ADDIS ABABA INSTITUTE OF TECHINOLOGY (AAIT)
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

EVALUATION OF WATER QUALITY AND SUPPLY SYSTEM PERFORMANCE OF GEFERSA BY PASS SUB SYSTEM
(CASE STUDY OF KOLFE)

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Degree of Master of Science in Civil& Environmental Engineering
(Major in Water Supply & Environmental Engineering)

By

Seifedin Bedru Nasir

Advisor

Dr.ing. Geremew Sahilu

September, 2020

Addis Ababa, Ethiopia

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Approved by Board of Examiners

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ABSTRACT

*This research focused on the performance of water supply network of Kolfe keraniyo areas found in Kolfe keraniyo sub city of Addis Ababa Ethiopia. The main objective of this research was to evaluate the supply performance and chlorine concentration level of existing network of Gefersa by-pass sub system in Kolfe keraniyo areas. The area is known with high number of yearly diarrhea cases with average of 850 children with age of under-five. The basic tasks done in the research are measurement of sample data for pressure and chlorine residual from different locations of the study area followed by bottle test analyses for the chlorine residual, and use of simulation model of Bentley Water GEMS Software to identify the pressure effect on residual chlorine in the water supply distribution system. The model is used to identify the zone of high pressure and low pressure in junctions and the level of chlorine residual and velocity through pipes. The study results showed that the water supply coverage of the study area is 66.24% as GTPII set per capita demand of level I towns. This indicates that there is high gap between demand and supply. Aged pipes are observed on the area, 43% and 71.3% of the pipes are greater than 25and 15 years respectively which can be the cause for leakage and water quality problems. The conducted simulation result shows chlorine residual is inversely related with water age in the system. The aggregated bill consumption data and NRW estimated from the branch office and review of recent research result is used. As it is estimated 40% of the production i.e. 1492220.667*m^3*/year is lost as NRW. 7 to 8mg/l of Chlorine is being added in Gefersa treatment plant reservoir as disinfectant and the model for water quality is based on it and adopted 8 mg/l for the source for the model simulation. The residual chlorine was calibrated by adjusting wall reaction coefficient. It is modeled with first order reaction based on the test of sample data by resulting -0.75/day of bulk reaction rate and -0.55 /day of first order wall reaction rate the effect of pressure can be seen in both ways either increasing or retarding chlorine consumption based on the scope and hydraulics of the system. Majority of the simulation results for the area showed that residual chlorine has direct relationship with the change of pressure in the distribution systems. For the improved system, 8958.3*m^3*/d should be added on the existing network in order to fill the gap with introducing some pressure reducing valves to minimize excess loaded pressure.*

Key words: ADDIS ABABA, KOLFE, WATER GEMS, NRW, PRESSURE, RESIDUAL CHLORINE

DECLARATION

The work provided in this thesis is my own work except the one which is paraphrased in the document or mentioned under the reference part and has not been submitted elsewhere for any other degree or qualification.

Student's name: Seifedin Bedru Nasir

Signature: _______________

Date: September, 2020

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List of Abbreviations

JMP	Joint Monitoring Program
UFW	Unaccounted for Water
MoWR	Ministry of Water Resource
CGAA	City Government of Addis Ababa
EACE	Ethiopian Association of Civil Engineers
AAWSA	Addis Ababa water and sewerage authority
WSS	Water Supply Stage
AAWSP	Addis Ababa water and sewerage project
ft	feet
lb	pound
GPS	Global Positioning System
M	Meter
D	Day
THMS	Tri halo methane
HPC	Heterotrophic Plate COUNT
L/c/d	Liter per Capita per Day
l/s	liter per second
MDG	Millennium Development Goal
SDG	Sustainable Development Goal
NRW	Non-Revenue Water
EPA	United States Environmental Protection Agency
EPS	Extended Period Simulation
GIS	Geographical Information System
HDPE	High Density Poly Ethylene pipe
DCI	Ductile cast iron
GTP	Growth and Transformation Plan
WDS	Water Distribution System
GLAAS	Global Analysis and Assessment of Sanitation and Water
USGS	United State geological survey

CHAPTER ONE

1. Introduction

1.1. General Background

Water plays a fundamental role to life no matter where it is found. It is no surprise then that water covers over 71% of the Earth's surface and is also found in large quantities throughout the ground and air (USGS, 2014). Despite its essentiality to humans and to life in general, adequate treatment of water to avoid illness and death from its consumption was largely unaddressed for the majority of recorded history(Jeremy S. Carlston, 2015).

The Sustainable Development Goals (SDGs), as part of the 2030 Agenda for Sustainable Development, build upon the many achievements made under the Millennium Development Goals (MDGs), but are more aspirational, extensive and ambitious. Goal6 is focused on clean water and sanitation. Going beyond "improved" drinking-water and sanitation, Target 6.1 calls for universal and equitable access to safe and affordable drinking-water, and Target 6.2 aspires to access to adequate and equitable sanitation and hygiene for all, as well as the end of open defecation (GLAAS, 2017).

At the end of the Millennium Development Agenda in 2015, the results achieved by the Millennium Development Goals (MDGs) were mixed. According to the United Nations, the water-related MDG target had been achieved, yet in 2015 there were still 663 million people without access to an improved drinking water source. Furthermore, even where a water point is deemed to be 'improved', this is no guarantee that the water point is operational, or that water is available and is safe to drink. Thus, it is estimated that at least 1.8billion people around the world are using water sources contaminated with faecal bacteria in 2015 ((Colette Génevaux, 2018).

As they cited from WHO 2017b, drinking water and sanitation access is key to disease prevention. Diarrheal disease alone is responsible for the deaths of 1.5 million people every year, including 360,000 children under the age of five, mostly in low-income countries. It is estimated that 58% of diarrheal diseases can be attributed to unsafe water supply, sanitation and hygiene (Weststrate, 2018).

A well performing urban water supply system should provide water supply for human being and livestock consumption, for industrial and other uses in terms of coverage, quantity, reliability and acceptable quality taking the existing and future realities of the city in to consideration. Even though safe drinking water is one of the basic necessities for human beings billions of people in the world have no access for safe drinking water. Significant number of the population is from the developing countries. The most vulnerable parts of the society are particularly women and children. Each day in the world and in Ethiopia significant numbers of children are dying due to lack of safe drinking water, appropriate sanitation and hygiene (MOWIE, 2015). Specifically, diarrheal diseases are among the main contributors to global child mortality, causing about 10% of all deaths in children under five years (GLAAS, 2017).

Improved water supply and sanitation, and better management of water resources, can boost countries' economic growth and can contribute greatly to poverty reduction. In 2010, the UN general assembly explicitly recognized the human right to water and sanitation. Everyone has the right to sufficient, continuous, safe, acceptable, physically accessible, and affordable water for personal and domestic use. However, population growth and economic development are putting constant pressure on water resources (WEF, 2014).

Target 6.1 'To achieve universal and equitable access to safe and affordable drinking water for all' is measured by the indicator 'proportion of population using safely managed drinking water services'. Safely managed drinking water services, in their turn, are defined as 'drinking water from an improved source which is located on the premises, available when needed and free from contamination and priority contamination' (WEF, 2014).

As cited from UNICEF and WHO,2015 from authors, including Solo *et al.*, (1993) and Cronin *et al*. (2008) have summarized the major constraints that hinder the efforts of the various institutions to provide adequate water supply and sanitation as follows: institutional inadequacy and insufficiency of conventional approaches that did not recognize progressive improvement of infrastructure; supply-driven infrastructure provision sticking to rigid planning/ design standards and regulations; and high cost of conventional systems that did not recognize progressive improvement of infrastructure. Countries in which less than 50% of the population using improved drinking water sources are all located in Sub Saharan Africa and Oceania (UNICEF and WHO, 2015).

The majority of citizens in Ethiopia are unable to get access to the quantity and quality of potable water (Bekele, 2016).

As the result of Ethiopia's substantial progress in increasing water supply coverage, the country has developed a strong policy and planning framework. This includes the ambitious government led Universal Access Program that is backed by increased resource mobilization from both government and donor agencies (WSP, 2015).

Water Distribution Networks (WDN) provides adequate water requirements for various usages, including domestic, commercial, and industrial purposes. They must meet demands at each node at all times and at a sufficient pressure head.

However, the main challenge currently in the operation of WDNs comes from pressure deficiencies resulting from events such as loss from leaks and bursts, as well as loss of hydraulic capacity because of deterioration of aging water pipes. These conditions affect the hydraulic performance of the system and water quality. Thus, it is necessary to consider the effect of such conditions on the hydraulic and water quality behavior in WDNs). According to the World Bank 'real losses' from these systems globally amount to more than 32 billion $m^3$of treated water annually an estimated global average of 20%. Even more concerning, in some low-income countries, this loss represents 40-50% of water supplied (Alsaydalani, 2019).

Most of the water supplies systems in developing countries do not guarantee the access to safe drinking water, due to either the intermittency nature of the systems or the poor operational practices in continuous supplies. These situations affect directly the efforts that the world is paying with regards to the achievement of water supply–related UN Millennium Development Goals (Action faim, 2008).

Addis Ababa was established as the capital city of Ethiopia in 1886 and has grown to become the largest urban and commercial center in the country. During its early years, the principal sources of water were the numerous springs located at the foot of Entoto Mountain and hand dug wells located in the lower areas. The larger springs were tapped and fed into a number of small tanks for local distribution Continued growth necessitated the construction, in 1938, of a plant at the foot of Entoto to treat water from a number of springs and the nearby Kechene River, and in 1944 the original Gefersa dam located North West of the city was constructed. The *Gefersa* Dam was raised and a treatment plant built in 1960, while many of the springs were taken out of service because their quality was deteriorated. In 1966, the raw water storage capacity in the *Gefersa* watershed was increased with the construction of another small dam north of the existing dam. This dam was also assumed to assist as a sediment trap. At this time primary source of Addis Ababa's water supply relied on the *Gefersa* facilities. The supply from *Gefersa* was transmitted via twin 400mm pipelines to nine service reservoirs for distribution. (EACE, 1998)

Addis Ababa City is supplied with water from groundwater (wells bored at Akaki wellfields, Legedadi well field and other well fields), various springs and wells scattered throughout the city and three main surface water sources (Legedadi, Dire and Geffersa reservoirs). The current accelerated urbanization of Addis Ababa has posed threats since the size and location of cities to some extent determine the types of threats posed and the types of possible solutions (GWP, 2011).

Ethiopia is one of the participant countries that decided the millennium development announcement with its main impartial of poverty reduction. This resulted in prioritizing accessibility to improved drinking water quality. Therefore, to achieve these goals, drinking water quality concerns are often the most important component for measuring access to enhanced water supply sources & treatment distribution systems for the public. Acceptable water quality shows the safety of drinking water in terms of its physical, chemical, and bacteriological parameters (WHO, 2004). User communities‟ perceptions of quality also carry great weight in their drinking water safety (Doria, 2010).

As discussed from (WHO, 2011) Chlorine residual is used worldwide as hygienic barrier in drinking water system. Chlorine concentration decreases as the water travels throughout the system where its levels must be enough to assure the disinfectant effectiveness. As the formation of toxic disinfection by products increase with chlorine concentration, this must be maintained in drinking water within a quite narrow range, usually between 0.2 and 1.0 mg/L((David Manuel Duarte Figueiredo, 2014).

Each year large volume of treated water is being lost through background leakage, pipe bursts from the distribution systems and managing inefficiency, for this reason it is getting harder to fulfill the gaps in relation with the mounting number of urban population. Also, additional large amount of water from treatment plants is driven in to distribution systems and delivered to consumers but not invoiced because of poor metering, corruption, theft and diverse managing problems. As a result, the water yields no revenue and leads the water supply service unsatisfactory (AAWSA, 2011).

The quality of drinking water is an influential environmental determinant of health, management has been a key pillar of primary prevention for more than 150 years, and it continues to be foundation for the prevention and control of water borne diseases. Water is essential for life, but it can and does transmit disease in countries in all continents from the poorest to the wealthiest. The most predominant water borne disease, diarrhea, has an estimated annual incidence of 4.6 billion episodes and causes 2.2 million deaths every year (UNICEF/WHO, 2012).

1.2. Statement of the Problem

Presently Addis Ababa faces a serious deficit in the water supply due to increased population and expanded economic activity in and around the subsystems. There is no continuous supply of water but water provision for the area under the subsystem is on fixed days per week. Leakage is a major problem for water utilities, as they affect the environmental and financial sustainability of urban water service and often a large source of unaccounted for water and a result of either lack of maintenance or failure to renew ageing systems. There are some areas in the existing distribution system with static heads in excess of over and above the maximum permissible static head (TAHAL, 2003).

Drinking water problem arises not only in terms of shortage of water or limited network distribution; rather it is because of large amount of water loss. As a result, in some undetected leakage areas intermittent supply possess a significant health problem letting the sewerage and non - potable water entering to the leak pipes during supply interruptions time and at a very low or negative pressure periods. So, solving of this health risk can be sufficient to detect leakage problems and allow standard continuous supply in the system.

Water infrastructure in the city is as old as the city itself with severely deteriorated quality and capacity due to long years of service. This aging of infrastructures is likely to pose significant challenge to sustain and advance their achievements in protecting public health and the environment; (Getinet, 2019).

According to the report of (AAWSA, 2014),most of the treated water supply that delivered to the demand is 60% from the total production, the remaining 40% considered as NRW.

This research to be carried in Kolfe keraniyo sub city is due to the presence of number of problems related to water. The supplied water is intermittent as other sub cities in Addis Ababa. The supplied water is usually highly turbid at end user. Since Kolfe is known with old history of infrastructure having old water sub system, it is known for high diarrhea incidence.

1.3. Objective

1.3.1. General Objective

The main objective of this research was to evaluate the supply performance and quality concerning residual chlorine concentration level of existing network of Gefersa by pass sub system in Kolfe areas and discuss on improved network.

1.3.2. Specific Objectives `

In addition to the above general objective, the following specific objectives are achieved.

- To evaluate water demand and supply at the study area.
- To quantify water loss in the area.
- To model the existing water distribution network of the study area.
- To check chlorine residual in the distribution system.
- To suggest improved network.

1.4. Research *Questions*

1. What is current gap between water supply and demand of areas under the subsystem?
2. What is the effect of pressure on residual chlorine?
3. How much of produced water is lost?
4. What looked like the chlorine residual in the distribution system?
5. What could be the solution to satisfy the demand?

1.5. Significance of the Study

The thesis document would be important to model and evaluate the other areas of Addis Ababa water distribution systems easily by using it as procedures.

The model might be used to solve continuous problems, analyze proposed operational changes, and prepare for newly proposed cases. By comparing model results with field observation, the operator can determine the cause of problems in the system and formulate solutions that will work correctly the first time, instead of trying to trail and- error changes in the actual system, like: low-pressure problems, finding closed valves, and low demand problems. In general, the research would be significant for AAWSA specially Addis ketema branch to cross check the performance of the system and to avoid the shortage of supply.

1.6. Organization of Research

This thesis included the following five chapters with detail discussions under each section portion.

Chapter one: Contains general introduction of water supply of Addis Ababa, description of the study area, statement of the problem, Significance of the Study and research objectives.

Chapter two: Discuss literature review related to water supply distribution system, components and basic aspects of general water losses and leakage parameter on water supply distribution system in relation with modeling practices and monitoring. Also, it discusses relating water quality, water age and their relation with pressure. Additionally, it is discussed on different computer modeling types and their application.

Chapter three: Discussion about the process of study area selection, data collections, methodology for the model preparation and procedure of the study.

Chapter four: The “Result and Discussion’’ section links the findings with global literatures and the results and observations that were observed relating with water supply problems in the study area.

Chapter five: This chapter deals on the conclusion and recommendation.

CHAPTER TWO

2. Literature Review

2.1. Urban water supply

Water is the most vital public resource on earth for its indispensable role in sustaining life, ecosystems, economic and social values towards sustainable development of countries (Cutter et al., 2015). This precious and most important limited resource is unevenly distributed across space and time. The rising water scarcity is becoming a leading world problem (Chigwenya, 2010). As Getnet cited from (Jägerskog, 2015),Providing sufficient, affordable and safe water and sanitation for all has become a critical challenge of increasing concern in the 21st century due to freshwater shortage, rapid population growth, water pollution, and unsustainable use of water resources, adverse climate change impacts, rapidly growing water demand and absence of cooperative water management frameworks. Water underpins many of the millennium Development Goals (MDGs) in that water is a vital role in food production, which constitutes one part of eradicating hunger, and water has a fundamental role in hygiene which is the main vehicle for reducing infections and child mortality but so far, less attention has been paid to it (Getnet, 2019).

2.2. Water supply sources

The metropolitan area of Addis Ababa is supplied with water from groundwater and three main surface water sources: Legedadi, Dire and Geffersa reservoirs. They are all situated in the upper northwestern Awash sub basin. Intensive crop cultivation and free grazing by livestock, soil erosion, chemical pollution and siltation of Legedadi and Gefersa dams are becoming very serious problems. The situation has drastically reduced the water holding capacity of the dams worsening shortages in the water supply. AAWSA expends millions of Birrs annually for treatment of the dams. Water from Dire reservoir is transferred to Legedadi for treatment (Antonaropoulos and associates, 2012) and water from Gefersa dam are treated at the Gefersa treatment plant. Gefersa dam, the first conventional surface water supply for Addis Ababa source is situated west of Addis Ababa along the road to Ambo town was originally constructed in 1942. It consisted of a masonry structure approximately 9 m in height. The dam was raised to 16 m crest height in 1955 which translated to an increased storage capacity of 6,200, 000 m3. The operation of the treatment plant was commissioned in 1960. Gefersa III earth fill dam with an impoundment capacity of 1,200,000 m3 and approximate height of 15 m and a crest length of 220 m was constructed in 1966 to augment the Gefarsa main reservoir. Gefersa subsystem comprises supplies from Gefersa water treatment plant to service reservoirs of Rufael, Saint Paul, and Ras Hailu. This first dam in the capital has the capacity to disperse 30,000m^3/d. (Getnet, 2019).

2.3. Water Quality and Public Requirements

‘’Waterborne diseases are transmitted by poor water, and can affect other illnesses transmitted by the faecal-oral route. Efforts to reduce diseases are useless unless people use safe water and basic sanitation. Like all standards, those for drinking water have some drawbacks. To isolate effects, research often tends to consider one specific material rather than multiple combinations of contaminations in water. The same regulations are later applied for a variety of contaminants, and also the standards for drinking water are often the same for all people regardless of age, and gender. There are three specific individuals, classified as high-risk exposure groups, including: i) infants and young children; ii) pregnant women; and iii) elderly people, sick persons and/or those who has an immune system that has been impaired by disease or treatment (Immune-compromised people). The higher the exposure to chemical and microbiological contaminants in water, the higher the vulnerability is for high-risk individuals. Nevertheless, current standards generally do not propose higher protections for more vulnerable people, partly because of the overwhelming complexity of doing so.’’
(Mahdi Moradi Jalal, 2008).

2.4. Effect of Pressure on Water quality

The distance travelled and residence times have been causing to increase bacterial growth Heterotrophic Plate Count (HPC), chlorine consumption and hydraulic change (pressure) in water distribution system. Pressure has a reversed relationship with bacterial growth (HPC) and Pressure has a direct relationship with residual chlorine. Hydraulic change (pressure) has been causing to increase chlorine consumption more. (Hossein et al, 2012).

As discussed by hossein and others, systems that have big transmission line may have problem on changes of pressure in the distribution system. Because flow rate changes have been too much between water treatment plant and dead ends in distribution system. So, the systems will have low pressure in the downstream distribution system. High hydraulic changes has been responsible for the separation of bacteria from the pipe wall, the volume of bacteria will increase in those parts and once this happens, chlorine consumption will be high and may not be enough to be effective over the required area (Hossein et al, 2012).

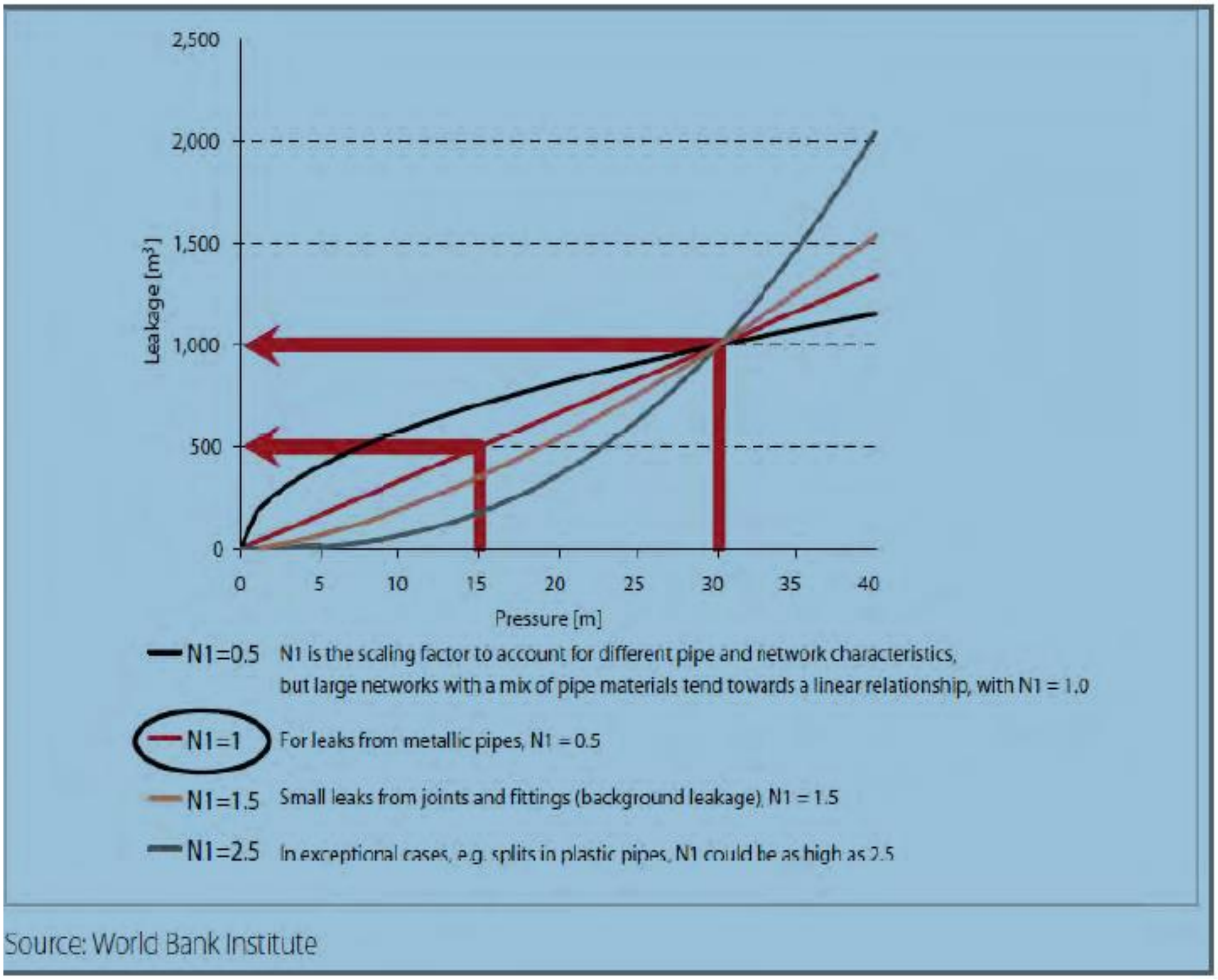
During operations of water supply system, cases of pressure drops, leakages and contamination occur and the main challenge is the lack of simple tool to accurately predict zones of low pressure and areas where quality is compromised. (Christopher Bwire et al, 2015)

‘’Pipes located below the water table are subject to pressure from the exterior water depending on the height of the water table above the pipe and thus an opportunity exists where water exterior to pipe could intrude into the pipe under low or negative pressure conditions within the pipe**.** Transient pressure events occur in distribution systems; that during these negative pressure events pipeline leaks provide a potential portal for entry of groundwater into treated drinking water; and that fecal indicators and cultivable human viruses’’ **(**Mark W et al., 2004).

2.5. Pressure and Leakage relationship

This concept is used to forecast the increasing or decreasing rate of real losses using a change in pressure. The simplest versions of the FAVAD concepts are leakage rate L (Volume/unit time) varies with pressure exponent N1, as: L1/L0 = (P1/P0) N1

N1 values might be in the order of 1 to 1.15 in the distribution system which contains different pipe materials. The higher the N1 value, the more sensitive existing leakage flow rates will be (Malcolm Farley, et al., 2008). As a result, a linear relationship of leakage flow rate and pressure can be assumed.



Source: World Bank Institute

Figure 2.1 Relation between pressure and leakage

2.6. Water Distribution Systems

The distribution network is responsible for delivering water from the source or treatment facilities to its consumers at serviceable pressures and mainly consists of pipes, pumps, junctions (nodes), valves, fittings, and storage tanks (Hopkins M. , 2012)

WDS are required to supply water to domestic, commercial, and industrial entities above or at a threshold pressure with consumer demands that vary throughout the day, weak, season and year. The minimum pressure that should be observed at junctions throughout the system varies depending on the type of water consuming sector and regulations governing the distribution system, but a typical operating range are between 28–70mH2O (Action faim, 2008).

Although the size and complexity of water distribution systems vary dramatically, they all have the same basic purpose to deliver water from the source (or treatment facility) to the customer.

For efficient distribution it is required that the water should reach to every consumer with required rate of flow. Water supply systems are generally constructed to provide sufficient water to the users with a specified pressure, quantity and quality. Water supply systems are comprised of three primary components; water source, treatment, and distribution network. Water sources can be reservoirs, rivers, and groundwater wells. The water that comes from water source is treated until it satisfies the water quality standards prior to delivering it to its consumers. The distribution network is responsible for delivering water from the source or treatment facilities to its consumers at serviceable pressures and mainly consists of pipes, pumps, junctions (nodes), valves, fittings and storage tank (Hopkins M. , 2012).

2.7. Leakage and NRW

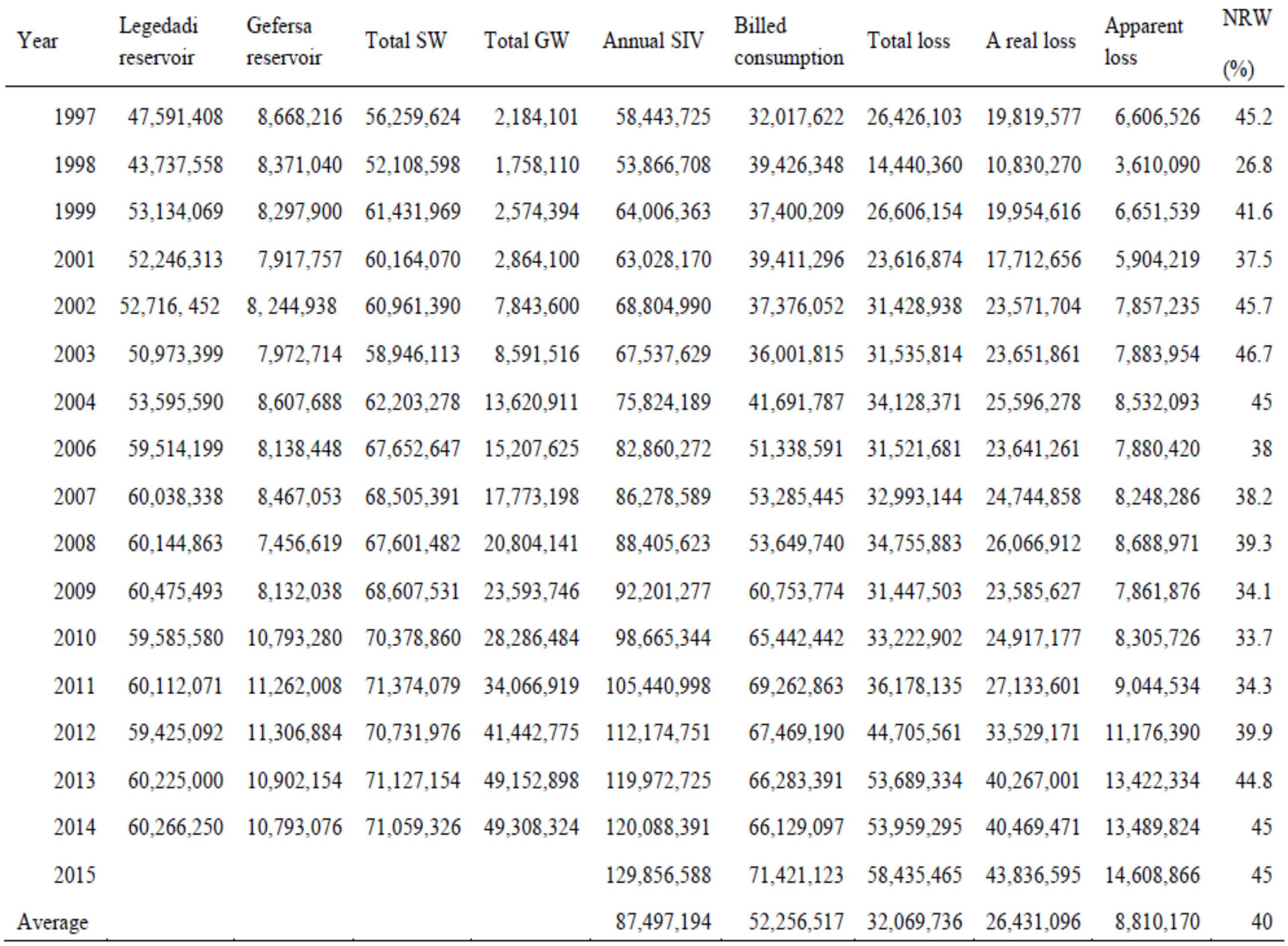
The country's plan showed the non -functional rural water supply systems will be reduced from 11.2% to 7% and Urban Fault Waters (UFW) is planned to decrease from 39% to 20% in the period. (GTP, 2016).

While pipelines are designed and constructed to maintain their integrity, it is difficult to avoid the occurrence of leakage in a pipeline system during its life time (Hovey and Farmer 1999). The daily leakage from a pipe network can be a major portion of about 10–80% of the total daily water consumption in different networks. The leakage may occur either by the failure of one or more pipes or by small openings and leaks located in the pipe walls and around the pipe junctions. (Massoud Tabesh et al, 2011).

There are different types of leaks, including service line leaks, and valve leaks, but in most cases, the largest portion of unaccounted-for water is lost through leaks in supply lines.
(EPD, 2007)

Research result done by Getinet Assabu in 2019 for certain last years as shown on Table 2.2 showed that the NRW from Legedadi and Gefersa reservoirs ranges from 26.8%to 46.7 % with average value of 40%. The same way branch offices in Addis Ababa are using this average value to estimate the water lost in the town. This research is also done based on these statistics to quantify the volume of water which is lost.

