AFRICA CENTER OF EXCELLENCE FOR WATER MANAGEMENT

ADDIS ABABA UNIVERSITY

SUSTAINABILITY ASSESSMENT OF URBAN WATER DISTRIBUTION SYSTEM: A CASE OF BAHIR DAR CITY, ETHIOPIA.

By: Yirged Antehun Mengstie

A THESIS SUBMITTED TO THE AFRICAN CENTER OF EXCELLENCE FOR WATER MANAGEMENT (ACEWM) IN PARTIAL FULFILLMENT OF REQUIREMENT FOR MASTER'S DEGREE IN WATER MANAGEMENT (WATER SUPPLY AND SANITATION) OF ADDIS ABABA UNIVERSITY

11th October,2021

Addis Ababa,Ethiopia

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Supervisors
Prof.Dr.-Ing-Esayas Alemayehu
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11th October, 2021

DECLARATION

I, Yirged Antehun Mengstie declare that, this submission is my original thesis work and it is not presented previously published by another person nor has been accepted for the award of any other academic degree of the University. Where assistance was sought, it has been accordingly acknowledged.

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Date 11th October,_2021

APPROVAL SHEET

This research report entitled "**Sustainability Assessment Of Urban Water Distribution System: A Case Of Bahir Dar City, Ethiopia.**" by **Yirged Antehun Mengstie** is submitted with my approval to the African Centre of Excellence for Water Management, Addis Ababa University in fulfillment of the requirements for the award of Master's Degree of science in water management(water supply and sanitation)

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ABSTRACT

One of the most fundamental requirements of human life is water. As a result, everybody should have access to adequate and safe water on a continuous basis. For adequate and safe water supply, proper design and execution of the new distribution and the operation of the existing distribution network is needed. The study aimed to assess the sustainability of Bahir Dar City's pressure zone-1 water supply distribution system. For assessing the hydraulic sustainability, an analytical model (WaterGEMS V8i) was used to model the WDN and produce hydraulic parameters (velocity and pressure). Sustainability indicators (reliability, resilience, and vulnerability) were calculated based on these parameters and used to determine the sustainability index. The WaternetGEN tool was used to assess the distribution network's hydraulic performance. A geographic positioning system (GPS) and Arc GIS 10.4.1 was used to check the existing layout and to generate the study area. The results showed that; the distribution system has overall sustainability indexes of 0.71 for the current peak hour demand, with sustainability indexes of 0.97 and 0.43 for pressure and velocity, respectively. Based on the result of this analysis the distribution network sustainability is acceptable for current demand. However, the overall sustainable indexes for forecasted demand has been reduced to 0.32, which is in the medium range but unacceptable. It is found that also Pressure in a WDN had a technical performance index of 86.53 %, while the performance indexes of velocity in the distribution system is 57.86% after optimization of the hydraulic parameters in WDN. Water age was determined at low demand hour. Analysis for water age was based on assumption that the distribution system was loaded with continuous flow. The maximum water age in the distribution system is 19.93 hour which is less than a day and acceptable. In general, the result of this study showed that the current distribution network is sustainable for the current water demand.

Keywords*: sustainability assessment, sustainability & performance indexes; WaterGEMS V8i; Water distribution networks; and WaterNetGen tools.*

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ACRONYMS

ARC	American Research Council
BWSSO	Bahir Dar Water Supply and Sewerage office
AWWA	American Water Work Association
BS	Bentley Systems
CAD	Computer-Aided Design
CSA	Central Statistics Agency
DGWSP	Design guideline for water supply projects
GEM	Geospatial Engineering Model
GIS	Geographical Information System
GPS	Geographic Positioning System
L/c/d	Liter per Capita per Day
Masl	Mean Sea Level
MOWIE	Ministry of Water and Irrigation Electricity
MoWR	Ministry of Water Resource
NRC	National Research Council
OWNP	One wash National Programme
TPI_{press}	Technical performance index for nodal pressure state variable
TPI_{vel}	Technical performance index for pipe flow velocity state variable
UNICEF	United Nations Children's Emergency Fund
Vmax	the maximum allowed pipe flow velocity
WDN	Water distribution network

1 INTRODUCTION

1.1 Background

Water is the precious gift of nature, and its role in human survival and health is well known (NRC, 2007). Therefore, the availability of fresh water is directly linked to the welfare and prosperity of our society (Thogersen, 2014). The adequate provision of urban services, and in particular, water related services like, water supply, sanitation provision and drainage are vital in the quest to eradicate poverty and ultimately provide the environment for sustainable development (Christoffoleti *et al*., 2007). However, fresh water is a limited, sometimes even scarce resource and rapid global changes, such as population growth, economic development, migration and urbanization, are placing new strains on water resources and on the infrastructure that supplies drinking water to citizens, businesses, industries and institutions (World Bank, 2016).The issue of sustainability is critical when resource scarcity and equity matters are raised. The sustainability of water supply projects and the benefits they deliver are some of the overriding concerns of the water sector (Howard and Bartram, 2003).

Ethiopia is working towards achieving sustainable development goal, GTP II, having standard for water supply access for rural a minimum service level of 25 l/c/day within a distance of 1 km from the water delivery point and for urban water supply access: a minimum service level of 100 L/c/day for category-1 towns/cities, 80 l/c/day for category-2 towns/cities, 60 l/c/day for category-3 towns/cities, 50 l/c/day for category-4 towns/cities, up to the premises and 40 l/c/day for category-5 towns/cities within a distance of 250m with piped system (MoWR,2016). However, Inadequacies of water supply along with the deterioration of water quality in a distribution system are the major problems facing city water works all over the world. The problem is especially severe in most developing-country like Ethiopian cities Where increased urbanization, population growth, poor city planning, and shortage of sufficient resources creating combined effect (Chalchisa *et al*., 2018).

All these global pressures can have a significant impact on the performances of existing WDS during their lifespan and can be investigated with a scenario analysis (Zischg *et al*., 2017). There is a need for regular review on water distribution system because of the varying demands with time. Such as; evaluation of hydraulic performance in the distribution system is significant. For example, a computer model can predict pressures and flows within a water system to evaluate a design and compare system performance against design standards (AWWA, 2012). Water1GEMS V8i and WaterNetGen are one of computer modeling software are useful in designing, optimizing and evaluating the water distribution network (Utkarsh *et al*., 2015).How well a water supply and distribution system can satisfy its diverse objectives can be determined by evaluation of its functional performance (Jalal and Bhunya, 2008). Because, designed water distribution systems (WDSs) in urban areas may subject to different internal and external pressures. All these global pressures can have a significant impact on the sustainability of existing WDS during their lifespan and can be investigated with a scenario analysis and they must be continuously updated to ensure a sufficient high level of service at all times.It is because that water is desired to be supplied continuously in the required quantities with adequate pressure and flow from sources to all customers (Zischg *et al*., 2017).However, there may be some disruptions owing to system component failures and demand variations (Jalal and Bhunya, 2008).

The objective of this work is to assess the water distribution system sustainability by considering different hydraulic criteria's and optimize some hydraulic parameters. A methodology was presented to generate and assess water networks. It includes hydraulic assessments (pressure head, velocity, qualitative statements (water age) and performance indexes.

1.2 Statement of the problem

Modern society is highly reliant on critical infrastructures such as communication, power, transportation, and water supply systems (Zischg *et al*., 2017).The United Nations General Assembly also recognized access to safe water and sanitation as a human right in 2010. However, governments around the world, face significant challenges in effectively managing their water resources, and billions of people still lack access to safe drinking water and adequate sanitation (Dugassa Girsha,2016).Increased urbanization, population expansion, inadequate city design, and insufficient resources combine to create a significant challenge in most developing countries, such as Ethiopia (Tessema Mintesnot, 2020).

improved water supply and sanitation coverage in Ethiopia is considerably greater in urban areas and while there has been a generally positive trend in urban WaSH coverage (MOWIE, 2015). However, the National urban water supply access was 84.2% in 2006EFY and 91% in 2007EFY, however, this figure decreased to 52.5% in 2008EFY due to the change in standard from GTP I to GTP II. In Ethiopia, 60%–80% of communicable diseases are attributed to limited access to safe water, inadequate sanitation and hygiene services (OWNP, 2018).The water service level in various parts of Ethiopia is below than the required standards due to its unreliability and non-sustainable nature (Solomon, 2011).While existing water resources are deteriorating in quality as and accessibility, sustainable water resources management activities around the world are escalating in the search for alternative solutions for water stress (Aydin & Schmitt ,2014). Water distribution networks (WDNs) collectively form a key component of the water supply system. The sustainability of such systems is significant factors in ensuring public safety and normal city operations. However, failure is unavoidable during the life time of a WDN, which can reduce the integrity of the supply system and interrupt its continuous operation (Qing Shuang,*et al*. 2017).

According to the report of Amhara National Regional State Water, Irrigation and Energy Development, 2017 for both of the water supply areas of Bahir Dar city (pressure Zone 1 and 2), there are problems such as the amount of water source is not sufficient, working conditions such as chlorine injection is unsafe, unable to grasp the water supply/distribution amount because flow meters are not installed except the water sources and it is suggested that the improvement of water supply facilities is thought to be urgent and critical issue. it is also confirmed that that customer satisfaction level in the city was not equal and continuous water supply, water pressure and scheduling of water service is required (Tessema Mintesnot,2020).For this reason, assessment of the hydraulic sustainability of the water distribution system in the city for the existing and newly developed scenario is vital.

1.3 Significance of the study

Primary, this research finding will be substantial input to Bahir Dar city Water Work sector to reconsider their system and to take any necessary measure on the distribution system. In addition it will also use for governmental and non-governmental organizations as effective method of designing water supply distribution system sustainably. Furthermore, this finding will also be a necessary document for other researchers for further study.

1.4 Research questions

1. What are the level of velocity and pressure in the existing water distribution system?
2. what is water age in the distribution system
3. What is the hydraulic sustainability status of water distribution system at different scenario?
4. What is the performance index for pressure and velocity in the distribution network?

1.5 Objectives

1.5.1 General objective

The principal aim of the study was to assess the sustainability of water distribution system for Bahir Dar city using Bentley WaterGEMS and WaterNetGen software

1.5.2 Specific objectives

The detailed objectives of the study were the following

1. To evaluate the hydraulic parameters (pressure and velocity) in the distribution system;
2. To estimate water age in the distribution system;
3. To evaluate the hydraulic sustainability status of the distribution and optimize the hydraulic parameters
4. To assess the technical performance index of pressure and velocity in the distribution network using the WaterNetGen tool

1.6 Scope of the study

The scope of this study focuses on assessing the sustainability of the water supply distribution system considering the sustainability status index, hydraulic performance index and water age analysis. The hydraulic parameters pressure and velocity were determined. The hydraulic sustainability of the system was checked by determining the sustainability index. On the other hand, the hydraulic performance index was determined by WaterNetGen on the system to assess the hydraulic performance. It was only limited to assess the hydraulic sustainability of water distribution system pressure zone I in Bahir Dar city, Ethiopia.

2 LITERATURE REVIEW

2.1 The concept of sustainability in water supply

The sustainable provision of adequate and safe drinking water is the most important of all public services. Therefore, anything that disturbs the sustainable provision and supply of water tends to disturb the survival of humanity (Muranho *et al*., 2014). The proper functioning of water supply network is directly linked to the well-being of modern societies. However, water supply activities tend to be natural domination, so to guarantee good service levels in a sustainable way the water supply systems performance must be evaluated. Performance assessment is described as "any method that allows for the evaluation of the efficiency or effectiveness of a process or operation through the development of performance measures," The future changes in demographic, climatic and socioeconomic developments are going to be the key drivers for changing the system's structure and operation (Jonatan *et al*., 2017).

2.4 Sustainability index in water distribution system

Sustainability theories first came from the effects of the ecosystem and efforts to protect natural resources and environmental processes from over-extraction, shocks, or stresses. However, the convergence of other economic, social and institutional aspects has also been expanded. The topic of sustainability is given serious consideration in any recent development endeavor. Consequently, various organizations and researchers have been given to sustainable development (WCED, 1987). Sustainable access to water supply is central to social and economic development, improving health and educational achievement, reducing child mortality, and improving livelihoods (Hutton, 2004). In a water distribution system a sustainability index (SI) is a term that describes how well a water system performs in relation to specified levels of satisfaction (Loucks, 1997). In this study WDS sustainability index has been determined using reliability, resiliency, and vulnerability performance indicators.

2.4.1 Reliability

Qing Shuang and his colleagues (2017) stated that WDN reliability is classified into mechanical reliability and hydraulic reliability. Mechanical reliability focuses on the study of network topology and the system's connection due to a malfunction, but lacks the system's capacity to supply water effectively. Hydraulic reliability refers to the capacity of the system to satisfy water flow and pressure requirements, and focuses on failures caused by demand changes, ageing pipes, and inadequate supply of water, both of which cause WDN to fail to meet the water demand.

2.4.2 Resilience

Resilience determines how easily it is possible that a system can recover from failure. If failures are prolonged events and the recovery of the system is slow relative to the natural system's actions, it means that the design of the system's design has a serious flaw and requires careful re-examination. Therefore, a good designer would like to develop a system that can easily recover from a failure and return to a satisfactory state (Jain & Bhunya, 2008).

2.4.3 Vulnerability

Vulnerability is a measure of the probable harm in the event of failure and relates, if one happens, to the probable severity of a failure. The implications of the failure of a low-probability event may often be considerable; prior strategies should therefore be implemented to deal with the potential effects of failures due to such events. The principle of secure failure as opposed to secure failure is relevant here; it is also often referred to as survivability (Jain :&Bhunya, 2008).

Table 2.1: Hydraulic Sustainability range based on sustainability index.

SI range	State
0-0.25	Unacceptable
0.25-0.5	Medium but unacceptable
0.5-0.75	Acceptable
0.75-1	Ideal

(Source: HUNYA, 2010)

2.5 Water supply sustainability in Ethiopia

Under its Universal Access Plan (UAP), Ethiopia has made considerable progress in expanding access to better water supplies. It is verified from other literature that there is a clear upward trend in water supply coverage. Ensuring the investment translates into sustainable services continues to meet the needs of consumers in terms of water quantity, efficiency, accessibility and reliability is a crucial challenge (Roger *et al*., 2013).

2.2 urban Water Demand

Drinking, cooking, ablution, washing clothes and utensils, and cleaning houses are all common uses of water in the home. It is also uses for non-domestic purposes such as public, commercial, industrial and firefighting institutions, and livestock watering. In addition unaccounted for water should be considered while calculating the total water requirement of the system (Geleta, 2010). The average amount of water used per person per day varies from country to country as well as from place to place within a country.

2.3 Domestic water demand by modes of services

Domestic demand includes water furnished to residential houses for sanitary, drinking, washing, bathing and other purposes. It varies according to living conditions of consumers such as habit, social status, climatic conditions and customs of the people (MoWR, 2006).

Table 2.2: Town category based on population.

Population Range	Level of Town	Per Capita Water Demand l/c/day
>1,000,000	1	100
100,000 - 1,000,000	2	80
50,000-100,000	3	60
20,000-50,000	4	50
<20,0000	5	40

(Source: OWNP, 2017 Annual Report)

For a given year, the estimated average per capita domestic water demand is obtained by multiplying the per capita demand for each category for the same year by multiplying the corresponding population figures obtained for the same year, summing the results for all demand categories.

2.4 Factors affecting the rate of Domestic Water demand

Adjustment factors for climate

A change in climate is a factor that affects the water demand of the population under

Table 2.3: Adjustment due to climatic effect.

Group	Mean annual rainfall in mm	Factor
A	600 or less	1.1

B	601-900	1.05
C	901 and more	1.00

With a mean annual precipitation of 1451mm, Bahir Dar city is classified as group C and has a climate adjustment factor of 1.00. (BWSSO, 2009).

Table 2.4: Adjustment factor due to socio-economic conditions.

Category	Description	Factor
A	Cities with good living standards and significant development potential	1.1
B	Cities with very high development potential but low living standards at present	1.05
C	Cities in normal conditions	1.00
D	Rural cities which are advanced	0.95

Source: (BWSSO, 2009).

A given community's socio-economic status often plays an important role in deciding the intake of water. Bahir Dar is regarded at present as a city with a very high growth potential but lower living standard, and is thus graded with a factor of 1.05 with the cites of category B.

2.6 Non-domestic water demand

2.6.1 Industrial water demand

Water used by factories, paper mills, cloth mills, cotton mills, breweries, sugar refineries, and other industries falls under the category of industrial use. The quantity of water demand for industrial purpose is around 20 to 25% of the total demand (DGWSP, 2008).

2.4.1 Commercial and public water demands

Commercial demand includes restaurant water requirements; cinema; houses; railways; bus stations; centers of hope; and local drinks. Where: school water required; hospitals; public offices; military camps; public parks; dispensaries; day care centers and so on are included as institutional / public demand. If it is not possible to make an exhaustive estimate of public and commercial establishments, it is proposed that 20 to 40 percent of domestic water demand should be taken into account, depending on the size of the population (DGWSP, 2008).

2.6.2 Water for Fire fighting

Fire may occur through short-circuiting, fire catching objects, fires, bad intentions of criminals or other unexpected incidents due to defective electrical wires. Water demand for firefighting is normally taken from previous experiences as 10 to 15 percent of the amount of the service reservoir (DGWSP, 2008).

2.6.3 Water Loss or Unaccounted for water (UL)

Not all water, which goes in distribution pipes, reaches the consumer. This is usually taken as 15 to 25% of the total demands which depends on the condition and management of the system (DGWSP, 2008).

2.5 Variation in water demand

In the dry season, water needs are higher than in the rainy season. Water use is often more significant on weekends than on working days. When people come back from work, more water is also needed at rush hours than at regular working hours. Therefore, the average day demand is scaled up by some variables to achieve the full day demand and peak hour demand to accommodate this variety in demand (ADSWE, 2016). Consequently, the following criteria are taken into account: - total average daily water demands, Maximum daily water demands and Peak hourly water demand.

2.6.4 Average daily water demand

The average daily demand is the sum of domestic demands, public demand, industrial and unaccounted for water. The demand for water in a day varies over time due to users lifestyle and other factors.

2.6.5 Maximum daily water demand

The highest demand of any one 24-hour period in any given year is the maximum day demand. It represents the change in demand with the season. Source capacity, riser mains, and service reservoirs are all designed with this demand (MoWR, 2006).

Table 2.5: Maximum Day factor.

Population	Maximum Day factor
0_20000	1.30

20001_50000	1.25
50001 and above	1.20

Source: MoWR,(2006)

2.6.6 peak hour demand

The peak hour factor (PHF) utilized to calculate the peak hour demand shows similar dependencies as the maximum day factor for the maximum day demand.

Table 2.6: Peak Hour factor

Population Range	Peak Hour factor
<20000	2
20001-50000	1.9
50001-100000	1.8
>100000	1.6

(Source: MoWR, 2006)

2.7 Design period

The design period refers to the number of years that the water works' designs have been completed. Mainly water works are designed for design period of 22-30 years, which is fairly good period. Reservoirs, treatment plants, and distribution networks are all part of water supply scheme, which is massive and expensive. These works should be designed and built with enough capacity to satisfy the city's potential demand for many years (Venkateswara, 2005).

