150mm
23	784467	917695	1729	Megenagna square
24	784460	917534	1725	infront of NOC 225
25	784423	917299	1727	PL13
26	784401	917093	1734	PL14
27	784390	916930	1745	PL15
28	784444	916691	1756	PL16
29	784475	916548	1757	PL17
30	784434	916537	1760	Reservoir 1500m^3
31	784860	918830	1681	from indale school to bishanmagaala 80mm
32	784693	918888	1686	DL18
33	784490	918954	1696	from menafesha to Zone admn
34	784410	918963	1689	fom Hall T cross to 4kilo and zone water office 80mm
35	784453	919041	1688	DL19
36	784536	919139	1690	DL20
37	784602	919205	1691	end at zone water office
38	784372	918888	1690	to sena hotel 80mm
39	784357	918715	1689	DL21
40	784321	918404	1701	infront of sena Hotel
41	784150	918473	1695	T cross to 4kilo and Health center
42	784121	918637	1688	DL22
43	784097	918762	1694	DL23
44	784071	919030	1680	DL24
45	784063	919119	1679	End at around health center
46	784266	917732	1720	From Megenagna square to Hospital
47	784133	917752	1717	DL25

48	784032	917809	1713	DL26
49	784014	917834	1713	hospital end to 4kilo
50	784118	917935	1711	DL27
51	784293	918067	1709	DL28
52	784192	917988	1712	4kilo square to bishari
53	784103	918053	1706	bajaj station to bishari
54	784008	918154	1711	DL29
55	783914	918195	1709	DL30
56	783752	918255	1692	DL31
57	783607	918426	1686	DL32
58	783510	918544	1689	DL33
59	783361	918705	1676	Bishari end to TTC
60	783296	918774	1674	DL34
61	784907	918330	1688	from around MekanaYesus church to 4kilo
62	784819	918250	1697	DL35
63	784692	918152	1707	DL36
64	784545	918081	1713	DL37
65	784349	917967	1717	DL38