Table 2. 1 NRW for different years and their average



Year	Legedadi reservoir	Gefersa reservoir	Total SW	Total GW	Annual SIV	Billed consumption	Total loss	A real loss	Apparent loss	NRW (%)
1997	47,591,408	8,668,216	56,259,624	2,184,101	58,443,725	32,017,622	26,426,103	19,819,577	6,606,526	45.2
1998	43,737,558	8,371,040	52,108,598	1,758,110	53,866,708	39,426,348	14,440,360	10,830,270	3,610,090	26.8
1999	53,134,069	8,297,900	61,431,969	2,574,394	64,006,363	37,400,209	26,606,154	19,954,616	6,651,539	41.6
2001	52,246,313	7,917,757	60,164,070	2,864,100	63,028,170	39,411,296	23,616,874	17,712,656	5,904,219	37.5
2002	52,716, 452	8, 244,938	60,961,390	7,843,600	68,804,990	37,376,052	31,428,938	23,571,704	7,857,235	45.7
2003	50,973,399	7,972,714	58,946,113	8,591,516	67,537,629	36,001,815	31,535,814	23,651,861	7,883,954	46.7
2004	53,595,590	8,607,688	62,203,278	13,620,911	75,824,189	41,691,787	34,128,371	25,596,278	8,532,093	45
2006	59,514,199	8,138,448	67,652,647	15,207,625	82,860,272	51,338,591	31,521,681	23,641,261	7,880,420	38
2007	60,038,338	8,467,053	68,505,391	17,773,198	86,278,589	53,285,445	32,993,144	24,744,858	8,248,286	38.2
2008	60,144,863	7,456,619	67,601,482	20,804,141	88,405,623	53,649,740	34,755,883	26,066,912	8,688,971	39.3
2009	60,475,493	8,132,038	68,607,531	23,593,746	92,201,277	60,753,774	31,447,503	23,585,627	7,861,876	34.1
2010	59,585,580	10,793,280	70,378,860	28,286,484	98,665,344	65,442,442	33,222,902	24,917,177	8,305,726	33.7
2011	60,112,071	11,262,008	71,374,079	34,066,919	105,440,998	69,262,863	36,178,135	27,133,601	9,044,534	34.3
2012	59,425,092	11,306,884	70,731,976	41,442,775	112,174,751	67,469,190	44,705,561	33,529,171	11,176,390	39.9
2013	60,225,000	10,902,154	71,127,154	49,152,898	119,972,725	66,283,391	53,689,334	40,267,001	13,422,334	44.8
2014	60,266,250	10,793,076	71,059,326	49,308,324	120,088,391	66,129,097	53,959,295	40,469,471	13,489,824	45
2015					129,856,588	71,421,123	58,435,465	43,836,595	14,608,866	45
Average					87,497,194	52,256,517	32,069,736	26,431,096	8,810,170	40

Source: Getinet, 2019

2.8. Water Age associated with water quality problems

The increase in water age is dependent on the difference between the production and consumption rates, high residence time in pipes and storage duration in water tanks. According to (EPA, 2004) water age could cause chemical, physical and biological problems in the water distribution system and furthermore (Buligame et al. , 2011)observed that water age may be responsible for by-products in the distribution systems.

Table 2. 2 Summary of water quality problems associated with water age

Chemical issues	Biological Issues	Physical Issues
*Disinfection by-product Formation	*Disinfection by-product Biodegradation	Temperature increases
Disinfectant decay	*Nitrification	Sediment Deposition
*Corrosion control effectiveness	*Microbial regrowth / recovery / shielding	Colour
Taste and odour	Taste and odour	

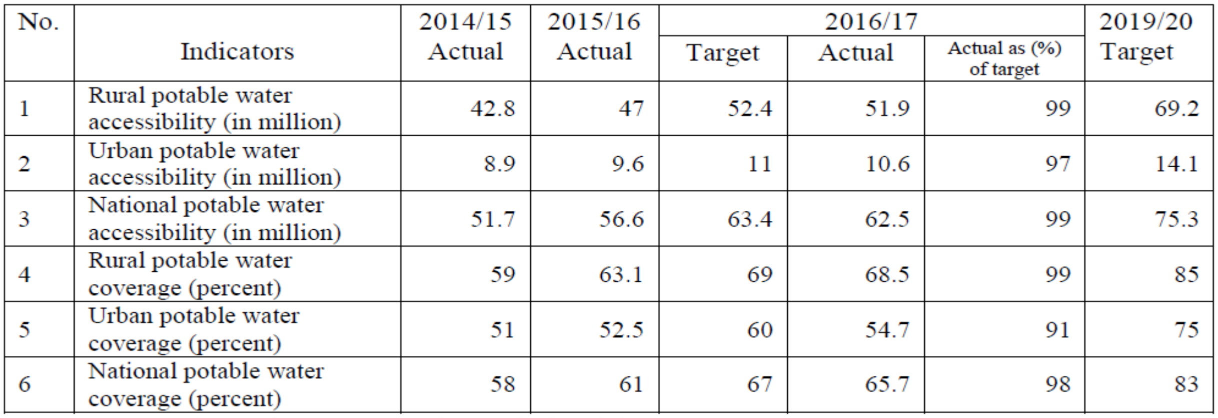
* Denotes water quality problem with direct potential public health impact.
Source: (J. Leonardo et al, 2006)

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. As the bulk water travels through the distribution system, it undergoes various chemical, physical and aesthetic transformations, impacting water quality (EPA, 2002).

2.9. *Water Supply and Population status*

The main objective of the water supply development program is to provide access to safe and sustainable supply of drinking water to the population in both the rural and urban areas of the country. Potable water accessibility at the national level had reached 56.6 million (rural 47 million, urban 6.6 million) at the end of 2015/16, up from 51.7 million (rural 42.8 million, urban 8.9 million) in 2014/15 – i.e., at the start of the GTP II period. In the fiscal year 2016/17, it was planned to further increase it by constructing 42,308 rural water facilities and 90 water schemes in urban areas. (GTPII, 2018).

Table 2. 3 Performance of potable water supply development, 2014/15 to 2016/17.



No.	Indicators	2014/15 Actual	2015/16 Actual	2016/17 Target	2016/17 Actual	2016/17 Actual as (%) of target	2019/20 Target
1	Rural potable water accessibility (in million)	42.8	47	52.4	51.9	99	69.2
2	Urban potable water accessibility (in million)	8.9	9.6	11	10.6	97	14.1
3	National potable water accessibility (in million)	51.7	56.6	63.4	62.5	99	75.3
4	Rural potable water coverage (percent)	59	63.1	69	68.5	99	85
5	Urban potable water coverage (percent)	51	52.5	60	54.7	91	75
6	National potable water coverage (percent)	58	61	67	65.7	98	83

Source: Ministry of Water, Irrigation and Electricity

2.10. Population and Development

The four key indicators of the population and development sector plan included in the GTP II are total Population size, population growth rate, dependency ratio and urban population. The annual targets for each one of these indicators were based on CSA‟s projections. The projections indicated that the total population of Ethiopia, growing at an average yearly rate of 2.3 percent, would increase from 89 million in 2014/15 (the base year of the GTP II) to 99.8 million in 2019/20 (the end year of the GTP II). It was also projected that, in the same period, the share of the urban population would increase from 19.5 percent to 22 percent (GTP II, 2018).

2.11. Pressure in water distribution system

The magnitude of the pressure change is influenced by the materials of construction, pipe characteristics, and the water velocity. Operational characteristics can further affect the significance of pressure transients, including: non-networked and dead-end pipelines, a lack of elevated distribution system storage tanks, undulating topography, entrained air, valve characteristics, and frequent power failures of pumping stations **(**Mark W et al., 2004).

2.12. Drinking water level

The main MDG indicator was "the proportion of population using an improved drinking water source". The criticisms rose during international consultations notably focused on the fact that criteria such as affordability, availability and quality were not taken into account. The key proposed indicator for the SDGs is indicator 6.1.1: "percentage of population using safely managed drinking water services".

It includes four criteria:

- ✓ an improved water source (using the MDG indicator definition of "improved": for instance, piped water into dwellings, yards or plots; public taps or standpipes; boreholes or tube wells; protected dug wells; protected springs and rainwater)
- ✓ that is located on premises,
- ✓ available when needed,
- ✓ and is free of faecal and chemical contamination.

Table 2. 4 Domestic drinking water ladders

Safely managed service	A basic (improved) drinking water source, which is located on premises, available when needed and free of fecal and priority chemical contamination
Basic service	An improved water point provided collection time is no more than 30 minutes for a round trip, including queuing
Limited service	Drinking water from unprotected dug wells, unprotected springs, carts with small tank/drum, tanker trucks or basic sources with a total collection time of more than 30 minutes for a round trip, including queuing
No service	Water coming from surface water: river, dam, lake, pond, stream, canal, or irrigation channel

Source (WASH, 2016)

2.13. Water Distribution Modelling

As he cited from Jeffrey A. Gilbert P.E, a model is a tool that can be used to determine the likely response of a system to a given set of stimuli without having to actually impose those stimuli on the system. Today, water distribution modeling is a critical part of designing and operating water distribution systems that are capable of serving communities reliably, efficiently, and safely, both now and in the future. With today’s technology and expedient software packages, we are able to model a system relatively quickly. This saves us from the repetitive iterations that determine the flows and pressures (Amdework Belay 2012).

2.14. Modelling tools

Epanet is a computer program that performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. Epanet tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of residual chlorine throughout the distribution network (rossman, 2000). Was dim being a computer based model which utilizes the principles of hardy cross technique of network analysis which is a trial and error method by which corrections are applied to assumed piezometric heads at junction points until acceptable hydraulic balance of the system is achieved. The model permits accurate computation of rates of flow through the system and the resulting head losses by utilizing Darcy weisbach formula for head loss computation and von- karma's friction factor formula for turbulent flow condition. Watercadv8i is a robust and user-friendly water distribution modeling program used for water distribution modeling and management. Fire flow, hydraulics, operations, criticality, and water quality can be modeled. The program can be run as a windows standalone program or run from within micro station. Water Gems unlike the others it includes different additional features maintaining its easiness for converting a data and maintaining a constant connection between the source and the model. Also for exporting a data back to the source in different formats and linking of the preference directly with cad or GIs and running the models inside the micro station of Auto Cad or Arc GIS is applicable.

The advantages of water Gems v8i over other software: it is tool for a simplified model building with geospatial modules like water quality modeling, fire flow analysis, optimization and scenario management etc. water Gems v8i is thus easy to use as a multipurpose water distribution schemes as well as quality modeling. in addition, the main advantage of water Gems v8iapplication is its various tools like Darwin designer for analyzing cost of pipes and pipe catalogue tools which are found to be very effective for modeling, design and optimization of water distribution network with respect to strong data management and integration along with auto cad, ArcGIS and other related software packages (Bentley systems, 2014) The research is done using Water Gems v8i software for its advantages over others.

2.15. Model Calibration

Hydraulic simulation models are nowadays widely used by planners, water utility personnel, consultants and others involved in the analysis, design, operation, or maintenance of WDSs. To make network simulation models applicable, it is necessary to calibrate them (Walski, 1983).

This is achieved by determining various parameters that, when are entered into a hydraulic simulation model, yield a reasonable match between measured and predicted parameters in the network **(**Shamir and Howard 1968). (Elsheikh, 2013)reviewed the discussion and finding of (Walski, 1983)and ATSDR (2000). described 7 steps process for model calibration, including: identifying model use, determining parameter estimates, collection of calibration data, evaluation of model results, macro calibration, sensitivity analysis, and micro calibration. Pipe grouping for roughness calibration was based on pipe type, age, and size. of (Walski, 1983)suggested that pressure-measuring devices should be located near points of high demand, near the perimeter of the skeletonized network, and generally distant from water sources.

2.16. Chlorine Residual

Some systems have big transmission system because the path length is long and are far from sources. These systems have high levels of chlorine injected to the system to ensure, there is still chlorine remaining in the network system at the end of the system. Although the chlorine is a major factor needed to work against bacteria in the distribution system, chlorine won’t be able to kill all of the bacteria in the distribution system. Velocity is important factor for the chlorine consumption and to decrease amount bacteria HPC in the water distribution systems. The effect of high residual chlorine, volume and high flow led to increased DBPs (THMs) in the distribution system. (Hossein et al, 2012). Depending on the results of the water quality tests, a long-lasting treatment solution (usually chlorine) could be used to prevent biological contamination. (GDP, 2018).

CHAPTER THREE

3. Methodology and Material

3.1. Study area description

This study was conducted in Addis Ababa city Kolfe three weredas i.e wereda 10, 11 and 12. The area is found in Kolfe subcity which is one of the ten sub cities found in Addis Ababa.

Addis Ababa was selected as the study area since it is known with its projected rate of urbanization, and the competition pressures on resources specially drinking water which made this city very important to be assessed for its water supply. The city is currently confronting with increased demand and scarcity of water supply which is associated with socioeconomic development of the city. Also Kolfe is currently known with dense population with different types of trade activities that increased the demand for water.

Location- Addis Ababa is located in the middle (heart) of the country between 8º55´- 9º05´ North latitude and 38º40´-38º50´ East longitude (Mahiteme, 2007). Its altitude varies between 2300 m in the south of the city and 3000 m in the north (CGAA, 2013)The research focused in Kolfe keraniyo sub city with three weredas (i.e. wereda10, 11 and12) as case study. These areas are similar with taking their water supply source from Gefersa reservoir as by pass sub system or taking directly from main line without balancing storage.

The study area is located between 9º0.1’- 9º03’North latitude and 38º41’40’’-38º42’40’’ east longitude. The elevation is between 2340m and 2490m.

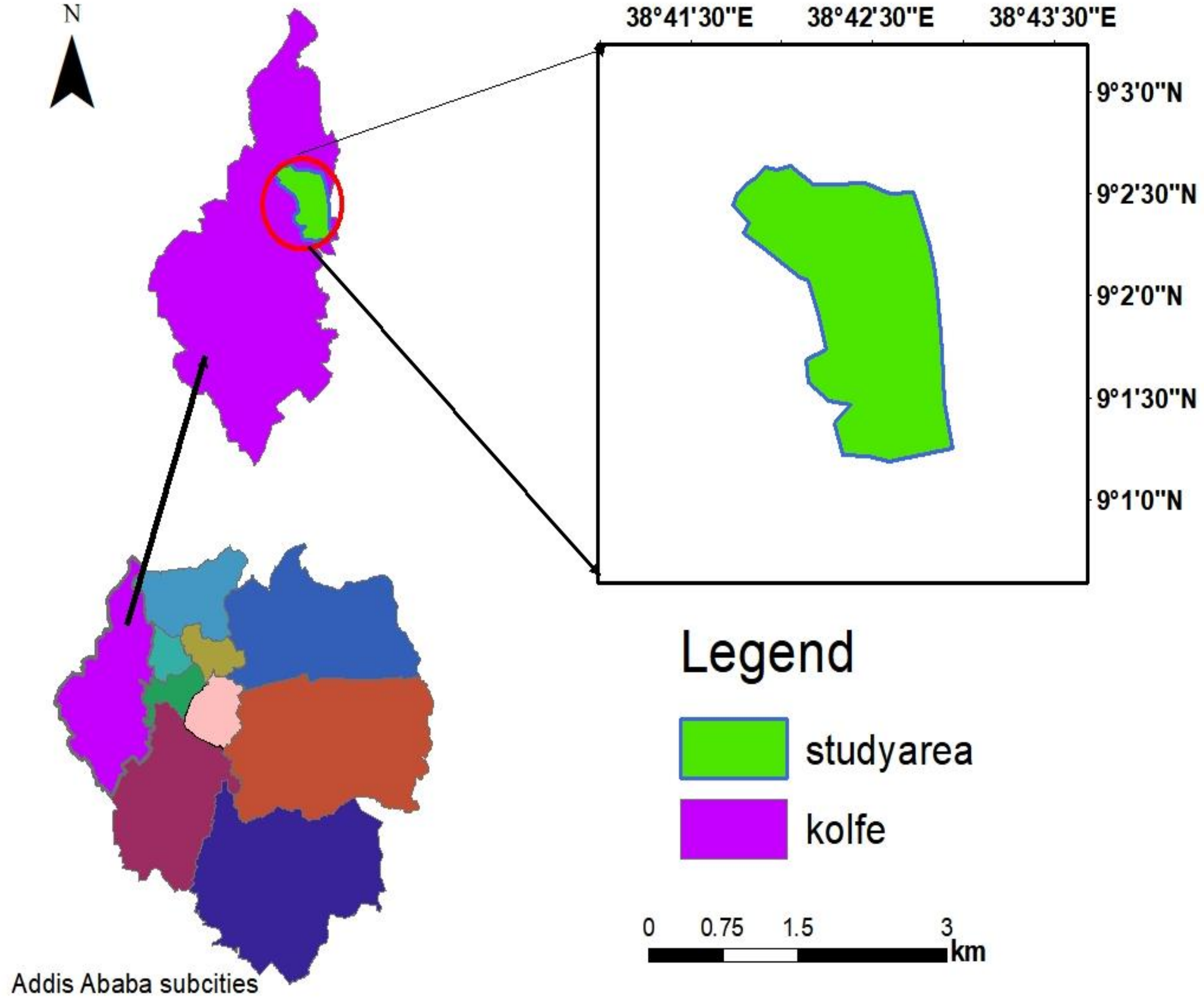


Figure 3.1. Location map of study area

Addis Ababa is divided into ten Sub-Cities stemming from the 2003 reforms onwards and every sub-city has its own administrative autonomy. The spatial organization shows that Lideta, Kirkos, Arada and Addis-Ketema represent the core or central area where as Akaki, Nefas-Silk-Lafto, Kolfe Keraniyo, Gulele,Yeka and Bole correspond partly to the expansion areas at their peripheries. The research is done in three weredas found in Kolfe keraniyo sub city that get their source from Gefersa reservoir.

The public institution AAWSA is responsible for the supply of potable water. At present, it delivers 608, 000m3/day to the city. AAWSA's head office is located at Megenagna. It is divided into eight branch offices across Addis Ababa city to render efficient services. The eight branches are Gurd Shola, Megenagna, Arada, Gulele, Addis Ketema, Nifas Silk, Mekanisa, and Akaki branches. Their principal functions are the provision, connection and maintenance of minor water and sewer cannels (Kombe, 2015)

Currently the city of Addis Ababa gets its water supply from both surface water and ground water sources. There are three main surface water dams as sources for the surface water supply. These are Gefersa, Legedadi and Dire dam. The ground water source is from Legedadi ground water, Akaki ground water (Akaki well field) and from spring and wells within and near Addis Ababa.

There are two conventional water treatment facilities, namely Legedadi water treatment plant and Gefersa water treatment plant to supply the city treated water from the above different sources. Gefersa dam is situated 18 km west of Addis Ababa; Legedadi dam is situated 25 km east of Addis Ababa; and Akaki well field is situated south east of Akaki town and about 22 km south of Addis Ababa.

3.2. Materials and Methods used

For evaluation of residual chlorine, performance and modeling of existing water supply system and to improve water supply service in the area, the following materials and methods are used.

3.2.1. Data Collection

Both primary and secondary data were used in this study. Details of the collected data are presented here. Available Secondary data is collected both from Addis ketema branch office and AAWSA head office. The layout in auto CAD format is taken to have the distribution network in order to know the skeleton of the network in the study area. The collected annual Billed data is also taken to evaluate the balance between demand and supply by comparing it with standard per capita demand and available demand for the study area. Total Chlorine dose in Gefersa treatment plant is known from branch office. It is 0.007-0.008kg per cubic meter. The population is found from each wereda's office in order to estimate the demand and supply gap. The type of pipe materials, fittings and valves are observed from the lay out taken from AAWSA in order to identify whether the system has material quality problem, aged pipes pressure reducing valves or not. The field data ran through pressure and chlorine residual in the distribution system. Both are measured from field taking random location of junction to calibrate the model.

3.2.2. Billed volume and Population data

The area is combination of three weredas having their own health office. Current collected population data is not available. Their respective collected population data in 2017 is taken from health office as stated in the table below. Using geometric incremental method, it is forecasted for current year. The growth rate of 2007 to 2037 is 3.7% as (CSA, 2013)

1. $Pn = Po\ (1 + r/100)^{n}$

Where, Po= initial known population i.e. the population at the end of 2017

Pn = population after n years i.e. population of 2020 which is present population

r= growth rate and n= number of years of the concerned period, 3 for this case

Table3. 1 Population data of the study area

Wereda Name	Pop in2017
wereda10	26228
wereda11	41000
wereda12	15788
total	83016
Growth rate (%)	3.7
forecasted population (present)	92576

Source: Wereda health office.

Table3. 2 Monthly consumption of the area

Month of 2019	Consumption in m3
January	216779
February	201939
march	193201
April	182484
may	201561
June	172404
July	152960
August	166246
September	184943
October	152027
November	212920
December	200867
sum	2238331

Source: AAWSA Addis ketema branch

3.3. Un- accounted for water

The difference between the total production without considering the water loss (system input volume) and total water distributed is known as volume of non-revenue water (unaccounted for water). It is the volume for which revenue is not collected by the water supply utility. Non-revenue water (NRW) can be aggregated value of the whole water supply system or disaggregated value of branches.

Water loss is a serious problem in Addis Ababa City Water Supply system, causing both severe water shortage and causing huge financial loss. Percentage by volume is used for calculating NRW as % of system input volume (Liemberger and Farley, 2004). Water loss can be calculated from total water production and net supply as follows: NRW (%) = (system input volume- billed volume)/system input volume **100%* Where system input volume is assumed to be the total production without considering water loss. Total billed consumption is the sum of the billed volumes of water used by all types of customers (domestic, non-domestic and public tap). For this research since the study area is specific and the system is intermittent to have constant system input volume, the average calculated value from AAWSA is taken as NRW (%). The appropriate book number or document files for the collected bill data for the specific area were 141,152,153and 154.The data collected was annual data and it is changed into average day demand.

3.4. Modelling of the distribution network

By using data for elevation, secondary and estimated data of Size of pipe, material type and other relevant parameters the water supply network is modeled by using Water GEMS software.

The hydraulic analysis has been done under the following conditions.

- ✓ Average loading condition
- ✓ Peak loading condition
- ✓ Under low loading condition

Elevation, demand, length, pipe size and type of materials and chlorine dose at the source were the input of water GEMS and velocity at pipe and pressure, chlorine residual and water age at every junction is developed as an output.

The boundary of the water distribution system is taken from AAWSA of whole distribution system in order to focus on the study area for this research.

Primary data is also required to calibrate and validate the model. The research is accomplished by taking field data for pressure and chlorine residual.

3.5. Modelling tool (Water GEMS)

Water GEMsv8i is a versatile hydraulic modeling software package with the advancements in the interoperability, optimization of networks; model building supported with geospatial tools and cost management tools. Water Gemsv8i is highly efficient and dynamic modeling software which provides the wide regime of analysis and solutions for fire-flow analysis, water quality modeling, energy and capital cost management, etc. Many of the features and functions are common in Water CADv8i and WaterGemsv8i which are streamlined model building, integration with the GIS and Auto CAD functionalities, optimized model calibration, design and its operations. The best part in the WaterGemsv8i is the presentation of obtained results which is very attractive and appealing and can be presented with variety of graphical tools. With the ever increasing number of users WaterGemsv8i has proved one of the most popular and user friendly hydraulic modeling and optimization software package. WaterGemsv8i has strong design algorithm to meet the criteria of accuracy in design of water distribution networks, control of distribution network variables like flow, pressure and velocity along with their optimization (Sonaje, 2015). Water GEMS is thus easy to use as a multipurpose water distribution schemes as well as quality modeling. In addition, the main advantage of Water GEMS application is its various tools like Darwin designer for analyzing cost of pipes and pipe catalogue tools which are found to be very effective for modeling, design and optimization of water distribution network with respect to strong data management and integration along with Auto CAD, ArcGIS and other related software packages (Bentley Systems, Incorporated, 2014).

Junctions: are points in the network where links join and where water enters or leaves the network (Rossman, 2000). The basic input data required for junctions are elevation above some reference (usually mean sea level), location (X-coordinate, Y-coordinate) and water demand (rate of withdrawal from the network).

Reservoirs: are nodes that represent an infinite external source or sink of water to the network. The primary input property for a reservoir is its hydraulic head. Because a reservoir is a boundary point to a network, its head is not affected by what happens within the network. Therefore, it has no computed output properties. For this research the source of water is

Gefersa reservoir which assists the clear water to the network after treatment from the treatment plant.

Pipes: are links that convey water from one point in the network to another. Flow direction is from the end at higher hydraulic head to that at lower head. The principal hydraulic input parameters for pipes during analysis were start and end nodes, diameter, length, roughness coefficient and status (open or closed). The computed outputs for pipes included head loss, velocity and flow. To compute friction head losses, Hazen-Williams equation were used with the assumption that viscosity is constant. Hazen William equation to compute friction head loses was as follows:

$$Hf = 10.68 * LQ^{1.85} / C^{1.852} D^{4.87} \tag{3.1}$$

Where, Hf= Head friction; Q= discharge (m^3/s); L=Length of the pipe (m); D=Diameter (mm) and C= Roughness coefficient which varies for different pipe materials and age.

The pipe roughness coefficient refers to a value that defines the roughness of the interior of a pipe. Two common roughness coefficients are the Hazen-Williams C-value and the Darcy-Weisbach f-value. Although the Darcy-Weisbach term is generally considered more accurate and flexible by giving information about flow regime, it is also more complicated and difficult to determine. Therefore, the Hazen-Williams C-value is commonly used in network modeling as used in case of this research. The higher the value, the smoother the interior surface of the pipe and the greater the carrying capacity of the pipe. Since the determination of C-values at the site is very difficult, generally the approximate values in literature are used by knowing the material type and installation year of each pipe. The Hazen William roughness coefficients value of different pipe materials are given in table 3.3.

Table3. 3 Hazen - William roughness coefficient for pipe material

Pipe age (years)	Pipe type		
	PVC	GI	DI
new	150	120	130
10-20	125	105	105
>20	105	96	96

Source: (chase et al, 2003)

The C- value is accordingly selected based on the above criteria by calibrating with the model values.

3.6. Demand allocation

The first procedure after the setting up of all the required information is allocation of estimated base demand. The demand is estimated based on the NRW and billed data. NRW is taken from recent research and branch office assumption being 40%. The billed data is taken from branch office to know how much water is effectively consumed by customers. Finally, the total base demand to be loaded in the source is the sum of the billed volume which is known and wasted water which is 40% of the total loaded volume. The total base demand is allocated for each junctions based on their proportional area by using a thiessen polygon tool found in the Water GEMS software.

3.7. Water Quality Modelling

Water quality modeling is a direct extension of hydraulic network modeling and can be used to perform many useful analyses. Designers of hydraulic network simulation models recognized the potential for water quality analysis and began adding water quality calculation features to their models in the mid-1980s (Thomas et al., 2003). Transport, mixing, and decay are the fundamental physical and chemical processes typically represented in water quality models. Water quality simulations also use the network hydraulic solution as part of their computations. Flow rates in pipes and the flow paths that define how water travels through the network are used to determine mixing, residence times, and other hydraulic characteristics affecting disinfectant transport and decay. The results of an extended period hydraulic simulation can be used as a starting point in performing a water quality analysis.

In the large water supply network systems, water travels a large distance with a long water residence time. The problem could affect water quality. Thus might be due to low pressure, big and multiple reservoir storages, inadequate disinfection in the system, leaking, fracture and work loose of joints, and so on. Even though, the problems of quantity are basic agents in the decay of water quality in distribution systems. One of the parameter that could reason to decrease water quality in distribution system is pressure change in network. (Shamsaei et al., 2013) .

A bottle test allows the bulk reactions to be unglued from other processes that affect water quality, and thus the bulk reaction can be evaluated exclusively as a function of time. The parameter of bulk reaction used to express the rate of the reaction occurring within the bulk fluid is called the bulk reaction coefficients can be determined using a simple experimental procedure called a bottle test. In addition, a bottle test allows for the evaluation of the impact of transport time on water quality and for an experimental determination of the parameters necessary to model this process accurately. Determining the length of the bottle test and the frequency of sampling is the first and most critical decision (Thomas, et al, 2003)

To get the bulk reaction coefficient, sample is taken to know chlorine decay in a given time interval to have decay constant or K_b value. The wall reaction (k_w) is calibrated based on the field value of chlorine residual in order to model the whole system of the study area chlorine residual.

3.8. Pressure and velocity variation

Ethiopian guideline criteria for the minimum and maximum operating pressure value in the distribution network are 15 and 70 m respectively ((MOWR, 2006)

The design criteria used in the design of water supply distribution system components, nodal pressure during the period of peak demand, and optimum velocities of the transfer and distribution mains are as follows. (TAHAL, 2003).

Minimum static head is 20 m, which can supply a 4-storey building from the distribution system.

Maximum static head within a pressure zone was limited to 80 m.

Control on the flow velocities in water distribution networks should be maintained in order to avoid structural problems or undesirable hydraulic regimes caused by high velocities, or in order to minimize the unfavorable consequences of too low velocities on the quality of the transported water (Tamminen etal, 2008).Optimum velocities of the transfer and distribution mains are as follows. (TAHAL, 2003)

- ✓ Maximum velocities of major transfer mains <2.5 m/s
- ✓ Maximum velocities of distribution mains < 2 m/s.

The absolute minimum velocity of flow in a pipeline is in the range 0.1m/s-0.3m/s, in order to avoid stagnation and water quality problems in the water system (Action faim 2008)

3.9. The variation of residual chlorine with pressure

The analysis of the effects of pressure changes on the residual chlorine in water distribution systems are carried out by using pressure gauge and colorimeter at selected sampling location of public fountains and customer tap point. The effect of pressure change on chlorine residual is observed based on the variation of concentration of chlorine residual with pressure change. In order to assess the relationship between the pressure and residual chlorine concentration in the system, the measured pressures and chlorine residual collected at different locations were used for calibration and validation of water Gems software for water quality model. The pattern of the simulated results for both is observed graphically to see the relation.

3.10. Network Simulation

Most small and medium towns do not have very complex networks as compared to cities; however, they have poor data and records regarding their systems. In such cases, when one has to evaluate the hydraulics and the water quality of the distribution systems, it is advantageous to use computer models. Computer models making use of hydraulic simulation software are capable of representing the behavior of a real time system and have the capability of predicting the performance of the same system for future ‘what if ‘scenarios (Haestad, 2003). Simulation can be used for analysis of the existing system to improve the supply in terms of pressure / flows/ and minimize leakage. Simulation of a network is also important to make decisions about the network augmentation requirements due to increase in water demand or expansion of a water servicing area. The understanding of pipe network flows and pressures is important for making such decisions for a water supply system (Swamee, 2008).