2.8 Components of water distribution network

Components of water distribution network Transmission and distribution mains in the water distribution system; piping system is often categorized as transmission/trunk mains and distribution mains (Tomas et al., 2003).

2.8.1 Transmission mains

Rising and gravity transmission mains from source to distribution should be designed for the maximum day demand, based on the design hours of water source operation (MoWIE, 2006).Transmission mains are consisted of components that transport huge amounts of water across long distances, usually between major distribution systems. Transmission mains are primarily used to transfer water from treatment plants to service reservoirs/storage tanks in most water supply systems. It is rare that individuals served from these mains. (NRC, 2006).

2.8.2 Distribution mains

Water is delivered from a transmission main to customers through distribution mains, which are intermediate pipelines. The distribution mains are typically smaller in diameter than transmission mains and following the topography and alignment of city streets. To join pipes, various fittings such as elbows, tees, reducers, crosses, and a variety of other accessories are needed. Other maintenance and operational appurtenances like fire hydrants and valves are also directly connected to the distribution mains. In addition, services lines are installed and transmit water from distribution mains to end users. (NRC,2006).

2.8.3 Reservoir and storage tanks

Reservoirs and storage tanks are used in the water distribution system to accommodate fluctuations in water demand and to maintain pressure within the system. Similarly, it can used to store water in case of an emergency. The common type reservoirs in the water delivery system are round and/or rectangular, and are made of concrete or steel. Furthermore, such facilities should be located mostly in higher places outside of service regions. (MoWIE, 2006).

2.8.4 Pumps

Pumps are used to convey energy to the water in order to boost water at higher elevations. Most pumps used in the water supply systems are centrifugal, and are installed to improve the water distribution, if gravity is insufficient to supply water at an adequate pressure. So that, to control the operational condition of pumps switch boards was provided in the station.(NRC, 2006 & Chambers *et al*., 2004).

2.8.5 Accessory Equipment

Fittings, valves (such as control valves, air release valves, pressure lowering valves, and so on), hydrants, drainage facilities, flow meters etc. are examples of accessory equipment found in water distribution pipelines(Bhadbhade, 2009). All this accessory has been installed at places were necessary for connecting the network, controlling and management of the system, and for maintenance purposes during failure (Bogale, 2016).

2.9 Distribution system performance measure

Performance measures are distribution system characteristics that can be objectively quantified. These characteristics include the distribution system attributes with which water utility personnel are most familiar. Performance can be measure directly and indirectly, an example of direct performance measure is measuring pressure using pressure gauges and software package and indirect performance measure is information obtain from customer and water utility (Arun *et al*., 1995).

2.9.1 Hydraulic parameters

The following design parameters used in the design of the pressure region's boundaries, nodal pressure during peak demand, and optimum transmission and distribution main velocity:

a) Pressure design criteria

The anticipated pressure is the first variable to check when evaluating a system's efficiency. Pressure changes at a single place over the course of 24 hours should likewise be kept to a minimum of 20 or 30 psi. (AWWA, 2012).

Table 2.7: The operating pressures in the distribution network.

Conditions	Normal conditions	Exceptional conditions
Minimum water head (mH_2O)	15	10
Maximum water head (mH_2O)	60	70

(Source: MoWR, 2006)

b) Velocity design criteria

The pipe velocity should be ideally between 0.5 and 2.0 m / s during the design flow, but not less than 0.2 and not higher than 3 m / s. The pipes' self-cleaning ability will be lost with too low flows, and sediments will permanently settle. The flow becomes unstable with too high velocities and can become damaging for pipes filled with air or particles (Dick Bouman, 2014).

Table 2.8: Pipe velocity design criteria given by the different organization.

Distribution type	MoWR (2006)	World Bank (2012)
Maximum velocity in main pipe (m/s)	2	3

Maximum velocity in distribution m/s)	2	1.5
Minimum velocity in distribution m/s)	0.6	0.4

2.9.2 Water age in water distribution

Water age is a major factor in water quality deterioration within the distribution system. The two main mechanisms for water quality deterioration are interactions between the pipe wall and the water, and reactions within the bulk water itself. Increased water age values are connected to water quality problems such as formation of disinfection-by-products, nitrification, microbial re-growth, pathogens intrusion, increased temperature, sediment deposition, etc (AWWA, 2002). Water quality will deteriorate with the increment of retention time in the water distribution system, leading to malfunctions such as disinfection by-product formation, disinfectant decay, corrosion, taste, and odor (Zhou, 2015) The average water age in a network has been measured at 1.3 days, while the maximum is 3.0 days, according to the results of a survey involving over 800 water supply networks in the USA (Patelis,*et al*.,2020).

Table 2.9: Water quality problems associated with water age

Physical issues	Chemical issues	Biological issues
Color Formation	Disinfection by-product formation	Disinfection by-product Biodegradation
Segmentation deposition	Disinfectant decay	Nitrification
Corrosion control effectiveness	Corrosion control effectiveness	Microbial growth
Temperature increase		Taste and odor

(Source: AWWA, 2002).

2.10 Water Distribution Modelling

The number of equations that must be set up and solved in a system hydraulics problem is enormous, even for the simplest basic water distribution system. The value of a computer model is that tiresome calculations are accomplished considerably more quickly and more correctly than manual computations. In addition, the computer is an effective technique of managing vast volumes of data necessary to study a water distribution system (AWWA, 2012).

Optimizing pressure in water distribution

Optimization is used in a wide range of systems and circumstances, making it a significant technological paradigm. We either minimize (resource consumption, cost) or maximize (resource consumption, cost) when we seek to optimize (profit, system performance). In reality, money, time, and resources are all limited, so operation optimization is critical (Awe *et al*., 2019). Due to high operational pressure, water distribution networks experience high amounts of water losses due to leaks and breakage. Pressure management is one of the most well-known ways for reducing water losses (Kourbasis et al., 2020).

2.10.1 WaterGEMS v8i Bentley

WaterGEMS V8i is user-friendly software that can be used as a water delivery network decision support tool. This software tool is helpful in understanding infrastructure activity as a scheme and its responses to organizational strategies. As population and demand increase, a water supply scheme should evolve, and this program simulates the same. WaterGEMS V8i is hydraulic simulation software with advanced interoperability, geospatial model creation, and optimization and asset management tools for water delivery systems. (Udhane *et al*.,2018).

2.10.2 WaterNetGen

WaterNetGen is an EPANET extension for automatically build water distribution network (WDN) synthetic models, do pipe sizing, compute technical performance indicators, and allowed demand-driven and pressure-driven simulations (WNGUM, 2011). It also enables for the examination of critical scenarios such as firefighting and pipe bursts, as well as the evaluation of technical performance. WaterNetGen solves a least-cost design model for pipe design using the Simulated Annealing technique. As the pressure-driven hydraulic model included in WaterNetGen allows assessing background and bursts leakages, it was now adapted to also solve an optimal operation model (Soua *et al*., 2014).

2.10.3 Comparison of modelling software

The basic approach of hydraulic analysis methods, which were manual; such as Hardy Cross, which is full of iteration, susceptible to mistake, and time consuming; were used to be applicable for modeling, design, and installation of water supply and other distribution networks (Mengistu, 2016). EPANET can simulate certain fundamental elements, but for a real system with a variety of parts, it lacks capabilities such as valve and hydrant isolation. Furthermore, it is not possible to convert data into pipes and nodes, nor is it possible to bring tabular data, such as in Excel format. WaterGEMS V8i, unlike the others, contains a variety of extra capabilities while preserving its ease of data conversion and a constant connection between the source and the model. It is also possible to export data back to the source in various formats, to integrate directly with CAD or GIS, and to run models inside the AutoCAD or ArcGIS (Mengistu, 2016).

2.11 Water Modelling Analysis

Further refining of the model can be done once the basic components and network configuration have been specified, depending on the model's intended use. A model can carry out several different types of simulations. The two most basic types of simulation are steady-state and extended-period simulation (Thomas, *et al*., 2003).

2.11.1 Steady-State simulation

A steady-state analysis captures the state of a pipe system at any given time. Maximum day, peak hour, and fire flow conditions are typically assessed using steady-state analyses (AWWA, 2012).

2.11.2 Extended-Period Simulation

A sequence of steady-state simulations at predefined intervals carried over a set of time period is known as an extended-period simulation. This functionality might be used, for example, to simulate the operation of a water system over the course of 24 hours, with an hourly analysis run. Modeling demand changes, reservoir operations, water quality, and water transfers through transmission pipelines can be done by such a simulation (AWWA, 2012).

2.12 Hydraulic Model Calibration

The practice of comparing model findings to field data is known as model calibration and making model adjustments as needed to match the field outcomes as nearly as feasible. Device connection alterations, operating controls, building configurations, daytime patterns, elevations, etc. Water levels in storage tanks, pump run times, static and residual fire flow test pressures, and pipeline roughness coefficients are all utilized to determine whether the model accurately simulates field conditions (Zimoch and Bartkiewicz, 2018).

3 MATERIALS AND METHODS

3.1 Description of the study area

Bahir Dar is a city in Ethiopia's northwestern region. It's at 11o 38' north latitude and 37o 15' east longitude. In relative terms, Bahir Dar city is located distance of 567 km along with Addis Ababa to Debre Markos road and 465 km along Addis to Motta road. (Haimanot Mebratu, 2009).

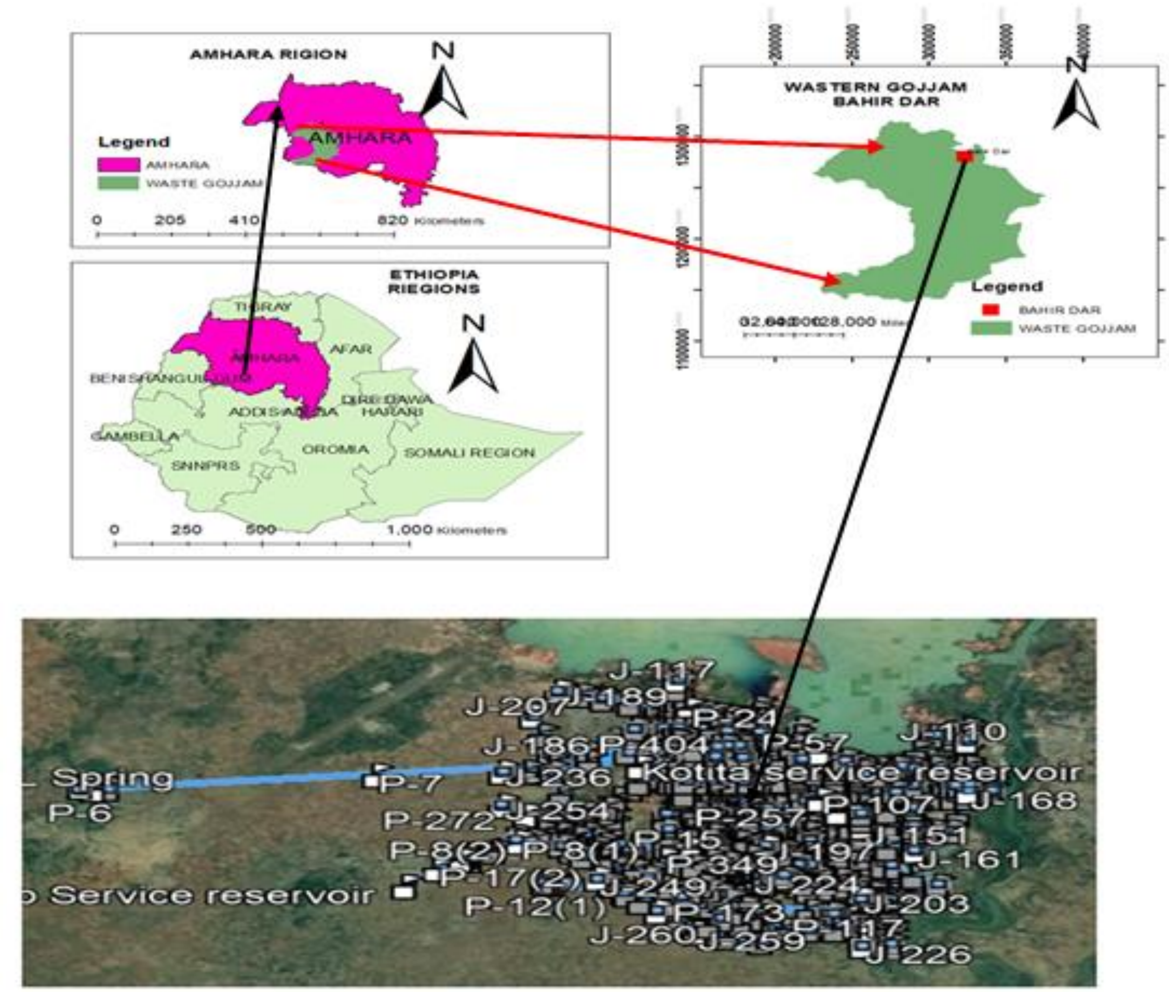

Figure 3.1: Map of the study area.

(Source: Arc map 10.4)

3.2 Data collection process

In order to attempt the research, two major data gathering techniques were used: primary and secondary data collection methods.

3.2.1 Primary data collection

Actual field measurements and observations of city water supply at the locations were used to gather the necessary data in order to determine the current state of the water supply. Geographic positioning systems (GPS) and pressure gauges were used to collect data from the field.

3.2.2 Secondary data collection

Secondary data were collected from books, journals, legal organizations, agencies, other similar previous studies, and from reviewing the documents of Bahir Dar city water supply and sewerage enterprises

3.3 Study design

This research used the Bahir Dar water supply distribution network as a case study. The flow design chart for analyzing the data was as follows: both primary and secondary data were collected, and the flow design chart for analyzing the data was as follows.

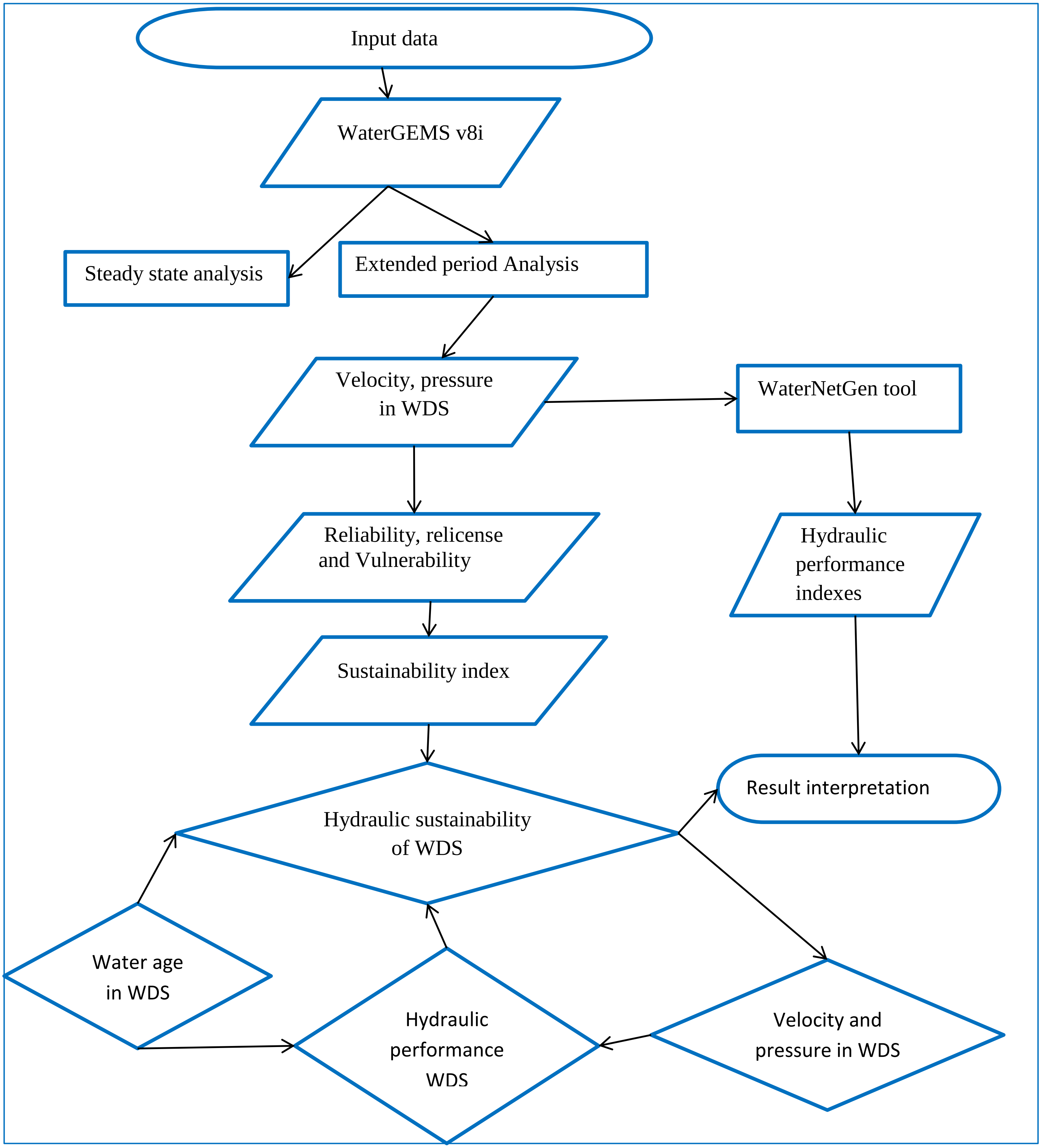

Figure 3.2: Flow of study design.

3.1 Materials

3.1.1 Equipment

The GPS was used to collect the appropriate elevation, northing and easting data and a Pressure gauge was used to measure the actual pressure for the calibration purpose.

3.2 Hydraulic model: WaterGEMS V8i , WaterNetGen

WaterGEMS V8i software was used to simulate the network and see the distribution velocity and pressure. For the mapping of the study area, ArcGIS was used and WaterNetGen was also used to evaluate the water distribution system performance technically.

3.3 Data entering technique

In this study the elevation of each junction, source, pump, and reservoirs; the demand, pipe size and length as well as the materials were arranged using Microsoft excel. After having this using model builder which is tool of WaterGEMS V8i the data were imported to the software.

3.4 Data analysis

The hydraulic modeling of the WDN using mathematical models is the first step of the methodology used in this study. WaterGEMS V8i and WaterNetGen was the software tools employed in this research. The WDN model was created by taking into account all of the data for the tanks, pipes, and equipment, as well as topographical information. Data on water demand and losses are also included in the model. Water demand patterns (both residential and commercial) were considered for a 24-hour (daily) period using a hydraulic time step of 1 hour. The hydraulic and water age analyses were carried out for seven days in a row throughout the network's operation. Nodal pressure and velocity used for determining, reliability, durability and vulnerability values using the numerical formula.