3.10.1.Steady-state simulation

It is the simplest simulation type and solves the system of equations as if the system Junction demands and tank elevations kept constant.

3.10.2.Extended-period simulations

Demand patterns: - the amount of water that consumed in the morning when everyone is getting ready for work is different at midnight. The extended-period simulation was chosen for this analysis because of its capability to model varying demands. The total simulation time was 24 hours with a one-hour time-step. Analysis at peak and minimum time consumption was simulated to identify the current problems of the system. This method is preferred for the research because it enables to quality modeling and timely varied output of the model.

3.11. Hydraulic parameters and variables

The main hydraulic variables in water distribution networks are the Pressure and the Flow rate, other relevant design factors are the pipe diameters, velocities, and the hydraulic gradients. The pressure at nodes depends on the adopted minimum and maximum pressures within the network, topographic circumstances, and the size of the network. The minimum pressure should maintain to ensure that consumers' demand provided at all times. The maximum pressure also contains limitation of leakage and lead to water losses in distribution system.

3.12. Model Calibration and Validation

Once a water distribution model has been developed, it must be calibrated so that it represents the actual working real life water distribution network under a variety of condition. This involves making minor adjustment to the input data then the model will simulate the pressure and chlorine residual in the system. Pressure and chlorine residual are measured on random sample locations in the water distribution system using pressure gage and colorimeter respectively to use the data for model calibration.

For the pressure the following standard value is used as standard (CAD/GEMs, 2008)

(1) 85% of field test measurements should be within ± 0.5 m or ± 5% of the maximum head loss across the system, whichever is greater.

(2) 95% of field test measurements should be within ± 0.75 m or ± 7.5% of the maximum head loss across the system, whichever is greater.

(3) 100% of field test measurements should be within ± 2 m or ± 15% of the maximum Head loss across the system, whichever is greater.

For the residual chlorine the following standard value is applied

The optimum chlorine residual in a small, communal water supply is in the range of 0.2 to 0.5mg/l (faim, 2008)

The maximum allowable WHO value for free chlorine residual in drinking water is 5 mg/L. The minimum recommended WHO value for free chlorine residual in treated drinking water is 0.2 mg/L. CDC recommends not exceeding 2.0 mg/L due to taste concerns, and chlorine residual decays over time in stored water (*CDC SWS Project).*

The calibrations have been carried for selected junctions. Majority of Both the pressure and residual chlorine are within acceptable range. The Calibrations for the two parameters were within the acceptable level checked for un- steady state at every time variation. Hence the model is valid for extended period simulation for both variables i.e. pressure and residual chlorine.

Calibration is an iterative procedure of parameter evaluation and adjustment by comparing simulated and observed values.

The hydraulic model calibration parameters that are typically set and adjusted include pipe roughness factors and Control valve setting. The changes in these parameters affect head losses, demands at node, pressure and residual chlorine. The result shows that when the Hazen-Williams roughness coefficient increases the value of pressure increases and head losses decreases. Based on this the Hazen-Williams roughness coefficient is iteratively used till the simulated result is well calibrated.

There are many ways to judge on the performance of model calibration. The evaluation was made by calculating the squared relative difference between observed and simulated pressure for each test. The evaluation criteria used was statistical method using correlation coefficient (R2) and graphical method.

$$R^2 \quad = \quad \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\Sigma}(y-y)^2} \qquad (3.2)$$

Where R^2 = Correlation Coefficient, x and y are measured and simulated values respectively, $\bar{x}$ $\bar{y}$ are average measured and simulated values respectively.

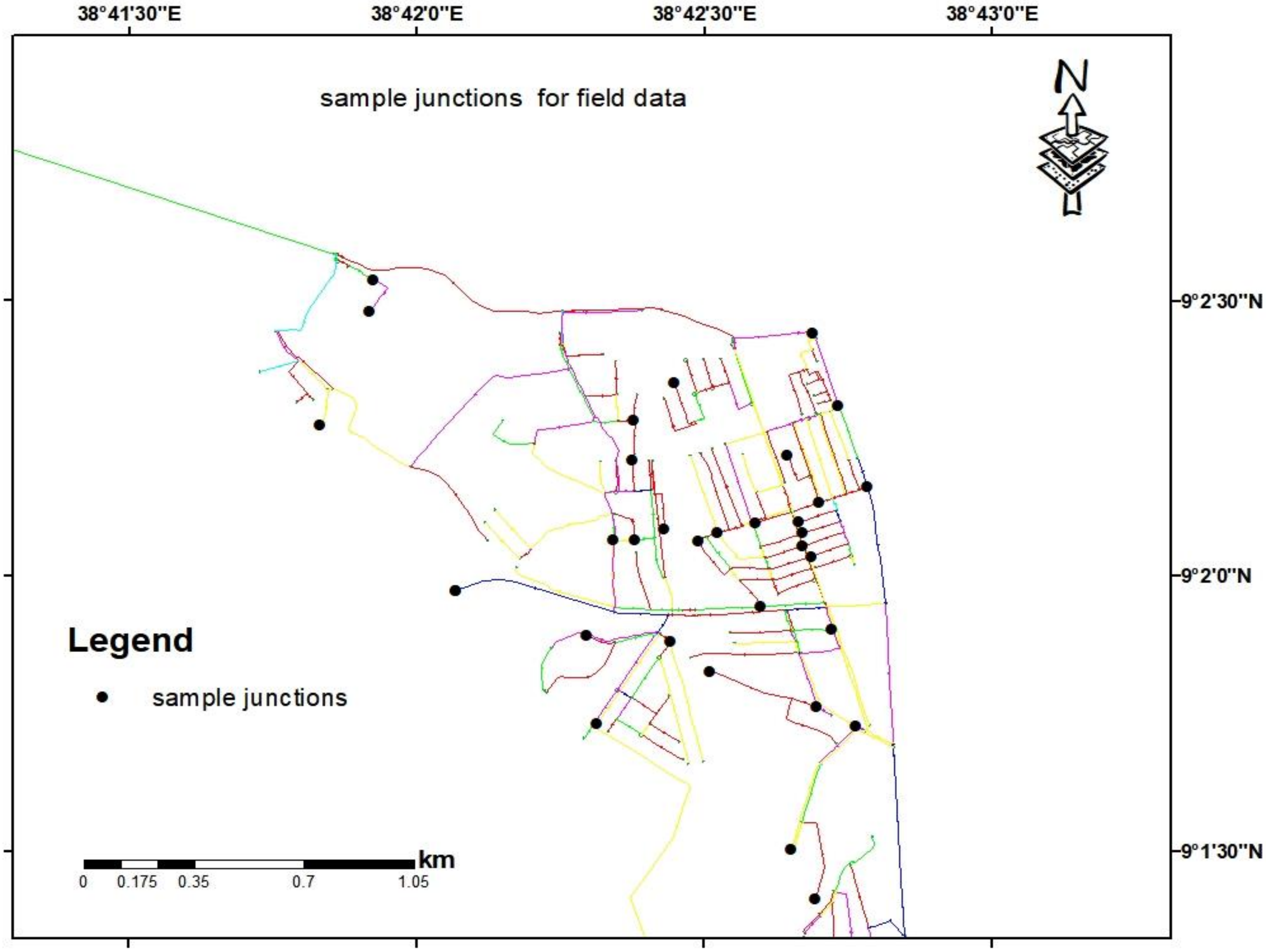


Figure 3.12 sample locations for data analysis

3.13. Materials used

The research is done using both hydraulically specified materials and common materials for data collection, calibration, document preparation and others. Pressure gage and colorimeter is used to measure field value of pressure and chlorine residual respectively. GPS device is used to collect the required elevation data during field data reading. It will be used to know exact location of data taken from field for calibration and validation. Also flash disk white paper and other related materials are used for the entire research period.

Figure 3.13. Photo for colorimeter captured on March 12,2020

3.14. Peak Daily and Hourly Factors

Many communities exhibit a demand cycle that is higher in one day of the week than in others. This situation shall be taken into account by the use of a peak day factor. Some consultants have used peak day demand factors of between 1.0 and 1.3. The value adopted for the design of each individual scheme shall be selected according to judicious observance of the habits of consumers and the knowledge of the community and system operators. It is expected that any value selected for the peak day factor would not fall outside the above range. Also Water demand varies greatly during the day. The distribution system must be designed to cope with the peak demand, which is taken into account by the use of a peak hour factor. The factors depend on the population consuming from the system.

Table3. 4 Peak Day and hourly Factor

Population	**MDF**	**PHF**
0 – 20,000	1.3	2
20,010 - 50,000	1.25	1.9
50,001 and above	1.2	1.8

Source: Design Manual of MoWR (2006)

3.15. Sensitivity Analysis of Parameters in Water Quality

The theoretical study of water quality management has the goal of developing mathematical models based on real water quality. Conclusions and information on water quality changes have been obtained by discussing and analyzing these models. ((y. z. tao and jiang), 2008)

Sensitivity analysis is a tool that may be used to ascertain

Forward use: how much the outputs of a given model depend on each or some of the input parameters;

Backward use: how variation in the outputs of a model can quantitatively or qualitatively be apportioned to different uncertain inputs (Frey et al, 2002)

There are a number of sources of uncertainty in drinking water distribution system modeling. Uncertain parameters include pipe diameters, consumer demands, hydraulic energy loss coefficients, reaction coefficients and others. Understanding the relative importance of these sources of uncertainty can improve the allocation of resources for model refinement and calibration, as well as, aid knowledge inference from monitoring data.

For this study the effect of reaction factors is observed. Both wall reaction coefficient and bulk reaction coefficients have effects on water quality with different sensitivity.

CHAPTER FOUR

4. Result and Discussion

4.1. Coverage of potable water

The annual water consumption data was converted to average daily per capita consumption using the population data. The annual billed data is divided by the population number to be percapita and by 365 to change the time into days and then by 3600 into seconds. The percapita demand became 66.24l/c/d. However, according to GTP II standard for urban area based on demand categories, Addis Ababa is found in level I because of population number of Addis Ababa is greater than one million and should have 100l/c/d. comparing the actual demand it is satisfied only 66.24% for the study area. The main reason for decrease in the town's per capita water consumption is the increase in the population number of the city and seasonal fluctuation of the source. The population number of the town is increasing from time to time with increasing demand on the existing water supply system of the city and the study area.

4.2. Total production and Water losses

In order to evaluate the consumed water and loss of water in the distribution system, consumption data of each customer's water volume were collected from billed data. The rate of water consumption at a node depends on the population served by that node, type of the demand (domestic, public, commercial, etc.), time of the year and the time of the day. Even for the existing water distribution systems, the nodal demands change due to many factors, such as new users or an increase in the number of existing users (Misirdali, 2003)

According to (Mckenzie et al , 2006)the system efficiency is good (acceptable) if above 75% of water produce reaches the consumer. Thus, the study area water supply system is not good. Even if there is no specific data for annual water supplied and consumption volume at the area, the aggregated bill consumption data and NRW estimated from the branch and review of recent research result is used. As it is estimated 40% of the production i.e. 1492220.667m^3/year is lost as NRW. Here the annual production for the specific study area is the sum of billed data which is 60% and the volume of water lost as NRW. The total production in terms of volume is estimated to be 3730552m^3/year.

4.3. Diameter, Age and types of Pipe for the WDS

Input parameters for pipes during analysis were start and end nodes, diameter, roughness coefficient and status. As observed in Table 4.1around33.65% of the distribution system is covered by pipe of less than or equal to50 mm, 34.26% is between 50mm and 100mm and 32.07 % is with diameter of greater than 100mm . Majority of the pipes are with material types of PVC with different standards. Regarding pipe age, 43% and 71.3% of the pipes are greater than 25and 15 years respectively. These shows there might be problem with corrosion and pipe breakage for intrusion of contaminants into the pipe line.

Table4. 1 Diameter status of the WDS

Pipe diameter(mm)	Percentage (%)
<=50	33.65
50<D<=100	34.26
D>100	32.07

Table4. 2 Material type of the pipes

Material type	Percentage (%)
ISOPE	20.85
HDPE	16.33
ISOPVC	20.75
JISPVC	21.31
GS and DCI	20.73

4.4. Water distribution network simulation

Distribution network starts from the point of water production, where water is produced and made ready to be used (Wonduante, 2013)For this research the network starts from Gefersa treatment plant and clear water storage. The system is gravity based and it feeds the study area through by pass with three points.

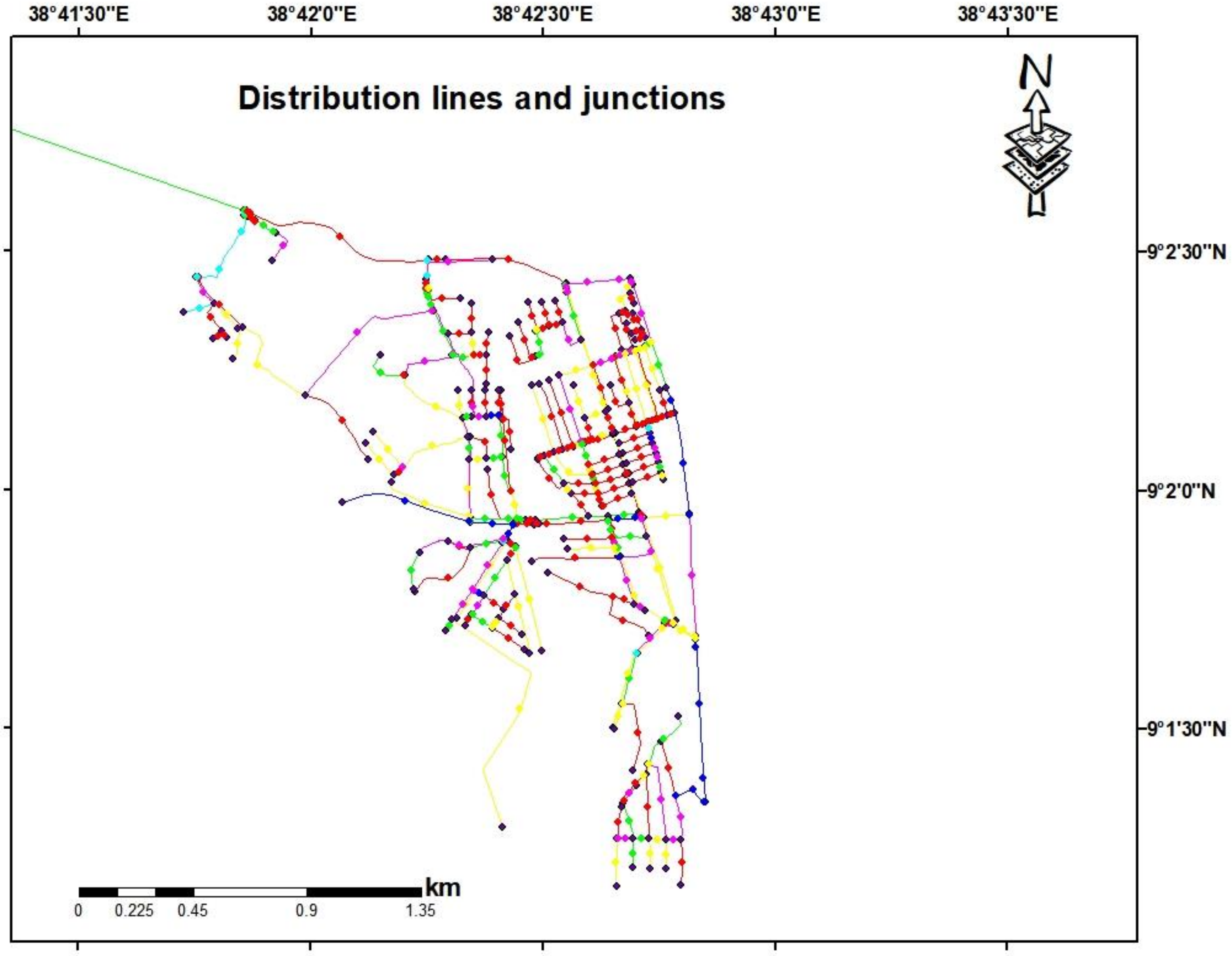


Figure 4.1 Distribution network skeleton of Kolfe study area with my modifications

The source starts from Gefersa reservoir and treatment plant. It feeds toward Giorgis reservoir and other two reservoirs on its path. But currently the two reservoirs i.e. k1 and k2 are not functional. For this study area the source is taken directly from the main line as by-pass system while the line is passing towards Rufael, Ras Hailu and St.Paul reservoirs. There are three locations to take water as by-pass for the area under study. These points are nearby Lomi meda, Philipos church and millennium preparatory school. The remaining area takes with gravity from these by-pass points. The study area is divided in to three zones based on their majority elevation and topography as well as wereda boundary in order to study pressure and elevation effect on the system. zone1 is from the beginning of study area from Lomi meda towards most part of wereda 11. Zone2 is combination of both wereda 11 and 12 with less elevation than zone1. Zone3 covers areas with lowest elevation including all wereda 10 towards far end points of the distribution system of the study area.

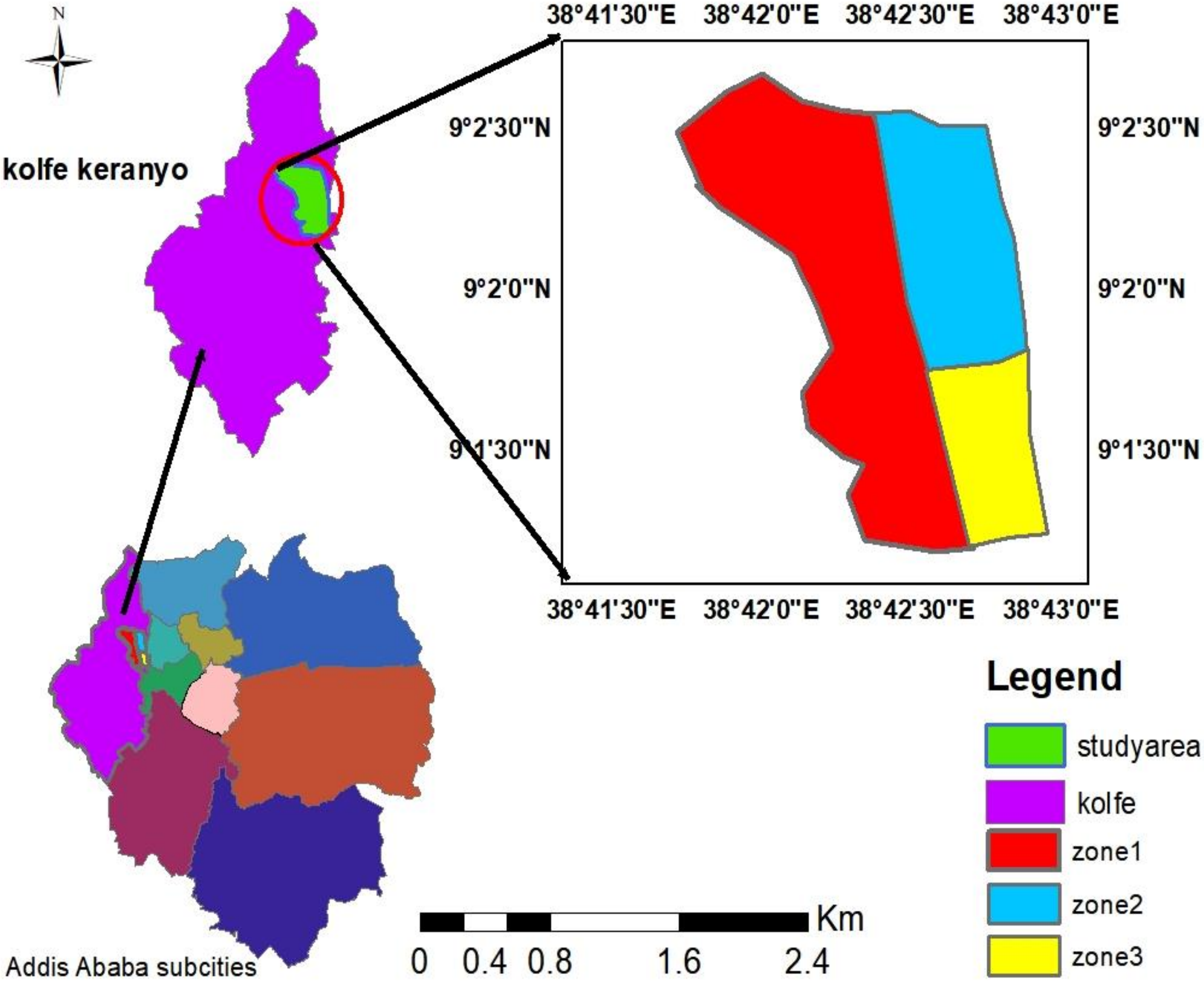


Figure 4.2 Zones of study area

4.5. Sensitivity analysis for residual chlorine

Different parameters affect residual chlorine concentration in the distribution system differently. As illustrated with bulk and wall reaction coefficients taking three values for each parameters, it resulted with different concentration of chlorine. Kw value of -0.55/d and Kb value of -0.75/d of initial values are changed to observe their sensitive effect on chlorine residual concentration.

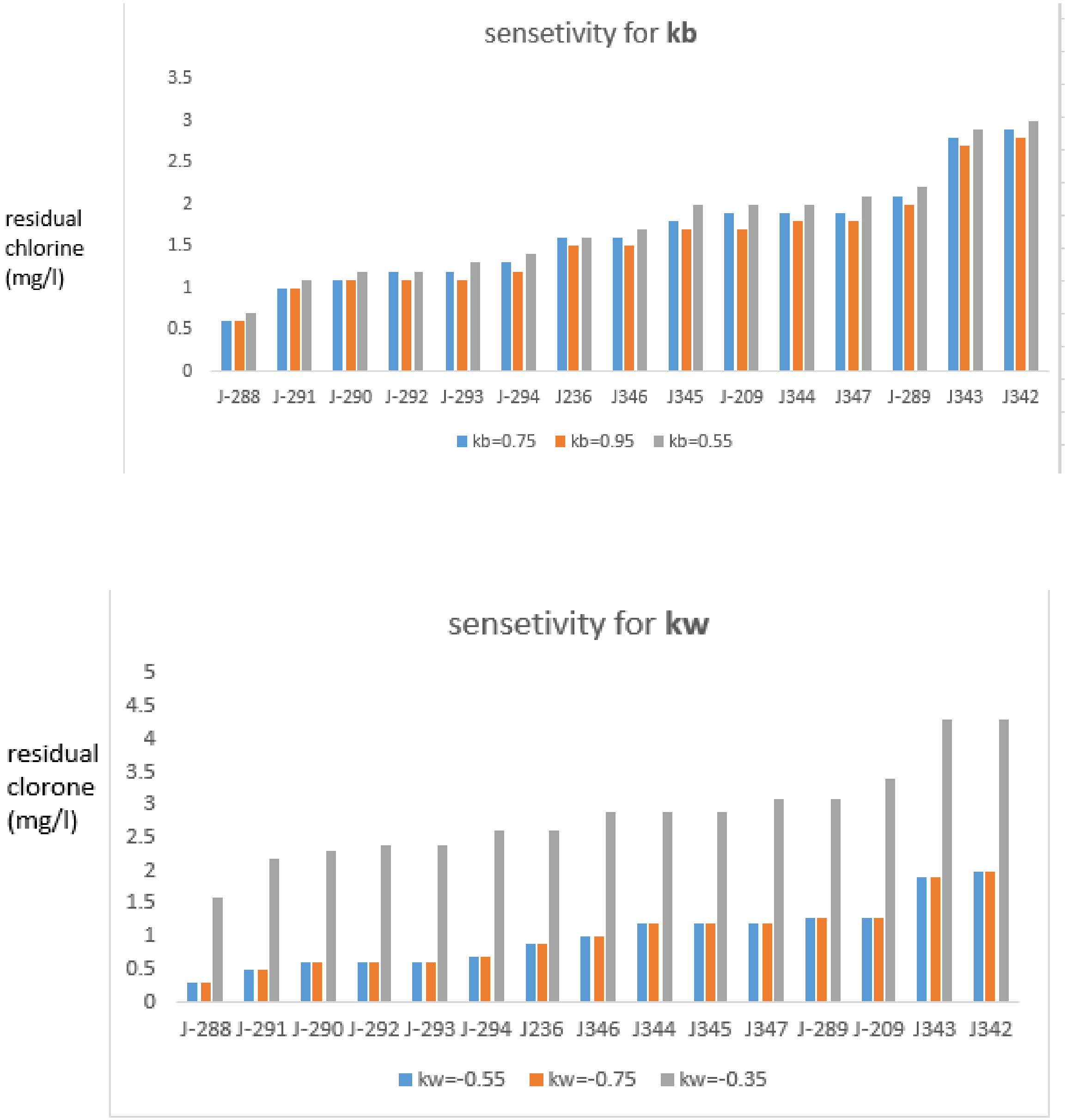


Figure 4.3 Effcet of reaction cofficients on residual chlorine

As it observed from the magnitude of change of residual chlorine concentration,it is more sensetive for wall reaction cofficient. The safest and properly replaced and maintained pipes will result a good proportopn of residual chlorine in the system. In the same way the chlorine will be consumed highly due to reaction of pipe walls with water causing minimum residual chlorine concentration.

4.6. Water demand factor

Water demand in a distribution system fluctuates over time. This variation in demand over time can be modeled using demand patterns. Demand patterns are multipliers that vary with time and are applied to a given base demand, most typically the average daily demand. Demand patterns are applied based on the customer activities related with water. In the morning at the end of the day, when people back to home and at lunch break time they need much water. Based on this fact, multipliers are applied for different time intervals as follows based on demand variation with time.

Table4. 3 Hourly demand factor

Time from start (hours)	3	6	9	12	15	18	21	24
Multiplier	0.4	1	1.3	1.6	1.1	1.3	0.8	0.5

This shows as the simulation starts at 12:00am or midnight, the minimum demand is expected at 3:00am or 3 hours after the simulation and the maximum demand is expected at 12pm or 12 hours after the simulation began. This is based on the multipliers used according to the demand expected. The data is measured on these peak demand times in order to simulate the model.

Based on the population number for the area, it is grouped under the third category. PHF of 1.8 and MDF of 1.2 are adopted for the Peak Hour Demand and Maximum Day Demand respectively. Multiplying these factors with average day demand of 10220.694m^3/d PDD and PHD will be 12264.83m^3/d and 766.55m^3/hour respectively. Low day demand is expected to be 3 hours after mid night when people are not active.

Simulation results and the network for peak hour demand are shown on index

During hydraulic modeling of the area 248 junctions and 346 pipes were identified. Of them 75nodes are found in zone1, 103 nodes are found in zone2 and 70 nodes are found in zone3. In zone2 8.6% of the nodes are above the accepted range (80m) and in zone3 it is found that only two nodes are below the limit set by MOWR, 2006 (15m). Others are with the limit mentioned above for the base demand of existing network. The bypass points at Lomi meda, Philipos and Millennium school from left to right respectively are shown.

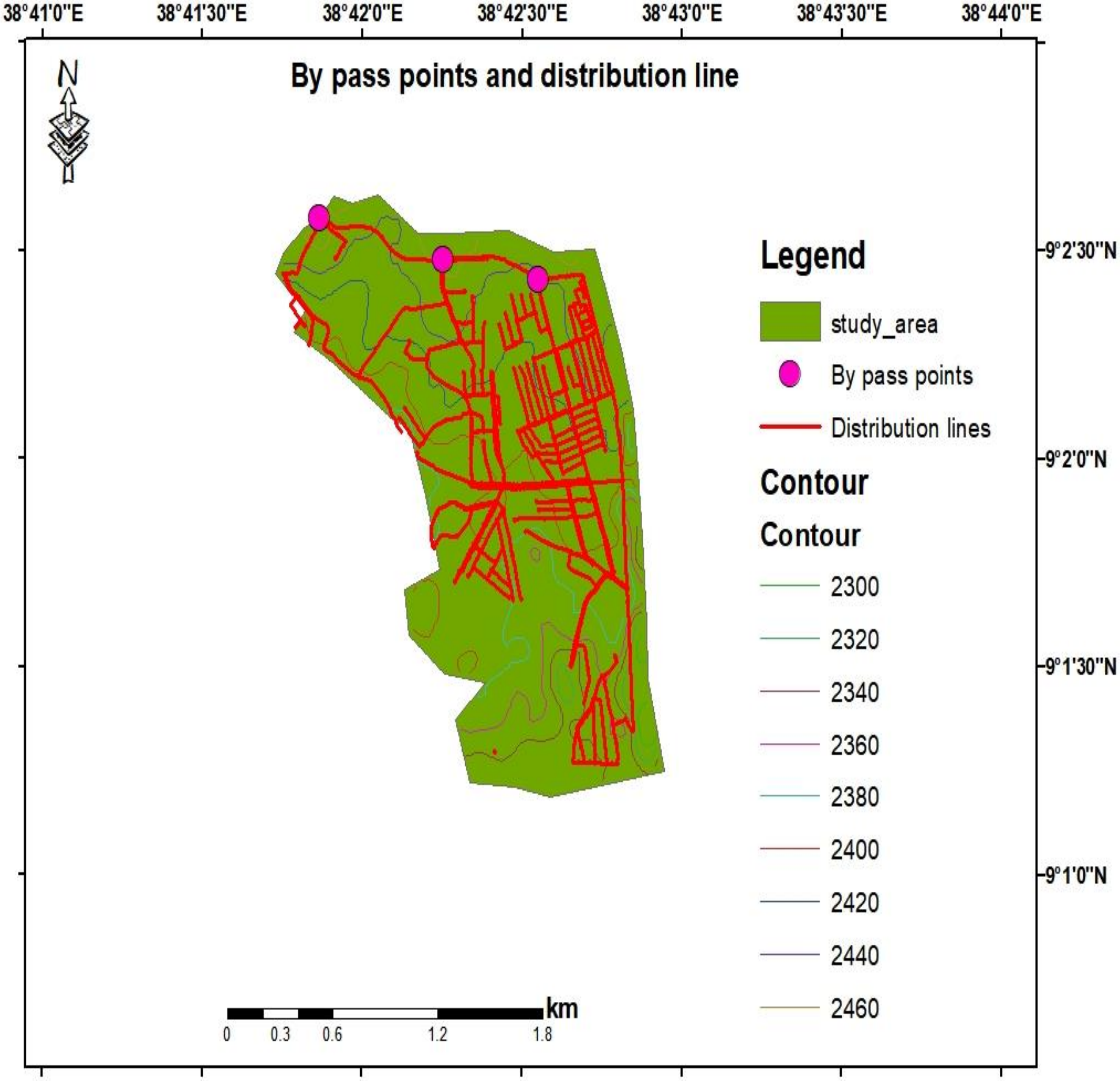


Figure 4.4 Contour map showing elevation for study area

Majority of the higher pressures in the area (>70 m) were observed at zone2 around Asrasimnt mazoria to mehal gebeya Lukanda. Most of the average value (30-60m) and the minimum valued nodes are observed in zone 1 and zone 3 around Fetno derash police camp, Lomi meda and St.Phlilipos.