3.4.1 Population forecasting

Geometric population forecasting methods are preferred for fast-growing cities where relatively robust economic activity is seen and city expansion is encountered at the same time for various causes.

Mathematically it is expressed as follows:-

$P_n = Po*(1+r)^n$ …………………………………………………………………….Eq.(3.1)

Where, Pn= population at year n,Po= Base population r = Population growth rate and is number of years

The amount of water consumed for household purposes can be calculated by converting annual consumption statistics to average daily per capita consumption based on the population.

$$\text{Per capita consumption (L/p/d)} = \frac{\text{Annual consuption}(m^3)\times 1000\ L/m^3}{\text{Population Number}\times 365}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq.(3.2)$$

3.4.2 Base demand calculation on node

Demand for each node was calculated and analyzed based on the number of inhabitants for each consumption node, and the period of supplying water to calculate the peak factor of demand for each node. Method for determining and assigning the expected to the model demand nodes depend on available data. Referring to Bhadbhade N.M. (2009), the following formula was adopted to calculate the nodal water demand of the area.

Base water demand for a supply node

$$= \frac{Population\ served\ by\ that\ node}{Total\ population\ of\ the\ town} * \text{ peak hour consumption of the city}\ldots\ldots\ldots\ldots Eq.(3.3)$$

3.4.3 Sustainability Index Calculation

The satisfactory and unsatisfactory states for both parametres (velocity and nodal pressures) counted as 1 for satisfactory and 0 for unsatisfactory.

P j; t=unsatisfactory P j; t <Pmin or P j; t >Pmax

Satisfactory P j; t ≥Pmin or P j; t ≤ Pmax

Where, Pj, t is the pressure at node j in at time t; Pmin is the minimum pressure; and Pmax is the maximum pressure.

V p; t=unsatisfactory (V p; t <Vmin or V p; t >Vmax)

Satisfactory (V p; t ≥Vmin or V P; t ≤ Vmax.)

Where, V p, t is the velocity at pipe p in at time t; Vmin is the minimum velocity; and Vmax is the maximum velocity ((Hashimoto *et al*., 1982)). Refering Hashimoto *et al.*,1982 the following equations were adopted for performance indicators;

a) Vulnerability

The cumulative extent of unsatisfactory values could be divided by the sum of all values throughout the simulation time to determine vulnerability. It can be expressed mathematically.

Vulnerability ($VUL_{k)}$ $= \frac{\sum \text{unsatisfactory values}}{\sum \text{all values}}$…………………………………….*Eq.(*3.4)

Where k refers to pressure or velocity

b) Reliability

The likelihood that the WDS is in a satisfactory state can be determined as reliability (REL).

$REL_k = \frac{\#\text{times satisfactory occurs}}{\text{total \# of time steps}}$……………………….……….. …………..*Eq.(*3.5)

In this case, k stands either pressure or velocity.

c) Resiliency

The term resiliency (RES) refers to how quickly a system rebounds from a breakdown.

$RESk = \frac{\text{times of satisfactory follows unsatisfactory}}{\text{total of times unsatisfactory occurs}}$ …………………… ………..*Eq*.(3.6)

Where k refers to pressure or velocity

Overall, Sustainability index then was calculated by the following formulae.

$$SI = [REL*RES*(1-VUL)]^{1/3}$$ ………………………………………… *Eq*.(3.7)

Where, REL= Reliability, RES= Resiliency, VUL=Vulnerability

The SI key feature is that it has a scale that goes from 0 to 1.

3.13 Technical performance analysis

The evaluation of TPIs was done by WaterNetGen software. The network was imported to this software from WaterGEMS V8i and simulated to check the performance. By selecting the constraint (velocity and pressure), the model was simulated and collected the performance value of pressure and velocity from each node and links. So that, according to Muranho *et al*., (2014) the global performance index for pressure and velocity computed by using the following formulae:

$$TPI_{press} = \sum_{i=1}^{NN} w_i p_i$$ ……………………...*Eq3.8*

$$w_i = \frac{Q_i}{\sum_j^{NN} Q_j}$$ ……………………………………………………................*Eq3.* 9

$$TPI_{vel} = \sum_{k=1}^{NP} w_k p_k$$ ……………………………………………………….......*Eq 3.10*

$$w_k = \frac{L_k D^2{}_k}{\sum_j^{NP} L_j D^2{}_j} \quad \text{......} \quad \textit{Eq3.11}$$

NN: is the number of node in the network; pi: is the performance value; wi: is the weight; Qi: is the water demand of node i; Qj: water demand at all node; NP: is the number of pipes in the network; pk: is the performance value; wk: is the weight; Lk and Dk are the length and diameter of pipe k; TPIpress: technical performance index for nodal pressure state variable and; TPIvel: technical performance index for pipe flow velocity state variable.

3.14 Model Calibration

Model calibration entails comparing model simulation results to actual field data and making model corrections and modifications to obtain close agreement between model predicted values and field measurements or manual computation. Pressures were used as typical comparison values in this investigation.

4 RESUALT AND DISCUTION

4.1 The existing water supply system

The Water supply in the city is from two types of sources: springs and deep ground water. The distribution system is divided in to two pressure zones. The Abay River is the dividing boundary of the pressure zones. Portion of the city located on the way to Addis Ababa from the Abay River is pressure zone-I and the portion of the city on the way to Gondar from Abay river (Abay Mado) is pressure zone-II. The study focus on Pressure zone-l which obtains largest water supply sources from Areki springs with 18144 m3/day safe yield capacity. Water from the three springs is pumped to kotita with a capacity of 3000 m^3 by the raising main of 400mm and the water from the wells are pumped to kotetina reservoir. The Areki spring source has highest contribution to city (Figure 4.1).The current average domestic water demand of the study area is 18126.48 m^3 /day. However, this demand will raised up to 367950.2 m^3 /day in 2030.

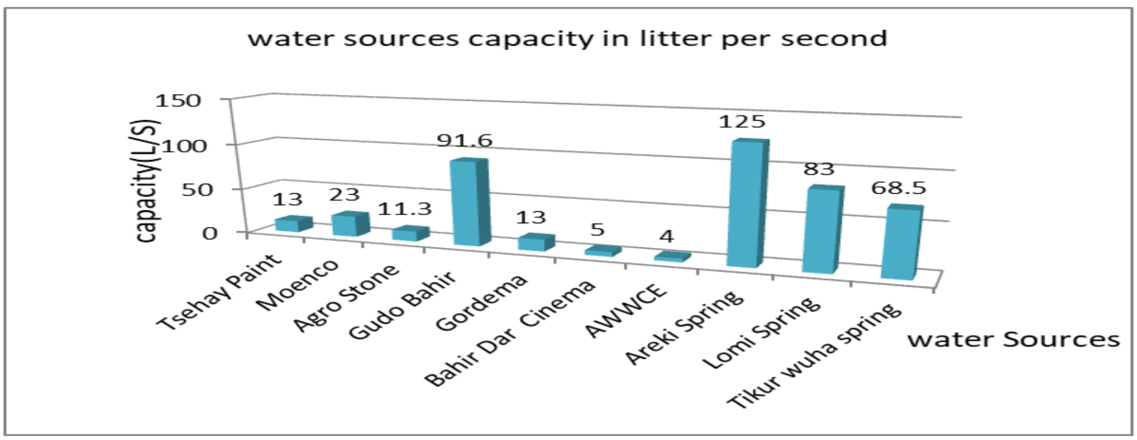

Figure 4.1: Water sources capacity in litter per second.
(Source: BWSSO, 2020)

4.3 Simulation results

Two types of simulations, steady-state and extended time simulation, can be carried out by Water GEMS V8i. The model of existing systems was evaluated by running the model with various scenarios at the current year and forecasted daily average at peak and temporal variation of demand. The simulated water distribution network was exported to WaterNetGen for technical hydraulic performance evaluation. The results are discussed as follows.

4.3.1 Demand pattern

With a given time increase of an hour and at 6:00 AM (Morning) starting model run time, the system condition was calculated over 24 hours. The model was simulated for every hour set up in the twenty-four hour cycle. The demand for water during the day is not constant and varies greatly throughout the day. The demand is usually low at late night and high during the morning (Figure 4.2).The distribution system must be designed to handle peak demand, which is taken into account by using the peak hour factor.

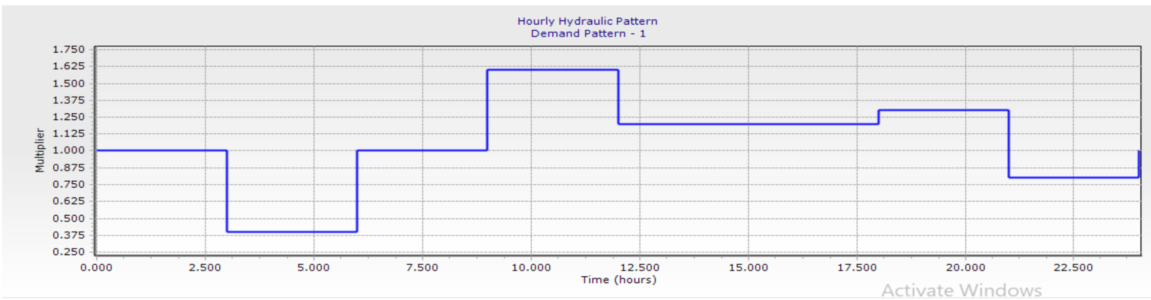

Figure 4.2: Hourly hydraulic pattern.

4.3.2 Pressure and velocity of distribution network of Bahir dar city

The Ethiopian guideline criteria for the minimum and maximum operating pressure value in the distribution network are 15 and 70 m respectively (MOWR, 2006). In this study For the existing water demand from the total junctions 97.7% nodes has pressure of water supply distribution system was within design guideline .This indicates, the pressure full fill the criteria of Ethiopian urban water supply design guideline criteria maximum and minimum requirements. The simulation result of pressure for the existing and future demand have showed with different color coding on figure 4.3 below

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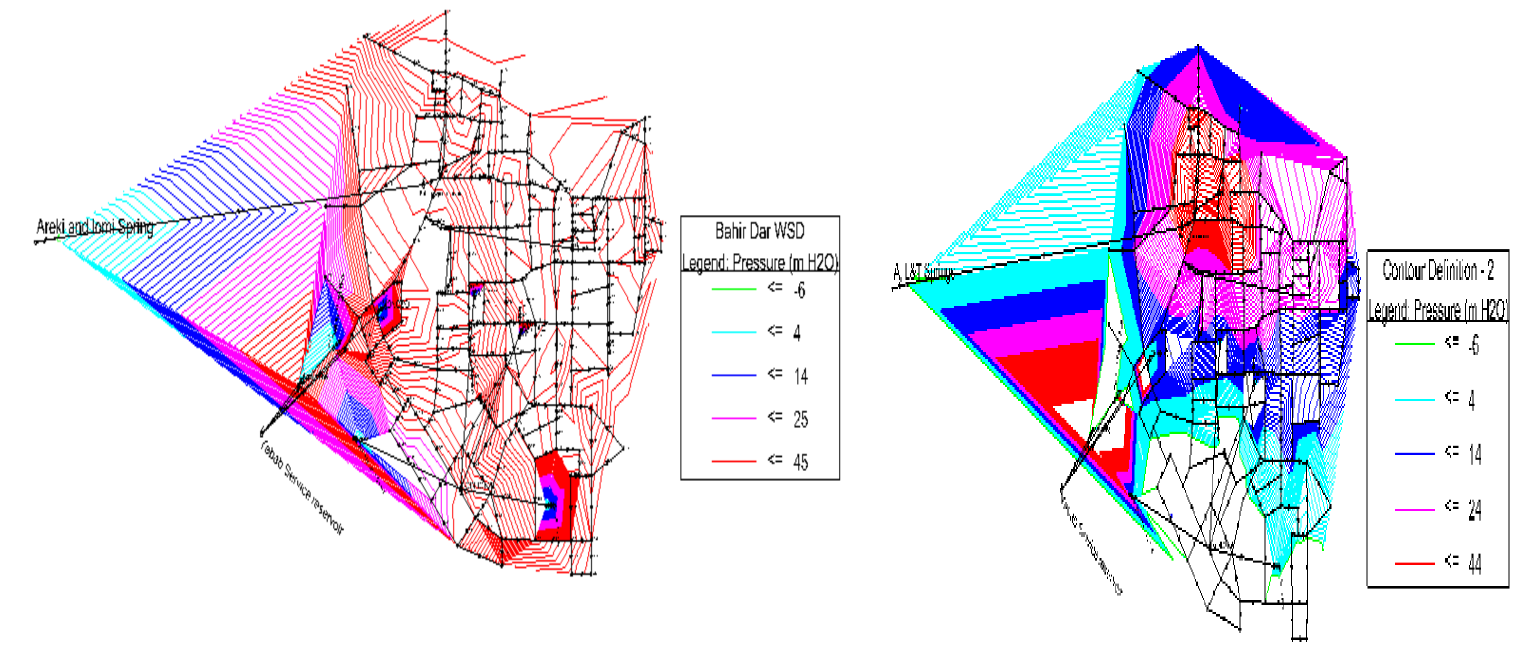


a) Pressure distribution at 2020 b) pressure distribution for 2030

Figure 4.3: simulated pressure in the existing and forecasted demand at WDS

After the model was built from the existing data input, the project inventory dialog box program reported a total of 177 nodes. The result shows that, out of the recommended good strain, 97.70% of the junctions meet the allowable pressure limit. Only 2.25% is out of the recommended range. On the other hand, in comparison to the pressure simulation result of existing demand, the pressure for the second scenario node with pressure outside the recommended range increased to 59.32 %, .(fig.4.3b).

b) Velocity

Controlling flow velocities in water distribution networks is necessary to avoid structural difficulties or undesired hydraulic regimes produced by excessive velocities, or to reduce the negative effects of excessively low velocity on delivered water quality (Tamminen R., 2008). The investigation results show that the majority of distribution networks have a velocity of less than 0.5 m/s. The green coding in the picture represent velocity values below the permitted limit (i.e. 0.6 m / s). (See Figure 4.4) .

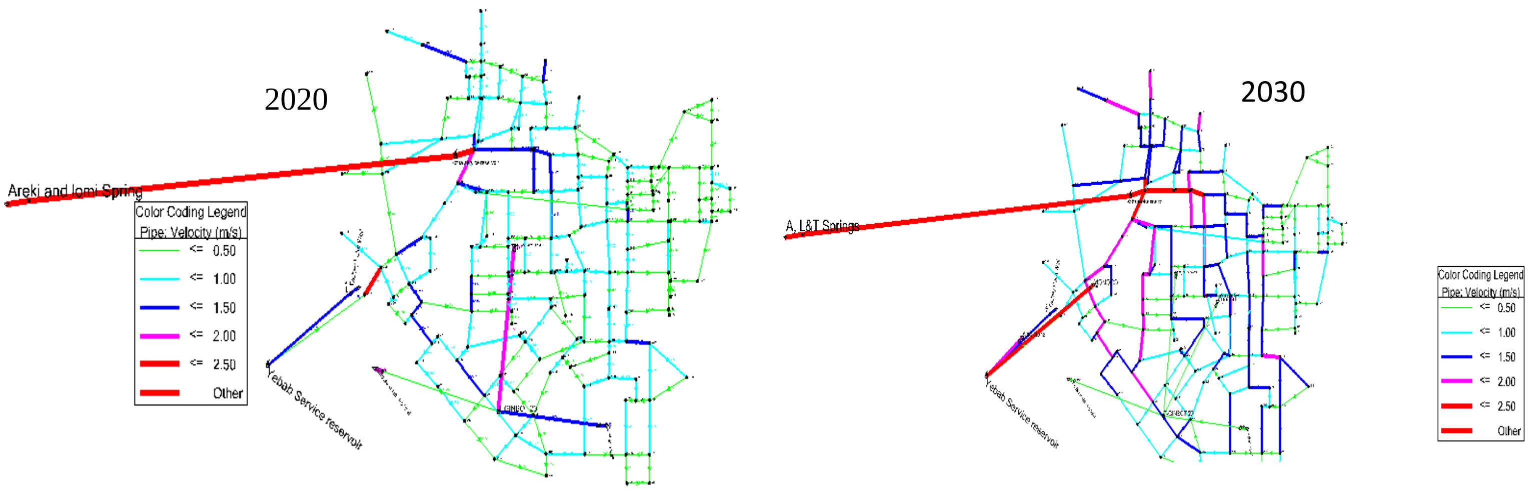


Figure 4.4: Velocity variation at 2020 and 2030 in the WDN at maximum demand.

Solids settled at velocity less than 0.6 m/s, affecting water quality. However, a velocity of more than 2 m/s may erode the pipe (Besner, 2005). Based on the result of the analysis of the study 59.7% of the velocity for the existing WDS (Figure on the left above) is in the acceptable level. On the other hand, for the second scenario (projected demand) velocity within acceptable ranges has increased from to 66.20 .on the other hand, 3.79 percent of pipes exceeded the maximum permissible velocity, while 45.31 % of pipes were below the MoWR's 2006 acceptable limit. Table 4.1 shows a summary of the velocity simulation result.

Table 4.1: Velocity for water supply distribution network

Velocity range (m/s)	2020		2030		Effect
	Count	Percentage	Count	Percentage	
<0.6	40	13.79	87	45.31	Siltation
0.6-2	174	59.7	192	66.20	Normal
>2	76	26.20	11	3.79	head loss

4.3.3 Water age at low demand flow

The cumulative residence time of water in the system, or water age has come to be regarded as a reliable replacement for water quality, but seems to be of little value as an indicator for specific microbial water quality. Water age was determined at low demand hour. Analysis for water age was based on assumption that the distribution system was loaded with continuous flow. Thus, any findings for this parameter were limited to this assumption. Water quality simulation requires a series of runs to understand the movement of water and water quality transformation in the system. A variation of water quality in distribution system from hour to hour of a particular day. As shown in figure 4.5 below, the maximum water age in the distribution system is 19.93 hour which is less than one day and acceptable. According to (WHO, 2014), the water age in the distribution system should be minimum.