The simulation value resulted with 23.7% of the pipes have velocity less than 0.3m/s, 36.7%of the pipes have velocity between 0.3 and 1m/s, 27.6% of the pipes have between 1 and 2m/s and 12.42% of them have velocity between 2 and 2.5m/s. This shows the simulation resulted with acceptable range except few of pipes having less than the lower limit value of 0.1 m/s as stated with Action faim 2008. Also as discussed by (B.U.ANYATA, 2011) , by citing (Vreeburg and others, 2008), regular occurring velocity of 0.2m/s or less may be enough in the system for self-cleansing and avoid sedimentation.

By citing from Shaher Hussni Abdul Razaq Zyroud (2003), (Siraj Abduro, 2020) discussed that the absolute minimum velocity of flow in a pipeline is in the range 0.1m/s to 0.3m/s, in order to avoid stagnation and quality problems in the system. TAHAL (2003). Recommends maximum velocity should be less than 2 m/s in distribution system. So the simulation results are good according to the set values discussed above.

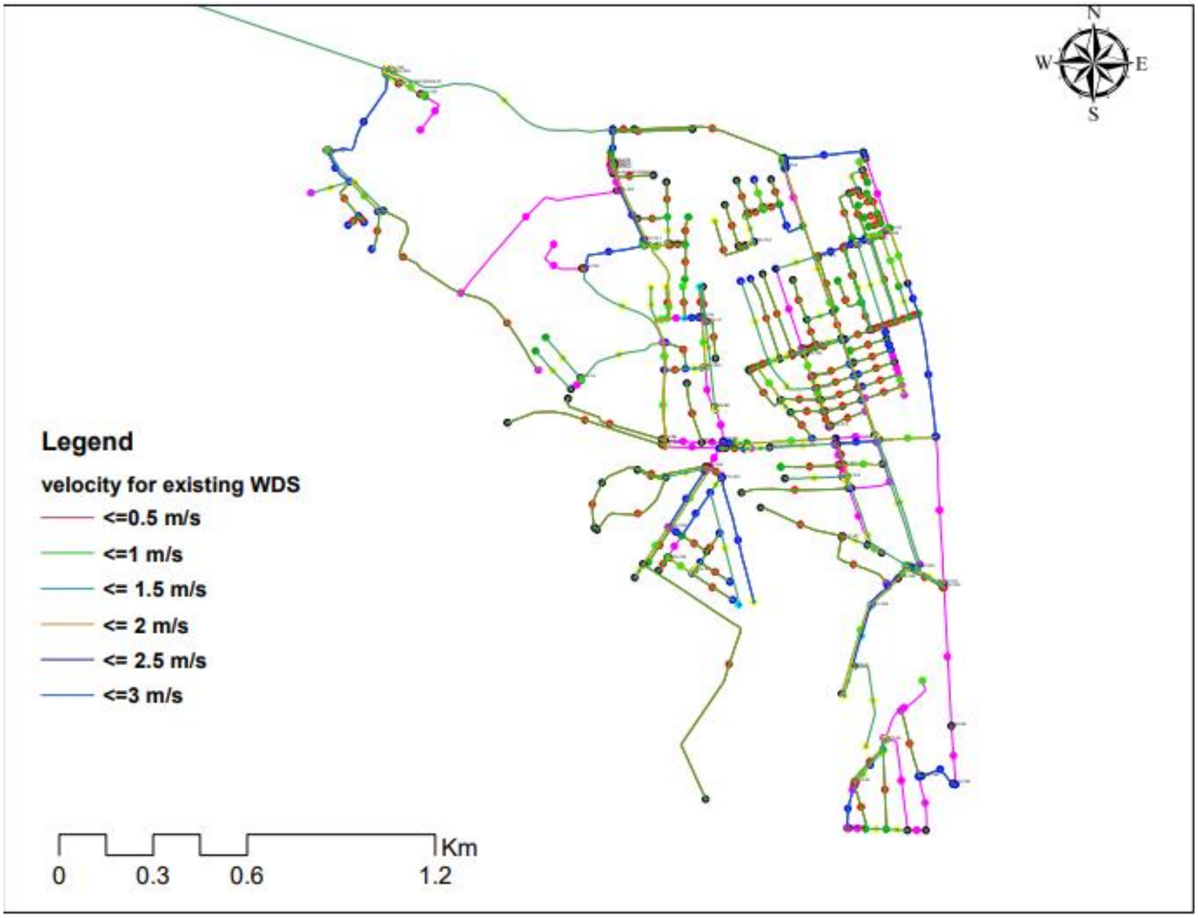


Figure 4.5 Velocity variation of the existing network

4.7. Pressure calibration and validation along nodes

The calibration of pressures was done both graphical and statistical method as shown on table 4.4 and Figure 4.6 below. The figure shows the graphical representation of measured and computed pressure at different locations nearby respective nodes at the time of peak expected demand.

Table4. 4 Observed versus Compute Pressure during calibration (mH2O)

Junctions	Observed	Simulated	Elevation	X	Y	time
j-330	58	56	2,375.80	468,255.73	997,240.51	7:00am
J-200	56	53	2,480.20	467,831.18	998,329.72	7:15am
j-327	68	64	2,395.00	468,432.14	997,111.30	7:30am
j-324	42	44	2,428.00	468,410.16	997,492.49	8:00am
j-6415	51	49	2,450.00	466,528.52	999,144.04	8:15am
J-146	64	66	2,475.93	468,317.62	999,001.79	8:30am
j-249	63	64	2,460.58	467,569.66	999,061.53	9:00am

Junctions	Observed	Simulated	Elevation	X	Y	time
J-75	63	65	2,480.60	468,193.73	998,764.61	9:15am
j-172	52	53	2,410.23	467,802.47	998,188.00	3:00pm
j-161	74	72	2,454.51	467,588.14	998,979.04	3:30pm
j-97	71	70	2,446.03	468,390.57	998,604.33	4:00pm

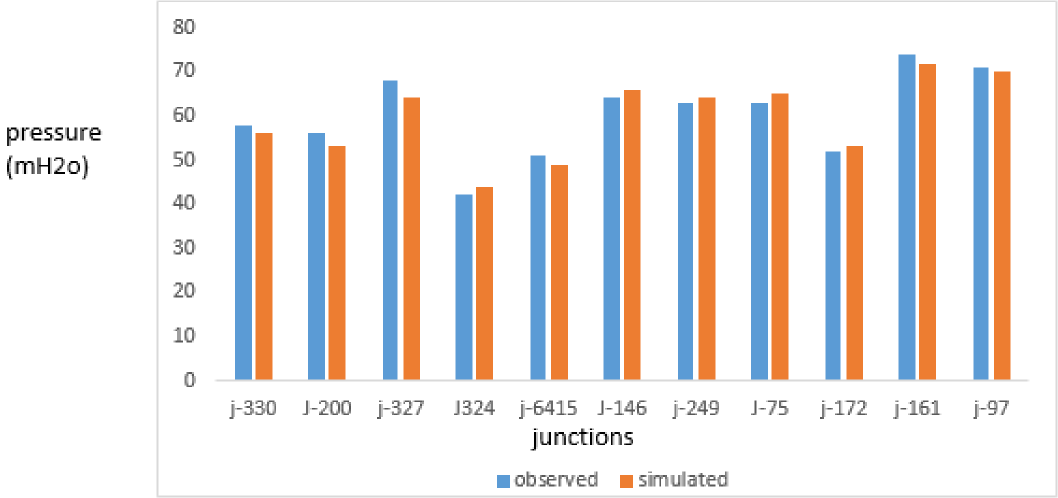


Figure 4.6 Graphical representation for pressure calibration

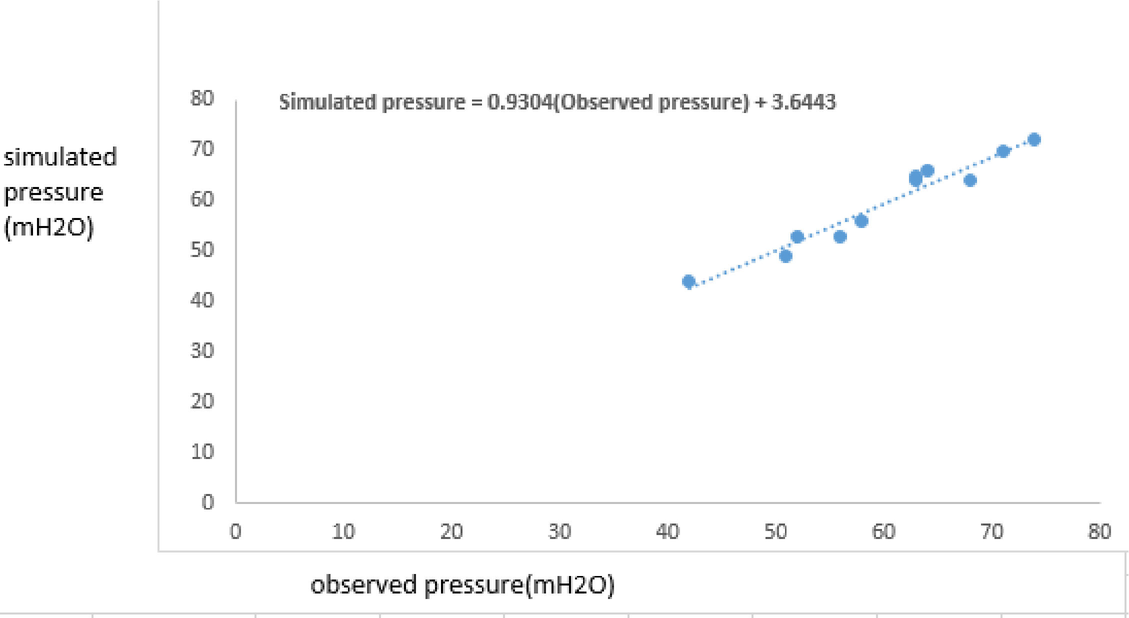


Figure 4.7 Correlated plot of observed versus computed pressure during calibration

According to (CAD/GEMS, 2008) the pressure observed and simulated results are well fit to the set values. The correlated plot is also good as the values are approaching each other.

Table4. 5 Observed versus Compute Pressure during validation

Label	Observed pressure (mH2O)	Simulated pressure(mH2O)	Elevation (m)	X (m)	Y (m)	time
J-16	73	74	2,467.39	468,465.52	998,758.32	9:00am
J-29	67	69	2,490.75	468,291.09	999,274.80	9:15am
J-69	44	45	2,420.61	467,838.96	998,241.84	9:30am
J-102	63	64	2,436.60	468,303.14	998,021.52	10:00am
J-108	48	50	2,446.90	467,724.03	998,582.74	10:15am
J-275	72	74	2,452.21	468,247.66	998,641.10	10:30am
J-276	62	66	2,450.24	468,260.32	998,603.28	11:00am
J-281	48	50	2,452.20	468,287.29	998,525.84	11:15am
J-287	59	60	2,428.47	468,126.84	998,360.10	3:00pm
J-295	60	64	2,435.50	467,962.85	998,139.45	4:00pm
J236	53	51	2,459.00	466,722.48	998,965.02	4:30pm
J313	59	63	2,484.00	467,155.59	998,411.81	5:00pm
J318	60	63	2,445.00	467,818.52	998,616.07	5:30pm
J341	64	65	2,458.00	467,570.11	998,260.76	6:00pm

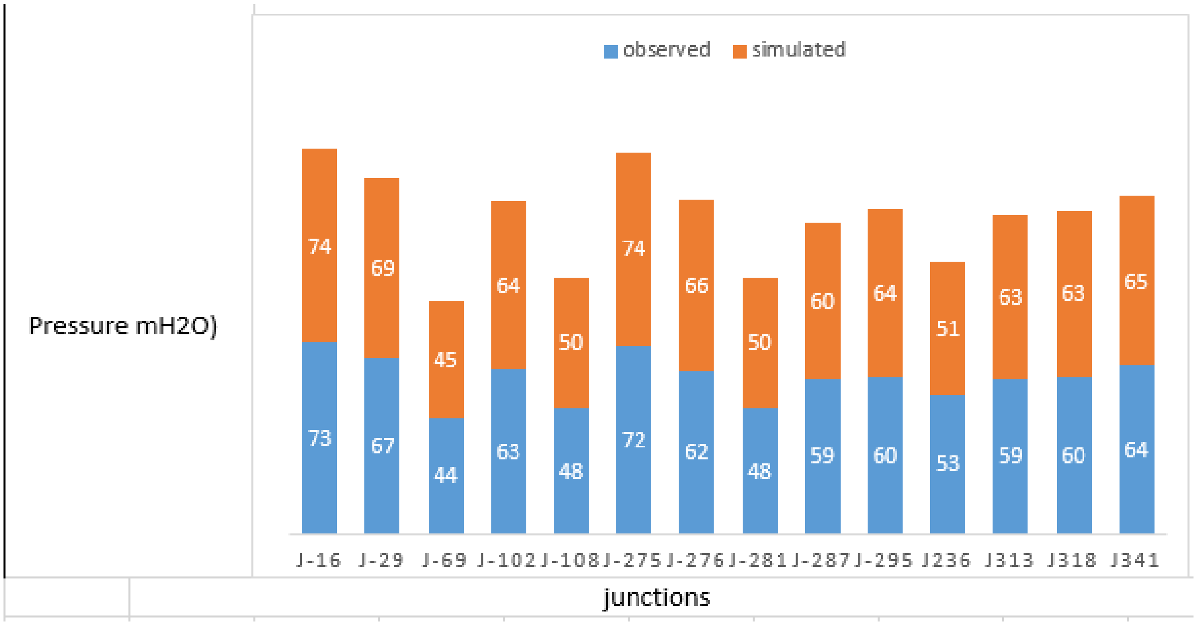


Figure 4.8 Graphical representation of pressure for validation

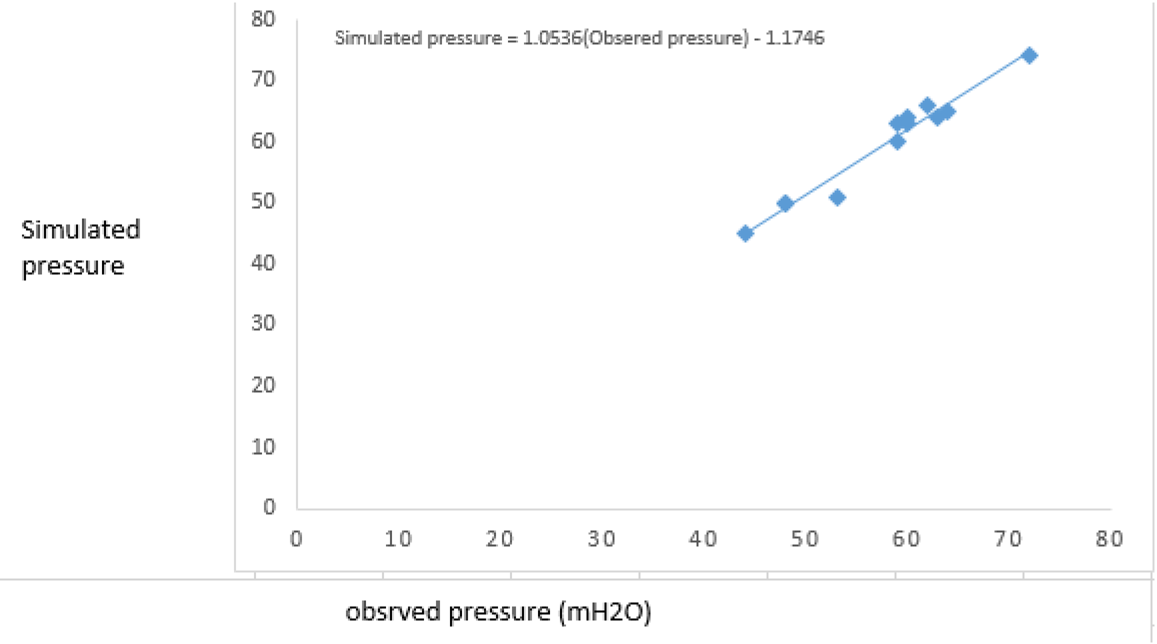


Figure 4.9 Correlated plot of observed versus computed pressure during validation

As the graph and correlated plot show, the calibrated model is valid for the nodes observed above for different time series and location as of (CAD/GEMS, 2008) and (TAHAL2003). The simulated pressure values are within the standards and they are well approached to the field data hence the model is valid for extended period simulation for the base demand.

4.8. Residual chlorine calibration and validation along nodes

In parallel to hydraulic model calibration and validation, water quality model calibration has to be performed independently. To this effort data sets were collected from different location of the distribution networks. Table 4-9 shows residual chlorine model calibration according to guide line recommends having an average error of roughly 0.1 to 0.2 mg/l ((Thomas et al., 2003). The bulk flow reactions depend only on chemical composition of distributed water in the network. It is not affected by pipe characteristics, age material type or formed biofilm in the pipe. So a bottle test was conducted to calculate its value.

To estimate the first-order decay coefficient for bulk decay (kb), a water sample was taken from the distribution network. The sample was tested for residual chlorine every certain hour using the first test as initial point. Taking the average value, the bulk reaction coefficient is -0.031/hour. The samples are analyzed as shown on table 4-6.

Table4. 6 Bottle test for residual chlorine

Time for test	chlorine residual mg/l	change
7:00am	0.73	
9:00am	0.6	0.13
11:00am	0.48	0.12
1:00pm	0.37	0.11
3:00pm	0.31	0.06
5:00pm	0.28	0.03
7:00pm	0.26	0.02
9:00pm	0.25	0.01
11:pm	0.24	0.01
average per 2hrs		0.06125
average per hr.		0.031

7 to 8 mg/l of Chlorine is being added in Gefersa treatment plant reservoir as disinfection. 8mg/l is adopted for this model. The residual chlorine was calibrated by adjusting wall reaction coefficient. The corresponding value of residual chlorine decreases in the pipe networks from reservoir to end point of users. This implies that the wall reaction of materials of pipe decrease the residual chlorine. It is modeled with first order reaction based on the test of sample data as shown on Table 4-8 by resulting -0.75/day of bulk reaction rate and -0.55m /day of first order wall reaction rate. The model is calibrated by adjusting wall reaction rate.

Table 4. 7 Observed versus Computed residual chlorine during calibration

Label	Observed	Simulated	X (m)	Y (m)	time
J-32	0.55	0.6	468,584.03	997,255.51	7:00am
J-34	0.95	1.3	468,522.36	998,364.81	7:15am
J-75	1.2	1.7	468,193.73	998,764.61	7:30am
J-97	0.3	0.2	468,390.57	998,604.33	8:00am
J-118	1.6	2.3	468,097.91	999,038.43	8:15am
J-133	1	1.1	467,659.47	998,237.64	8:30am
J-146	0.3	0.2	468,317.62	999,001.79	9:00am
J-161	0.9	1.3	467,588.14	998,979.04	9:15am
J324	0.28	0.2	468,410.16	997,492.49	3:00pm
J327	0.24	0.2	468,432.14	997,111.30	3:30pm
J330	0.21	0.2	468,255.73	997,240.51	4:00pm

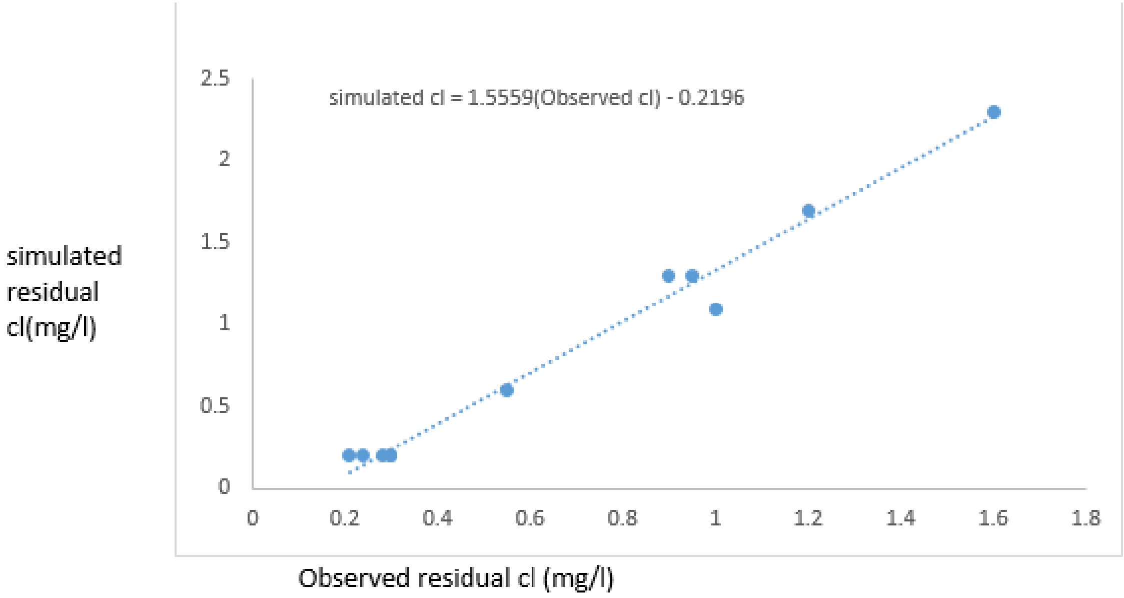


Figure 4.10 Correlated plot of residual chlorine during calibration

According to The maximum allowable WHO value for free chlorine residual in drinking water to be 5 mg/Land the   minimum recommended WHO value for free chlorine residual in treated drinking water is 0.2 mg/L, the model is well calibrated because of the values are found in the range.

Table 4. 8 Observed versus Compute residual chlorine during validation

Junction	Observed	Simulated	Elevation	X	Y	time
j-330	0.22	0.2	2,375.80	468,255.73	997,240.51	9:00am
j-152	0.35	0.3	2,385.00	468,366.27	997,002.41	9:15am
j-327	0.42	0.4	2,395.00	468,432.14	997,111.30	9:30am
j-323	0.25	0.3	2,423.06	468,478.52	997,587.41	10:00am
j-6415	1.8	2.4	2,450.00	466,528.52	999,144.04	10:15am
j-2	0.45	0.5	2,494.00	468,227.42	999,553.62	10:30am
j-249	0.42	0.5	2,460.58	467,569.66	999,061.53	11:00am
j-118	1.35	1.7	2,470.20	468097.91	999038.43	11:15am
j-32	1.7	2.2	2,449.40	468,584.03	997,255.51	3:00pm
j-34	2.2	3	2,445.70	468,522.36	998,364.81	3:30pm
j-133	1.9	2.5	2,444.50	467,659.47	998,237.64	4:00pm
j-63	0.8	1	2,433.78	467,629.95	998,737.03	4:30pm
j-172	1.35	1.6	2,410.23	467,802.47	998,188.00	5:00pm
j-161	2.1	2.5	2,454.51	467,588.14	998,979.04	5:30pm

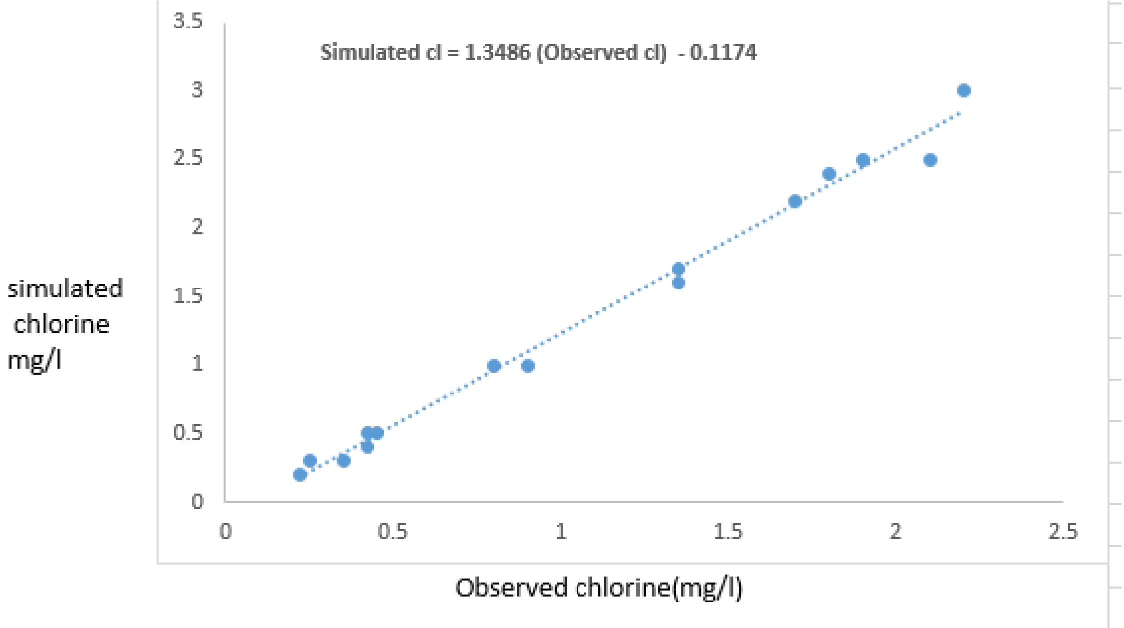


Figure 4.11 Correlated plot of residual chlorine during validation

Samples are taken with different location and time series in period of peak demand. The simulated values are within the range to be recommended according to WHO, so the model is valid for the network.

4.9. Variation of Pressure with Residual chlorine in system

The residual chlorine concentration in the distribution system decreases from the source reservoir to dead end of the pipe network. This can be due to high residence time and lower elevation as it is observed at the far end points in zone3 having low pressure value with corresponding minimum value of residual chlorine. Also it is observed when the area is with high pressure, it is less probable for infiltration and contamination in to the pipe and chlorine consumption will be minimized.

In large distribution networks and systems, hydraulic changes are high, there is so much pressure along the distribution lines and this might cause fractures or cracks in pipes even at the dead end areas of the system. Pressure variation will be too much in the big network and long transmission lines. High hydraulic changes can be responsible for the separation of bacteria from the pipe wall and the volume of bacteria might increase in the system and once this happens, chlorine consumption might be high. So the effect of pressure can be seen in both ways either increasing or retarding chlorine consumption based on the scope and hydraulics of the system.

For this research from the observed samples, with exception of few nodes, observed samples show that the residual chlorine is directly related with pressure in the system. This can be due to adequate pressure prevents bio film formation, intrusion through leaking; fracture and loosening of joints that minimize chlorine decay.

Table 4. 9 Variation of pressure with residual chlorine.

Label	Pressure (m H2O)	residual cl (mg/l)	X (m)	Y (m)
J-10	82	0.25	468,312.16	998,705.98
J-13	64	0.22	468,108.28	998,639.17
J-18	72	0.28	467,989.13	998,606.07
J-40	78	1.75	468,373.46	999,030.91
J-73	47	0.4	468,427.47	997,956.21
J-116	58	0.65	467,655.42	998,579.76
J-142	71	0.25	468,298.90	997,116.21
J-160	76	0.44	467,722.97	998,980.18
J-197	75	1.55	466,892.19	999,451.67
J-241	42	1.4	466,877.41	999,345.95
J-255	25	0.3	467,715.04	998,846.66
J-261	69	0.35	467,849.04	999,105.86
J-265	76	0.4	468,209.96	998,864.59
J-278	57	0.45	468,259.49	998,560.56
J-297	61	0.25	467,927.38	998,576.55
J303	70	0.35	467,603.86	997,965.91
J313	63	0.55	467,155.59	998,411.81
J321	68	0.26	468,221.31	997,546.05
J337	15	0.28	468,299.06	997,377.69

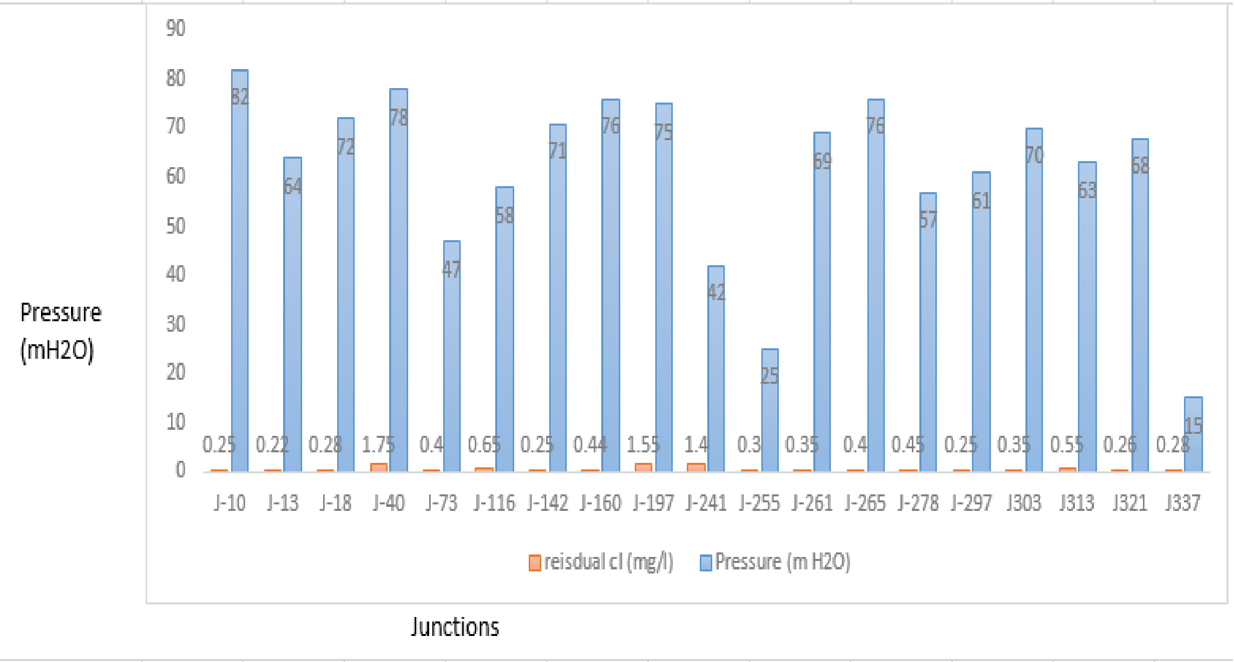


Figure 4.12 Variation of residual chlorine with pressure

Taking a portion of the line system as a continuous, after the bypass points, the residual chlorine has direct relation with pressure. This relation shows when the system has adequate pressure, contaminant intrusion will be minimized and much chlorine will be found in the system.