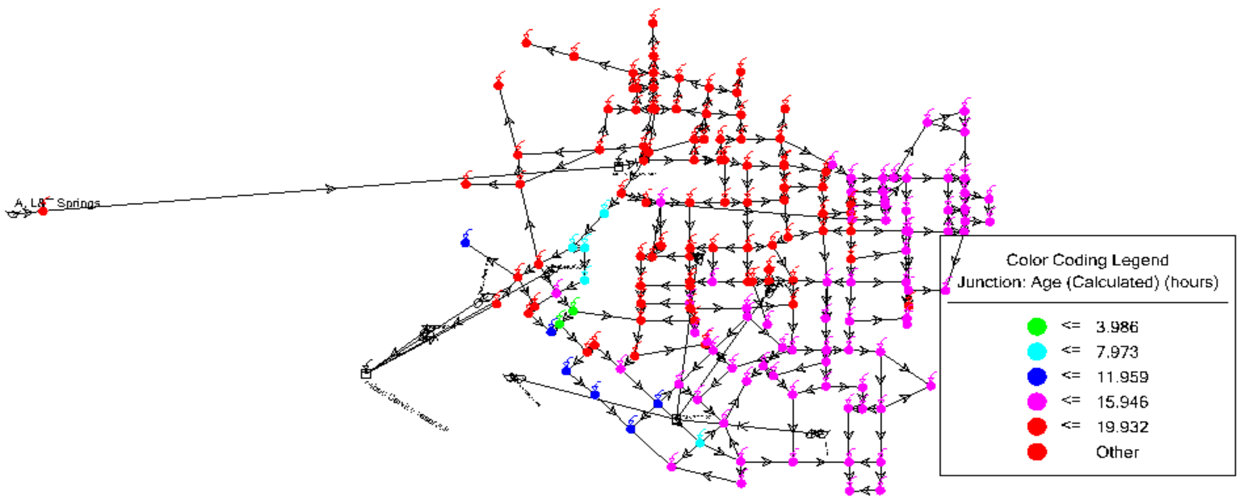


Figure 4.5: water age in water distribution network (WDN)

The red and purple colored nodes in the WDN above received less than 19.93 and 15.95 hours, respectively, accounting for about half of the distribution network. The age of the water in the distribution system was inversely proportional to pressure and velocity. Water age decreased as velocity rose, whereas water age became more as velocity decreased at low demand. Water age is also inversely related to calculation time (the graph below shows the relationship between the two).

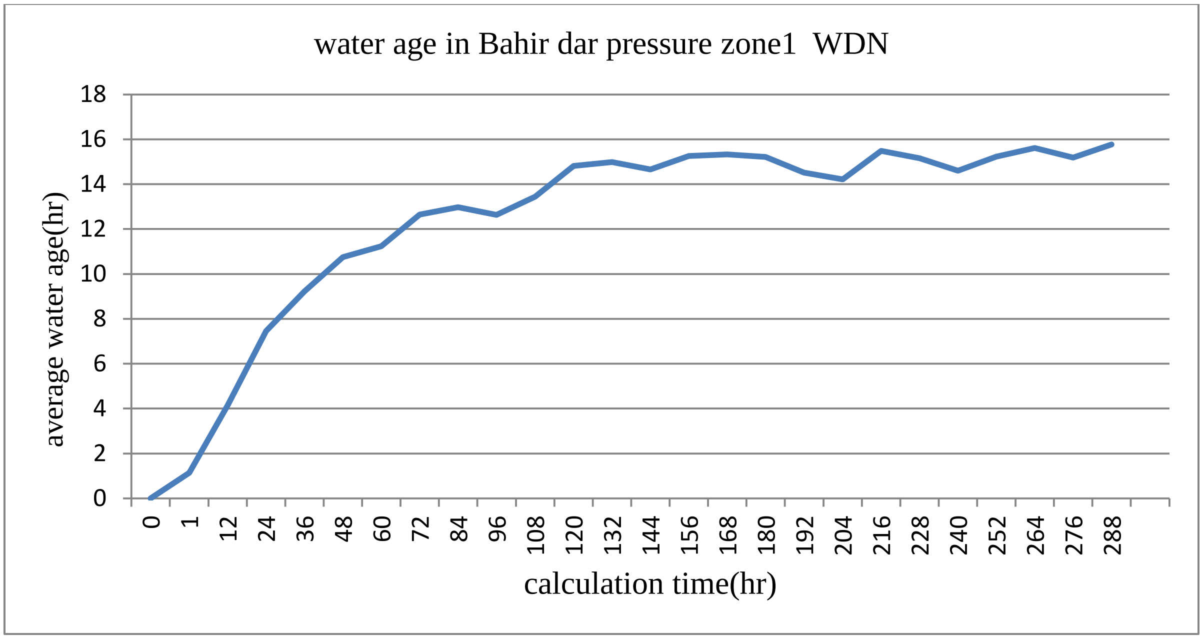


Figure 4.6: average water age (hr) per hour for Bahir Dar Pressure zone- 1WDN

the figure above showed that the average water age versus the time.it is found that the average water age in Bahir Dar pressure zone-1 water distribution system is less than 16 hour which is even less than a day which is acceptable ..

4.3.4 The hydraulic Sustainability indexes at 2020

The reliability, vulnerability, and resilience values were used to determine each index for pressure and velocity. The result of the analysis shows that the WDN is more vulnerable in terms of velocity than pressure (Table 4.2).

Table 4.2: Sustainability indicators for Bahir Dar water distribution network.

	Pressure	Velocity	Average	SI due to pressure	SI due to velocity	Overall SI
Reliability	0.977	0.600	1.577	0.97	0.43	0.71
Resiliency	1	0.345	1.345			
Vulnerability	0.019	0.612	0.632			

Damte Tegegne (2016) rated sustainability indexes as unacceptable, medium but unacceptable, and acceptable. The overall sustainability index in this study was 0.71, with velocity and pressure values of 0.43 and 0.97, respectively. Although the velocity sustainability indicator was at an unsatisfactory level, most junctions were within normal pressure ranges. Based on the categories, the current Bahir Dar water supply distribution system is sustainable for present demand.

4.3.5 The Hydraulic Sustainability index at 2030

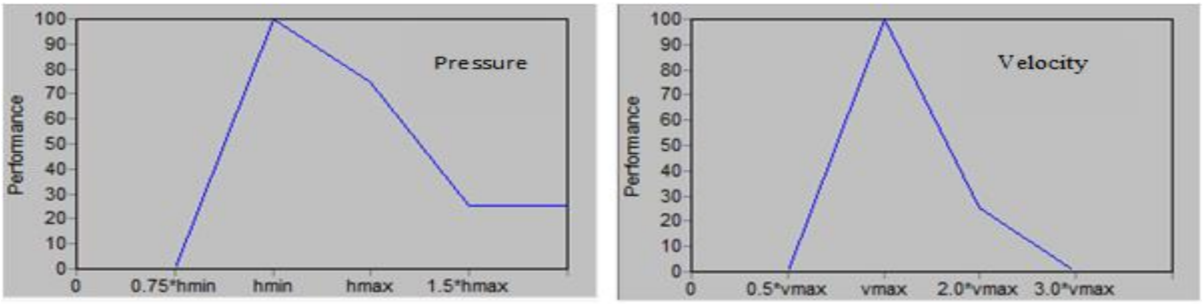
For the water distribution Hydraulic sustainability of newly determined population and the respective water demand. The overall sustainable indexes for forecasted demand has been reduced to 0.32 (table 4.3 below), which is in the medium range but unacceptable. However, unlike to pressure the sustainability index of the velocity for the projected demand is increased to 0.475 compared to the status of sustainability indexes of velocity for existing demand. The same method has been followed and the summary is tabulated in the table below.

Table 4.3: Summary of sustainability index at 2030.

Indictors	Due to pressure	Due to velocity	average	SI due to pressure	SI due to velocity	Overall SI
Reliability	0.400	0.181	0.581	0.166	0.475	0.320
Resiliency	0.526	0.138	0.664			
Vulnerability	0.490	1.18	1.672			

4.3.6 Technical hydraulic performance evaluation of the distribution network

The performance curves gave values ranging from 0% to 100% for no services and Optimum service. This means that there was no service level at 75 % of minimum pressure and 50 % of maximum velocity in the distribution system, but the optimal service level occurred when the distribution system's pressure and velocity met the minimum and maximum design standards, respectively. The curves (figure 4.8) were created in WaterNetGen windows using a software-adjusted equation.



: nodal pressure and pipe flow velocity performance curves.

i) The technical performance of pressure

Different colors highlighted the nodes and in the existing distribution system, most of the nodes have red indicator (figure 4.3).However, it is impossible to conclude that the nodes with red color had good or bad performance and seeing the performance indexes is important. As seen in Figure 4.7, there are some areas which had low performance in maintaining minimum pressure at peak hour period..

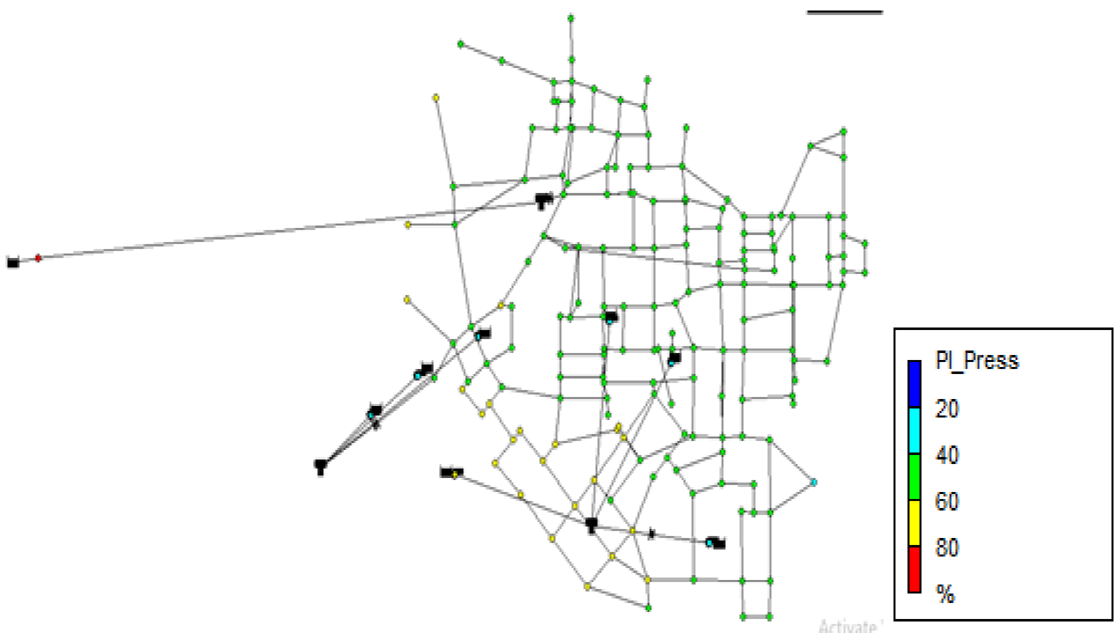


Figure 4.7: Nodal pressure performance at peak hour demand.

The global performance index of the networks was computed using Equations (3.7) and (3.9). The global performance index of pressure and velocity at peak consumption was 85.53% and 57.86% respectively, this indicated that even though the distribution network is sustainable at the existing demand but it is not guarantee for the performance of the distribution system. WaterNetGen tool can solve the performance problem by using slack variable concept of each element (Wendesen Mekonnen & Addisu Befekadu, 2020).Based on Figure 4.8; the finding showed that, the high slack pressure occurred for some of the distribution networks (Atse Minilik Sub-city) these areas can be used as the most preferable point for future network expansion.

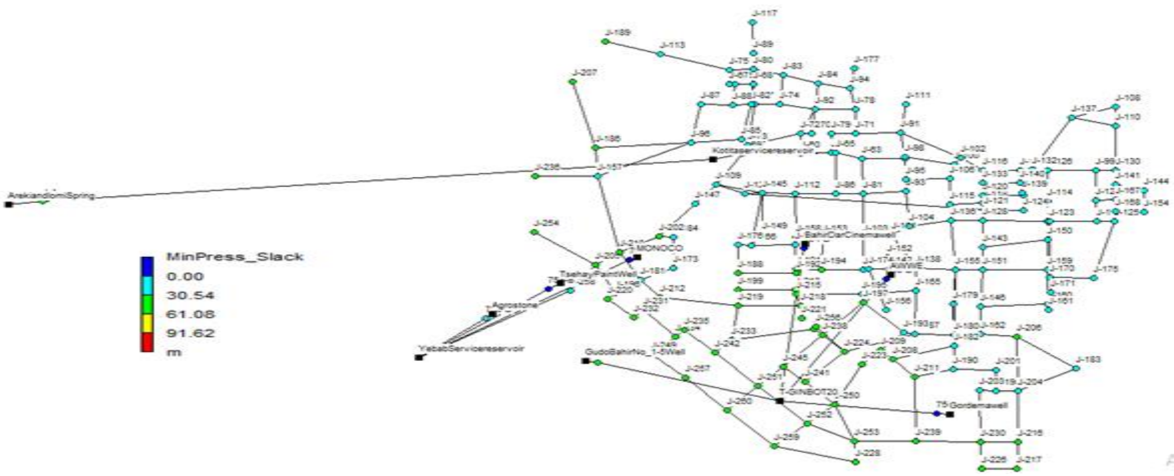


Figure 4.8: Minimum pressure network slack.

4.7 Pressure calibration

The computed and simulated pressure used for calibration at peak hour demand. However, as it is shown in the figure below the result shows that the actual measured pressure values on the tap is much less than the simulated value because one node consist more than one taps. Appendix F contains time series representations of the calibrated pressure and head difference in relation to these.

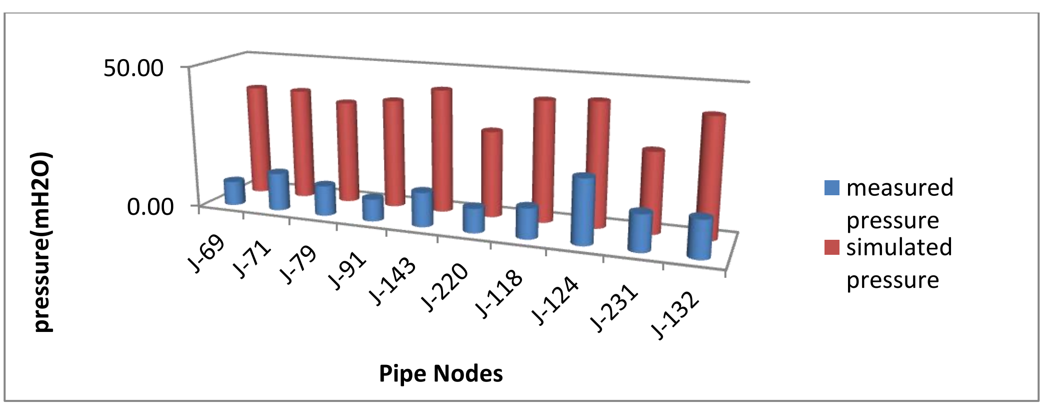


Figure 4.9: Simulated model pressure and the Field measured pressure

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In conclusion, based on the demand analysis result, Bahir Dar City water supply source can meet the current demand but additional water source will be required for the future demand .The model showed that for the existing peak demand 97.70% of the nodes in the distribution system meet the design requirements of pressure during peak hour demand, while only about 2.25 % do not. The velocity was also evaluated at peak hour demand to give sufficient water during high consumption and 59.7 % of pipes have velocity within the standard and this valve increased to 66.20% for the second scenario.

The sustainability indexes for pressure and velocity were found to be 0.986 and 0.431, respectively, for the existing peak hour demand, with an overall sustainability index of 0.71 for the distribution system. Based on the sustainability index result of the analysis the distribution network is acceptable and sustainable for current demand. The overall sustainable indexes for forecasted demand, on the other hand, has been reduced to 0.32, which is within the medium range but unacceptable.

Accordingly, the global performance value of pressure and velocity was 85.53% and 57.86%, respectively. The minimum slack value of pressure and velocity for each area was assessed. Atse minilik sub-city has high slack pressure but the distribution systems slack velocity is almost null. The cumulative residence time of water in the system, or water age has come to be regarded as a reliable replacement for water quality, but seems to be of little value as an indicator for specific microbial water quality. The maximum water age in the distribution system is 19.93 hour which is less than one day and acceptable In general, based on this study the current water distribution network of Bahir Dar city is sustainable.

5.2 Recommendations

To improve Bahir Dar City water distribution system, both design and operational modifications are necessary in the future. Based on the finding the following sets of recommendations are drawn as follows:

i. while designing the water distribution system the authority (the responsible person for designing) should consider pressure gauges at the required area throughout the distribution which is very important to monitor the system

ii. To fill data gap and available for the intended purpose BWSSE should Document Data with a simple and reliable manner as a means of producing a well-organized management and a key for completing several tasks at once; otherwise, it hinders a wide range of operations in terms of time, cost, and quality. As a result, every piece of evidence must be recorded and documented in order to establish different target plans and compare performance.

iii. As the population of Bahir Dar City is highly increasing due to the vast expansion of the City, the water demand was linearly increased. Therefore, the production of water may insufficient for the future population. Therefore, increase the potential of supply should be considered.

iv. The modeling results showed that, the current hydraulic performance of the Bahir Dar City water supply system is poor particularly, for the velocity. So, the water distribution system should be improved or upgraded by resizing the pipe, increasing the source and dividing the area into different pressure zone.

v. The findings also revealed that slack pressure existed in a few parts of the distribution systems of sub-city; this indicated that extension is conceivable in that area to utilize the constraint variable.

vi. In this study, the factors considered are pressure , velocity and water age were used to determine hydraulic sustainability and efficiency. As a result, researchers will broaden their research to include more hydraulic characteristics and situations.