4.10. Effect of Water age on Chlorine residual

Water age is a major factor in water quality deterioration within the distribution system. Water age is primarily controlled by system design and system demands. Thus, water age can vary significantly within a given system. Increased temperatures typically associated with increased water age can cause reactions to proceed faster and go further to consume the disinfectants. Water quality problems that can be resulted by increased water age include disinfection bi products (DBP) formation, corrosion problem, nitrification, and microbial growth. Due to these phenomena chlorine consumption is high resulting with minimum chlorine residual. The research conducted by relating effect of water age with chlorine residual. It resulted with chlorine residual concentration is inversely related with water age in the system.

Table 4. 10 Variation of water age with residual chlorine

Label	Pressure (m H2O)	X (m)	Y (m)	Concentration (Maximum) (mg/L)	Age max (hrs.)
J-10	82	468,312.16	998,705.98	0.2	6.19
J-13	64	468,108.28	998,639.17	0.2	6.48
J-18	72	467,989.13	998,606.07	0.2	6.68
J-40	78	468,373.46	999,030.91	2.2	5.18
J-73	47	468,427.47	997,956.21	0.5	6.1
J-116	58	467,655.42	998,579.76	0.7	5.6
J-142	71	468,298.90	997,116.21	0.2	6.7
J-160	76	467,722.97	998,980.18	0.4	5.07
J-197	75	466,892.19	999,451.67	2.5	3.67
J-241	42	466,877.41	999,345.95	1.7	3.79
J-255	25	467,715.04	998,846.66	0.2	6.11
J-261	69	467,849.04	999,105.86	0.3	5.68
J-265	76	468,209.96	998,864.59	0.2	6.2
J-278	57	468,259.49	998,560.56	0.2	7.2
J-297	61	467,927.38	998,576.55	0.2	7.1
J303	70	467,603.86	997,965.91	0.4	5.17
J313	63	467,155.59	998,411.81	0.7	5.04
J321	68	468,221.31	997,546.05	0.2	6.42
J337	15	468,299.06	997,377.69	0.2	6.74

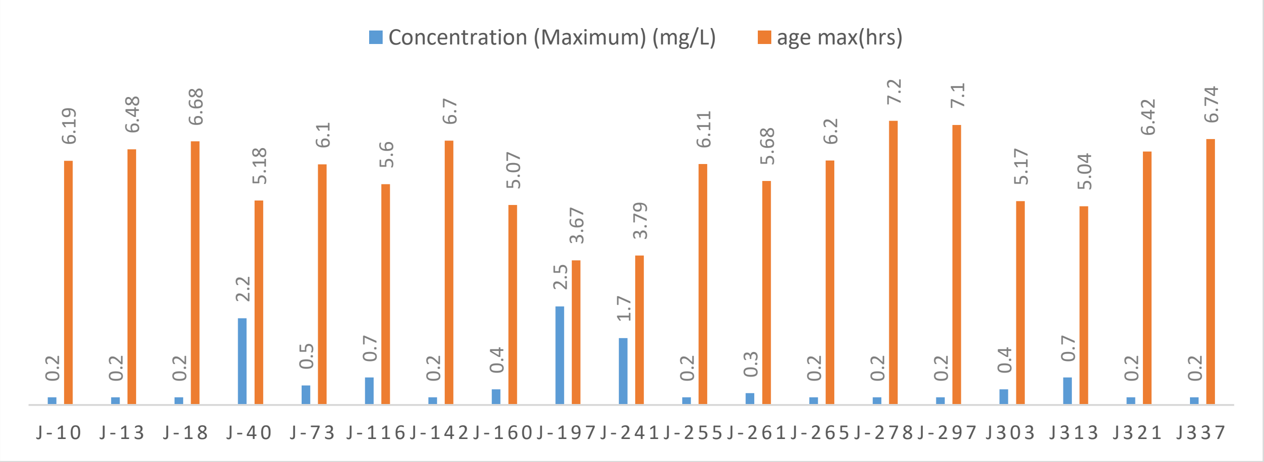


Figure 4.13 Variation of residual chlorine with water age with.

The result shows as the water stays in the system the residual chlorine is consumed according to the time stayed in it. The maximum expected residual chlorine is due to passage of water in larger diameters extended from the bypass points minimizing the exposure for contamination and intrusion of contaminants. It is also observed only the minimum recommended value of residual chlorine in the nodes which have maximum age.

4.11. Improved network suggestion

The existing supplysystem saitisfied only 66.24% of the demand.To increase the demand in to 100l/c/d as of GTP II, 8958.3m^3/d is added on the existing system. This resulted on the addition of 60.28l/s of extra load to be allocated on distribution network. The base demand is changed to 180l/s which is loaded in the source and the model is developed based on the new demand. For this case the model resulted maximum pressure on the system especially on zone2. Diameter of some pipes is enlarged in order to carry the extra flow added for the network. To balance this maximum pressure, pressure reducing valves (PRV) are introduced in the network. The simulated network and results are shown on the index.

4.12. Limitations of the research

Sample location: Both pressure and residual chlorine are taken from yard faucets which is near by selected nodes. Not to take directly from these points is due to no convenience to interrupt the flow while cutting the line.

Isolated WDS: the study area is isolated from the Gefersa sub system. Isolating this small area may be affected with some constraints of the system which is not considered here due to the scope of the study.

Problem statement identification: The study didn’t check the observed problems with other parts of the city. The complexity of the work limits only to focus on the study area which has visible problems. Other researchers can go further with other study area.

CHAPTER FIVE

5. Conclusion and Recommendations

5.1. Conclusion

Provision of adequate quantity and acceptable quality is one of the basic needs of every society. But the provision of potable water for Addis Ababa also Kolfe (i.e. the study area) is inefficient. The status is getting worse due to the population growth and its intermittency.

The findings of this study showed that the current average per capita domestic water consumption of the area was found to be 66.24 L/c/d which only satisfies 66.24% of the standard urban water consumption value set by GTPII for level I cities which should be 100l/c/d.

The use of Water GEMS and Arc GIS has greater acceptance in terms of simplified model building with geospatial modules and tools like hydraulic and water quality modeling. The research is mainly done by integrating these tools with Auto CAD. The existing sources of water for the area are Gefersa reservoir and treatment plant that feeds the area on its path as by-pass. The research has observed that the gap between demand and supply in the city as well as in the study area is not only low water production but the water to be lost is very high which is estimated to be 40%.

During base demand it is observed that in zone 2, 8.6% of the nodes are above the accepted range (80m) and in zone3 it is found that two nodes are below the limit set by MoWR, 2006 (15m). Others are with the limit set by MoWR.

During peak hour consumption, the simulation shows that the distribution system is with a risk of obtaining no water because of the pressure in the distribution system is below permissible minimum requirement as well as negative pressure is observed except some mid night periods.

The simulation results of selected nodes with Water GEMS Software have indicated that the effect of pressure on residual chlorine concentration in the water supply networks systems is directly related with the gravity distribution system of the networks with few exceptional nodes. Regarding pipe age, 43% and 71.3% of the pipes are greater than 25and 15 years respectively. It shows there might be problem with corrosion and pipe breakage for intrusion of contaminants into the pipe line. Also this can be the cause for pipe failure and water loss.

The health problem of diarrheal incident observed in Lukanda is not due to minimum pressure and minimum chlorine residual of the system; rather it might be sanitary issue due to highly dense population leaving in the area.

Integrated estimation from the Addis ketema branch and literature review showed that Non revenue water is high (40%) in the town as well as in the study area through illegal connection (theft), leakage, during installation and pipe bursting. Water age is a major factor in water quality deterioration within the distribution system. It resulted with chlorine residual is inversely related with water age in the system. The research resulted on need of additional 60.28l/s of extra load to be allocated on distribution network is based on the standard per capita demand to increase the supply for the network to satisfy the per capita demand set by GTPII.

5.2. Recommendation

Based on the findings of this study, the following recommendations are put to the corresponding stakeholders to minimize related problems

To prevent the gravity main pipe line from bursting, especially in zone2, pressure reduction components like PRV should be provided.

The development of improved network should provide extra load of 60.28l/s on the network in order to meet increasing water demand and to avoid supply intermittency.

Water supply system should be well managed by controlling faults and losses in order to minimize NRW

Awareness on Sanitary and hygiene problems should be given for the community in order to avoid the observed diarrhea incidence especially in Lukanda area.

The oldest pipes should be replaced to avoid contamination and water loss through breaks and failure points.

Large water consuming industries and commercial areas should be trained to recycle their wastewater to minimize their pressure on clear water for non-domestic demands which doesn’t matter on high quality.

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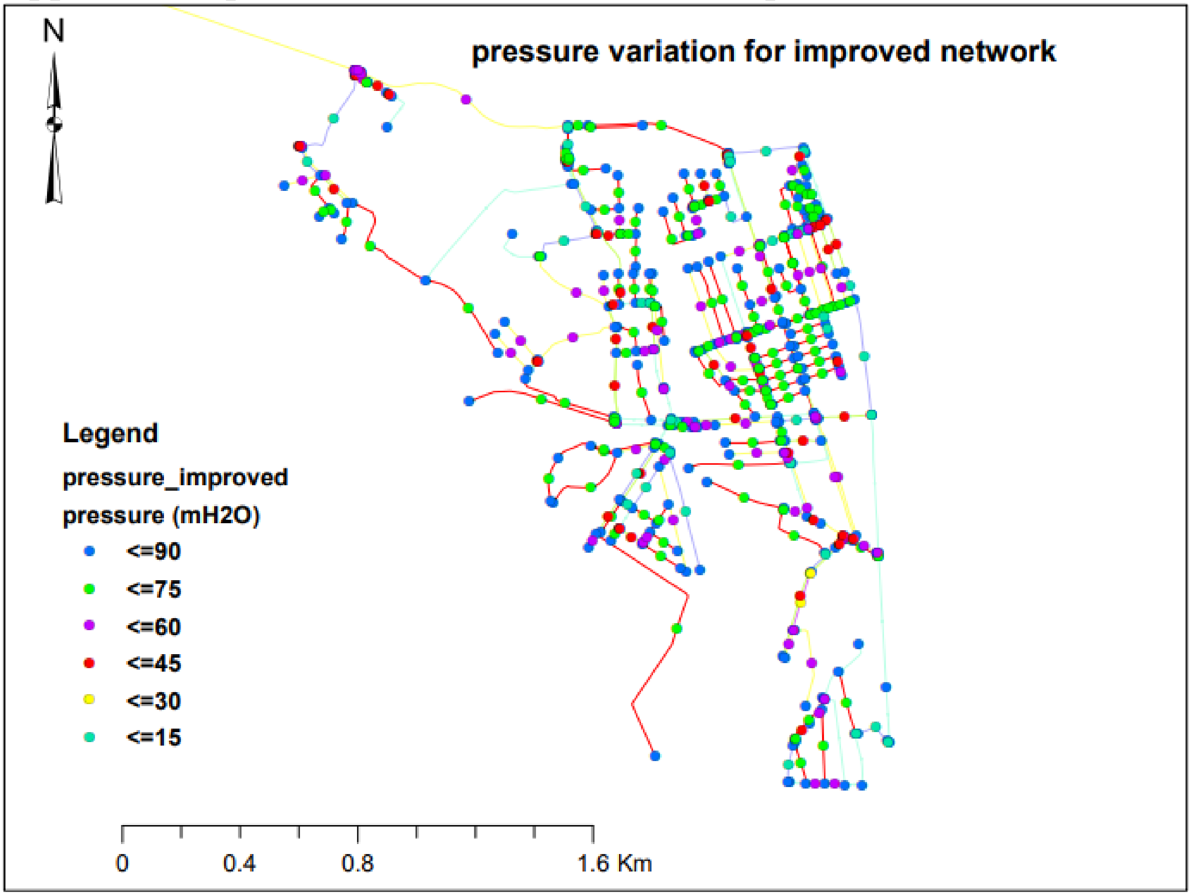
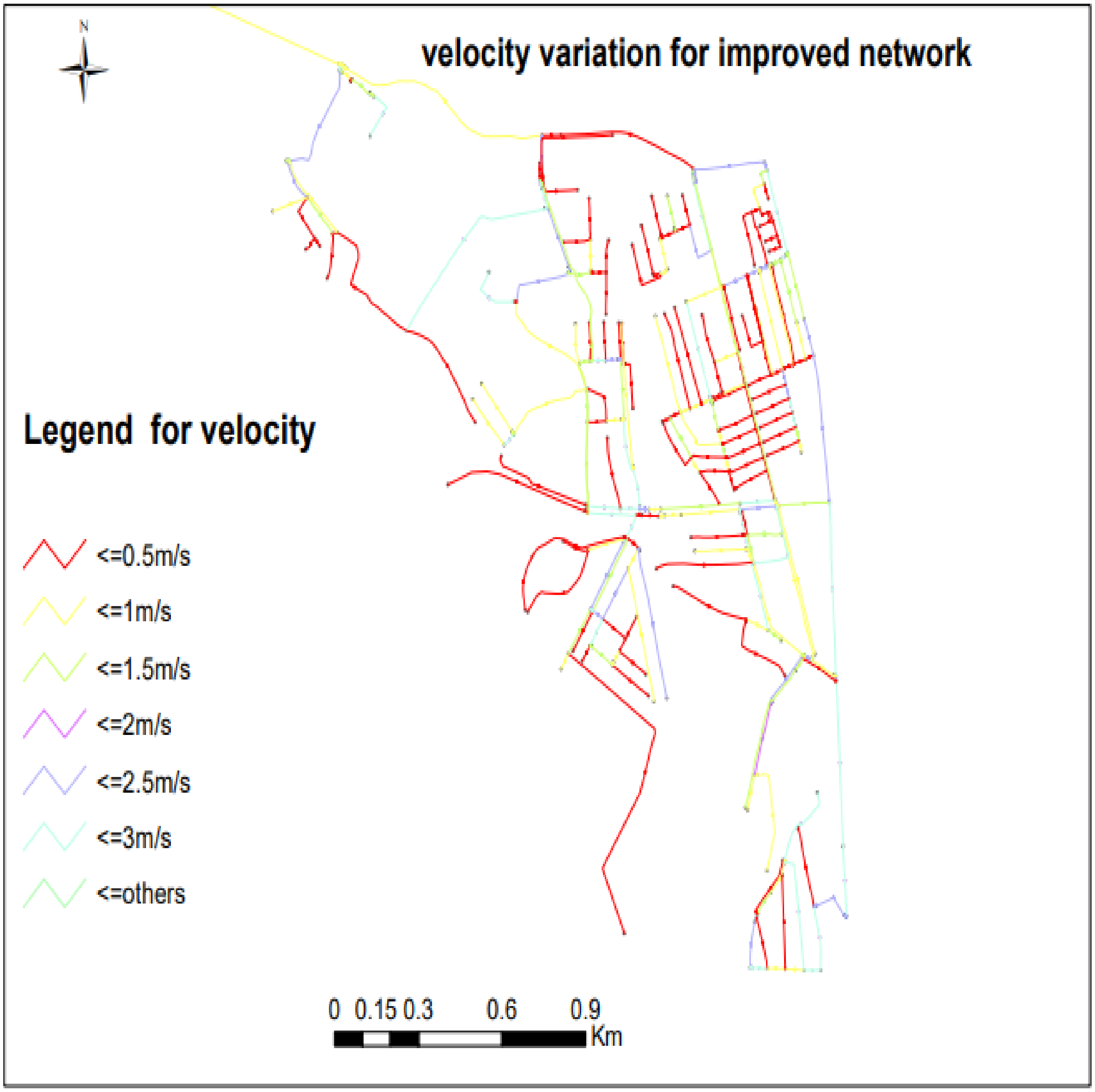
Appendices

Appendix A: results of Bentley water gems simulation.

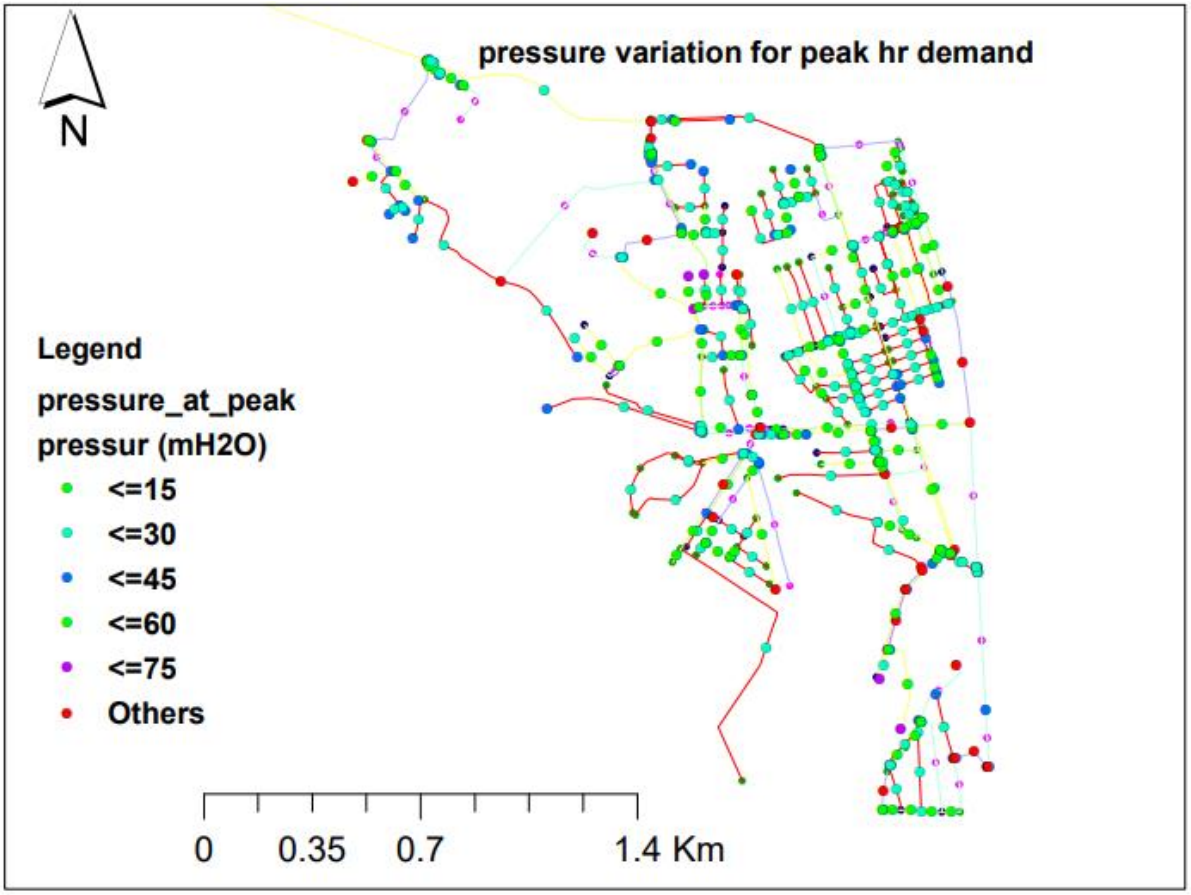
AppendixA1: pressure variation of nodes for improved network



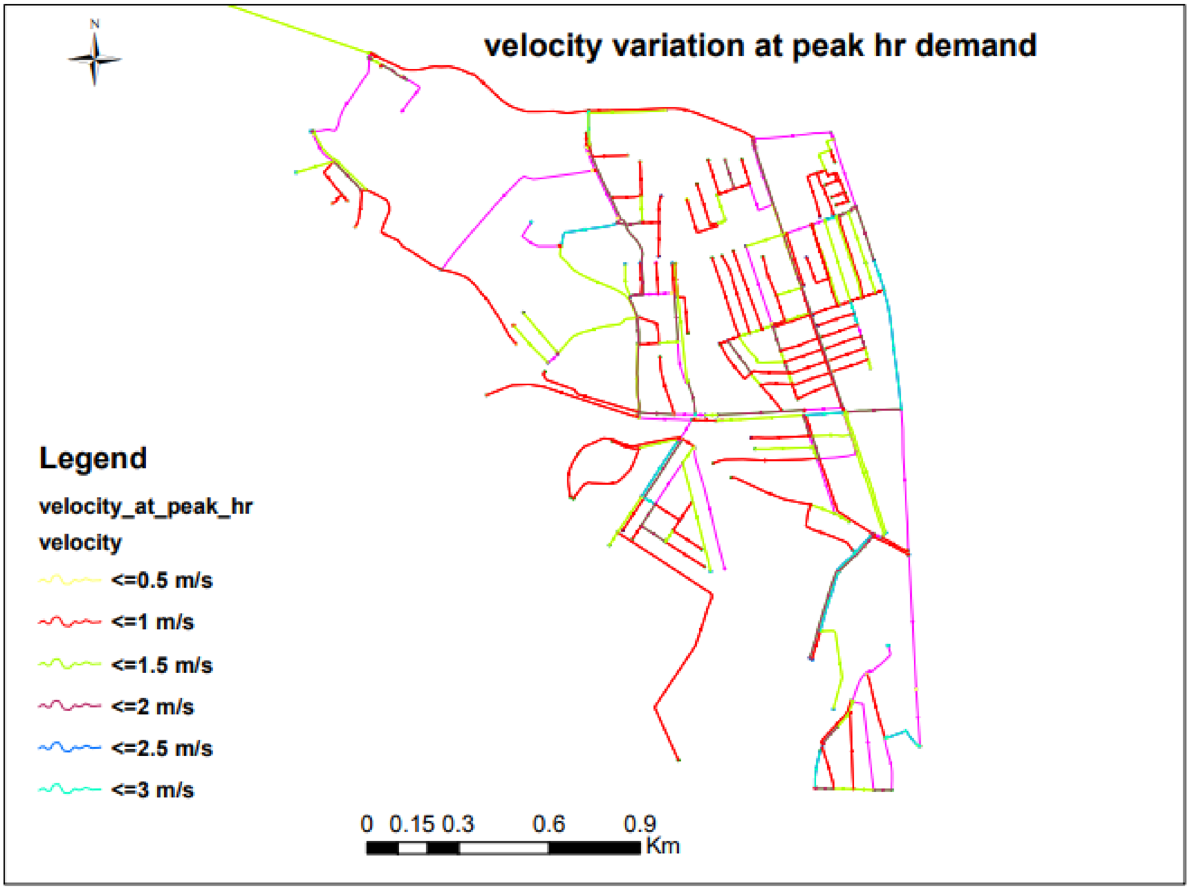
AppendixA2: velocity variation of pipes for improved network



AppendixA3: pressure variation of nodes for peak hour demand at 12:00am



AppendixA4: velocity variation of pipes for peak hour demand at 12:00am



AppendixA5: simulation result for junction for base scenario at 12:00am

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
2397	2,410.20	Zone - 1	74	467,276.81	998,682.67	1.4	0.2
J-4	2,446.26	Zone - 2	59	468,221.85	998,675.15	0.06	0.2
J-6	2,461.81	Zone - 2	80	468,354.28	998,720.50	0.055	0.4
J-7	2,462.18	Zone - 2	79	468,361.38	998,723.14	0.053	0.5
J-8	2,463.80	Zone - 2	78	468,390.71	998,732.63	0.07	0.6
J-9	2,464.25	Zone - 2	77	468,398.04	998,735.06	0.1	0.5
J-10	2,459.33	Zone - 2	82	468,312.16	998,705.98	0.16	0.2
J-11	2,459.72	Zone - 2	82	468,319.93	998,708.49	0.062	0.5
J-12	2,441.06	Zone - 2	64	468,097.45	998,641.17	0.075	0.2
J-13	2,441.90	Zone - 2	64	468,108.28	998,639.17	0.057	0.2
J-14	2,430.63	Zone - 2	74	467,951.39	998,589.97	0.2	0.2
J-15	2,466.36	Zone - 2	75	468,437.65	998,748.39	0.18	0.4
J-16	2,467.39	Zone - 2	74	468,465.52	998,758.32	0.57	1.7

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-17	2,438.12	Zone - 2	67	468,065.05	998,627.13	0.18	0.2
J-18	2,432.78	Zone - 2	72	467,989.13	998,606.07	0.31	0.2
J-19	2,435.39	Zone - 2	69	468,023.50	998,615.15	0.26	0.2
J-29	2,490.75	Zone - 2	69	468,291.09	999,274.80	0.87	2.7
J-30	2,478.80	Zone - 2	88	468,037.70	999,256.03	0.011	3
J-32	2,433.30	Zone - 3	53	468,584.03	997,255.51	1.3	0.6
J-33	2,468.00	Zone - 3	44	468,548.10	997,885.58	1	0.9
J-34	2,451.70	Zone - 2	74	468,522.36	998,364.81	1	1.3
J-35	2,458.00	Zone - 2	68	468,522.28	998,367.42	0.55	1.5
J-36	2,464.60	Zone - 3	48	468,545.87	997,899.20	0.44	1.1
J-37	2,489.41	Zone - 2	69	468,299.22	999,253.59	0.24	2.5
J-38	2,470.82	Zone - 2	81	468,432.31	998,855.29	0.45	2
J-39	2,454.36	Zone - 2	64	468,341.67	998,356.53	0.25	1.1
J-40	2,476.29	Zone - 2	78	468,373.46	999,030.91	0.46	2.2
J-41	2,470.00	Zone - 3	44	468,458.89	997,941.87	0.17	0.8
J-42	2,466.13	Zone - 2	72	468,144.16	998,943.79	0.38	0.5
J-43	2,454.64	Zone - 2	83	468,010.75	998,901.96	0.32	0.3
J-44	2,484.40	Zone - 1	64	467,657.13	998,337.14	0.22	2.5
J-46	2,490.80	Zone - 1	78	466,778.48	999,516.40	0.13	4.1
J-48	2,493.60	Zone - 1	76	466,767.89	999,521.83	0.62	4.9
J-50	2,498.80	Zone - 1	65	467,491.58	999,234.94	0.0096	3.9
J-51	2,500.20	Zone - 1	70	467,491.92	999,347.36	2.4	4.9
J-52	2,445.87	Zone - 1	30	467,720.62	998,744.66	0.22	0.2
J-53	2,444.61	Zone - 1	21	467,664.61	998,743.21	0.15	0.2
J-54	2,415.00	Zone - 1	65	467,357.74	998,518.43	0.17	0.2
J-55	2,415.00	Zone - 1	74	467,391.98	998,546.94	1.3	0.5
J-56	2,455.00	Zone - 1	51	467,402.05	998,902.65	1.5	1
J-57	2,468.30	Zone - 2	72	467,971.74	999,091.22	0.25	1.4
J-59	2,443.30	Zone - 1	50	467,650.74	998,667.08	0.35	0.6
J-60	2,427.70	Zone - 3	72	467,675.58	998,073.91	0.12	0.8
J-61	2,422.12	Zone - 3	43	467,802.39	998,266.38	0.057	0.3
J-63	2,443.78	Zone - 1	18	467,629.95	998,737.03	0.65	0.2
J-64	2,467.60	Zone - 3	44	468,427.95	997,944.71	0.1	0.4
J-65	2,461.60	Zone - 3	50	468,434.16	997,952.59	0.019	0.6
J-66	2,424.80	Zone - 3	53	468,467.35	997,282.56	0.93	0.3
J-67	2,486.00	Zone - 1	49	466,576.49	999,279.86	1	2.9
J-68	2,458.60	Zone - 1	53	466,741.56	999,084.50	0.17	1.2
J-69	2,420.61	Zone - 3	45	467,838.96	998,241.84	0.2	0.3
J-70	2,461.20	Zone - 1	49	467,785.41	998,733.79	0.46	0.3

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-71	2,398.80	Zone - 3	45	468,266.66	997,263.24	0.52	0.2
J-72	2,446.00	Zone - 3	49	468,317.39	997,831.52	1.6	0.2
J-73	2,464.60	Zone - 3	47	468,427.47	997,956.21	0.17	0.5
J-75	2,480.60	Zone - 2	65	468,193.73	998,764.61	0.17	1.7
J-76	2,470.20	Zone - 2	85	468,333.84	998,353.75	0.1	2.4
J-77	2,465.60	Zone - 2	89	468,335.06	998,357.13	0.0035	2.8
J-78	2,452.60	Zone - 3	69	468,220.61	998,277.37	0.19	0.9
J-79	2,446.00	Zone - 3	75	468,229.25	998,276.23	0.13	0.6
J-80	2,449.80	Zone - 3	64	468,243.73	998,203.04	0.3	0.5
J-81	2,446.00	Zone - 3	69	468,252.48	998,201.72	0.42	0.9
J-84	2,470.94	Zone - 2	74	468,404.94	998,846.51	0.36	0.6
J-85	2,452.22	Zone - 2	48	468,413.30	998,528.89	0.27	0.2
J-86	2,479.30	Zone - 2	64	468,139.11	998,654.41	0.21	0.9
J-88	2,433.07	Zone - 2	56	468,180.42	998,398.92	0.15	0.2
J-89	2,438.46	Zone - 2	58	468,137.79	998,522.03	0.17	0.2
J-90	2,439.34	Zone - 2	59	468,124.77	998,557.05	0.25	0.2
J-91	2,446.60	Zone - 3	69	468,232.99	998,239.64	0.2	0.5
J-92	2,459.54	Zone - 2	67	468,365.69	998,678.94	0.12	0.2
J-93	2,457.96	Zone - 2	58	468,378.10	998,642.34	0.21	0.2
J-94	2,436.66	Zone - 2	55	468,150.18	998,485.28	0.16	0.2
J-95	2,434.71	Zone - 2	55	468,162.01	998,448.29	0.19	0.2
J-96	2,453.79	Zone - 2	49	468,403.20	998,566.81	0.34	0.2
J-97	2,440.00	Zone - 2	68	468,390.57	998,604.33	0.26	0.2
J-98	2,428.69	Zone - 2	63	468,026.61	998,483.54	0.46	0.2
J-99	2,429.31	Zone - 2	60	468,058.48	998,445.12	0.37	0.2
J-102	2,436.60	Zone - 3	64	468,303.14	998,021.52	0.57	0.4
J-104	2,457.70	Zone - 2	67	468,200.65	998,344.80	0.075	1.6
J-105	2,476.00	Zone - 2	69	468,220.09	998,682.13	0.11	1.3
J-106	2,476.60	Zone - 2	66	468,110.14	998,740.27	0.55	0.9
J-107	2,469.30	Zone - 2	74	468,283.39	998,795.73	0.41	0.3
J-108	2,446.90	Zone - 1	53	467,724.03	998,582.74	0.2	0.3
J-109	2,475.43	Zone - 2	77	468,347.17	999,013.23	0.15	1.7
J-110	2,473.69	Zone - 2	71	468,227.67	998,972.48	0.2	0.6
J-112	2,476.33	Zone - 2	75	468,308.33	998,999.29	0.062	1.4
J-113	2,477.19	Zone - 2	70	468,271.13	998,987.27	0.088	0.9
J-114	2,442.89	Zone - 1	47	467,774.76	998,748.06	0.15	0.4
J-115	2,444.00	Zone - 1	57	467,785.82	998,587.30	0.25	0.6
J-116	2,441.60	Zone - 1	58	467,655.42	998,579.76	0.82	0.7
J-117	2,469.90	Zone - 2	71	468,022.91	999,107.22	0.34	1.6