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APPENDIXES

Appendix A; Bahir Dar existing water supply distribution network junction result

FlexTable: Pipe Table					
Current Time: 8.00 hours					
Label	Elevation (m)	X	Y	Pressure	Age (Calculated) (hours)
J-100	1792.13	(m)	(m)	(m H2O)	14.427
J-101	1789.52	323,914.00	1,282,341.00	41	14.105
J-102	1792.3	323,178.00	1,281,252.00	42	15.662
J-103	1791.11	324,001.00	1,282,444.00	41	13.978
J-104	1789.52	322,839.00	1,281,209.00	43	14.138
J-106	1791.88	323,389.00	1,281,371.00	42	14.145
J-108	1790.03	323,869.00	1,282,112.00	41	18.097
J-109	1799	325,819.00	1,283,237.00	41	12.902
J-110	1789.46	321,103.00	1,282,019.00	36	18.086
J-111	1790.92	325,821.00	1,282,927.00	32	14.342
J-112	1795	323,353.00	1,283,273.00	42	13.247
J-113	1790	322,043.00	1,281,888.00	39	13.915
J-114	1790.72	320,448.00	1,284,051.00	40	16.939
J-115	1791.81	325,020.00	1,281,762.00	41	14.337
J-116	1793.01	323,870.00	1,281,719.07	41	15.963
J-117	1791.06	324,260.00	1,282,251.00	40	13.782
J-118	1791.37	321,536.00	1,284,544.00	35	14.583
J-119	1788.86	324,258.00	1,281,735.00	41	16.284
J-120	1791.54	325,598.00	1,281,456.00	43	14.727
J-121	1791	324,260.00	1,281,853.00	41	15.441
J-122	1789.24	324,269.00	1,281,633.00	40	15.612
J-123	1789.24	325,018.00	1,281,460.00	43	15.712
J-124	1791	325,051.00	1,281,459.00	43	15.393
J-125	1787.89	324,737.00	1,281,621.00	30	16.377
J-126	1791.84	325,817.00	1,281,454.00	42	16.251
J-127	1789.32	325,024.00	1,282,247.00	40	16.981
J-128	1790.68	325,594.00	1,281,772.00	41	14.743
J-129	1799.4	324,260.00	1,281,461.00	42	13.35
J-130	1791.73	321,438.00	1,281,885.00	35	17.191
J-131	1792.22	325,821.00	1,282,249.00	39	15.819
J-132	1792.22	324,698.00	1,282,247.00	40	16.01
J-133	1792.37	324,844.00	1,282,253.00	40	15.543

J-135	1792.64	324,260.00	1,282,045.00	39	15.042
J-136	1791.83	324,732.00	1,281,851.00	39	14.821
J-137	1792.72	323,873.00	1,281,464.00	40	17.417
J-138	1789.22	325,311.00	1,283,068.00	39	14.543
J-139	1792.96	323,461.00	1,280,732.00	41	15.098
J-140	1792.96	324,724.00	1,281,901.00	39	15.361
J-141	1790.76	324,698.00	1,282,046.00	39	17.33
J-142	1790.19	325,822.00	1,282,026.00	40	14.602
J-143	1789.88	323,130.00	1,280,720.00	43	15.002
J-144	1788	324,258.00	1,281,046.00	42	17.637
J-145	1799.4	326,157.00	1,281,935.00	41	15.224
J-146	1787.92	321,644.00	1,281,891.00	35	15.406
J-147	1799	324,235.00	1,280,125.00	39	22.746
J-149	1798.33	320,863.00	1,281,722.00	36	13.777
J-150	1790.67	321,647.00	1,281,244.00	35	15.681
J-151	1789.84	325,015.00	1,281,171.00	39	15.247
J-152	1790.19	324,259.00	1,280,704.00	42	14.695
J-153	1795.73	323,129.00	1,280,892.00	42	14.708
J-154	1789.51	322,358.00	1,281,211.00	38	17.002
J-155	1790.68	326,167.00	1,281,600.00	39	15.021
J-156	1790.3	323,927.00	1,280,704.00	39	15.601
J-157	1800	323,109.00	1,280,074.00	42	13.96
J-158	1796.33	319,707.00	1,282,157.00	31	14.113
J-159	1790.25	322,045.00	1,281,209.00	37	15.831
J-160	1789.28	325,016.00	1,280,701.00	37	16.097
J-161	1789.28	325,026.00	1,280,165.00	36	16.173
J-162	1787.92	325,031.00	1,280,078.00	35	15.786
J-164	1796.33	324,229.00	1,279,699.00	38	14.195
J-165	1790	322,042.00	1,281,087.00	37	14.896
J-166	1798.33	323,461.00	1,280,376.00	40	13.424
J-167	1791.86	321,524.00	1,281,081.00	34	17.243
J-168	1791.85	325,824.00	1,281,789.00	38	16.554
J-170	1790.25	325,824.00	1,281,605.00	38	15.998
J-171	1790.25	325,049.00	1,280,584.00	40	11
J-172	1795.42	325,056.00	1,280,353.00	70	14.335
J-173	1795	322,837.00	1,280,708.00	38	24.199
J-174	1795.42	320,594.00	1,280,732.00	36	14.409
J-175	1790.25	322,905.00	1,280,717.00	38	16.829
J-176	1798.33	325,560.00	1,280,578.00	36	13.54

J-177	1790.98	321,362.00	1,281,085.00	34	13.962
J-179	1791.74	322,738.00	1,283,822.00	26	15.392
J-180	1787.92	323,907.00	1,280,173.00	37	15.514
J-181	1795	323,921.00	1,279,695.00	40	15.502
J-182	1787.92	320,205.00	1,280,540.00	35	15.651
J-183	1783	323,915.00	1,279,526.00	40	16.32
J-184	1800	325,357.00	1,279,167.00	36	24.166
J-186	1803	320,594.00	1,281,214.00	32	13.51
J-187	1790.3	319,677.00	1,282,592.00	22	15.438
J-188	1799.21	323,450.00	1,279,697.00	39	13.731
J-189	1795	321,362.00	1,280,649.00	32	14.259
J-190	1788	319,791.00	1,284,247.00	34	15.91
J-191	1799.21	323,910.00	1,279,162.00	40	15.114
J-192	1799.21	322,045.00	1,280,711.00	33	14.752
J-193	1790	322,046.00	1,280,649.00	33	15.564
J-194	1799.86	323,316.00	1,279,735.00	35	15.395
J-195	1793	322,350.00	1,280,707.00	33	15.372
J-196	1798	322,824.00	1,280,320.00	38	13.002
J-197	1793	319,907.00	1,280,343.00	32	15.5
J-198	1785	322,835.00	1,280,196.00	38	16.189
J-199	1799.21	324,414.00	1,278,825.00	35	14.164
J-201	1787	321,364.00	1,280,392.00	32	16.1
J-202	1805	324,415.00	1,279,145.00	35	24.166
J-203	1785	320,425.00	1,281,215.00	29	16.275
J-204	1787	324,222.00	1,278,836.00	34	16.342
J-205	1801	324,670.00	1,278,828.00	33	14.65
J-206	1791.74	319,677.00	1,280,776.00	31	16.018
J-207	1805	324,663.00	1,279,670.00	34	14.225
J-208	1790.3	319,409.00	1,283,620.00	18	16.172
J-209	1790.3	323,191.00	1,279,317.00	36	15.694
J-210	1803	323,052.00	1,279,462.00	33	14.65
J-211	1790	319,962.00	1,280,971.00	31	16.219
J-212	1800	323,455.00	1,279,040.00	35	19.158
J-213	1801.88	320,437.00	1,280,273.00	30	15.139
J-215	1801.88	322,042.00	1,280,392.00	31	14.718
J-216	1784	322,045.00	1,280,321.00	30	16.684
J-217	1783	324,668.00	1,278,036.00	30	16.967
J-218	1801.88	324,662.00	1,277,616.00	28	14.928
J-219	1801.88	322,104.00	1,280,138.00	30	14.729

J-220	1803	321,366.00	1,280,140.00	28	13.002
J-221	1801.88	319,822.00	1,280,242.00	27	15.048
J-223	1793	322,110.00	1,279,954.00	28	15.902
J-224	1793	322,823.00	1,279,237.00	29	15.801
J-226	1785	322,624.00	1,279,433.00	31	17.144
J-228	1790	324,242.00	1,277,612.00	26	16.24
J-230	1788	322,749.00	1,277,723.00	33	16.716
J-231	1805	324,231.00	1,278,036.00	23	18.592
J-232	1807	320,245.00	1,280,083.00	24	20.959
J-233	1805	320,133.00	1,279,964.00	22	14.778
J-234	1805	321,284.00	1,279,611.00	24	14.837
J-235	1805	320,629.00	1,279,665.00	24	14.837
J-236	1815	320,729.00	1,279,768.00	23	13.979
J-237	1801.88	318,959.00	1,282,156.00	-2	14.604
J-238	1801.88	322,255.00	1,279,787.00	24	15.953
J-239	1795	322,361.00	1,279,691.00	24	16.496
J-241	1800	323,461.00	1,278,039.00	26	15.668
J-242	1807	322,148.00	1,278,965.00	23	16.045
J-245	1803	321,088.00	1,279,417.00	20	15.107
J-249	1810	321,890.20	1,279,192.00	21	15.752
J-250	1802	320,344.00	1,279,387.00	17	17.643
J-251	1807	322,510.00	1,278,614.00	20	17.726
J-252	1805	321,602.00	1,278,902.00	19	16.677
J-253	1803	322,181.00	1,278,319.00	21	18.34
J-254	1815	322,743.00	1,278,047.00	23	13.946
J-256	1801.88	318,954.00	1,281,285.00	6	16.454
J-257	1810	322,280.00	1,279,819.00	22	18.996
J-258	1820	320,736.00	1,279,033.00	14	12.849
J-259	1805	319,381.00	1,280,380.00	33	18.287
J-260	1810	321,791.00	1,277,969.00	18	17.168
J-60	1791.54	321,228.00	1,278,526.00	12	12.893
J-63	1788.71	322,100.00	1,282,510.00	44	13.142
J-64	1791.87	322,826.00	1,282,433.00	46	12.926
J-65	1791.87	322,469.00	1,282,513.00	43	12.971
J-66	1791.06	322,515.00	1,282,513.00	43	13.169
J-67	1791.06	321,318.00	1,283,576.00	41	13.203
J-68	1791.06	321,260.00	1,283,576.00	40	13.039
J-69	1797.93	321,540.00	1,283,587.00	39	12.444
J-70	1794.23	321,409.00	1,282,506.00	38	12.969

J-71	1790.75	322,235.00	1,282,821.00	39	13.548
J-72	1795.3	322,747.00	1,282,820.00	43	12.891
J-73	1797.93	322,101.00	1,282,816.00	39	12.518
J-74	1792.05	321,477.93	1,282,629.87	36	12.866
J-75	1791.06	321,854.00	1,283,270.00	36	13.335
J-77	1795.63	321,260.00	1,283,804.00	40	12.864
J-78	1790.75	321,561.00	1,283,266.00	37	13.714
J-79	1792.39	322,747.00	1,283,186.00	38	13.404
J-80	1791.06	322,461.00	1,282,818.00	42	13.261
J-81	1789.38	321,541.00	1,283,808.00	37	13.495
J-82	1795.63	322,836.00	1,281,888.00	45	12.883
J-83	1791.15	321,524.00	1,283,268.00	37	13.37
J-84	1790.98	321,895.00	1,283,728.00	35	13.287
J-85	1797.93	322,305.00	1,283,588.00	37	12.596
J-86	1790.74	321,408.00	1,282,719.00	37	13.343
J-87	1795.63	322,521.00	1,281,888.00	43	13.478
J-88	1795.63	320,916.00	1,283,268.00	37	12.973
J-89	1791.06	321,302.00	1,283,261.00	36	13.53
J-91	1790.92	321,541.00	1,284,057.00	36	13.971
J-92	1794.55	323,285.00	1,282,832.00	42	13.101
J-93	1790.36	322,268.00	1,283,197.00	35	13.95
J-94	1790.98	323,342.00	1,281,923.00	43	13.954
J-95	1790.23	322,690.00	1,283,514.00	36	13.913
J-96	1797.93	323,342.00	1,282,108.00	43	13.123
J-97	1791.59	320,802.00	1,282,667.00	37	13.469
J-98	1791.7	323,339.00	1,282,430.00	42	13.549
J-99	1788.3	323,339.00	1,282,447.00	42	17.054
J-4	1939.67	325,596.00	1,282,248.00	43	11.071

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Appendix B; Bahir Dar city existing water supply distribution network pipe result

FlexTable: Pipe Table					
Current Time: 8.00 hours					
Label	Length (Scaled) (m)	Diameter (mm)	Material	Hazen-Williams C	Velocity
P-208	650	10.0	HDPE		(m/s)
P-229	518	10.0	HDPE	130	0.03
P-108	481	10.0	HDPE	130	0.11
P-367	787	10.0	HDPE	130	0.12
P-107	493	10.0	HDPE	130	0.13
P-54	433	10.0	HDPE	130	0.15
P-151	399	10.0	HDPE	130	0.15
P-157	639	10.0	HDPE	130	0.16
P-310	233	10.0	HDPE	130	0.16
P-262	679	10.0	HDPE	130	0.17
P-32	766	10.0	HDPE	130	0.18
P-115	357	10.0	HDPE	130	0.18
P-55	478	10.0	HDPE	130	0.18
P-271	1,213	10.0	HDPE	130	0.19
P-29	938	10.0	HDPE	130	0.19
P-239	792	10.0	HDPE	130	0.19
P-306	779	10.0	HDPE	130	0.21
P-10	420	10.0	HDPE	130	0.22
P-381	356	25.0	HDPE	130	0.24
P-213	679	50.0	PVC	130	0.39
P-78	684	25.0	PVC	130	0.39
P-278	697	25.0	HDPE	130	0.4
P-231	504	50.0	HDPE	130	0.41
P-15	738	25.0	HDPE	130	0.42
P-38	458	100.0	HDPE	130	0.43
P-80	792	25.0	PVC	130	0.43
P-158	639	50.0	HDPE	130	0.44
P-22	438	10.0	HDPE	130	0.45
P-403	517	100.0	HDPE	130	0.45
P-57	814	200.0	PVC	130	0.46
P-276	71	10.0	PVC	130	0.46
P-83	989	25.0	HDPE	130	0.47
P-119	437	25.0	HDPE	130	0.47
P-40	678	25.0	HDPE	130	0.48
P-281	256	25.0	HDPE	130	0.5

P-6x	487	150.0	HDPE	130	0.53
P-13	939	200.0	PVC	130	0.53
P-12	201	300.0	Ductile Iron	130	0.55
P-156	2,842	25.0	Ductile Iron	130	0.55
P-17	147	300.0	PVC	130	0.56
P-68	184	25.0	Ductile Iron	130	0.56
P-396	206	25.0	PVC	130	0.6
P-58	585	75.0	PVC	130	0.6
P-26	146	300.0	PVC	130	0.62
P-37	386	75.0	Ductile Iron	130	0.64
P-74	335	25.0	HDPE	130	0.64
P-304	62	100.0	PVC	130	0.67
P-59	135	25.0	PVC	130	0.69
P-175	686	25.0	PVC	130	0.72
P-34	180	200.0	HDPE	130	0.73
P-300	305	250.0	PVC	130	0.75
P-4	2,071	100.0	PVC	130	0.76
P-62	758	300.0	Ductile Iron	130	0.78
P-177	668	25.0	PVC	130	0.78
P-61	387	100.0	HDPE	130	0.79
P-117	424	50.0	PVC	130	0.8
P-258	504	100.0	HDPE	130	0.81
P-18	572	150.0	PVC	130	0.81
P-286	568	300.0	PVC	130	0.82
P-314	382	200.0	PVC	130	0.83
P-255	438	100.0	PVC	130	0.83
P-56	389	50.0	PVC	130	0.83
P-227	434	100.0	PVC	130	0.84
P-273	354	300.0	PVC	130	0.84
P-53	420	50.0	PVC	130	0.85
P-36	547	200.0	PVC	130	0.86
P-236	383	75.0	PVC	130	0.88
P-216	361	100.0	HDPE	130	0.88
P-109	481	250.0	PVC	130	0.88
P-23	535	150.0	PVC	130	0.88
P-218	342	200.0	PVC	130	0.89
P-165	608	250.0	PVC	130	0.91
P-181	770	25.0	PVC	130	0.91
P-324	143	75.0	HDPE	130	0.93
P-8	485	100.0	HDPE	130	0.93
P-282	426	250.0	PVC	130	0.95
P-263	867	25.0	PVC	130	0.96
P-368	237	25.0	Galvanized	130	0.98

			iron		
P-178	624	200.0	PVC	130	0.99
P-217	670	350.0	PVC	130	1
P-79	613	25.0	PVC	130	1
P-374	257	75.0	HDPE	130	1.01
P-400	478	75.0	PVC	130	1.01
P-103	647	100.0	PVC	130	1.01
P-163	531	100.0	PVC	130	1.03
P-219	342	250.0	PVC	130	1.04
P-315	382	300.0	PVC	130	1.04
P-72	471	75.0	PVC	130	1.07
P-64	33	200.0	PVC	130	1.08
P-237	169	250.0	PVC	130	1.1
P-116	417	100.0	PVC	130	1.1
P-210	392	50.0	PVC	130	1.11
P-211	392	50.0	PVC	130	1.12
P-387	204	75.0	HDPE	130	1.12
P-348	523	300.0	PVC	130	1.14
P-270	1,208	100.0	PVC	130	1.14
P-110	467	250.0	PVC	130	1.16
P-259	679	200.0	PVC	130	1.16
P-153	17	100.0	PVC	130	1.16
P-30	305	100.0	PVC	130	1.17
P-325	124	200.0	PVC	130	1.17
P-69	767	75.0	PVC	130	1.18
P-71	332	50.0	PVC	130	1.18
P-152	399	250.0	PVC	130	1.18
P-81	242	100.0	PVC	130	1.19
P-265	875	75.0	PVC	130	1.19
P-257	762	100.0	PVC	130	1.2
P-173	530	25.0	PVC	130	1.21
P-279	364	200.0	HDPE	130	1.23
P-320	225	250.0	PVC	130	1.24
P-77	511	50.0	PVC	130	1.24
P-224	675	50.0	PVC	130	1.24
P-330	482	100.0	PVC	130	1.26
P-14	822	300.0	PVC	130	1.26
P-378	686	150.0	Ductile Iron	130	1.27
P-260	476	50.0	PVC	130	1.28
P-154	322	250.0	PVC	130	1.28
P-155	323	100.0	PVC	130	1.29
P-256	415	300.0	PVC	130	1.29
P-397	206	25.0	PVC	130	1.31

P-313	501	200.0	PVC	130	1.33
P-342	501	200.0	PVC	130	1.33
P-60	185	400.0	PVC	130	1.33
P-346	69	250.0	Ductile Iron	130	1.34
P-301	249	200.0	PVC	130	1.34
P-114	1,062	100.0	PVC	130	1.35
P-223	376	250.0	PVC	130	1.35
P-235	420	50.0	PVC	130	1.35
P-11(2)	1,863	100.0	HDPE	130	1.36
P-150	315	400.0	PVC	150	1.37
P-328	163	75.0	Ductile Iron	130	1.38
P-169	132	100.0	HDPE	130	1.38
P-180	324	50.0	PVC	130	1.38
P-8(1)	165	160.0	HDPE	130	1.41
P-8(2)	1,867	160.0	PVC	150	1.42
P-7x	51	200.0	PVC	150	1.42
P-307	779	200.0	Ductile Iron	130	1.42
P-65	225	100.0	PVC	130	1.42
P-214	122	250.0	PVC	130	1.43
P-365	356	200.0	PVC	130	1.43
P-305	192	75.0	PVC	130	1.43
P-308	192	75.0	PVC	130	1.44
P-225	987	100.0	HDPE	130	1.44
P-253	538	150.0	PVC	130	1.44
P-309	446	75.0	PVC	130	1.45
P-212	679	400.0	PVC	130	1.46
P-384	347	50.0	Ductile Iron	130	1.46
P-160	343	50.0	PVC	130	1.47
P-14x	192	25.0	PVC	130	1.47
P-272	884	75.0	PVC	130	1.47
P-147	479	100.0	HDPE	130	1.48
P-183	754	100.0	PVC	130	1.49
P-401	487	150.0	PVC	130	1.49
P-312	554	100.0	PVC	130	1.5
P-303	679	200.0	PVC	130	1.5
P-404	213	300.0	PVC	130	1.5
P-66	678	25.0	PVC	130	1.51
P-162	536	100.0	PVC	130	1.51
P-389	435	200.0	PVC	130	1.51
P-16	472	200.0	PVC	130	1.52
P-120	436	25.0	Ductile Iron	130	1.53
P-352	1,001	75.0	HDPE	130	1.53
P-340	255	75.0	HDPE	130	1.53