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-118	2,480.20	Zone - 2	73	468,097.91	999,038.43	0.64	2.3
J-119	2,500.20	Zone - 1	70	466,786.58	999,529.53	0.019	5.7
J-120	2,500.30	Zone - 1	70	466,791.98	999,526.92	0.28	5.4
J-121	2,503.20	Zone - 2	66	468,034.87	999,252.96	0.096	4.5
J-124	2,458.90	Zone - 1	60	466,679.70	999,070.90	0.17	1.5
J-126	2,446.30	Zone - 1	60	467,656.88	998,356.03	0.79	0.9
J-127	2,478.57	Zone - 2	76	468,346.49	999,048.25	0.044	0.7
J-128	2,485.60	Zone - 2	70	468,272.64	999,151.61	0.063	1.3
J-129	2,485.22	Zone - 2	70	468,245.28	999,142.58	0.46	1
J-130	2,484.52	Zone - 2	71	468,301.10	999,141.82	0.13	1
J-131	2,480.84	Zone - 2	74	468,335.35	999,077.97	0.26	0.8
J-132	2,487.96	Zone - 2	69	468,288.44	999,217.52	0.22	1.8
J-133	2,454.50	Zone - 3	70	467,659.47	998,237.64	0.53	1.1
J-134	2,469.60	Zone - 1	66	466,586.29	999,280.11	0.88	3.7
J-135	2,460.62	Zone - 1	76	467,668.70	998,979.16	0.26	0.7
J-136	2,463.91	Zone - 1	71	467,665.56	999,067.44	0.29	0.4
J-137	2,430.00	Zone - 3	64	467,588.16	997,959.76	0.012	0.9
J-138	2,427.70	Zone - 3	65	467,787.60	997,210.00	0.48	0.2
J-141	2,390.00	Zone - 3	75	468,238.62	997,117.81	1.2	0.2
J-142	2,396.60	Zone - 3	71	468,298.90	997,116.21	0.29	0.2
J-143	2,393.14	Zone - 3	75	468,364.40	997,114.71	0.38	0.2
J-144	2,436.30	Zone - 3	64	468,224.48	998,050.12	1.4	0.3
J-145	2,457.70	Zone - 3	70	467,784.57	998,257.16	0.19	1.5
J-146	2,475.93	Zone - 2	66	468,317.62	999,001.79	0.095	0.2
J-147	2,477.16	Zone - 2	71	468,279.96	998,990.24	0.078	1.2
J-149	2,474.10	Zone - 2	71	468,232.15	998,974.17	0.072	0.8
J-150	2,464.20	Zone - 1	47	467,007.32	998,824.51	3	0.9
J-151	2,405.36	Zone - 3	45	468,362.17	997,403.62	0.22	0.2
J-156	2,445.20	Zone - 3	18	468,255.59	997,634.69	1.6	0.2
J-158	2,492.20	Zone - 2	76	468,038.80	999,221.71	0.049	3
J-159	2,506.00	Zone - 2	63	468,037.25	999,236.24	0.037	4
J-160	2,460.30	Zone - 1	76	467,722.97	998,980.18	0.36	0.4
J-161	2,470.00	Zone - 1	73	467,588.14	998,979.04	0.55	1.3
J-162	2,470.60	Zone - 2	68	467,916.10	998,976.78	0.51	0.5
J-163	2,469.60	Zone - 2	70	467,915.57	999,070.56	0.14	0.9
J-164	2,469.20	Zone - 1	71	467,922.97	999,073.12	0.12	1.2
J-165	2,493.60	Zone - 1	70	467,494.91	999,234.94	0.16	3.1
J-166	2,494.40	Zone - 2	75	468,040.86	999,222.19	0.2	3.7
J-167	2,428.40	Zone - 3	72	467,668.02	998,078.76	0.53	1.2

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-168	2,421.04	Zone - 3	72	467,711.20	998,051.55	0.28	0.6
J-169	2,422.78	Zone - 3	54	467,744.90	997,929.02	0.62	0.2
J-170	2,419.71	Zone - 3	56	467,770.42	997,966.09	0.17	0.2
J-171	2,422.15	Zone - 3	62	467,665.79	997,981.08	0.22	0.4
J-172	2,414.00	Zone - 3	54	467,802.47	998,188.00	0.42	0.4
J-175	2,455.00	Zone - 3	70	467,457.74	998,219.24	0.52	0.8
J-176	2,446.50	Zone - 1	71	467,818.71	998,454.52	0.63	0.9
J-177	2,465.50	Zone - 3	63	467,793.10	998,269.24	0.066	1.8
J-178	2,470.20	Zone - 1	89	467,513.73	999,152.07	0.76	2
J-182	2,450.00	Zone - 1	76	467,843.46	998,346.62	0.11	1.6
J-183	2,496.00	Zone - 1	67	467,486.70	999,234.93	0.69	3.3
J-194	2,459.00	Zone - 2	85	468,202.73	998,361.70	0.088	2.5
J-196	2,550.00	Zone - 1	19	466,810.99	999,498.21	0.44	3.7
J-197	2,490.30	Zone - 1	75	466,892.19	999,451.67	2.8	2.5
J-199	2,483.30	Zone - 1	65	467,657.38	998,339.80	0.041	2.8
J-200	2,480.20	Zone - 1	53	467,831.18	998,329.72	0.11	2.1
J-205	2,501.10	Zone - 1	69	467,560.48	999,348.17	1.1	4.8
J-209	2,455.50	Zone - 3	69	467,442.18	998,070.35	0.043	0.9
J-239	2,465.36	Zone - 1	63	466,760.64	999,087.11	1.7	2
J-241	2,511.00	Zone - 1	42	466,877.41	999,345.95	3.2	1.7
J-245	2,440.20	Zone - 1	43	467,303.24	998,980.89	3.4	0.7
J-246	2,460.00	Zone - 1	76	467,722.05	998,868.69	0.19	0.3
J-247	2,458.52	Zone - 1	77	467,731.79	999,066.44	0.34	0.3
J-248	2,472.66	Zone - 1	62	467,661.83	999,178.96	0.56	0.3
J-249	2,470.58	Zone - 1	64	467,569.66	999,061.53	0.53	0.3
J-250	2,492.00	Zone - 1	71	467,484.76	999,273.18	0.96	2.6
J-251	2,495.00	Zone - 1	66	467,745.59	999,348.06	0.87	1.6
J-252	2,496.30	Zone - 1	67	467,620.30	999,201.25	0.46	1.8
J-253	2,443.50	Zone - 1	15	467,612.68	998,842.72	0.63	0.2
J-254	2,450.20	Zone - 1	15	467,662.34	998,845.41	0.21	0.2
J-255	2,450.64	Zone - 1	25	467,715.04	998,846.66	0.12	0.2
J-256	2,451.30	Zone - 1	39	467,768.36	998,844.81	0.1	0.3
J-257	2,441.78	Zone - 2	58	467,899.32	998,862.91	0.5	0.2
J-258	2,444.95	Zone - 2	58	467,931.26	998,869.95	0.29	0.2
J-259	2,442.00	Zone - 2	63	467,969.17	998,885.60	0.22	0.2
J-260	2,525.00	Zone - 2	13	467,816.09	999,054.49	0.35	0.3
J-261	2,469.00	Zone - 2	69	467,849.04	999,105.86	0.33	0.3
J-262	2,471.30	Zone - 2	68	467,886.56	999,184.25	0.65	0.7
J-263	2,470.00	Zone - 2	53	467,942.11	999,186.04	0.3	0.2

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-264	2,474.40	Zone - 2	66	467,996.32	999,187.29	0.19	1.1
J-265	2,465.42	Zone - 2	76	468,209.96	998,864.59	0.43	0.2
J-268	2,476.00	Zone - 2	64	468,066.71	998,866.60	0.47	0.6
J-273	2,476.60	Zone - 2	66	468,109.38	998,644.66	0.042	0.8
J-274	2,459.00	Zone - 2	83	468,232.96	998,677.41	0.088	0.2
J-275	2,452.21	Zone - 2	75	468,247.66	998,641.10	0.13	0.2
J-276	2,450.24	Zone - 2	66	468,260.32	998,603.28	0.098	0.2
J-277	2,440.00	Zone - 2	58	468,246.54	998,598.31	0.13	0.2
J-278	2,440.00	Zone - 2	57	468,259.49	998,560.56	0.11	0.2
J-279	2,448.35	Zone - 2	60	468,274.51	998,565.39	0.11	0.2
J-280	2,439.20	Zone - 2	53	468,272.78	998,521.43	0.1	0.2
J-281	2,452.20	Zone - 2	50	468,287.29	998,525.84	0.1	0.2
J-282	2,436.60	Zone - 2	53	468,285.13	998,483.95	0.098	0.2
J-283	2,450.40	Zone - 2	49	468,298.22	998,489.84	0.12	0.2
J-284	2,442.35	Zone - 2	46	468,296.25	998,447.74	0.26	0.2
J-285	2,441.90	Zone - 2	63	468,326.41	998,371.73	0.15	0.2
J-287	2,428.47	Zone - 2	60	468,126.84	998,360.10	0.39	0.2
J-288	2,451.43	Zone - 2	48	468,422.07	998,499.18	0.64	0.2
J-289	2,473.50	Zone - 3	41	468,471.76	997,958.56	1.1	0.6
J-290	2,434.40	Zone - 3	64	468,349.64	997,994.74	0.52	0.2
J-291	2,448.60	Zone - 3	64	468,040.77	998,234.06	0.62	0.2
J-292	2,445.00	Zone - 3	74	468,027.52	998,270.48	0.38	0.4
J-293	2,452.30	Zone - 3	68	468,209.18	998,342.70	0.12	0.5
J-294	2,450.36	Zone - 3	61	468,352.63	998,279.97	1	0.4
J-295	2,435.50	Zone - 3	64	467,962.85	998,139.45	0.52	0.2
J-296	2,430.00	Zone - 2	74	467,923.94	998,581.46	0.22	0.2
J-297	2,430.00	Zone - 2	61	467,927.38	998,576.55	0.24	0.2
J-298	2,422.15	Zone - 3	35	467,894.04	997,831.02	1.6	0.3
J-299	2,390.00	Zone - 3	13	467,940.74	997,839.52	2.1	0.2
J-300	2,420.00	Zone - 3	56	467,874.28	997,845.92	0.6	0.2
J-301	2,418.77	Zone - 3	56	467,864.88	997,903.95	0.58	0.2
J-6400	2,409.00	Zone - 3	62	468,490.57	997,111.32	0.93	0.3
J-6404	2,395.18	Zone - 3	53	468,312.96	997,319.48	0.31	0.2
J-6406	2,391.00	Zone - 3	77	468,353.92	997,366.62	0.22	0.2
J-6407	2,459.10	Zone - 1	60	466,651.46	999,180.35	0.81	2
J-6415	2,466.60	Zone - 1	49	466,528.52	999,144.04	0.78	1.2
J-6419	2,502.20	Zone - 1	68	466,773.69	999,538.45	0.16	5.8
J-6420	2,508.00	Zone - 1	62	466,766.50	999,537.78	0.57	6.1
J1	2,475.50	Zone - 2	79	468,329.25	998,369.96	0.063	3

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J236	2,459.00	Zone - 1	51	466,722.48	998,965.02	0.78	0.9
J302	2,423.19	Zone - 3	61	467,637.32	997,939.20	0.22	0.4
J303	2,428.00	Zone - 3	70	467,603.86	997,965.91	0.16	0.4
J304	2,425.00	Zone - 3	68	467,791.77	998,000.22	0.23	0.4
J305	2,416.54	Zone - 3	59	467,832.31	998,059.44	0.59	0.2
J306	2,430.20	Zone - 3	63	467,561.37	997,917.54	1.5	0.7
J307	2,454.40	Zone - 3	70	467,433.41	998,076.17	0.34	0.5
J308	2,478.00	Zone - 1	55	467,910.82	998,327.16	0.12	1.7
J309	2,489.00	Zone - 1	42	467,932.31	998,328.79	0.26	1.1
J310	2,454.00	Zone - 1	77	467,918.37	998,345.91	0.25	2.1
J311	2,457.30	Zone - 1	73	467,876.76	998,345.39	0.13	2
J312	2,446.60	Zone - 3	65	467,902.15	998,186.94	0.38	0.2
J313	2,484.00	Zone - 1	63	467,155.59	998,411.81	0.44	0.7
J314	2,443.00	Zone - 1	62	467,347.95	998,488.18	0.61	0.4
J315	2,400.00	Zone - 1	77	467,244.60	998,640.64	0.69	0.2
J317	2,450.00	Zone - 1	66	467,727.12	998,537.40	0.42	0.7
J318	2,445.00	Zone - 1	63	467,818.52	998,616.07	0.41	0.2
J319	2,447.10	Zone - 1	52	467,658.90	998,667.15	0.18	0.2
J320	2,444.46	Zone - 1	67	467,778.73	998,844.73	0.32	0.4
J321	2,431.80	Zone - 3	68	468,221.31	997,546.05	2.2	0.2
J322	2,444.80	Zone - 3	17	468,228.66	997,539.87	0.61	0.2
J323	2,400.20	Zone - 3	26	468,478.52	997,587.41	2.2	0.2
J324	2,428.00	Zone - 3	49	468,410.16	997,492.49	0.93	0.2
J325	2,396.30	Zone - 3	69	468,261.62	997,251.99	0.11	0.2
J327	2,405.00	Zone - 3	64	468,432.14	997,111.30	0.33	0.2
J328	2,458.69	Zone - 2	80	468,200.62	998,772.88	0.18	0.2
J330	2,385.80	Zone - 3	50	468,255.73	997,240.51	1.2	0.2
J332	2,400.00	Zone - 3	44	468,356.13	997,405.07	0.18	0.2
J334	2,450.00	Zone - 3	49	468,364.12	997,900.13	0.46	0.2
J336	2,461.00	Zone - 1	49	467,253.94	998,578.58	0.39	0.4
J337	2,444.60	Zone - 3	15	468,299.06	997,377.69	0.66	0.2
J341	2,458.00	Zone - 3	65	467,570.11	998,260.76	0.82	0.9
J342	2,462.20	Zone - 1	56	466,697.89	999,050.64	0.14	1.2
J343	2,459.00	Zone - 1	60	466,646.21	999,042.49	0.27	1.3
J345	2,477.03	Zone - 2	78	468,299.06	999,004.55	0.027	0.8
J346	2,477.16	Zone - 2	78	468,254.78	998,999.95	0.15	0.5
J347	2,478.58	Zone - 2	76	468,307.55	999,036.75	0.052	0.7
J348	2,480.71	Zone - 2	74	468,293.95	999,063.92	0.092	0.7
J349	2,483.21	Zone - 2	72	468,273.76	999,103.26	0.16	0.8

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J350	2,485.84	Zone - 2	71	468,303.39	999,178.33	0.27	1.5

Appendix A6 FlexTable: Pipe Table for base scenario at 12:00am

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P--18	47	J-124	J343	48	HDPE	125	0.27	0.15
P-1	318	J-81	J-73	35	JISPVC	140	0.51	0.53
P-2	344	J312	J-80	35	JISPVC	125	-0.38	0.4
P-3	36	J-53	J-63	35	JISPVC	100	1.3	1.34
P-5	56	J-52	J-53	35	JISPVC	100	1.6	1.71
P-7	69	J-108	J-116	35	JISPVC	100	0.19	0.19
P-8	84	J-117	J-264	35	JISPVC	125	0.19	0.19
P-9	97	J-256	J-114	35	JISPVC	100	-0.1	0.1
P-10	142	J-118	J-117	45	JISPVC	150	3.2	2
P-12	69	J-51	J-205	485	DCI	120	63	0.34
P-14	500	J-205	J-121	485	DCI	150	62	0.34
P-16	758	J-120	J-51	485	DCI	150	97	0.52
P-16	6	J-121	FCV-96	235	Ductile Iron	110	62	1.43
P-17	27	J-124	J342	35	HDPE	125	0.14	0.14
P-17	11	FCV-96	J-159	235	Ductile Iron	110	62	1.43
P-18	15	J-159	J-166	235	Ductile Iron	110	56	1.3
P-19	88	J-116	J-59	48	HDPE	100	2.3	1.28
P-19	900	J-166	J1	137.4	Ductile Iron	110	18	1.2
P-20	14	J1	J-77	137.4	Ductile Iron	95	7.5	0.51
P-21	124	J-68	J236	48	HDPE	125	0.78	0.43
P-23	370	J-59	J-56	48	HDPE	100	-1.6	0.86
P-25	29	J-128	J-129	48	HDPE	140	0.65	0.36
P-25	174	J-6400	J-66	75	JISPVC	150	-8.1	1.83
P-26	40	J-128	J-130	48	HDPE	140	0.73	0.4
P-26	58	J327	J-6400	75	Ductile Iron	150	-7.1	1.62
P-27	32	J-131	J-127	48	HDPE	140	0.096	0.05
P-27	42	J311	J310	137.4	Ductile Iron	75	-9.9	0.67
P-28	55	J-37	J-132	48	HDPE	125	1.9	1.07
P-28	22	J308	J309	35	Ductile Iron	75	0.75	0.78

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-29	41	J-127	J347	35	HDPE	140	0.052	0.05
P-30	42	J-132	J350	48	HDPE	140	0.27	0.15
P-31	44	J-131	J348	48	HDPE	140	0.092	0.05
P-32	66	J-130	J349	35	HDPE	140	0.16	0.16
P-32	60	J309	Fire Hydrant (Point)-170	35	JISPVC	85	0.49	0.51
P-33	97	J-132	J-128	48	HDPE	140	1.4	0.79
P-33	209	Fire Hydrant (Point)-170	J-104	35	JISPVC	95	0.49	0.51
P-34	80	J-130	J-131	48	HDPE	140	0.44	0.25
P-35	170	J-129	J346	48	HDPE	140	0.15	0.09
P-36	151	J-129	J345	45	HDPE	140	0.027	0.02
P-36	59	J-178	Fire Hydrant (Point)-54	95	JISPVC	120	-14	1.91
P-37	308	J-133	J-209	48	HDPE	115	0.043	0.02
P-37	23	Fire Hydrant (Point)-54	FCV-56	95	JISPVC	120	-14	1.91
P-38	419	J-289	J-39	48	HDPE	140	-1.1	0.58
P-38	11	FCV-56	J-183	95	JISPVC	120	-14	1.91
P-39	33	J-109	FCV-31	100	ISOPVC	125	-12	1.58
P-40	7	FCV-31	J-40	110	ISOPVC	115	-12	1.3
P-42	344	J-134	J-48	63	ISOPE	125	-6.9	2.21
P-44	96	J-136	J-249	48	ISOPE	110	0.53	0.3
P-45	112	J-136	J-248	48	ISOPE	120	0.56	0.31
P-46	984	J-137	J-138	48	ISOPE	150	0.48	0.27
P-50	29	J-30	FCV-6	150	ISOPVC	90	-38	2.17
P-51	66	J-142	J-143	63	ISOPE	150	-2.8	0.89
P-51	11	FCV-6	J-166	150	ISOPVC	115	-38	2.17
P-53	124	J-141	J330	25	ISOPE	150	1.2	2.38
P-55	95	J-133	J341	48	ISOPE	90	0.82	0.45
P-57	132	J-145	J-133	48	ISOPE	105	1.4	0.77
P-58	279	J-146	J-9	48	ISOPE	140	-0.095	0.05
P-58	105	J-50	FCV-10	135	Ductile Iron	105	-31	2.2
P-59	8	FCV-10	J-51	135	Ductile Iron	120	-31	2.2
P-60	281	J-149	J-11	48	ISOPE	140	1.2	0.67
P-61	363	J-150	J336	48	ISOPE	100	0.39	0.22
P-62	442	J-68	J-150	48	ISOPE	125	0.18	0.1
P-63	257	J-239	FCV-13	48	ISOPE	125	-1.7	0.93
P-64	243	J323	J-151	38	ISOPE	150	-2.2	1.94
P-64	7	FCV-13	J-134	48	ISOPE	125	-1.7	0.93
P-66	8	J-55	FCV-14	35	Ductile Iron	100	1.4	1.45

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-67	170	FCV-14	2397	45	Ductile Iron	150	1.4	0.87
P-68	99	J322	J-156	38	ISOPVC	150	-0.61	0.54
P-68	45	J-52	FCV-16	35	ISOPVC	100	-2	2.06
P-69	9	FCV-16	J-114	35	[SOPVC	100	-2	2.06
P-70	6	J-70	FCV-17	35	ISOPE	100	0.41	0.42
P-71	141	J-142	J325	18	ISOPVC	150	0.11	0.42
P-71	135	FCV-17	J318	35	ISOPE	100	0.41	0.42
P-72	269	J-43	FCV-18	60	JISPVC	105	5.6	1.98
P-73	6	FCV-18	J-12	60	JISPVC	105	5.6	1.98
P-74	84	J-106	FCV-19	35	JISPVC	105	-0.3	0.31
P-75	17	J-158	J-159	60	ISOPVC	110	-5.4	1.92
P-75	6	FCV-19	J-86	35	JISPVC	105	-0.3	0.31
P-76	6	J-94	FCV-20	35	JISPVC	90	0.1	0.11
P-77	123	FCV-20	J-280	35	JISPVC	130	0.1	0.11
P-78	5	J-89	FCV-21	35	JISPVC	90	0.11	0.11
P-79	87	J-105	J-75	48	ISOPVC	105	-0.66	0.37
P-79	123	FCV-21	J-278	35	JISPVC	150	0.11	0.11
P-80	88	J-160	J-247	48	ISOPVC	115	0.34	0.19
P-80	188	J-32	FCV-95	85	ISOPVC	150	-11	1.99
P-81	443	FCV-95	J-33	85	ISOPVC	150	-11	1.99
P-82	20	J-200	FCV-94	75	ISOPVC	90	0.86	0.2
P-83	112	J-246	J-160	48	ISOPVC	100	-0.19	0.11
P-83	60	FCV-94	J308	75	ISOPVC	90	0.86	0.2
P-84	84	J-136	FCV-91	48	ISOPVC	110	-1.4	0.76
P-85	195	J-260	J-162	48	ISOPPVC	150	-0.35	0.19
P-85	4	FCV-91	J-135	48	ISOPVC	110	-1.4	0.77
P-86	6	J-182	FCV-89	50	ISOPVC	90	4.9	2.48
P-87	106	FCV-89	J-176	63	ISOPVC	110	4.9	1.56
P-88	387	J320	FCV-88	50	ISOPVC	105	-1.2	0.6
P-89	193	J-118	J-158	63	ISOPVC	110	-5.4	1.72
P-89	6	FCV-88	J-176	50	ISOPVC	100	-1.2	0.6
P-90	9	J-126	FCV-86	48	HDPE	100	0.61	0.34
P-91	291	J-75	J-118	48	ISOPVC	120	-1.5	0.85
P-91	349	FCV-86	J314	48	HDPE	105	0.61	0.34
P-92	321	J-285	J-4	35	ISOPVC	140	-0.15	0.16
P-92	6	J-135	FCV-90	48	ISOPVC	110	0.89	0.49
P-93	49	FCV-90	J-160	48	ISOPVC	100	0.89	0.49
P-94	6	J-17	FCV-23	35	JISPVC	105	0.22	0.23

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-95	270	FCV-23	J-259	35	JISPVC	150	0.22	0.23
P-96	42	J-168	J-60	63	ISOPVC	105	-7.2	2.3
P-96	180	J-107	FCV-27	35	JISPVC	140	-0.43	0.45
P-97	96	J304	J-168	48	ISOPVC	105	-0.23	0.13
P-97	5	FCV-27	J-110	35	JISPVC	140	-0.43	0.45
P-98	44	J-61	J-69	48	ISOPVC	105	0.58	0.32
P-98	5	J-110	FCV-27	35	Ductile Iron	140	0.43	0.45
P-99	180	FCV-27	J-107	35	Ductile Iron	140	0.43	0.45
P-100	51	J-171	J302	48	ISOPVC	105	0.22	0.12
P-100	5	J-110	FCV-27	35	Ductile Iron	140	0.43	0.45
P-101	65	J-172	J-69	48	ISOPVC	105	1.7	0.93
P-101	180	FCV-27	J-107	35	Ductile Iron	140	0.43	0.45
P-102	84	J-168	J-171	48	ISOPVC	105	3	1.66
P-102	272	J-6	FCV-28	35	JISPVC	140	-0.71	0.74
P-103	7	FCV-28	J-113	35	JISPVC	140	-0.71	0.74
P-104	112	J-170	J305	48	ISOPVC	105	0.59	0.33
P-104	6	J-156	FCV-41	38	ISOPVC	150	0.67	0.59
P-105	113	J-170	J-301	48	ISOPVC	105	0.58	0.32
P-105	303	FCV-41	J337	38	ISOPVC	150	0.66	0.59
P-106	154	J-169	J-300	48	ISOPVC	105	0.6	0.33
P-106	4	J-64	FCV-44	75	GS	150	-2.4	0.55
P-107	164	J-168	J-172	48	ISOPVC	105	3.7	2.03
P-107	6	FCV-44	J-65	75	GS	150	-2.4	0.55
P-108	369	J-172	J-298	48	ISOPVC	115	1.6	0.87
P-110	14	J-50	FCV-100	135	DCI	120	15	1.03
P-111	978	FCV-100	J-199	115	DCI	150	15	1.42
P-112	3	J-42	FCV-101	95	ISOPVC	150	5.9	0.84
P-113	137	FCV-101	J-43	95	ISOPVC	150	5.9	0.84
P-114	5	J-149	J-110	75	ISOPVC	125	8	1.81
P-114	4	J-90	FCV-102	35	JISPVC	105	0.13	0.14
P-115	9	J-147	J-113	75	ISOPVC	110	10	2.28
P-115	124	FCV-102	J-277	35	JISPVC	150	0.13	0.14
P-116	30	J-112	J-147	75	ISOPVC	110	10	2.3
P-116	7	J-42	FCV-103	35	GS	140	0.18	0.19
P-117	173	FCV-103	J328	35	GS	140	0.18	0.19
P-118	41	J-113	J-149	75	ISOPVC	140	9.3	2.1
P-118	4	J-109	FCV-104	35	JISPVC	140	1.1	1.09
P-119	41	J-109	J-112	100	ISOPVC	125	11	1.42

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-119	172	FCV-104	J-84	35	JISPVC	140	1.1	1.1
P-120	88	J-110	J-42	63	ISOPVC	140	6.5	2.08
P-120	6	J-112	FCV-105	35	JISPVC	140	0.96	1
P-121	145	J-115	J-176	48	ISOPVC	105	-3	1.69
P-121	273	FCV-105	J-8	35	JISPVC	140	0.96	1
P-122	151	J-175	J307	48	ISOPVC	105	0.34	0.19
P-122	201	J-156	FCV-106	38	ISOPVC	150	-2.8	2.5
P-123	161	J-114	J-115	48	ISOPVC	100	-2.2	1.24
P-123	6	FCV-106	J-72	38	ISOPVC	150	-2.8	2.5
P-124	171	J-72	FCV-107	50	ISOPE	150	-4.5	2.27
P-125	4	FCV-107	J-73	63	ISOPE	150	-4.5	1.43
P-126	6	J-41	FCV-108	85	ISOPVC	150	-7	1.23
P-127	436	FCV-108	J-39	95	ISOPVC	140	-7	0.98
P-128	130	J-64	FCV-109	25	JISPVC	150	0.082	0.17
P-129	5	FCV-109	J-33	25	JISPVC	150	0.083	0.17
P-130	91	J-41	FCV-110	25	JISPVC	150	0.25	0.51
P-131	7	FCV-110	J-36	25	JISPVC	150	0.25	0.51
P-132	263	J-81	FCV-111	45	JISPVC	105	-3	1.87
P-133	5	FCV-111	J-76	45	JISPVC	95	-3	1.87
P-134	64	J-78	FCV-112	63	JISPVC	125	-4.8	1.55
P-135	150	J-197	J-241	48	ISOPVC	125	3.2	1.75
P-135	6	FCV-112	J-104	63	JISPVC	95	-4.8	1.55
P-136	7	J-88	FCV-113	35	JISPVC	95	0.26	0.27
P-137	8	J-163	J-164	48	ISOPVC	125	-1.3	0.74
P-137	119	FCV-113	J-284	35	JISPVC	95	0.26	0.27
P-138	5	J-95	FCV-114	35	JISPVC	95	0.099	0.1
P-139	111	J320	J-70	50	ISOPVC	100	0.87	0.44
P-139	124	FCV-114	J-282	35	JISPVC	90	0.098	0.1
P-140	5	J-141	FCV-115	45	ISOPE	150	-2.4	1.51
P-141	15	J-145	J-177	95	JISPVC	105	-12	1.72
P-141	55	FCV-115	J-142	45	ISOPE	150	-2.4	1.51
P-142	50	J306	J-137	50	JISPVC	105	-1.5	0.75
P-143	72	J-177	J-200	95	JISPVC	105	-13	1.85
P-144	143	J-137	J-167	50	JISPVC	105	-2	1
P-144	5	J-183	FCV-117	75	ISOPVC	120	0.96	0.22
P-145	213	J-167	J-145	75	JISPVC	105	-11	2.4
P-145	33	FCV-117	J-250	75	ISOPVC	120	0.96	0.22
P-146	150	J-252	FCV-118	48	ISOPVC	120	-0.46	0.25
P-147	3	J-50	J-165	60	JISPVC	120	1.5	0.53