P-102	507	400.0	PVC	130	1.54
P-364	575	200.0	Ductile Iron	130	1.54
P-63	313	150.0	PVC	130	1.56
P-73	87	75.0	PVC	130	1.56
P-369	231	50.0	PVC	130	1.56
P-264	513	250.0	PVC	130	1.57
P-168	490	100.0	PVC	130	1.57
P-20	118	200.0	PVC	130	1.58
P-164	913	100.0	Ductile Iron	130	1.58
P-252	460	100.0	PVC	130	1.6
P-238	706	100.0	PVC	130	1.6
P-266	228	250.0	PVC	130	1.62
P-267	58	250.0	PVC	130	1.62
P-118	201	25.0	PVC	130	1.64
P-382	223	50.0	HDPE	130	1.65
P-383	223	50.0	HDPE	130	1.65
P-343	308	75.0	PVC	130	1.65
P-386	849	200.0	HDPE	130	1.65
P-106	388	400.0	PVC	130	1.66
P-377	792	75.0	Ductile Iron	130	1.67
P-182	192	100.0	HDPE	130	1.67
P-284	748	50.0	PVC	130	1.68
P-268	315	250.0	HDPE	130	1.71
P-113	222	50.0	PVC	130	1.71
P-222	545	400.0	HDPE	130	1.71
P-76	231	10.0	Ductile Iron	130	1.72
P-15(1)	80	100.0	HDPE	130	1.72
P-15(2)	2,268	100.0	Ductile Iron	130	1.74
P-174	666	50.0	PVC	130	1.74
P-35	316	50.0	HDPE	130	1.74
P-319	1,009	200.0	PVC	130	1.74
P-70	757	75.0	PVC	130	1.74
P-321	333	50.0	PVC	130	1.74
P-277	368	100.0	PVC	130	1.74
P-269	222	250.0	PVC	130	1.76
P-355	592	200.0	Ductile Iron	130	1.76
P-105	393	400.0	PVC	130	1.76
P-24	363	50.0	Ductile Iron	130	1.76
P-67	529	25.0	PVC	130	1.8
P-209	46	400.0	PVC	130	1.8
P-104	527	400.0	Ductile Iron	130	1.8
P-354	800	75.0	Ductile Iron	130	1.8
P-167	494	50.0	HDPE	130	1.8

P-323	728	300.0	HDPE	130	1.81
P-233	321	100.0	PVC	130	1.83
P-13(1)	59	100.0	PVC	130	1.83
P-13(2)	2,389	100.0	PVC	150	1.88
P-82	612	75.0	PVC	150	1.88
P-179	718	100.0	PVC	130	1.89
P-338	625	350.0	PVC	130	1.94
P-220	470	100.0	PVC	130	1.94
P-176	343	100.0	PVC	130	1.95
P-283	857	100.0	PVC	130	2.01
P-234	471	100.0	PVC	130	2.01
P-149	286	150.0	PVC	130	2.04
P-171	502	150.0	PVC	130	2.04
P-339	390	200.0	PVC	130	2.04
P-351	380	100.0	PVC	130	2.04
P-207	691	600.0	PVC	130	2.05
P-232	524	75.0	Ductile Iron	130	2.07
P-345	415	400.0	HDPE	130	2.09
P-344	369	400.0	Ductile Iron	130	2.1
P-185	144	150.0	Ductile Iron	130	2.13
P-170	184	50.0	PVC	130	2.13
P-398	319	75.0	PVC	130	2.16
P-327	842	100.0	PVC	130	2.16
P-6	414	400.0	PVC	130	2.18
P-7	7,945	400.0	Ductile Iron	130	2.19
P-287	528	100.0	Ductile Iron	130	2.19
P-275	436	300.0	PVC	130	2.22
P-311	274	300.0	PVC	130	2.23
P-280	320	100.0	PVC	130	2.24
P-322	333	75.0	PVC	130	2.24
P-399	172	50.0	HDPE	130	2.25
P-385	540	75.0	PVC	130	2.25
P-254	819	300.0	PVC	130	2.27
P-274	162	300.0	Ductile Iron	130	2.28
P-317	219	100.0	PVC	130	2.28
P-166	345	100.0	PVC	130	2.35
P-337	321	400.0	PVC	130	2.36
P-329	398	100.0	Ductile Iron	130	2.37
P-251	642	200.0	PVC	130	2.4
P-366	575	400.0	PVC	130	2.4
P-302	393	100.0	Ductile Iron	130	2.41
P-261	151	50.0	PVC	130	2.42
P-372	221	75.0	PVC	130	2.42

P-11(1)	156	75.0	PVC	130	2.42
P-318	289	100.0	PVC	150	2.44
P-316	556	350.0	PVC	130	2.46
P-350	693	100.0	PVC	130	2.48
P-230	409	100.0	PVC	130	2.52
P-17(1)	100	100.0	PVC	130	2.54
P-17(2)	998	100.0	Ductile Iron	130	2.55
P-347	1,127	100.0	Ductile Iron	130	2.55
P-353	505	100.0	PVC	130	2.56
P-28	468	25.0	PVC	130	2.59
P-16(1)	96	100.0	PVC	130	2.64
P-16(2)	2,917	100.0	Ductile Iron	130	2.65
P-75	306	150.0	PVC	130	2.65
P-349	535	250.0	PVC	130	2.66
P-341	103	25.0	PVC	130	2.68
P-215	342	150.0	PVC	130	2.78
P-375	252	250.0	PVC	130	2.83
P-373	169	75.0	PVC	130	2.92
P-326	442	100.0	PVC	130	2.93
P-402	257	250.0	PVC	130	3.02
P-228	270	150.0	PVC	130	3.03
P-395	37	150.0	PVC	130	3.04
P-111	331	150.0	PVC	130	3.06
P-184	366	50.0	PVC	130	3.1
P-226	495	150.0	PVC	130	3.13
P-221	561	150.0	PVC	130	3.16
P-161	579	150.0	Ductile Iron	130	3.18
P-376	276	200.0	PVC	130	3.27
P-12(1)	144	400.0	PVC	130	3.35
P-12(2)	2,230	400.0	PVC	150	3.35
P-148	281	100.0	Ductile Iron	130	3.35
P-371	416	75.0	PVC	130	3.4
P-112	310	50.0	PVC	130	3.42
P-336	377	100.0	PVC	130	3.65
P-370	134	100.0	PVC	130	3.65
P-394	293	75.0	PVC	130	3.71
P-1	358	600.0	PVC	130	3.84
P-159	230	25.0	Ductile Iron	130	4
P-101	142	150.0	PVC	130	4.27
P-388	139	75.0	PVC	130	4.58
P-405	312	50.0	PVC	130	4.77

Appendix C; Bahir Dar city water supply distribution network pridicted juncton result for 2030

FlexTable: Junction Table					
Current Time: 8.00 hours					
Label	Elevation (m)	Demand Collection	X (m)	Y (m)	Pressure (m H2O)
J-100	1,792.13	<Collection: 1 items>	323,914.00	1,282,341.00	21
J-101	1,789.52	<Collection: 1 items>	323,178.00	1,281,252.00	18
J-102	1,792.30	<Collection: 1 items>	324,001.00	1,282,444.00	20
J-103	1,791.11	<Collection: 1 items>	322,839.00	1,281,209.00	19
J-104	1,789.52	<Collection: 1 items>	323,389.00	1,281,371.00	18
J-106	1,791.88	<Collection: 1 items>	323,869.00	1,282,112.00	19
J-108	1,790.03	<Collection: 1 items>	325,819.00	1,283,237.00	18
J-109	1,799.00	<Collection: 1 items>	321,103.00	1,282,019.00	23
J-110	1,789.46	<Collection: 1 items>	325,821.00	1,282,927.00	18
J-111	1,790.92	<Collection: 1 items>	323,353.00	1,283,273.00	19
J-112	1,795.00	<Collection: 1 items>	322,043.00	1,281,888.00	20
J-113	1,790.00	<Collection: 1 items>	320,448.00	1,284,051.00	13
J-114	1,790.72	<Collection: 1 items>	325,020.00	1,281,762.00	17
J-115	1,791.81	<Collection: 1 items>	323,870.00	1,281,719.07	17
J-116	1,793.01	<Collection: 1 items>	324,260.00	1,282,251.00	18
J-117	1,791.06	<Collection: 1 items>	321,536.00	1,284,544.00	13
J-118	1,791.37	<Collection: 1 items>	324,258.00	1,281,735.00	17
J-119	1,788.86	<Collection: 1 items>	325,598.00	1,281,456.00	15
J-120	1,791.54	<Collection:	324,260.00	1,281,853.00	16

		1 items>			
J-121	1,791.00	<Collection: 1 items>	324,269.00	1,281,633.00	17
J-122	1,789.24	<Collection: 1 items>	325,018.00	1,281,460.00	15
J-123	1,789.24	<Collection: 1 items>	325,051.00	1,281,459.00	15
J-124	1,791.00	<Collection: 1 items>	324,737.00	1,281,621.00	16
J-125	1,787.89	<Collection: 1 items>	325,817.00	1,281,454.00	14
J-126	1,791.84	<Collection: 1 items>	325,024.00	1,282,247.00	16
J-127	1,789.32	<Collection: 1 items>	325,594.00	1,281,772.00	14
J-128	1,790.68	<Collection: 1 items>	324,260.00	1,281,461.00	15
J-129	1,799.40	<Collection: 1 items>	321,438.00	1,281,885.00	20
J-130	1,791.73	<Collection: 1 items>	325,821.00	1,282,249.00	16
J-131	1,792.22	<Collection: 1 items>	324,698.00	1,282,247.00	16
J-132	1,792.22	<Collection: 1 items>	324,844.00	1,282,253.00	16
J-133	1,792.37	<Collection: 1 items>	324,260.00	1,282,045.00	16
J-135	1,792.64	<Collection: 1 items>	324,732.00	1,281,851.00	15
J-136	1,791.83	<Collection: 1 items>	323,873.00	1,281,464.00	14
J-137	1,792.72	<Collection: 1 items>	325,311.00	1,283,068.00	15
J-138	1,789.22	<Collection: 1 items>	323,461.00	1,280,732.00	12
J-139	1,792.96	<Collection: 1 items>	324,724.00	1,281,901.00	15
J-140	1,792.96	<Collection: 1 items>	324,698.00	1,282,046.00	15
J-141	1,790.76	<Collection: 1 items>	325,822.00	1,282,026.00	14
J-142	1,790.19	<Collection: 1 items>	323,130.00	1,280,720.00	12

J-143	1,789.88	<Collection: 1 items>	324,258.00	1,281,046.00	12
J-144	1,788.00	<Collection: 1 items>	326,157.00	1,281,935.00	13
J-145	1,799.40	<Collection: 1 items>	321,644.00	1,281,891.00	17
J-146	1,787.92	<Collection: 1 items>	324,235.00	1,280,125.00	10
J-147	1,799.00	<Collection: 1 items>	320,863.00	1,281,722.00	19
J-149	1,798.33	<Collection: 1 items>	321,647.00	1,281,244.00	16
J-150	1,790.67	<Collection: 1 items>	325,015.00	1,281,171.00	11
J-151	1,789.84	<Collection: 1 items>	324,259.00	1,280,704.00	10
J-152	1,790.19	<Collection: 1 items>	323,129.00	1,280,892.00	10
J-153	1,795.73	<Collection: 1 items>	322,358.00	1,281,211.00	13
J-154	1,789.51	<Collection: 1 items>	326,167.00	1,281,600.00	11
J-155	1,790.68	<Collection: 1 items>	323,927.00	1,280,704.00	9
J-156	1,790.30	<Collection: 1 items>	323,109.00	1,280,074.00	11
J-157	1,800.00	<Collection: 1 items>	319,707.00	1,282,157.00	16
J-158	1,796.33	<Collection: 1 items>	322,045.00	1,281,209.00	12
J-159	1,790.25	<Collection: 1 items>	325,016.00	1,280,701.00	8
J-160	1,789.28	<Collection: 1 items>	325,026.00	1,280,165.00	7
J-161	1,789.28	<Collection: 1 items>	325,031.00	1,280,078.00	7
J-162	1,787.92	<Collection: 1 items>	324,229.00	1,279,699.00	6
J-164	1,796.33	<Collection: 1 items>	322,042.00	1,281,087.00	11
J-165	1,790.00	<Collection: 1 items>	323,461.00	1,280,376.00	7
J-166	1,798.33	<Collection:	321,524.00	1,281,081.00	12

		1 items>			
J-167	1,791.86	<Collection: 1 items>	325,824.00	1,281,789.00	9
J-168	1,791.85	<Collection: 1 items>	325,824.00	1,281,605.00	9
J-170	1,790.25	<Collection: 1 items>	325,049.00	1,280,584.00	9
J-171	1,790.25	<Collection: 1 items>	325,056.00	1,280,353.00	9
J-172	1,795.42	<Collection: 1 items>	322,837.00	1,280,708.00	10
J-173	1,795.00	<Collection: 1 items>	320,594.00	1,280,732.00	12
J-174	1,795.42	<Collection: 1 items>	322,905.00	1,280,717.00	9
J-175	1,790.25	<Collection: 1 items>	325,560.00	1,280,578.00	7
J-176	1,798.33	<Collection: 1 items>	321,362.00	1,281,085.00	10
J-177	1,790.98	<Collection: 1 items>	322,738.00	1,283,822.00	4
J-179	1,791.74	<Collection: 1 items>	323,907.00	1,280,173.00	6
J-180	1,787.92	<Collection: 1 items>	323,921.00	1,279,695.00	3
J-181	1,795.00	<Collection: 1 items>	320,205.00	1,280,540.00	9
J-182	1,787.92	<Collection: 1 items>	323,915.00	1,279,526.00	2
J-183	1,783.00	<Collection: 1 items>	325,357.00	1,279,167.00	-1
J-184	1,800.00	<Collection: 1 items>	320,594.00	1,281,214.00	11
J-186	1,803.00	<Collection: 1 items>	319,677.00	1,282,592.00	9
J-187	1,790.30	<Collection: 1 items>	323,450.00	1,279,697.00	2
J-188	1,799.21	<Collection: 1 items>	321,362.00	1,280,649.00	6
J-189	1,795.00	<Collection: 1 items>	319,791.00	1,284,247.00	-1
J-190	1,788.00	<Collection: 1 items>	323,910.00	1,279,162.00	-1

J-191	1,799.21	<Collection: 1 items>	322,045.00	1,280,711.00	6
J-192	1,799.21	<Collection: 1 items>	322,046.00	1,280,649.00	5
J-193	1,790.00	<Collection: 1 items>	323,316.00	1,279,735.00	0
J-194	1,799.86	<Collection: 1 items>	322,350.00	1,280,707.00	5
J-195	1,793.00	<Collection: 1 items>	322,824.00	1,280,320.00	1
J-196	1,798.00	<Collection: 1 items>	319,907.00	1,280,343.00	6
J-197	1,793.00	<Collection: 1 items>	322,835.00	1,280,196.00	0
J-198	1,785.00	<Collection: 1 items>	324,414.00	1,278,825.00	-5
J-199	1,799.21	<Collection: 1 items>	321,364.00	1,280,392.00	3
J-201	1,787.00	<Collection: 1 items>	324,415.00	1,279,145.00	-5
J-202	1,805.00	<Collection: 1 items>	320,425.00	1,281,215.00	9
J-203	1,785.00	<Collection: 1 items>	324,222.00	1,278,836.00	-6
J-204	1,787.00	<Collection: 1 items>	324,670.00	1,278,828.00	-6
J-205	1,801.00	<Collection: 1 items>	319,677.00	1,280,776.00	5
J-206	1,791.74	<Collection: 1 items>	324,663.00	1,279,670.00	-3
J-207	1,805.00	<Collection: 1 items>	319,409.00	1,283,620.00	3
J-208	1,790.30	<Collection: 1 items>	323,191.00	1,279,317.00	-3
J-209	1,790.30	<Collection: 1 items>	323,052.00	1,279,462.00	-3
J-210	1,803.00	<Collection: 1 items>	319,962.00	1,280,971.00	5
J-211	1,790.00	<Collection: 1 items>	323,455.00	1,279,040.00	-6
J-212	1,800.00	<Collection: 1 items>	320,437.00	1,280,273.00	1
J-213	1,801.88	<Collection:	322,042.00	1,280,392.00	-1

		1 items>			
J-215	1,801.88	<Collection: 1 items>	322,045.00	1,280,321.00	-1
J-216	1,784.00	<Collection: 1 items>	324,668.00	1,278,036.00	-13
J-217	1,783.00	<Collection: 1 items>	324,662.00	1,277,616.00	-15
J-218	1,801.88	<Collection: 1 items>	322,104.00	1,280,138.00	-3
J-219	1,801.88	<Collection: 1 items>	321,366.00	1,280,140.00	-3
J-220	1,803.00	<Collection: 1 items>	319,822.00	1,280,242.00	0
J-221	1,801.88	<Collection: 1 items>	322,110.00	1,279,954.00	-4
J-223	1,793.00	<Collection: 1 items>	322,823.00	1,279,237.00	-8
J-224	1,793.00	<Collection: 1 items>	322,624.00	1,279,433.00	-10
J-226	1,785.00	<Collection: 1 items>	324,242.00	1,277,612.00	-17
J-228	1,790.00	<Collection: 1 items>	322,749.00	1,277,723.00	-16
J-230	1,788.00	<Collection: 1 items>	324,231.00	1,278,036.00	-19
J-231	1,805.00	<Collection: 1 items>	320,245.00	1,280,083.00	-6
J-232	1,807.00	<Collection: 1 items>	320,133.00	1,279,964.00	-5
J-233	1,805.00	<Collection: 1 items>	321,284.00	1,279,611.00	-12
J-234	1,805.00	<Collection: 1 items>	320,629.00	1,279,665.00	-11
J-235	1,805.00	<Collection: 1 items>	320,729.00	1,279,768.00	-12
J-236	1,815.00	<Collection: 1 items>	318,959.00	1,282,156.00	-5
J-237	1,801.88	<Collection: 1 items>	322,255.00	1,279,787.00	-15
J-238	1,801.88	<Collection: 1 items>	322,361.00	1,279,691.00	-17
J-239	1,795.00	<Collection: 1 items>	323,461.00	1,278,039.00	-24