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-147	4	FCV-118	J-165	48	ISOPVC	120	-0.46	0.25
P-148	5	J-183	J-50	95	JISPVC	120	-15	2.14
P-148	6	J-165	FCV-119	48	ISOPVC	120	0.87	0.48
P-149	350	FCV-119	J-251	48	ISOPVC	140	0.87	0.48
P-150	639	J-150	FCV-120	48	ISOPVC	140	-3.2	1.79
P-151	225	J-56	J-161	60	JISPVC	100	-6.4	2.27
P-151	10	FCV-120	J-178	48	ISOPVC	120	-3.2	1.79
P-152	218	J-66	J324	50	JISPVC	150	0.93	0.47
P-152	18	J-161	FCV-121	75	JISPVC	110	-9.5	2.15
P-153	224	J-126	J-116	60	JISPVC	110	2.9	1.04
P-153	174	FCV-121	J-178	75	JISPVC	120	-9.5	2.15
P-154	4	J-161	FCV-122	48	ISOPVC	110	2.5	1.41
P-155	78	FCV-122	J-135	48	ISOPVC	110	2.5	1.41
P-156	33	J311	J-182	75	JISPVC	90	9.7	2.2
P-156	9	J-56	FCV-123	185	GS	100	3.4	0.13
P-157	69	J-182	PRV-2	60	JISPVC	90	4.8	1.68
P-157	185	FCV-123	J-245	50	GS	100	3.4	1.72
P-158	118	PRV-2	J-126	60	JISPVC	90	4.3	1.53
P-160	3	J-119	FCV-125	485	DCI	125	97	0.53
P-161	3	FCV-125	J-120	485	DCI	125	97	0.53
P-162	6	J-115	FCV-126	35	JISPVC	100	0.57	0.59
P-163	84	J-144	J-102	75	JISPVC	140	-2.4	0.55
P-163	56	FCV-126	J-108	35	JISPVC	100	0.57	0.59
P-164	278	J-295	J-144	50	JISPVC	140	-0.52	0.26
P-164	6	J-177	FCV-128	48	ISOPVC	105	0.86	0.47
P-165	5	Fire Hydrant (Point)-12	J-196	45	JISPVC	125	-0.1	0.06
P-165	353	FCV-128	J-175	48	ISOPVC	105	0.86	0.47
P-166	12	J-48	J-46	85	JISPVC	110	6.6	1.16
P-166	4	J-60	FCV-129	75	ISOPVC	105	-8.1	1.83
P-167	52	J-164	J-57	85	JISPVC	125	-2.1	0.37
P-167	5	FCV-129	J-167	75	ISOPVC	105	-8.1	1.83
P-168	54	J-57	J-117	85	JISPVC	125	-2.7	0.47
P-168	5	J-171	FCV-130	48	ISOPVC	105	2.6	1.42
P-169	4	J-71	FCV-39	35	JISPVC	150	0.18	0.19
P-169	90	FCV-130	J-169	48	ISOPVC	105	2.6	1.42
P-170	179	FCV-39	J332	75	JISPVC	150	0.18	0.04
P-170	9	J-169	FCV-131	48	ISOPVC	105	1.3	0.74
P-171	36	FCV-131	J-170	48	ISOPVC	105	1.3	0.74
P-172	3	FCV-40	J-151	75	JISPVC	150	3.4	0.78

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-172	137	J-261	FCV-132	48	ISOPVC	125	-0.33	0.18
P-173	31	FCV-132	J-162	48	ISOPVC	125	-0.33	0.18
P-174	33	J-162	FCV-133	48	ISOPVC	125	-1.2	0.66
P-175	86	FCV-133	J-163	48	ISOPVC	125	-1.2	0.66
P-176	7	J-164	FCV-134	48	ISOPVC	125	0.65	0.36
P-177	110	FCV-134	J-262	48	ISOPVC	125	0.65	0.36
P-178	8	J-57	FCV-135	17	GS	125	0.3	1.33
P-179	92	FCV-135	J-263	17	GS	125	0.3	1.33
P-180	127	J1	J-194	85	ISOPVC	90	10	1.8
P-180	76	J-90	FCV-136	35	JISPVC	105	-1.1	1.15
P-181	8	J-6	J-7	85	JISPVC	105	-0.37	0.06
P-181	17	FCV-136	J-13	35	JISPVC	105	-1.1	1.15
P-182	8	J-8	J-9	85	JISPVC	125	0.47	0.08
P-182	77	J-196	FCV-137	75	ISOPVC	125	5.9	1.34
P-183	8	J-10	J-11	85	JISPVC	115	0.22	0.04
P-183	17	FCV-137	J-197	75	ISOPVC	115	5.9	1.34
P-184	15	J-12	J-13	85	JISPVC	105	1.4	0.24
P-185	29	J-296	J-14	63	JISPVC	110	-0.22	0.07
P-185	8	FCV-138	J-32	75	GS	150	-9.9	2.25
P-186	30	J-15	J-16	110	JISPVC	105	0.78	0.08
P-186	9	J-66	FCV-139	75	GS	150	-9.9	2.25
P-187	31	J-7	J-8	75	JISPVC	105	-0.42	0.09
P-187	127	FCV-139	FCV-138	75	GS	150	-9.9	2.25
P-188	35	J-17	J-12	85	JISPVC	105	-4.2	0.73
P-188	427	J321	FCV-140	50	GS	150	-2.2	1.14
P-189	36	J-18	J-19	85	JISPVC	105	-3.2	0.57
P-189	40	FCV-140	J-64	50	GS	150	-2.2	1.14
P-190	36	J-11	J-6	85	JISPVC	105	1.4	0.24
P-190	5	J-144	FCV-141	38	ISOPE	150	0.46	0.41
P-191	41	J-14	J-18	85	JISPVC	105	-1.6	0.29
P-191	245	FCV-141	J334	38	ISOPE	150	0.46	0.41
P-192	42	J-9	J-15	85	JISPVC	125	0.27	0.05
P-192	185	J-292	FCV-142	35	JISPVC	95	-0.38	0.4
P-193	43	J-19	J-17	85	JISPVC	105	-3.8	0.66
P-193	9	FCV-142	J-78	35	JISPVC	135	-0.39	0.4
P-194	84	J-274	J-10	45	JISPVC	115	-0.088	0.06
P-194	184	J-291	FCV-144	35	JISPVC	135	-0.62	0.65
P-195	122	J-13	J-4	63	JISPVC	125	0.21	0.07
P-195	8	FCV-144	J-91	35	JISPVC	135	-0.62	0.65

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-196	7	J-69	FCV-145	35	HDPE	105	2.1	2.15
P-197	408	FCV-145	J-299	35	HDPE	140	2.1	2.15
P-198	10	J-199	FCV-146	48	ISOPVC	90	0.44	0.24
P-199	515	FCV-146	J313	48	ISOPVC	110	0.44	0.24
P-203	68	J-143	J327	75	ISOPE	150	-3.4	0.77
P-204	99	J-151	J-6404	38	ISOPE	150	1	0.9
P-205	73	J-6404	J-71	28	ISOPE	150	0.7	1.14
P-206	285	J-194	J310	95	ISOPVC	95	10	1.43
P-207	255	J-29	J-30	150	ISOPVC	135	-38	2.17
P-211	3	J-34	J-35	110	ISOPVC	95	-22	2.29
P-211	319	J327	FCV-40	50	Ductile Iron	150	3.4	1.75
P-212	14	J-36	J-33	85	ISOPVC	150	12	2.15
P-212	252	J-143	J-6406	40	Ductile Iron	150	0.22	0.18
P-213	23	J-37	J-29	150	ISOPVC	135	-38	2.12
P-213	127	J-67	J-6407	45	GS	125	3.3	2.07
P-214	103	J-16	J-38	110	ISOPVC	90	-22	2.32
P-214	132	J-6407	J-68	35	GS	125	1.1	1.17
P-215	181	J-39	J-34	95	ISOPVC	85	-8.3	1.17
P-215	142	J-124	J-6407	48	HDPE	125	-0.58	0.32
P-216	185	J-38	J-40	150	ISOPVC	150	-23	1.27
P-217	235	J-40	J-37	150	ISOPVC	150	-35	2
P-219	395	J-35	J-16	110	ISOPVC	150	-22	2.34
P-221	466	J-36	J-34	95	ISOPVC	150	-12	1.75
P-223	174	J-200	J-44	95	ISOPVC	90	-14	1.99
P-224	37	J-46	J-196	115	ISOPVC	125	6.5	0.62
P-225	3	J-199	J-44	135	DCI	90	14	1
P-226	18	J-6419	J-48	95	ISOPE	125	14	1.99
P-228	102	J-52	J-255	35	GS	100	0.12	0.12
P-229	102	J-53	J-254	35	GS	100	0.21	0.22
P-230	167	J-54	J315	35	GS	150	0.69	0.71
P-234	128	J-6407	J-6415	35	JISPVC	125	0.78	0.81
P-235	45	J-55	J-54	25	GS	125	0.86	1.75
P-236	299	J-59	J-55	75	GS	115	3.5	0.8
P-237	130	J303	J-60	25	GS	105	-0.16	0.32
P-238	230	J-60	J-61	25	GS	105	0.64	1.3
P-240	109	J-63	J-253	35	GS	100	0.63	0.66
P-240	4	J-6420	FCV-152	485	Ductile Iron	125	1.10E+02	0.6
P-241	10	J-67	J-134	63	JISPVC	125	-4.3	1.38

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-242	3	FCV-152	J-6419	485	Ductile Iron	125	1.10E+02	0.6
P-243	16	J-6419	J-119	485	Ductile Iron	125	97	0.53
P-246	6,461	source reservoir	J-6420	485	Ductile Iron	125	1.10E+02	0.61
P-251	5	J-76	J-77	100	JISPVC	95	-7.5	0.96
P-253	8	J-73	J-65	60	JISPVC	150	-4.1	1.45
P-254	9	J-78	J-79	45	JISPVC	125	2.5	1.57
P-255	9	J-80	J-81	45	JISPVC	125	-3.3	2.05
P-259	27	J-65	J-41	63	JISPVC	150	-6.6	2.1
P-260	31	J-85	J-288	35	JISPVC	105	0.64	0.67
P-261	31	J-86	J-273	35	JISPVC	110	0.042	0.04
P-264	37	J-89	J-90	35	JISPVC	105	-0.72	0.75
P-265	38	J-80	J-91	35	JISPVC	125	-0.94	0.98
P-266	39	J-92	J-93	35	JISPVC	105	2.1	2.23
P-267	39	J-94	J-89	35	JISPVC	90	-1.2	1.25
P-268	39	J-95	J-94	35	JISPVC	90	-0.79	0.82
P-269	39	J-96	J-85	35	JISPVC	105	1	1.07
P-270	40	J-97	J-96	35	JISPVC	105	1.5	1.54
P-271	40	J-91	J-78	35	JISPVC	125	-1.8	1.83
P-272	40	J-93	J-97	35	JISPVC	105	1.8	1.92
P-273	44	J-6	J-92	35	JISPVC	105	2.4	2.49
P-274	50	J-98	J-99	35	JISPVC	90	0.66	0.69
P-276	53	J-88	J-95	35	JISPVC	95	-0.41	0.42
P-277	54	J-290	J-102	25	JISPVC	150	-0.52	1.06
P-279	69	J-293	J-79	35	JISPVC	125	-0.12	0.12
P-281	78	J-79	J-81	35	JISPVC	125	1.2	1.25
P-283	86	J-105	J-86	35	JISPVC	105	0.55	0.57
P-284	87	J-75	J-106	35	JISPVC	105	0.72	0.74
P-286	94	J-107	J-10	35	JISPVC	105	0.47	0.49
P-289	133	J-107	J-265	35	JISPVC	105	0.43	0.45
P-290	103	J-84	J-15	35	JISPVC	105	0.7	0.72
P-291	104	J-99	J-95	35	JISPVC	95	-0.098	0.1
P-292	126	J-108	J319	35	JISPVC	100	0.18	0.19
P-293	109	J-99	J-287	35	JISPVC	95	0.39	0.41
P-294	122	J-283	J-85	35	JISPVC	105	-0.12	0.13
P-295	122	J-279	J-97	35	JISPVC	100	-0.11	0.11
P-296	123	J-281	J-96	35	JISPVC	105	-0.1	0.1
P-297	124	J-79	J-294	35	JISPVC	105	1	1.09
P-298	128	J-98	J-94	35	JISPVC	90	-0.14	0.15

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-299	124	J-275	J-92	35	JISPVC	105	-0.13	0.13
P-300	124	J-276	J-93	35	JISPVC	100	-0.098	0.1
P-306	130	J-14	J-98	35	JISPVC	105	1.2	1.27
P-307	135	J-104	J-76	50	JISPVC	95	-4.4	2.26
P-308	134	J-106	J-268	35	JISPVC	105	0.47	0.49
P-310	165	J-297	J-98	35	JISPVC	105	-0.24	0.25
P-313	198	J-18	J-89	35	JISPVC	105	0.75	0.78
P-317	191	J-102	J-80	50	JISPVC	140	-3.5	1.79
P-320	196	PRV-2	J317	35	JISPVC	115	0.42	0.44
P-323	272	J-258	J-19	35	JISPVC	105	-0.29	0.3
P-324	272	J-18	J-257	35	JISPVC	105	0.5	0.52

Appendix A7 Flex Table: FCV Table for base scenario at 12:00am

Label	Elevation (m)	Diameter (Valve) (mm)	Flow (L/s)	Hydraulic Grade (From) (m)	Hydraulic Grade (To) (m)	Status (Initial)
FCV-6	2,464.98	50	38	2,569.05	2,569.05	Inactive
FCV-10	2,481.28	150	-31	2,569.61	2,569.61	Inactive
FCV-13	2,450.60	63	-1.7	2,535.76	2,535.76	Inactive
FCV-14	2,410.20	25	1.4	2,487.82	2,487.82	Inactive
FCV-16	2,433.37	50	-2	2,487.76	2,487.76	Inactive
FCV-17	2,431.54	50	0.41	2,510.02	2,510.02	Inactive
FCV-18	2,431.28	50	5.6	2,506.35	2,506.35	Inactive
FCV-19	2,436.01	50	-0.3	2,543.17	2,543.17	Inactive
FCV-20	2,426.90	50	0.1	2,492.11	2,492.11	Inactive
FCV-21	2,428.79	50	0.11	2,496.88	2,496.88	Inactive
FCV-23	2,428.32	50	0.22	2,505.19	2,505.19	Inactive
FCV-27	2,463.39	50	-0.43	2,544.91	2,544.91	Inactive
FCV-28	2,466.77	50	-0.71	2,547.48	2,547.48	Inactive
FCV-31	2,466.26	50	-12	2,553.88	2,553.88	Inactive
FCV-39	2,362.48	50	0.18	2,444.01	2,444.01	Inactive
FCV-40	2,380.53	40	3.4	2,450.29	2,450.29	Inactive
FCV-41	2,394.40	50	0.67	2,462.70	2,462.70	Inactive
FCV-44	2,420.92	50	-2.4	2,512.11	2,512.11	Inactive
FCV-56	2,471.38	75	-14	2,563.03	2,563.03	Inactive
FCV-86	2,410.85	100	0.61	2,506.65	2,506.65	Inactive
FCV-88	2,418.73	65	-1.2	2,517.37	2,517.37	Inactive
FCV-89	2,413.29	65	4.9	2,524.31	2,524.31	Inactive
FCV-90	2,450.08	50	0.89	2,536.88	2,536.88	Inactive

Label	Elevation (m)	Diameter (Valve) (mm)	Flow (L/s)	Hydraulic Grade (From) (m)	Hydraulic Grade (To) (m)	Status (Initial)
FCV-91	2,450.92	75	-1.4	2,536.84	2,536.84	Inactive
FCV-94	2,412.54	75	0.86	2,532.81	2,532.81	Inactive
FCV-95	2,406.45	100	-11	2,493.99	2,493.99	Inactive
FCV-96	2,465.61	100	62	2,569.74	2,569.74	Inactive
FCV-100	2,471.02	150	15	2,563.72	2,563.72	Inactive
FCV-101	2,455.89	50	5.9	2,538.69	2,538.69	Inactive
FCV-102	2,429.67	50	0.13	2,498.24	2,498.24	Inactive
FCV-103	2,455.85	50	0.18	2,538.70	2,538.70	Inactive
FCV-104	2,465.32	50	1.1	2,552.70	2,552.70	Inactive
FCV-105	2,466.05	50	0.96	2,551.63	2,551.63	Inactive
FCV-106	2,408.65	100	-2.8	2,494.58	2,494.58	Inactive
FCV-107	2,420.78	75	-4.5	2,511.76	2,511.76	Inactive
FCV-108	2,421.39	63	-7	2,513.94	2,513.94	Inactive
FCV-109	2,417.50	100	0.082	2,511.88	2,511.88	Inactive
FCV-110	2,418.09	50	0.25	2,512.61	2,512.61	Inactive
FCV-111	2,431.63	50	-3	2,553.96	2,553.96	Inactive
FCV-112	2,422.67	50	-4.8	2,524.64	2,524.64	Inactive
FCV-113	2,423.59	50	0.26	2,489.06	2,489.06	Inactive
FCV-114	2,425.06	50	0.099	2,489.89	2,489.89	Inactive
FCV-115	2,365.80	50	-2.4	2,464.95	2,464.95	Inactive
FCV-117	2,472.28	75	0.96	2,563.56	2,563.56	Inactive
FCV-118	2,471.68	50	-0.46	2,563.83	2,563.83	Inactive
FCV-119	2,471.78	50	0.87	2,563.79	2,563.79	Inactive
FCV-120	2,466.39	50	-3.2	2,558.01	2,558.01	Inactive
FCV-121	2,455.73	75	-9.5	2,544.72	2,544.72	Inactive
FCV-122	2,454.33	63	2.5	2,542.67	2,542.67	Inactive

Label	Elevation (m)	Diameter (Valve) (mm)	Flow (L/s)	Hydraulic Grade (From) (m)	Hydraulic Grade (To) (m)	Status (Initial)
FCV-123	2,442.19	25	3.4	2,506.01	2,506.01	Inactive
FCV-125	2,475.96	500	97	2,570.28	2,570.28	Inactive
FCV-126	2,423.91	50	-0.57	2,501.07	2,501.07	Inactive
FCV-128	2,411.99	50	0.86	2,528.48	2,528.48	Inactive
FCV-129	2,412.19	63	-8.1	2,500.14	2,500.14	Inactive
FCV-130	2,412.18	63	2.6	2,484.16	2,484.16	Inactive
FCV-131	2,412.19	63	1.3	2,476.68	2,476.68	Inactive
FCV-132	2,439.74	50	-0.33	2,538.46	2,538.46	Inactive
FCV-133	2,439.43	50	-1.2	2,538.96	2,538.96	Inactive
FCV-134	2,442.49	50	0.65	2,540.28	2,540.28	Inactive
FCV-135	2,448.51	32	0.3	2,539.10	2,539.10	Inactive
FCV-136	2,431.44	50	1.1	2,504.30	2,504.30	Inactive
FCV-137	2,465.99	63	5.9	2,566.48	2,566.48	Inactive
FCV-138	2,395.43	40	-9.9	2,485.94	2,485.94	Inactive
FCV-139	2,389.11	40	-9.9	2,478.48	2,478.48	Inactive
FCV-140	2,417.37	100	-2.2	2,511.01	2,511.01	Inactive
FCV-141	2,418.91	63	0.46	2,500.45	2,500.45	Inactive
FCV-142	2,421.93	50	-0.39	2,521.31	2,521.31	Inactive
FCV-144	2,422.62	50	-0.62	2,515.79	2,515.79	Inactive
FCV-145	2,410.58	100	2.1	2,463.41	2,463.41	Inactive
FCV-146	2,411.13	100	0.44	2,548.74	2,548.74	Inactive
FCV-152	2,496.00	500	-1.10E+02	2,570.29	2,570.29	Inactive

Appendix A8 Flex Table: Junction Table for peak hour at 12:00am

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
2397	2,410.20	Zone - 1	90	467,276.81	998,682.67	1.3	0.3

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-4	2,446.26	Zone - 2	71	468,221.85	998,675.15	0.054	0.2
J-6	2,461.81	Zone - 2	85	468,354.28	998,720.50	0.05	0.6
J-7	2,462.18	Zone - 2	85	468,361.38	998,723.14	0.048	0.7
J-8	2,463.80	Zone - 2	83	468,390.71	998,732.63	0.063	0.8
J-9	2,464.25	Zone - 2	83	468,398.04	998,735.06	0.092	0.7
J-10	2,459.33	Zone - 2	88	468,312.16	998,705.98	0.14	0.3
J-11	2,459.72	Zone - 2	88	468,319.93	998,708.49	0.055	0.7
J-12	2,441.06	Zone - 2	77	468,097.45	998,641.17	0.068	0.3
J-13	2,441.90	Zone - 2	76	468,108.28	998,639.17	0.051	0.3
J-14	2,430.63	Zone - 2	86	467,951.39	998,589.97	0.18	0.2
J-15	2,466.36	Zone - 2	81	468,437.65	998,748.39	0.16	0.6
J-16	2,467.39	Zone - 2	80	468,465.52	998,758.32	0.51	2.5
J-17	2,438.12	Zone - 2	79	468,065.05	998,627.13	0.16	0.2
J-18	2,432.78	Zone - 2	84	467,989.13	998,606.07	0.28	0.2
J-19	2,435.39	Zone - 2	81	468,023.50	998,615.15	0.23	0.2
J-29	2,490.75	Zone - 2	71	468,291.09	999,274.80	0.78	4.1
J-30	2,478.80	Zone - 2	90	468,037.70	999,256.03	0.0099	4.5
J-32	2,433.30	Zone - 3	68	468,584.03	997,255.51	1.2	0.9
J-33	2,468.00	Zone - 3	54	468,548.10	997,885.58	0.92	1.3
J-34	2,451.70	Zone - 2	82	468,522.36	998,364.81	0.94	1.9
J-35	2,458.00	Zone - 2	76	468,522.28	998,367.42	0.49	2.2
J-36	2,464.60	Zone - 3	58	468,545.87	997,899.20	0.4	1.5
J-37	2,489.41	Zone - 2	72	468,299.22	999,253.59	0.22	3.7
J-38	2,470.82	Zone - 2	85	468,432.31	998,855.29	0.4	3
J-39	2,454.36	Zone - 2	74	468,341.67	998,356.53	0.22	1.6
J-40	2,476.29	Zone - 2	81	468,373.46	999,030.91	0.41	3.4
J-41	2,470.00	Zone - 3	54	468,458.89	997,941.87	0.15	1.1
J-42	2,466.13	Zone - 2	79	468,144.16	998,943.79	0.35	0.6
J-43	2,454.64	Zone - 2	89	468,010.75	998,901.96	0.28	0.5
J-44	2,484.40	Zone - 1	68	467,657.13	998,337.14	0.2	3.9
J-46	2,490.80	Zone - 1	79	466,778.48	999,516.40	0.12	5.7
J-48	2,493.60	Zone - 1	77	466,767.89	999,521.83	0.56	7
J-50	2,498.80	Zone - 1	67	467,491.58	999,234.94	0.0086	5.7
J-51	2,500.20	Zone - 1	70	467,491.92	999,347.36	2.2	7.4
J-52	2,445.87	Zone - 1	47	467,720.62	998,744.66	0.2	0.2
J-53	2,444.61	Zone - 1	40	467,664.61	998,743.21	0.14	0.2
J-54	2,415.00	Zone - 1	82	467,357.74	998,518.43	0.16	0.3
J-55	2,415.00	Zone - 1	89	467,391.98	998,546.94	1.1	0.7
J-56	2,455.00	Zone - 1	63	467,402.05	998,902.65	1.3	1.4

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-57	2,468.30	Zone - 2	78	467,971.74	999,091.22	0.22	1.9
J-59	2,443.30	Zone - 1	64	467,650.74	998,667.08	0.31	0.8
J-60	2,427.70	Zone - 3	85	467,675.58	998,073.91	0.11	1.2
J-61	2,422.12	Zone - 3	62	467,802.39	998,266.38	0.052	0.5
J-63	2,443.78	Zone - 1	38	467,629.95	998,737.03	0.59	0.2
J-64	2,467.60	Zone - 3	55	468,427.95	997,944.71	0.09	0.6
J-65	2,461.60	Zone - 3	61	468,434.16	997,952.59	0.017	0.9
J-66	2,424.80	Zone - 3	70	468,467.35	997,282.56	0.84	0.4
J-67	2,486.00	Zone - 1	56	466,576.49	999,279.86	0.91	4
J-68	2,458.60	Zone - 1	64	466,741.56	999,084.50	0.15	1.6
J-69	2,420.61	Zone - 3	64	467,838.96	998,241.84	0.18	0.4
J-70	2,461.20	Zone - 1	60	467,785.41	998,733.79	0.41	0.5
J-71	2,398.80	Zone - 3	68	468,266.66	997,263.24	0.47	0.2
J-72	2,446.00	Zone - 3	63	468,317.39	997,831.52	1.5	0.3
J-73	2,464.60	Zone - 3	57	468,427.47	997,956.21	0.15	0.6
J-75	2,480.60	Zone - 2	70	468,193.73	998,764.61	0.15	2.4
J-76	2,470.20	Zone - 2	88	468,333.84	998,353.75	0.093	3.8
J-77	2,465.60	Zone - 2	92	468,335.06	998,357.13	0.0032	4.5
J-78	2,452.60	Zone - 3	76	468,220.61	998,277.37	0.17	1.4
J-79	2,446.00	Zone - 3	82	468,229.25	998,276.23	0.12	0.9
J-80	2,449.80	Zone - 3	72	468,243.73	998,203.04	0.27	0.8
J-81	2,446.00	Zone - 3	77	468,252.48	998,201.72	0.38	1.3
J-84	2,470.94	Zone - 2	79	468,404.94	998,846.51	0.32	0.9
J-85	2,452.22	Zone - 2	61	468,413.30	998,528.89	0.24	0.2
J-86	2,479.30	Zone - 2	69	468,139.11	998,654.41	0.19	1.2
J-88	2,433.07	Zone - 2	71	468,180.42	998,398.92	0.13	0.2
J-89	2,438.46	Zone - 2	72	468,137.79	998,522.03	0.15	0.2
J-90	2,439.34	Zone - 2	72	468,124.77	998,557.05	0.23	0.2
J-91	2,446.60	Zone - 3	77	468,232.99	998,239.64	0.18	0.8
J-92	2,459.54	Zone - 2	76	468,365.69	998,678.94	0.11	0.3
J-93	2,457.96	Zone - 2	68	468,378.10	998,642.34	0.19	0.2
J-94	2,436.66	Zone - 2	70	468,150.18	998,485.28	0.14	0.2
J-95	2,434.71	Zone - 2	70	468,162.01	998,448.29	0.17	0.2
J-96	2,453.79	Zone - 2	61	468,403.20	998,566.81	0.31	0.2
J-97	2,440.00	Zone - 2	80	468,390.57	998,604.33	0.24	0.2
J-98	2,428.69	Zone - 2	78	468,026.61	998,483.54	0.42	0.2
J-99	2,429.31	Zone - 2	75	468,058.48	998,445.12	0.33	0.2
J-102	2,436.60	Zone - 3	71	468,303.14	998,021.52	0.51	0.6
J-104	2,457.70	Zone - 2	74	468,200.65	998,344.80	0.068	2.4

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-105	2,476.00	Zone - 2	74	468,220.09	998,682.13	0.1	1.8
J-106	2,476.60	Zone - 2	72	468,110.14	998,740.27	0.49	1.2
J-107	2,469.30	Zone - 2	79	468,283.39	998,795.73	0.37	0.4
J-108	2,446.90	Zone - 1	66	467,724.03	998,582.74	0.18	0.4
J-109	2,475.43	Zone - 2	81	468,347.17	999,013.23	0.13	2.5
J-110	2,473.69	Zone - 2	76	468,227.67	998,972.48	0.18	0.9
J-112	2,476.33	Zone - 2	79	468,308.33	998,999.29	0.056	2.1
J-113	2,477.19	Zone - 2	75	468,271.13	998,987.27	0.079	1.3
J-114	2,442.89	Zone - 1	62	467,774.76	998,748.06	0.14	0.6
J-115	2,444.00	Zone - 1	70	467,785.82	998,587.30	0.22	0.9
J-116	2,441.60	Zone - 1	71	467,655.42	998,579.76	0.74	1
J-117	2,469.90	Zone - 2	77	468,022.91	999,107.22	0.31	2.3
J-118	2,480.20	Zone - 2	76	468,097.91	999,038.43	0.58	3.4
J-119	2,500.20	Zone - 1	71	466,786.58	999,529.53	0.017	8.1
J-120	2,500.30	Zone - 1	71	466,791.98	999,526.92	0.25	7.7
J-121	2,503.20	Zone - 2	67	468,034.87	999,252.96	0.087	6.9
J-124	2,458.90	Zone - 1	70	466,679.70	999,070.90	0.15	2.1
J-126	2,446.30	Zone - 1	72	467,656.88	998,356.03	0.71	1.4
J-127	2,478.57	Zone - 2	80	468,346.49	999,048.25	0.04	1.1
J-128	2,485.60	Zone - 2	73	468,272.64	999,151.61	0.057	1.9
J-129	2,485.22	Zone - 2	73	468,245.28	999,142.58	0.42	1.4
J-130	2,484.52	Zone - 2	74	468,301.10	999,141.82	0.12	1.4
J-131	2,480.84	Zone - 2	78	468,335.35	999,077.97	0.23	1.1
J-132	2,487.96	Zone - 2	72	468,288.44	999,217.52	0.2	2.6
J-133	2,454.50	Zone - 3	78	467,659.47	998,237.64	0.48	1.7
J-134	2,469.60	Zone - 1	73	466,586.29	999,280.11	0.79	5.2
J-135	2,460.62	Zone - 1	83	467,668.70	998,979.16	0.24	0.9
J-136	2,463.91	Zone - 1	78	467,665.56	999,067.44	0.26	0.5
J-137	2,430.00	Zone - 3	78	467,588.16	997,959.76	0.011	1.3
J-138	2,427.70	Zone - 3	79	467,787.60	997,210.00	0.43	0.3
J-141	2,390.00	Zone - 3	93	468,238.62	997,117.81	1.1	0.2
J-142	2,396.60	Zone - 3	89	468,298.90	997,116.21	0.26	0.2
J-143	2,393.14	Zone - 3	93	468,364.40	997,114.71	0.34	0.2
J-144	2,436.30	Zone - 3	71	468,224.48	998,050.12	1.3	0.5
J-145	2,457.70	Zone - 3	78	467,784.57	998,257.16	0.17	2.3
J-146	2,475.93	Zone - 2	71	468,317.62	999,001.79	0.086	0.6
J-147	2,477.16	Zone - 2	76	468,279.96	998,990.24	0.07	1.7
J-149	2,474.10	Zone - 2	76	468,232.15	998,974.17	0.065	1
J-150	2,464.20	Zone - 1	58	467,007.32	998,824.51	2.7	1.3