J-241	1,800.00	<Collection: 1 items>	322,148.00	1,278,965.00	-21
J-242	1,807.00	<Collection: 1 items>	321,088.00	1,279,417.00	-17
J-245	1,803.00	<Collection: 1 items>	321,890.20	1,279,192.00	-23
J-249	1,810.00	<Collection: 1 items>	320,344.00	1,279,387.00	-21
J-250	1,802.00	<Collection: 1 items>	322,510.00	1,278,614.00	-28
J-251	1,807.00	<Collection: 1 items>	321,602.00	1,278,902.00	-24
J-252	1,805.00	<Collection: 1 items>	322,181.00	1,278,319.00	-26
J-253	1,803.00	<Collection: 1 items>	322,743.00	1,278,047.00	-28
J-254	1,815.00	<Collection: 1 items>	318,954.00	1,281,285.00	-18
J-256	1,801.88	<Collection: 1 items>	322,280.00	1,279,819.00	-26
J-257	1,810.00	<Collection: 1 items>	320,736.00	1,279,033.00	-27
J-258	1,820.00	<Collection: 1 items>	319,381.00	1,280,380.00	-16
J-259	1,805.00	<Collection: 1 items>	321,791.00	1,277,969.00	-31
J-260	1,810.00	<Collection: 1 items>	321,228.00	1,278,526.00	-31
J-60	1,791.54	<Collection: 1 items>	322,100.00	1,282,510.00	34
J-63	1,788.71	<Collection: 1 items>	322,826.00	1,282,433.00	29
J-64	1,791.87	<Collection: 1 items>	322,469.00	1,282,513.00	30
J-65	1,791.87	<Collection: 1 items>	322,515.00	1,282,513.00	30
J-66	1,791.06	<Collection: 1 items>	321,318.00	1,283,576.00	27
J-67	1,791.06	<Collection: 1 items>	321,260.00	1,283,576.00	27
J-68	1,791.06	<Collection: 1 items>	321,540.00	1,283,587.00	27
J-69	1,797.93	<Collection:	321,409.00	1,282,506.00	32

		1 items>			
J-70	1,794.23	<Collection: 1 items>	322,235.00	1,282,821.00	29
J-71	1,790.75	<Collection: 1 items>	322,747.00	1,282,820.00	27
J-72	1,795.30	<Collection: 1 items>	322,101.00	1,282,816.00	30
J-73	1,797.93	<Collection: 1 items>	321,477.93	1,282,629.87	32
J-74	1,792.05	<Collection: 1 items>	321,854.00	1,283,270.00	27
J-75	1,791.06	<Collection: 1 items>	321,260.00	1,283,804.00	25
J-77	1,795.63	<Collection: 1 items>	321,561.00	1,283,266.00	28
J-78	1,790.75	<Collection: 1 items>	322,747.00	1,283,186.00	26
J-79	1,792.39	<Collection: 1 items>	322,461.00	1,282,818.00	27
J-80	1,791.06	<Collection: 1 items>	321,541.00	1,283,808.00	24
J-81	1,789.38	<Collection: 1 items>	322,836.00	1,281,888.00	25
J-82	1,795.63	<Collection: 1 items>	321,524.00	1,283,268.00	27
J-83	1,791.15	<Collection: 1 items>	321,895.00	1,283,728.00	24
J-84	1,790.98	<Collection: 1 items>	322,305.00	1,283,588.00	24
J-85	1,797.93	<Collection: 1 items>	321,408.00	1,282,719.00	29
J-86	1,790.74	<Collection: 1 items>	322,521.00	1,281,888.00	25
J-87	1,795.63	<Collection: 1 items>	320,916.00	1,283,268.00	27
J-88	1,795.63	<Collection: 1 items>	321,302.00	1,283,261.00	25
J-89	1,791.06	<Collection: 1 items>	321,541.00	1,284,057.00	21
J-91	1,790.92	<Collection: 1 items>	323,285.00	1,282,832.00	23
J-92	1,794.55	<Collection: 1 items>	322,268.00	1,283,197.00	25

J-93	1,790.36	<Collection: 1 items>	323,342.00	1,281,923.00	22
J-94	1,790.98	<Collection: 1 items>	322,690.00	1,283,514.00	21
J-95	1,790.23	<Collection: 1 items>	323,342.00	1,282,108.00	22
J-96	1,797.93	<Collection: 1 items>	320,802.00	1,282,667.00	26
J-97	1,791.59	<Collection: 1 items>	323,339.00	1,282,430.00	22
J-98	1,791.70	<Collection: 1 items>	323,339.00	1,282,447.00	22
J-99	1,788.30	<Collection: 1 items>	325,596.00	1,282,248.00	19
J-4	1,939.67	<Collection: 0 items>	313,143.54	1,281,759.37	8

Bahr Dar WS final of final.wtg	Bentley Systems, Inc. Haestad Methods Solution Center	WaterGEMS CONNECT Edition Update 1 [10.01.01.04]
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Appendix D; Bahir Dar city water supply distribution network pridicted pipe result for 2030

FlexTable: Pipe Table					
Current Time: 8.00 hours					
Label	Diameter (mm)	Material	Velocity (m/s)	Length (m)	Hazen-Williams C
P-10	50.0	HDPE	0.00	420	130.0
P-101	300.0	PVC	0.91	142	130.0
P-102	400.0	Ductile Iron	1.14	507	130.0
P-103	150.0	PVC	0.74	647	130.0
P-104	400.0	Ductile Iron	1.22	527	130.0

P-105	400.0	Ductile Iron	1.22	393	130.0
P-106	400.0	Ductile Iron	1.11	388	130.0
P-107	300.0	PVC	0.88	493	130.0
P-108	150.0	PVC	0.57	481	130.0
P-109	250.0	PVC	0.79	481	130.0
P-110	250.0	PVC	0.87	467	130.0
P-111	300.0	PVC	0.90	331	130.0
P-112	150.0	PVC	0.39	310	130.0
P-113	80.0	HDPE	0.31	222	130.0
P-114	150.0	PVC	0.64	1,062	130.0
P-115	80.0	HDPE	0.26	357	130.0
P-116	150.0	PVC	0.67	417	130.0
P-117	80.0	HDPE	0.33	424	130.0
P-118	50.0	HDPE	0.07	201	130.0
P-119	50.0	HDPE	0.32	437	130.0
P-12	400.0	Ductile Iron	0.10	201	130.0
P-120	50.0	HDPE	0.58	436	130.0
P-13	400.0	Ductile Iron	0.15	939	130.0
P-14	100.0	PVC	0.15	192	130.0
P-147	150.0	PVC	0.84	479	130.0
P-148	150.0	PVC	0.70	281	130.0
P-149	300.0	PVC	1.04	286	130.0
P-15	80.0	HDPE	0.13	738	130.0
P-150	400.0	Ductile Iron	1.35	315	130.0
P-151	100.0	PVC	0.58	399	130.0
P-152	250.0	PVC	1.03	399	130.0
P-153	150.0	PVC	0.69	17	130.0
P-154	250.0	PVC	1.05	322	130.0
P-155	250.0	PVC	0.99	323	130.0
P-156	100.0	PVC	0.54	2,842	130.0

P-157	50.0	PVC	0.41	639	130.0
P-158	100.0	HDPE	0.64	639	130.0
P-159	80.0	PVC	0.30	230	130.0
P-16	400.0	Ductile Iron	0.16	472	130.0
P-160	80.0	PVC	0.39	343	130.0
P-161	300.0	PVC	1.10	579	130.0
P-162	150.0	PVC	0.71	536	130.0
P-163	150.0	PVC	0.70	531	130.0
P-164	150.0	PVC	0.79	913	130.0
P-165	250.0	PVC	1.11	608	130.0
P-166	200.0	PVC	0.88	345	130.0
P-167	80.0	HDPE	0.54	494	130.0
P-168	150.0	PVC	0.82	490	130.0
P-169	150.0	PVC	0.80	132	130.0
P-17	400.0	Ductile Iron	0.06	147	130.0
P-170	100.0	PVC	0.58	184	130.0
P-171	300.0	PVC	1.31	502	130.0
P-173	50.0	HDPE	0.52	530	130.0
P-174	100.0	HDPE	0.53	666	130.0
P-175	80.0	HDPE	0.63	686	130.0
P-176	150.0	PVC	0.83	343	130.0
P-177	100.0	HDPE	0.67	668	130.0
P-178	200.0	PVC	1.03	624	130.0
P-179	150.0	PVC	0.87	718	130.0
P-18	350.0	PVC	0.19	572	130.0
P-180	80.0	HDPE	0.54	324	130.0
P-181	50.0	HDPE	0.29	770	130.0
P-182	150.0	PVC	0.77	192	130.0
P-183	150.0	PVC	0.76	754	130.0
P-184	80.0	PVC	0.48	366	130.0

P-185	300.0	PVC	1.33	144	130.0
P-20	400.0	Ductile Iron	0.16	118	130.0
P-207	600.0	Ductile Iron	2.14	691	130.0
P-208	150.0	PVC	0.95	650	130.0
P-209	400.0	Ductile Iron	1.64	46	130.0
P-210	80.0	PVC	0.64	392	130.0
P-211	80.0	HDPE	0.64	392	130.0
P-212	400.0	Ductile Iron	1.73	679	130.0
P-213	150.0	PVC	0.93	679	130.0
P-214	250.0	PVC	1.25	122	130.0
P-215	300.0	PVC	1.32	342	130.0
P-216	150.0	PVC	1.05	361	130.0
P-217	350.0	PVC	1.67	670	130.0
P-218	200.0	PVC	1.12	342	130.0
P-219	250.0	PVC	1.29	342	130.0
P-22	200.0	PVC	0.19	438	130.0
P-220	150.0	PVC	0.90	470	130.0
P-221	300.0	Ductile Iron	1.44	561	130.0
P-222	400.0	Ductile Iron	1.73	545	130.0
P-223	250.0	PVC	1.27	376	130.0
P-224	80.0	PVC	0.53	675	130.0
P-225	150.0	PVC	0.91	987	130.0
P-226	300.0	PVC	1.51	495	130.0
P-227	150.0	PVC	0.92	434	130.0
P-228	300.0	PVC	1.58	270	130.0
P-229	100.0	PVC	0.65	518	130.0
P-23	300.0	PVC	0.23	535	130.0
P-230	150.0	PVC	0.93	409	130.0
P-231	80.0	HDPE	0.72	504	130.0
P-232	100.0	HDPE	0.89	524	130.0

P-233	150.0	PVC	0.94	321	130.0
P-234	150.0	PVC	0.92	471	130.0
P-235	80.0	HDPE	0.57	420	130.0
P-236	100.0	HDPE	0.74	383	130.0
P-237	250.0	PVC	1.15	169	130.0
P-238	150.0	PVC	0.92	706	130.0
P-24	80.0	PVC	0.17	363	130.0
P-251	200.0	PVC	1.32	642	130.0
P-252	150.0	PVC	1.07	460	130.0
P-253	250.0	PVC	1.36	538	130.0
P-254	300.0	Ductile Iron	1.61	819	130.0
P-255	200.0	PVC	1.17	438	130.0
P-256	300.0	PVC	1.60	415	130.0
P-257	150.0	PVC	1.02	762	130.0
P-258	150.0	PVC	0.93	504	130.0
P-259	200.0	PVC	1.20	679	130.0
P-26	400.0	Ductile Iron	0.40	146	130.0
P-260	80.0	PVC	0.72	476	130.0
P-261	80.0	PVC	0.52	151	130.0
P-262	80.0	PVC	0.67	679	130.0
P-263	75.0	Galvanized iron	0.79	867	130.0
P-264	250.0	PVC	1.41	513	130.0
P-265	100.0	PVC	0.66	875	130.0
P-266	250.0	PVC	1.40	228	130.0
P-267	250.0	PVC	1.42	58	130.0
P-268	250.0	PVC	1.46	315	130.0
P-269	250.0	Ductile Iron	1.50	222	130.0
P-270	150.0	PVC	0.90	1,208	130.0
P-271	100.0	HDPE	0.73	1,238	130.0

P-272	100.0	HDPE	0.89	991	130.0
P-273	300.0	PVC	1.68	354	130.0
P-274	300.0	PVC	1.60	162	130.0
P-275	300.0	PVC	1.54	436	130.0
P-276	150.0	PVC	1.04	71	130.0
P-277	150.0	PVC	0.94	368	130.0
P-278	50.0	HDPE	0.73	697	130.0
P-279	200.0	PVC	1.25	364	130.0
P-28	100.0	PVC	0.27	468	130.0
P-280	150.0	PVC	0.98	320	130.0
P-281	50.0	HDPE	0.38	256	130.0
P-282	250.0	PVC	1.36	426	130.0
P-283	150.0	PVC	1.02	857	130.0
P-284	80.0	HDPE	0.71	748	130.0
P-286	300.0	PVC	1.68	568	130.0
P-287	150.0	PVC	1.21	528	130.0
P-29	50.0	HDPE	0.28	938	130.0
P-30	200.0	PVC	0.28	305	130.0
P-300	250.0	PVC	1.53	305	130.0
P-301	200.0	PVC	1.44	249	130.0
P-302	150.0	PVC	1.19	393	130.0
P-303	200.0	PVC	1.41	679	130.0
P-304	150.0	PVC	1.13	62	130.0
P-305	100.0	PVC	0.89	192	130.0
P-306	50.0	PVC	0.55	779	130.0
P-307	200.0	PVC	1.31	779	130.0
P-308	100.0	HDPE	0.89	192	130.0
P-309	100.0	PVC	0.87	446	130.0
P-310	80.0	PVC	0.76	233	130.0
P-311	300.0	PVC	1.72	274	130.0

P-312	150.0	PVC	1.13	554	130.0
P-313	200.0	PVC	1.34	501	130.0
P-314	200.0	PVC	1.36	382	130.0
P-315	300.0	PVC	1.75	382	130.0
P-316	350.0	PVC	1.94	556	130.0
P-317	150.0	PVC	1.01	219	130.0
P-318	150.0	PVC	1.11	289	130.0
P-319	200.0	PVC	1.30	1,009	130.0
P-32	100.0	HDPE	0.15	766	130.0
P-320	250.0	PVC	1.43	225	130.0
P-321	80.0	PVC	0.89	333	130.0
P-322	100.0	HDPE	1.02	333	130.0
P-323	300.0	PVC	1.78	728	130.0
P-324	100.0	HDPE	1.07	143	130.0
P-325	200.0	PVC	1.30	124	130.0
P-326	150.0	PVC	1.21	442	130.0
P-327	150.0	PVC	1.05	842	130.0
P-328	100.0	HDPE	1.15	163	130.0
P-329	150.0	PVC	1.29	398	130.0
P-330	150.0	PVC	1.12	482	130.0
P-336	150.0	PVC	1.27	377	130.0
P-337	400.0	Ductile Iron	2.33	321	130.0
P-338	350.0	PVC	1.94	625	130.0
P-339	200.0	PVC	1.43	390	130.0
P-34	300.0	PVC	0.38	180	130.0
P-340	100.0	PVC	0.98	255	130.0
P-341	100.0	PVC	0.22	103	130.0
P-342	200.0	PVC	1.34	501	130.0
P-343	100.0	HDPE	0.90	308	130.0
P-344	400.0	Ductile Iron	2.27	369	130.0

P-345	400.0	Ductile Iron	2.21	415	130.0
P-346	250.0	PVC	1.54	69	130.0
P-347	150.0	PVC	1.19	1,127	130.0
P-348	300.0	PVC	1.91	523	130.0
P-349	250.0	PVC	1.59	535	130.0
P-35	150.0	PVC	0.18	316	130.0
P-350	150.0	PVC	1.23	693	130.0
P-351	150.0	PVC	1.08	380	130.0
P-352	100.0	HDPE	1.04	1,001	130.0
P-353	150.0	PVC	1.14	505	130.0
P-354	100.0	HDPE	1.02	800	130.0
P-355	200.0	PVC	1.41	592	130.0
P-36	300.0	PVC	0.38	547	130.0
P-364	200.0	PVC	1.66	575	130.0
P-365	200.0	PVC	1.56	356	130.0
P-366	400.0	Ductile Iron	2.57	575	130.0
P-367	80.0	PVC	0.53	787	130.0
P-368	50.0	PVC	0.69	237	130.0
P-369	80.0	PVC	0.75	231	130.0
P-37	100.0	HDPE	0.47	386	130.0
P-370	150.0	PVC	1.29	134	130.0
P-371	150.0	PVC	1.42	416	130.0
P-372	100.0	PVC	1.05	221	130.0
P-373	150.0	PVC	1.30	169	130.0
P-374	150.0	PVC	1.25	257	130.0
P-375	250.0	PVC	1.82	252	130.0
P-376	200.0	PVC	1.46	276	130.0
P-377	100.0	HDPE	1.06	792	130.0
P-378	150.0	PVC	1.36	686	130.0
P-38	200.0	PVC	0.24	458	130.0

P-381	100.0	PVC	1.01	356	130.0
P-382	80.0	HDPE	0.88	223	130.0
P-383	80.0	PVC	0.88	223	130.0
P-384	80.0	PVC	0.83	347	130.0
P-385	150.0	PVC	1.43	540	130.0
P-386	200.0	PVC	1.77	849	130.0
P-387	100.0	PVC	1.26	204	130.0
P-388	150.0	PVC	1.35	139	130.0
P-389	200.0	PVC	1.67	435	130.0
P-394	150.0	PVC	1.48	293	130.0
P-395	100.0	PVC	1.37	37	130.0
P-396	100.0	PVC	0.96	206	130.0
P-397	100.0	PVC	1.12	206	130.0
P-398	100.0	PVC	1.15	319	130.0
P-399	80.0	PVC	0.94	172	130.0
P-40	80.0	HDPE	0.18	678	130.0
P-400	100.0	PVC	1.08	478	130.0
P-401	150.0	PVC	1.60	487	130.0
P-402	250.0	PVC	1.96	257	130.0
P-403	75.0	Galvanized iron	0.87	517	130.0
P-404	300.0	PVC	2.29	213	130.0
P-405	80.0	PVC	1.99	312	130.0
P-53	80.0	PVC	0.13	420	130.0
P-54	80.0	PVC	0.19	433	130.0
P-55	80.0	PVC	0.23	476	130.0
P-56	80.0	PVC	0.19	389	130.0
P-57	300.0	PVC	0.74	814	130.0
P-58	150.0	PVC	0.45	585	130.0
P-59	80.0	PVC	0.33	135	130.0

P-6	250.0	PVC	0.01	487	130.0
P-60	400.0	Ductile Iron	0.86	185	130.0
P-61	300.0	PVC	0.68	387	130.0
P-62	300.0	PVC	0.74	758	130.0
P-63	250.0	PVC	0.45	313	130.0
P-64	300.0	PVC	0.48	33	130.0
P-65	200.0	PVC	0.43	225	130.0
P-66	80.0	PVC	0.10	678	130.0
P-67	100.0	PVC	0.26	529	130.0
P-68	80.0	PVC	0.20	184	130.0
P-69	150.0	PVC	0.35	767	130.0
P-7	400.0	Ductile Iron	0.14	51	130.0
P-70	150.0	PVC	0.48	757	130.0
P-71	80.0	PVC	0.21	332	130.0
P-72	100.0	PVC	0.35	471	130.0
P-73	150.0	PVC	0.42	87	130.0
P-74	80.0	PVC	0.29	335	130.0
P-75	250.0	PVC	0.69	306	130.0
P-76	80.0	PVC	0.03	231	130.0
P-77	80.0	PVC	0.41	511	130.0
P-78	100.0	HDPE	0.36	684	130.0
P-79	50.0	HDPE	0.24	613	130.0
P-8	200.0	PVC	0.25	485	130.0
P-80	50.0	HDPE	0.21	792	130.0
P-81	300.0	PVC	0.63	242	130.0
P-82	150.0	PVC	0.54	612	130.0
P-83	50.0	HDPE	0.00	989	130.0
P-1	600.0	Ductile Iron	4.29	318	130.0
P-239	80.0	HDPE	0.61	791	130.0
P-4	600.0	Ductile Iron	0.00	2,868	130.0

P-6	400.0	Ductile Iron	2.20	540	130.0
P-7	400.0	Ductile Iron	2.20	9,273	130.0
P-12(1)	160.0	PVC	0.01	144	150.0
P-12(2)	400.0	Ductile Iron	0.00	2,222	130.0
P-11(1)	100.0	PVC	0.00	156	150.0
P-11(2)	100.0	PVC	0.00	1,874	150.0
P-13(1)	110.0	PVC	0.00	60	150.0
P-13(2)	110.0	PVC	0.00	2,440	150.0
P-8(1)	160.0	PVC	1.43	486	150.0
P-8(2)	160.0	PVC	1.43	5,964	150.0
P-14	300.0	Ductile Iron	1.24	822	130.0
P-17(1)	152.4	Ductile Iron	1.95	100	130.0
P-17(2)	152.4	Ductile Iron	1.95	998	130.0
P-16(1)	152.4	Ductile Iron	2.20	96	130.0
P-16(2)	152.4	Ductile Iron	2.20	2,917	130.0
P-15(1)	152.4	Ductile Iron	0.00	80	130.0
P-15(2)	152.4	Ductile Iron	0.00	2,268	130.0

Bahr Dar WS final of final.wtg	Bentley Systems, Inc. Haestad Methods Solution Center	WaterGEMS CONNECT Edition Update 1 [10.01.01.04]
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Apeendex:F Pressure calibration data

No	Level	Sample node location		Location for actual measurement		Simulated pressure (mH2O)	Observed /measured pressure		Remark
		X	Y	X	Y		Psi	mH2O	

1	J-69	321409.00	1282506.00	321450.63	1,282,345.10	39	12	8.50	Tana subcity
2	J-71	322461.00	1282820.00	3226478.80	1283034.42	39	19	13.25	Shimbit
3	J-79	322,747.00	1,282,820.00	322668.80	1282863.72	36	15	10.55	Shimbit
4	J-91	323,285.00	1282832.00	323306.50	128268.51	38	11	7.73	Fasilo
5	J-143	324258.00	1281046.00	324,300.17	1281182.83	43	17	11.95	Belay Zeleke
6	J-220	319898.00	1280242.00	319,768.95	1280225.23	30	12	8.44	Sefene Selam
7	J-118	324258.00	1281735.00	324260.45	1281786.46	42	15	10.55	Gishi Abay
8	J-124	324737.00	1281621.00	324,683.83	1281602.25	43	30	22.34	Atse Minilik
9	J-231	320,245.00	1,280,083.00	320,300.00	1,280,040.00	28	1800	12.66	Atse Minlik
10	J-132	324,844.00	1,282,253.00	324979.97	1282567.58	41	18.48	13.00	Shum abo

1 Metres of water = 1.4223 Pounds per square inch

Appendex G Pipe size and velocity before and after optimization

Before optimization		After optimization	
velocity (m/s)	Count	Velocity (m/s)	count
<0.6	281	<0.6	40
0.6-2	7	0.6-2	174
>2	2	>2	76

Before optimization			After optimization		
Network table links			Network table links		
Link Id	Diameter	velocity	Link Id	Diameter	Velocity
P-10	50	0.01	P-208	10	0.03
P-101	300	0.24	P-229	10.0	0.11
P-102	400	0.3	P-108	10.0	0.12
P-103	150	0.19	P-367	10.0	0.13
P-104	400	0.33	P-107	10.0	0.15
P-105	400	0.33	P-54	10.0	0.15
P-106	400	0.3	P-151	10.0	0.16
P-107	300	0.25	P-157	10.0	0.16
P-108	150	0.14	P-310	10.0	0.17
P-109	250	0.2	P-262	10.0	0.18
P-110	250	0.28	P-32	10.0	0.18
P-111	300	0.27	P-115	10.0	0.18

P-112	150	0.11	P-55	10.0	0.19
P-113	80	0.09	P-271	10.0	0.19
P-114	150	0.23	P-29	10.0	0.19
P-115	80	0.03	P-239	10.0	0.21
P-116	150	0.2	P-306	10.0	0.22
P-117	80	0.09	P-10	10.0	0.24
P-118	50	0.07	P-381	25.0	0.39
P-119	50	0.12	P-213	50.0	0.39
P-12	400	0.03	P-78	25.0	0.4
P-120	50	0.2	P-278	25.0	0.41
P-13	400	0.05	P-231	50.0	0.42
P-14	100	0.05	P-15	25.0	0.43
P-147	150	0.18	P-38	100.0	0.43
P-148	150	0.24	P-80	25.0	0.44
P-149	300	0.27	P-158	50.0	0.45
P-15	80	0.07	P-22	10.0	0.45
P-150	400	0.37	P-403	100.0	0.46
P-151	100	0.16	P-57	200.0	0.46
P-152	250	0.28	P-276	10.0	0.47
P-153	150	0.16	P-83	25.0	0.47
P-154	250	0.29	P-119	25.0	0.48
P-155	250	0.28	P-40	25.0	0.5
P-156	100	0.14	P-281	25.0	0.53
P-157	50	0.09	P-6x	150.0	0.53

P-158	100	0.14	P-13	200.0	0.55
P-159	80	0.05	P-12	300.0	0.55
P-16	400	0.03	P-156	25.0	0.56
P-160	80	0.06	P-17	300.0	0.56
P-161	300	0.34	P-68	25.0	0.6
P-162	150	0.24	P-396	25.0	0.6
P-163	150	0.22	P-58	75.0	0.62
P-164	150	0.26	P-26	300.0	0.64
P-165	250	0.35	P-37	75.0	0.64
P-166	200	0.01	P-74	25.0	0.67
P-167	80	2	P-304	100.0	0.69
P-168	150	0.28	P-59	25.0	0.72
P-169	150	0.24	P-175	25.0	0.73
P-17	400	0.01	P-34	200.0	0.75
P-170	100	0.12	P-300	250.0	0.76
P-171	300	0.36	P-4	100.0	0.78
P-173	50	0.12	P-62	300.0	0.78
P-174	100	0.19	P-177	25.0	0.79
P-175	80	0.15	P-61	100.0	0.8
P-176	150	0.21	P-117	50.0	0.81
P-177	100	0.15	P-258	100.0	0.81
P-178	200	0.33	P-18	150.0	0.82
P-179	150	0.32	P-286	300.0	0.83
P-18	350	0.05	P-314	200.0	0.83

P-180	80	0.17	P-255	100.0	0.83
P-181	50	0.21	P-56	50.0	0.84
P-182	150	0.28	P-227	100.0	0.84
P-183	150	0.2	P-273	300.0	0.85
P-184	80	0.04	P-53	50.0	0.86
P-185	300	0.37	P-36	200.0	0.88
P-20	400	0.03	P-236	75.0	0.88
P-207	600	0.56	P-216	100.0	0.88
P-208	150	0.25	P-109	250.0	0.88
P-209	400	0.44	P-23	150.0	0.89
P-210	80	0.12	P-218	200.0	0.91
P-211	80	0.12	P-165	250.0	0.91
P-212	400	0.47	P-181	25.0	0.93
P-213	150	0.25	P-324	75.0	0.93
P-214	250	0.32	P-8	100.0	0.95
P-215	300	0.38	P-282	250.0	0.96
P-216	150	0.29	P-263	25.0	0.98
P-217	350	0.42	P-368	25.0	0.99
P-218	200	0.33	P-178	200.0	1
P-219	250	0.38	P-217	350.0	1
P-22	200	0.06	P-79	25.0	1.01
P-220	150	0.27	P-374	75.0	1.01
P-221	300	0.4	P-400	75.0	1.01
P-222	400	0.47	P-103	100.0	1.03

P-223	250	0.33	P-163	100.0	1.04
P-224	80	0.06	P-219	250.0	1.04
P-225	150	0.28	P-315	300.0	1.07
P-226	300	0.43	P-72	75.0	1.08
P-227	150	0.22	P-64	200.0	1.1
P-228	300	0.43	P-237	250.0	1.1
P-229	100	0.18	P-116	100.0	1.11
P-23	300	0.06	P-210	50.0	1.12
P-230	150	0.25	P-211	50.0	1.12
P-231	80	0.19	P-387	75.0	1.14
P-232	100	0.24	P-348	300.0	1.14
P-233	150	0.24	P-270	100.0	1.16
P-234	150	0.26	P-110	250.0	1.16
P-235	80	0.19	P-259	200.0	1.16
P-236	100	0.25	P-153	100.0	1.17
P-237	250	0.35	P-30	100.0	1.17
P-238	150	0.24	P-325	200.0	1.18
P-24	80	0.22	P-69	75.0	1.18
P-251	200	0.36	P-71	50.0	1.18
P-252	150	0.28	P-152	250.0	1.19
P-253	250	0.36	P-81	100.0	1.19
P-254	300	0.42	P-265	75.0	1.2
P-255	200	0.33	P-257	100.0	1.21
P-256	300	0.47	P-173	25.0	1.23

P-257	150	0.29	P-279	200.0	1.24
P-258	150	0.24	P-320	250.0	1.24
P-259	200	0.34	P-77	50.0	1.24
P-26	400	0.11	P-224	50.0	1.26
P-260	80	0.2	P-330	100.0	1.26
P-261	80	0.01	P-14	300.0	1.27
P-262	80	0.19	P-378	150.0	1.28
P-263	75	0.21	P-260	50.0	1.28
P-264	250	0.37	P-154	250.0	1.29
P-265	100	0.19	P-155	100.0	1.29
P-266	250	0.43	P-256	300.0	1.31
P-267	250	0.42	P-397	25.0	1.33
P-268	250	0.43	P-313	200.0	1.33
P-269	250	0.43	P-342	200.0	1.33
P-270	150	0.3	P-60	400.0	1.34
P-271	100	0.07	P-346	250.0	1.34
P-272	100	0.54	P-301	200.0	1.35
P-273	300	0.47	P-114	100.0	1.35
P-274	300	0.43	P-223	250.0	1.35
P-275	300	0.41	P-235	50.0	1.36
P-276	150	0.28	P-11(2)	100.0	1.37
P-277	150	0.26	P-150	400.0	1.38
P-278	50	0.16	P-328	75.0	1.38
P-279	200	0.39	P-169	100.0	1.38

P-28	100	0.06	P-180	50.0	1.41
P-280	150	0.33	P-8(1)	160.0	1.42
P-281	50	0.12	P-8(2)	160.0	1.42
P-282	250	0.42	P-7x	200.0	1.42
P-283	150	0.33	P-307	200.0	1.42
P-284	80	0.44	P-65	100.0	1.43
P-286	300	0.46	P-214	250.0	1.43
P-287	150	0.31	P-365	200.0	1.43
P-29	50	0.09	P-305	75.0	1.44
P-30	200	0.05	P-308	75.0	1.44
P-300	250	0.39	P-225	100.0	1.44
P-301	200	0.48	P-253	150.0	1.45
P-302	150	0.3	P-309	75.0	1.46
P-303	200	0.38	P-212	400.0	1.46
P-304	150	0.28	P-384	50.0	1.47
P-305	100	0.21	P-160	50.0	1.47
P-306	50	0.15	P-14x	25.0	1.47
P-307	200	0.36	P-272	75.0	1.48
P-308	100	0.21	P-147	100.0	1.49
P-309	100	0.18	P-183	100.0	1.49
P-310	80	0.21	P-401	150.0	1.5
P-311	300	0.5	P-312	100.0	1.5
P-312	150	0.31	P-303	200.0	1.5
P-313	200	0.35	P-404	300.0	1.51

P-314	200	0.35	P-66	25.0	1.51
P-315	300	0.45	P-162	100.0	1.51
P-316	350	0.52	P-389	200.0	1.52
P-317	150	0.27	P-16	200.0	1.53
P-318	150	0.34	P-120	25.0	1.53
P-319	200	0.38	P-352	75.0	1.53
P-32	100	0.02	P-340	75.0	1.54
P-320	250	0.45	P-102	400.0	1.54
P-321	80	0.21	P-364	200.0	1.56
P-322	100	0.24	P-63	150.0	1.56
P-323	300	0.48	P-73	75.0	1.56
P-324	100	0.22	P-369	50.0	1.57
P-325	200	0.36	P-264	250.0	1.57
P-326	150	0.31	P-168	100.0	1.58
P-327	150	0.33	P-20	200.0	1.58
P-328	100	0.33	P-164	100.0	1.6
P-329	150	0.34	P-252	100.0	1.6
P-330	150	0.3	P-238	100.0	1.62
P-336	150	0.31	P-266	250.0	1.62
P-337	400	0.63	P-267	250.0	1.64
P-338	350	0.52	P-118	25.0	1.65
P-339	200	0.37	P-382	50.0	1.65
P-34	300	0.09	P-383	50.0	1.65
P-340	100	0.28	P-343	75.0	1.65

P-341	100	0.09	P-386	200.0	1.66
P-342	200	0.35	P-106	400.0	1.67
P-343	100	0.24	P-377	75.0	1.67
P-344	400	0.6	P-182	100.0	1.68
P-345	400	0.59	P-284	50.0	1.71
P-346	250	0.46	P-268	250.0	1.71
P-347	150	0.4	P-113	50.0	1.71
P-348	300	0.47	P-222	400.0	1.72
P-349	250	0.43	P-76	10.0	1.72
P-35	150	0.01	P-15(1)	100.0	1.74
P-350	150	0.35	P-15(2)	100.0	1.74
P-351	150	0.35	P-174	50.0	1.74
P-352	100	0.28	P-35	50.0	1.74
P-353	150	0.38	P-319	200.0	1.74
P-354	100	0.37	P-70	75.0	1.74
P-355	200	0.39	P-321	50.0	1.74
P-36	300	0.09	P-277	100.0	1.76
P-364	200	0.44	P-269	250.0	1.76
P-365	200	0.42	P-355	200.0	1.76
P-366	400	0.68	P-105	400.0	1.76
P-367	80	0.15	P-24	50.0	1.8
P-368	50	0.19	P-67	25.0	1.8
P-369	80	0.16	P-209	400.0	1.8
P-37	100	0.12	P-104	400.0	1.8

P-370	150	0.31	P-354	75.0	1.8
P-371	150	0.34	P-167	50.0	1.81
P-372	100	0.34	P-323	300.0	1.83
P-373	150	0.37	P-233	100.0	1.83
P-374	150	0.32	P-13(1)	100.0	1.88
P-375	250	0.49	P-13(2)	100.0	1.88
P-376	200	0.38	P-82	75.0	1.89
P-377	100	0.38	P-179	100.0	1.94
P-378	150	0.53	P-338	350.0	1.94
P-38	200	0.06	P-220	100.0	1.95
P-381	100	0.27	P-176	100.0	2.01
P-382	80	0.2	P-283	100.0	2.01
P-383	80	0.2	P-234	100.0	2.04
P-384	80	0.21	P-149	150.0	2.04
P-385	150	0.43	P-171	150.0	2.04
P-386	200	0.54	P-339	200.0	2.04
P-387	100	0.34	P-351	100.0	2.05
P-388	150	0.38	P-207	600.0	2.07
P-389	200	0.52	P-232	75.0	2.09
P-394	150	0.35	P-345	400.0	2.1
P-395	100	0.51	P-344	400.0	2.13
P-396	100	0.24	P-185	150.0	2.13
P-397	100	0.32	P-170	50.0	2.16
P-398	100	0.33	P-398	75.0	2.16

P-399	80	0.17	P-327	100.0	2.18
P-40	80	0.03	P-6	400.0	2.19
P-400	100	0.31	P-7	400.0	2.19
P-401	150	0.63	P-287	100.0	2.22
P-402	250	0.53	P-275	300.0	2.23
P-403	75	0.41	P-311	300.0	2.24
P-404	300	0.66	P-280	100.0	2.24
P-405	80	0.44	P-322	75.0	2.25
P-53	80	0.05	P-399	50.0	2.25
P-54	80	0.06	P-385	75.0	2.27
P-55	80	0.06	P-254	300.0	2.28
P-56	80	0.07	P-274	300.0	2.28
P-57	300	0.21	P-317	100.0	2.35
P-58	150	0.12	P-166	100.0	2.36
P-59	80	0.04	P-337	400.0	2.37
P-6	250	0.02	P-329	100.0	2.4
P-60	400	0.23	P-251	200.0	2.4
P-61	300	0.19	P-366	400.0	2.41
P-62	300	0.2	P-302	100.0	2.42
P-63	250	0.11	P-261	50.0	2.42
P-64	300	0.12	P-372	75.0	2.42
P-65	200	0.12	P-11(1)	75.0	2.44
P-66	80	0.03	P-318	100.0	2.46
P-67	100	0.07	P-316	350.0	2.48

P-68	80	0.08	P-350	100.0	2.52
P-69	150	0.1	P-230	100.0	2.54
P-7	400	0.03	P-17(1)	100.0	2.55
P-70	150	0.14	P-17(2)	100.0	2.55
P-71	80	0.09	P-347	100.0	2.56
P-72	100	0.18	P-353	100.0	2.59
P-73	150	0.15	P-28	25.0	2.64
P-74	80	0.09	P-16(1)	100.0	2.65
P-75	250	0.16	P-16(2)	100.0	2.65
P-76	80	0.02	P-75	150.0	2.66
P-77	80	0.16	P-349	250.0	2.68
P-78	100	0.09	P-341	25.0	2.78
P-79	50	0.04	P-215	150.0	2.83
P-8	200	0.05	P-375	250.0	2.92
P-80	50	0.08	P-373	75.0	2.93
P-81	300	0.18	P-326	100.0	3.02
P-82	150	0.12	P-402	250.0	3.03
P-83	50	0.07	P-228	150.0	3.04
P-1	600	1.15	P-395	150.0	3.06
P-239	80	0.19	P-111	150.0	3.1
P-4	600	0.04	P-184	50.0	3.13
P-6	400	2.21	P-226	150.0	3.16
P-7	400	2.21	P-221	150.0	3.18
P-12(1)	160	0.01	P-161	150.0	3.27

P-12(2)	400	0	P-376	200.0	3.35
P-11(1)	100	0	P-12(1)	400.0	3.35
P-11(2)	100	0	P-12(2)	400.0	3.35
P-13(1)	110	0	P-148	100.0	3.4
P-13(2)	110	0	P-371	75.0	3.42
P-8(1)	160	0.01	P-112	50.0	3.65
P-8(2)	160	0.01	P-336	100.0	3.65
P-14	300	0.34	P-370	100.0	3.71
P-17(1)	152.4	0.01	P-394	75.0	3.84
P-17(2)	152.4	0.01	P-1	600.0	4
P-16(1)	152.4	0.02	P-159	25.0	4.27
P-16(2)	152.4	0.02	P-101	150.0	4.58
P-15(1)	152.4	0	P-388	75.0	4.77
P-15(2)	152.4	0	P-405	50.0	4.79

Some sources captured on December,2020