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-151	2,405.36	Zone - 3	66	468,362.17	997,403.62	0.19	0.2
J-156	2,445.20	Zone - 3	37	468,255.59	997,634.69	1.4	0.2
J-158	2,492.20	Zone - 2	77	468,038.80	999,221.71	0.044	4.5
J-159	2,506.00	Zone - 2	64	468,037.25	999,236.24	0.033	6
J-160	2,460.30	Zone - 1	82	467,722.97	998,980.18	0.33	0.5
J-161	2,470.00	Zone - 1	78	467,588.14	998,979.04	0.49	1.8
J-162	2,470.60	Zone - 2	74	467,916.10	998,976.78	0.46	0.7
J-163	2,469.60	Zone - 2	77	467,915.57	999,070.56	0.13	1.2
J-164	2,469.20	Zone - 1	77	467,922.97	999,073.12	0.11	1.7
J-165	2,493.60	Zone - 1	72	467,494.91	999,234.94	0.15	4.4
J-166	2,494.40	Zone - 2	76	468,040.86	999,222.19	0.18	5.6
J-167	2,428.40	Zone - 3	85	467,668.02	998,078.76	0.47	1.8
J-168	2,421.04	Zone - 3	86	467,711.20	998,051.55	0.25	0.9
J-169	2,422.78	Zone - 3	71	467,744.90	997,929.02	0.55	0.3
J-170	2,419.71	Zone - 3	73	467,770.42	997,966.09	0.15	0.2
J-171	2,422.15	Zone - 3	78	467,665.79	997,981.08	0.2	0.6
J-172	2,414.00	Zone - 3	72	467,802.47	998,188.00	0.38	0.6
J-175	2,455.00	Zone - 3	78	467,457.74	998,219.24	0.47	1.3
J-176	2,446.50	Zone - 1	81	467,818.71	998,454.52	0.57	1.3
J-177	2,465.50	Zone - 3	71	467,793.10	998,269.24	0.06	2.8
J-178	2,470.20	Zone - 1	91	467,513.73	999,152.07	0.68	2.9
J-182	2,450.00	Zone - 1	84	467,843.46	998,346.62	0.1	2.5
J-183	2,496.00	Zone - 1	69	467,486.70	999,234.93	0.62	4.8
J-194	2,459.00	Zone - 2	90	468,202.73	998,361.70	0.079	4.1
J-196	2,550.00	Zone - 1	20	466,810.99	999,498.21	0.39	5
J-197	2,490.30	Zone - 1	77	466,892.19	999,451.67	2.5	3.4
J-199	2,483.30	Zone - 1	70	467,657.38	998,339.80	0.037	4.4
J-200	2,480.20	Zone - 1	60	467,831.18	998,329.72	0.1	3.3
J-205	2,501.10	Zone - 1	70	467,560.48	999,348.17	0.95	7.2
J-209	2,455.50	Zone - 3	77	467,442.18	998,070.35	0.038	1.4
J-239	2,465.36	Zone - 1	71	466,760.64	999,087.11	1.5	2.7
J-241	2,511.00	Zone - 1	46	466,877.41	999,345.95	2.9	2.3
J-245	2,440.20	Zone - 1	59	467,303.24	998,980.89	3	0.9
J-246	2,460.00	Zone - 1	83	467,722.05	998,868.69	0.17	0.3
J-247	2,458.52	Zone - 1	84	467,731.79	999,066.44	0.3	0.4
J-248	2,472.66	Zone - 1	69	467,661.83	999,178.96	0.5	0.4
J-249	2,470.58	Zone - 1	71	467,569.66	999,061.53	0.48	0.4
J-250	2,492.00	Zone - 1	73	467,484.76	999,273.18	0.87	3.6
J-251	2,495.00	Zone - 1	64	467,745.59	999,348.06	1.6	2.2

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-252	2,496.30	Zone - 1	69	467,620.30	999,201.25	0.41	2.6
J-253	2,443.50	Zone - 1	35	467,612.68	998,842.72	0.57	0.2
J-254	2,450.20	Zone - 1	34	467,662.34	998,845.41	0.19	0.2
J-255	2,450.64	Zone - 1	43	467,715.04	998,846.66	0.11	0.2
J-256	2,451.30	Zone - 1	53	467,768.36	998,844.81	0.09	0.4
J-257	2,441.78	Zone - 2	71	467,899.32	998,862.91	0.45	0.2
J-258	2,444.95	Zone - 2	70	467,931.26	998,869.95	0.26	0.2
J-259	2,442.00	Zone - 2	75	467,969.17	998,885.60	0.2	0.2
J-260	2,525.00	Zone - 2	20	467,816.09	999,054.49	0.31	0.4
J-261	2,469.00	Zone - 2	76	467,849.04	999,105.86	0.3	0.4
J-262	2,471.30	Zone - 2	75	467,886.56	999,184.25	0.59	1
J-263	2,470.00	Zone - 2	62	467,942.11	999,186.04	0.27	0.2
J-264	2,474.40	Zone - 2	72	467,996.32	999,187.29	0.17	1.6
J-265	2,465.42	Zone - 2	82	468,209.96	998,864.59	0.39	0.3
J-268	2,476.00	Zone - 2	70	468,066.71	998,866.60	0.42	0.8
J-273	2,476.60	Zone - 2	72	468,109.38	998,644.66	0.038	1.1
J-274	2,459.00	Zone - 2	88	468,232.96	998,677.41	0.079	0.2
J-275	2,452.21	Zone - 2	83	468,247.66	998,641.10	0.11	0.2
J-276	2,450.24	Zone - 2	76	468,260.32	998,603.28	0.089	0.2
J-277	2,440.00	Zone - 2	71	468,246.54	998,598.31	0.12	0.2
J-278	2,440.00	Zone - 2	70	468,259.49	998,560.56	0.095	0.2
J-279	2,448.35	Zone - 2	71	468,274.51	998,565.39	0.095	0.2
J-280	2,439.20	Zone - 2	67	468,272.78	998,521.43	0.093	0.2
J-281	2,452.20	Zone - 2	63	468,287.29	998,525.84	0.09	0.2
J-282	2,436.60	Zone - 2	68	468,285.13	998,483.95	0.088	0.2
J-283	2,450.40	Zone - 2	62	468,298.22	998,489.84	0.11	0.2
J-284	2,442.35	Zone - 2	61	468,296.25	998,447.74	0.23	0.2
J-285	2,441.90	Zone - 2	75	468,326.41	998,371.73	0.14	0.2
J-287	2,428.47	Zone - 2	75	468,126.84	998,360.10	0.35	0.2
J-288	2,451.43	Zone - 2	61	468,422.07	998,499.18	0.58	0.2
J-289	2,473.50	Zone - 3	51	468,471.76	997,958.56	0.95	1
J-290	2,434.40	Zone - 3	71	468,349.64	997,994.74	0.47	0.2
J-291	2,448.60	Zone - 3	72	468,040.77	998,234.06	0.56	0.3
J-292	2,445.00	Zone - 3	82	468,027.52	998,270.48	0.35	0.6
J-293	2,452.30	Zone - 3	76	468,209.18	998,342.70	0.1	0.7
J-294	2,450.36	Zone - 3	70	468,352.63	998,279.97	0.94	0.6
J-295	2,435.50	Zone - 3	70	467,962.85	998,139.45	0.93	0.3
J-296	2,430.00	Zone - 2	87	467,923.94	998,581.46	0.2	0.2
J-297	2,430.00	Zone - 2	76	467,927.38	998,576.55	0.22	0.2

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-298	2,422.15	Zone - 3	56	467,894.04	997,831.02	1.4	0.4
J-299	2,390.00	Zone - 3	43	467,940.74	997,839.52	1.9	0.2
J-300	2,420.00	Zone - 3	73	467,874.28	997,845.92	0.54	0.2
J-301	2,418.77	Zone - 3	73	467,864.88	997,903.95	0.52	0.2
J-6400	2,409.00	Zone - 3	80	468,490.57	997,111.32	0.84	0.4
J-6404	2,395.18	Zone - 3	74	468,312.96	997,319.48	0.28	0.2
J-6406	2,391.00	Zone - 3	95	468,353.92	997,366.62	0.2	0.2
J-6407	2,459.10	Zone - 1	70	466,651.46	999,180.35	0.73	2.7
J-6415	2,466.60	Zone - 1	59	466,528.52	999,144.04	0.7	1.6
J-6419	2,502.20	Zone - 1	69	466,773.69	999,538.45	0.14	8.4
J-6420	2,508.00	Zone - 1	63	466,766.50	999,537.78	0.51	8.9
J1	2,475.50	Zone - 2	83	468,329.25	998,369.96	0.057	5
J236	2,459.00	Zone - 1	63	466,722.48	998,965.02	0.7	1.2
J302	2,423.19	Zone - 3	77	467,637.32	997,939.20	0.19	0.5
J303	2,428.00	Zone - 3	83	467,603.86	997,965.91	0.14	0.7
J304	2,425.00	Zone - 3	82	467,791.77	998,000.22	0.21	0.7
J305	2,416.54	Zone - 3	76	467,832.31	998,059.44	0.53	0.2
J306	2,430.20	Zone - 3	77	467,561.37	997,917.54	1.3	1
J307	2,454.40	Zone - 3	78	467,433.41	998,076.17	0.3	1
J308	2,478.00	Zone - 1	62	467,910.82	998,327.16	0.11	2.5
J309	2,489.00	Zone - 1	49	467,932.31	998,328.79	0.23	1.5
J310	2,454.00	Zone - 1	85	467,918.37	998,345.91	0.22	3.4
J311	2,457.30	Zone - 1	81	467,876.76	998,345.39	0.12	3.1
J312	2,446.60	Zone - 3	73	467,902.15	998,186.94	0.35	0.4
J313	2,484.00	Zone - 1	68	467,155.59	998,411.81	0.4	1.8
J314	2,443.00	Zone - 1	74	467,347.95	998,488.18	0.55	0.6
J315	2,400.00	Zone - 1	94	467,244.60	998,640.64	0.62	0.2
J317	2,450.00	Zone - 1	76	467,727.12	998,537.40	0.38	1.2
J318	2,445.00	Zone - 1	75	467,818.52	998,616.07	0.37	0.2
J319	2,447.10	Zone - 1	65	467,658.90	998,667.15	0.16	0.2
J320	2,444.46	Zone - 1	78	467,778.73	998,844.73	0.28	0.7
J321	2,431.80	Zone - 3	80	468,221.31	997,546.05	2	0.3
J322	2,444.80	Zone - 3	36	468,228.66	997,539.87	0.55	0.2
J323	2,400.20	Zone - 3	52	468,478.52	997,587.41	2	0.2
J324	2,428.00	Zone - 3	65	468,410.16	997,492.49	0.83	0.3
J325	2,396.30	Zone - 3	88	468,261.62	997,251.99	0.096	0.2
J327	2,405.00	Zone - 3	82	468,432.14	997,111.30	0.29	0.3
J328	2,458.69	Zone - 2	86	468,200.62	998,772.88	0.16	0.3
J330	2,385.80	Zone - 3	74	468,255.73	997,240.51	1.1	0.2

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J332	2,400.00	Zone - 3	66	468,356.13	997,405.07	0.16	0.2
J334	2,450.00	Zone - 3	56	468,364.12	997,900.13	0.42	0.2
J336	2,461.00	Zone - 1	60	467,253.94	998,578.58	0.35	0.6
J337	2,444.60	Zone - 3	34	468,299.06	997,377.69	0.6	0.2
J341	2,458.00	Zone - 3	74	467,570.11	998,260.76	0.74	1.2
J342	2,462.20	Zone - 1	66	466,697.89	999,050.64	0.12	1.6
J343	2,459.00	Zone - 1	69	466,646.21	999,042.49	0.25	1.7
J345	2,477.03	Zone - 2	82	468,299.06	999,004.55	0.025	1.2
J346	2,477.16	Zone - 2	81	468,254.78	998,999.95	0.14	0.8
J347	2,478.58	Zone - 2	80	468,307.55	999,036.75	0.047	1
J348	2,480.71	Zone - 2	78	468,293.95	999,063.92	0.083	1.1
J349	2,483.21	Zone - 2	75	468,273.76	999,103.26	0.14	1
J350	2,485.84	Zone - 2	74	468,303.39	999,178.33	0.25	2.2

Appendix A9 Flex Table: Pipe Table for peak hour at 12:00am

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P--18	47	J-124	J343	63	HDPE	125	1.1	0.35
P-1	318	J-81	J-73	25	JISPVC	140	-0.33	0.66
P-2	344	J312	J-80	25	JISPVC	125	-0.21	0.43
P-3	36	J-53	J-63	25	JISPVC	100	0.7	1.43
P-5	56	J-52	J-53	25	JISPVC	100	0.9	1.83
P-7	69	J-108	J-116	25	JISPVC	100	0.3	0.61
P-8	84	J-117	J-264	25	JISPVC	125	0.1	0.21
P-9	97	J-256	J-114	25	JISPVC	100	-0.055	0.11
P-10	142	J-118	J-117	35	JISPVC	150	1.8	1.82
P-12	69	J-51	J-205	500	DCI	120	41	0.21
P-14	500	J-205	J-121	500	DCI	150	40	0.2
P-16	758	J-120	J-51	500	DCI	150	76	0.39
P-16	6	J-121	FCV-96	225	Ductile Iron	110	40	1.01
P-17	27	J-124	J342	30	HDPE	125	0.074	0.11
P-17	11	FCV-96	J-159	225	Ductile Iron	110	40	1.01
P-18	15	J-159	J-166	225	Ductile Iron	110	37	0.93
P-19	88	J-116	J-59	40	HDPE	100	1.3	1.06
P-19	900	J-166	J1	110	Ductile Iron	110	10	1.08

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-20	14	J1	J-77	150	Ductile Iron	95	4.2	0.24
P-21	124	J-68	J236	63	HDPE	125	2.6	0.84
P-23	370	J-59	J-56	40	HDPE	100	-0.88	0.7
P-24	174	J-184	J-6400	30	JISPVC	150	-0.093	0.13
P-25	29	J-128	J-129	40	HDPE	140	0.36	0.29
P-25	174	J-6400	J-66	65	JISPVC	150	-6.6	1.99
P-26	40	J-128	J-130	40	HDPE	140	0.4	0.32
P-26	58	J327	J-6400	65	Ductile Iron	150	-5.7	1.72
P-27	32	J-131	J-127	40	HDPE	140	0.058	0.05
P-27	42	J311	J310	150	Ductile Iron	75	-5.8	0.33
P-28	55	J-37	J-132	40	HDPE	125	1.1	0.86
P-28	22	J308	J309	15	Ductile Iron	75	-0.0025	0.01
P-29	41	J-127	J347	25	HDPE	140	0.028	0.06
P-30	42	J-132	J350	40	HDPE	140	0.16	0.12
P-31	44	J-131	J348	30	HDPE	140	0.051	0.07
P-32	66	J-130	J349	25	HDPE	140	0.086	0.17
P-32	60	J309	Fire Hydrant (Point)-170	25	JISPVC	85	-0.14	0.29
P-33	97	J-132	J-128	40	HDPE	140	0.8	0.64
P-33	209	Fire Hydrant (Point)-170	J-104	25	JISPVC	95	-0.14	0.29
P-34	80	J-130	J-131	40	HDPE	140	0.25	0.2
P-35	170	J-129	J346	40	HDPE	140	0.085	0.07
P-36	151	J-129	J345	25	HDPE	140	0.015	0.03
P-37	308	J-133	J-209	40	HDPE	115	0.52	0.41
P-37	23	Fire Hydrant (Point)-54	FCV-56	105	JISPVC	120	-8.8	1.01
P-38	419	J-289	J-39	40	HDPE	140	-0.61	0.48
P-38	11	FCV-56	J-183	110	JISPVC	120	-8.8	0.92
P-39	33	J-109	FCV-31	90	ISOPVC	125	-6.6	1.04
P-40	7	FCV-31	J-40	100	ISOPVC	115	-6.6	0.84
P-44	96	J-136	J-249	40	ISOPE	110	0.29	0.23
P-45	112	J-136	J-248	63	ISOPE	120	0.3	0.1
P-46	1,029	J-137	J-138	110	ISOPE	150	5.5	0.58
P-50	29	J-30	FCV-6	150	ISOPVC	90	-27	1.5
P-51	66	J-142	J-143	50	ISOPE	150	-2.4	1.2
P-51	11	FCV-6	J-166	150	ISOPVC	115	-27	1.5
P-53	124	J-141	J330	50	ISOPE	110	0.6	0.31
P-54	188	J-139	J-141	20	ISOPE	150	-0.18	0.56
P-55	95	J-133	J341	40	ISOPE	90	0.45	0.36

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-57	132	J-145	J-133	40	ISOPE	105	1.3	1
P-58	279	J-146	J-9	30	ISOPE	140	-0.052	0.07
P-58	105	J-50	FCV-10	125	Ductile Iron	105	-32	2.61
P-59	8	FCV-10	J-51	125	Ductile Iron	120	-32	2.61
P-60	281	J-149	J-11	40	ISOPE	140	0.9	0.72
P-61	363	J-150	J336	40	ISOPE	100	0.4	0.32
P-62	442	J-68	J-150	20	ISOPE	125	0.29	0.93
P-63	257	J-239	FCV-13	40	ISOPE	125	-0.92	0.73
P-64	243	J323	J-151	40	ISOPE	150	-1.6	1.3
P-64	7	FCV-13	J-134	80	ISOPE	125	-0.92	0.18
P-66	8	J-55	FCV-14	25	Ductile Iron	100	0.76	1.55
P-67	170	FCV-14	2397	35	Ductile Iron	150	0.76	0.79
P-68	99	J322	J-156	35	ISOPVC	150	-0.34	0.35
P-68	45	J-52	FCV-16	25	ISOPVC	100	-1.1	2.21
P-69	112	J-154	J-142	20	ISOPVC	150	-0.27	0.85
P-69	9	FCV-16	J-114	25	[SOPVC	100	-1.1	2.21
P-70	112	J-152	J-143	20	ISOPVC	150	-0.16	0.51
P-70	6	J-70	FCV-17	25	ISOPE	100	0.22	0.46
P-71	141	J-142	J325	15	ISOPVC	150	0.058	0.33
P-71	135	FCV-17	J318	35	ISOPE	100	0.22	0.23
P-72	269	J-43	FCV-18	50	JISPVC	105	3.1	1.57
P-73	6	FCV-18	J-12	50	JISPVC	105	3.1	1.57
P-74	84	J-106	FCV-19	25	JISPVC	105	-0.17	0.35
P-75	17	J-158	J-159	50	ISOPVC	110	-3	1.51
P-75	6	FCV-19	J-86	25	JISPVC	105	-0.17	0.35
P-76	6	J-94	FCV-20	25	JISPVC	90	0.057	0.12
P-77	123	FCV-20	J-280	25	JISPVC	130	0.057	0.12
P-78	5	J-89	FCV-21	25	JISPVC	90	0.058	0.12
P-79	123	FCV-21	J-278	25	JISPVC	150	0.057	0.12
P-80	88	J-160	J-247	40	ISOPVC	115	0.19	0.15
P-80	188	J-32	FCV-95	75	ISOPVC	150	-9.3	2.11
P-82	20	J-200	FCV-94	40	ISOPVC	140	0.062	0.05
P-83	112	J-246	J-160	40	ISOPVC	100	-0.11	0.08
P-83	60	FCV-94	J308	40	ISOPVC	120	0.062	0.05
P-84	84	J-136	FCV-91	40	ISOPVC	110	-0.76	0.6
P-85	195	J-260	J-162	63	ISOPPVC	150	-0.19	0.06
P-85	4	FCV-91	J-135	40	ISOPVC	110	-0.76	0.6
P-86	6	J-182	FCV-89	50	ISOPVC	90	2.9	1.47

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-87	106	FCV-89	J-176	63	ISOPVC	110	2.9	0.93
P-88	387	J320	FCV-88	50	ISOPVC	105	-0.65	0.33
P-89	193	J-118	J-158	50	ISOPVC	110	-2.9	1.5
P-89	6	FCV-88	J-176	50	ISOPVC	100	-0.65	0.33
P-90	9	J-126	FCV-86	40	HDPE	100	0.61	0.49
P-91	291	J-75	J-118	40	ISOPVC	120	-0.85	0.67
P-91	349	FCV-86	J314	40	HDPE	105	0.61	0.49
P-92	321	J-285	J-4	25	ISOPVC	140	-0.083	0.17
P-92	6	J-135	FCV-90	40	ISOPVC	110	0.49	0.39
P-93	49	FCV-90	J-160	40	ISOPVC	100	0.49	0.39
P-94	6	J-17	FCV-23	25	JISPVC	105	0.12	0.25
P-95	270	FCV-23	J-259	25	JISPVC	150	0.12	0.24
P-96	42	J-168	J-60	50	ISOPVC	105	-4.5	2.27
P-96	180	J-107	FCV-27	25	JISPVC	140	-0.23	0.47
P-97	96	J304	J-168	40	ISOPVC	105	-0.13	0.1
P-97	5	FCV-27	J-110	25	JISPVC	140	-0.23	0.47
P-98	44	J-61	J-69	50	ISOPVC	105	0.39	0.2
P-98	5	J-110	FCV-27	25	Ductile Iron	140	0.23	0.47
P-99	180	FCV-27	J-107	25	Ductile Iron	140	0.23	0.47
P-100	51	J-171	J302	40	ISOPVC	105	0.26	0.2
P-100	5	J-110	FCV-27	25	Ductile Iron	140	0.23	0.47
P-101	65	J-172	J-69	50	ISOPVC	105	0.84	0.43
P-101	180	FCV-27	J-107	25	Ductile Iron	140	0.23	0.47
P-102	84	J-168	J-171	40	ISOPVC	105	2	1.62
P-102	272	J-6	FCV-28	25	JISPVC	140	-0.31	0.64
P-103	7	FCV-28	J-113	25	JISPVC	140	-0.31	0.64
P-104	112	J-170	J305	50	ISOPVC	105	0.32	0.17
P-104	6	J-156	FCV-41	30	ISOPVC	150	0.36	0.51
P-105	113	J-170	J-301	50	ISOPVC	105	0.32	0.16
P-105	303	FCV-41	J337	75	ISOPVC	150	0.36	0.08
P-106	154	J-169	J-300	50	ISOPVC	105	0.52	0.27
P-106	4	J-64	FCV-44	65	GS	150	-1.4	0.41
P-107	164	J-168	J-172	50	ISOPVC	105	2.1	1.09
P-107	6	FCV-44	J-65	65	GS	150	-1.4	0.41
P-108	369	J-172	J-298	50	ISOPVC	115	1.1	0.54
P-110	14	J-50	FCV-100	150	DCI	120	20	1.14
P-111	978	FCV-100	J-199	125	DCI	150	20	1.64
P-112	3	J-42	FCV-101	80	ISOPVC	150	3.2	0.65

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-113	137	FCV-101	J-43	80	ISOPVC	150	3.2	0.65
P-114	5	J-149	J-110	65	ISOPVC	125	4.4	1.31
P-114	4	J-90	FCV-102	25	JISPVC	105	0.072	0.15
P-115	9	J-147	J-113	65	ISOPVC	110	5.7	1.7
P-115	124	FCV-102	J-277	25	JISPVC	150	0.071	0.14
P-116	30	J-112	J-147	65	ISOPVC	110	5.7	1.72
P-116	7	J-42	FCV-103	25	GS	140	0.098	0.2
P-117	173	FCV-103	J328	25	GS	140	0.097	0.2
P-118	41	J-113	J-149	65	ISOPVC	140	5.3	1.59
P-118	4	J-109	FCV-104	25	JISPVC	140	0.44	0.89
P-119	41	J-109	J-112	100	ISOPVC	125	6.1	0.78
P-119	172	FCV-104	J-84	25	JISPVC	140	0.43	0.89
P-120	6	J-112	FCV-105	25	JISPVC	140	0.38	0.78
P-121	145	J-115	J-176	50	ISOPVC	105	-1.9	0.95
P-121	273	FCV-105	J-8	25	JISPVC	140	0.38	0.78
P-122	151	J-175	J307	40	ISOPVC	105	1.2	0.92
P-122	201	J-156	FCV-106	40	ISOPVC	150	-1.6	1.23
P-123	161	J-114	J-115	40	ISOPVC	100	-1.2	0.97
P-123	6	FCV-106	J-72	30	ISOPVC	150	-1.6	2.2
P-124	171	J-72	FCV-107	40	ISOPE	150	-2.4	1.94
P-125	4	FCV-107	J-73	50	ISOPE	150	-2.4	1.24
P-126	6	J-41	FCV-108	75	ISOPVC	150	-4.5	1.03
P-127	436	FCV-108	J-39	80	ISOPVC	140	-4.5	0.9
P-128	130	J-64	FCV-109	20	JISPVC	150	0.15	0.47
P-129	5	FCV-109	J-33	20	JISPVC	150	0.15	0.47
P-130	91	J-41	FCV-110	20	JISPVC	150	0.24	0.76
P-131	7	FCV-110	J-36	20	JISPVC	150	0.24	0.76
P-132	111	J-153	J327	20	ISOPVC	150	-0.22	0.68
P-132	263	J-81	FCV-111	35	JISPVC	105	-1.6	1.64
P-133	5	FCV-111	J-76	35	JISPVC	95	-1.6	1.64
P-134	64	J-78	FCV-112	50	JISPVC	125	-2.4	1.21
P-135	150	J-197	J-241	40	ISOPVC	125	1.7	1.38
P-135	6	FCV-112	J-104	50	JISPVC	95	-2.4	1.21
P-136	7	J-88	FCV-113	25	JISPVC	95	0.14	0.29
P-137	8	J-163	J-164	30	ISOPVC	125	-0.73	1.03
P-137	119	FCV-113	J-284	25	JISPVC	95	0.14	0.28
P-138	5	J-95	FCV-114	25	JISPVC	95	0.054	0.11
P-139	111	J320	J-70	40	ISOPVC	100	0.48	0.38
P-139	124	FCV-114	J-282	25	JISPVC	90	0.054	0.11

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-140	5	J-141	FCV-115	35	ISOPE	150	-1.8	1.87
P-141	15	J-145	J-177	85	JISPVC	105	-15	2.69
P-141	55	FCV-115	J-142	35	ISOPE	150	-1.8	1.87
P-142	50	J306	J-137	50	JISPVC	105	-2.9	1.5
P-144	143	J-137	J-167	80	JISPVC	105	-8.6	1.7
P-144	5	J-183	FCV-117	85	ISOPVC	120	0.53	0.09
P-145	213	J-167	J-145	100	JISPVC	105	-14	1.77
P-145	33	FCV-117	J-250	63	ISOPVC	120	0.53	0.17
P-146	150	J-252	FCV-118	63	ISOPVC	120	-0.25	0.08
P-147	3	J-50	J-165	70	JISPVC	120	2.3	0.6
P-147	4	FCV-118	J-165	63	ISOPVC	120	-0.25	0.08
P-148	5	J-183	J-50	110	JISPVC	120	-9.7	1.02
P-148	6	J-165	FCV-119	50	ISOPVC	120	2	0.99
P-149	350	FCV-119	J-251	40	ISOPVC	140	2	1.55
P-150	639	J-150	FCV-120	50	ISOPVC	140	-3.1	1.58
P-151	225	J-56	J-161	50	JISPVC	100	-3.5	1.8
P-151	10	FCV-120	J-178	50	ISOPVC	120	-3.1	1.58
P-152	218	J-66	J324	40	JISPVC	150	0.51	0.4
P-152	18	J-161	FCV-121	65	JISPVC	110	-5.2	1.58
P-153	224	J-126	J-116	50	JISPVC	110	1.5	0.76
P-153	174	FCV-121	J-178	75	JISPVC	120	-5.2	1.18
P-154	4	J-161	FCV-122	40	ISOPVC	110	1.4	1.11
P-155	78	FCV-122	J-135	40	ISOPVC	110	1.4	1.11
P-156	33	J311	J-182	75	JISPVC	90	5.8	1.3
P-156	9	J-56	FCV-123	150	GS	100	1.8	0.1
P-157	69	J-182	PRV-2	63	JISPVC	90	2.8	0.9
P-157	185	FCV-123	J-245	40	GS	100	1.8	1.47
P-158	118	PRV-2	J-126	50	JISPVC	90	2.6	1.31
P-160	3	J-119	FCV-125	500	DCI	125	77	0.39
P-161	3	FCV-125	J-120	500	DCI	125	77	0.39
P-162	6	J-115	FCV-126	25	JISPVC	100	0.51	1.03
P-163	84	J-144	J-102	63	JISPVC	140	-1.6	0.52
P-163	56	FCV-126	J-108	25	JISPVC	100	0.51	1.03
P-164	278	J-295	J-144	40	JISPVC	140	-0.57	0.45
P-164	6	J-177	FCV-128	40	ISOPVC	105	2.1	1.65
P-165	5	Fire Hydrant (Point)-12	J-196	35	JISPVC	125	-0.1	0.1
P-165	353	FCV-128	J-175	40	ISOPVC	105	2.1	1.65
P-166	12	J-48	J-46	75	JISPVC	110	4.7	1.07
P-166	4	J-60	FCV-129	65	ISOPVC	105	-5	1.52

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-167	52	J-164	J-57	75	JISPVC	125	-1.2	0.26
P-167	5	FCV-129	J-167	65	ISOPVC	105	-5	1.52
P-168	54	J-57	J-117	75	JISPVC	125	-1.5	0.33
P-168	5	J-171	FCV-130	40	ISOPVC	105	1.7	1.32
P-169	4	J-71	FCV-39	25	JISPVC	150	0.1	0.2
P-169	90	FCV-130	J-169	40	ISOPVC	105	1.7	1.32
P-170	179	FCV-39	J332	50	JISPVC	150	0.1	0.05
P-170	9	J-169	FCV-131	40	ISOPVC	105	0.74	0.59
P-171	36	FCV-131	J-170	40	ISOPVC	105	0.74	0.59
P-172	3	FCV-40	J-151	65	JISPVC	150	2.3	0.7
P-172	137	J-261	FCV-132	50	ISOPVC	125	-0.18	0.09
P-173	31	FCV-132	J-162	50	ISOPVC	125	-0.18	0.09
P-174	33	J-162	FCV-133	30	ISOPVC	125	-0.65	0.92
P-175	86	FCV-133	J-163	30	ISOPVC	125	-0.65	0.92
P-176	7	J-164	FCV-134	30	ISOPVC	125	0.36	0.51
P-177	110	FCV-134	J-262	63	ISOPVC	125	0.36	0.12
P-178	8	J-57	FCV-135	40	GS	125	0.17	0.13
P-179	92	FCV-135	J-263	40	GS	125	0.17	0.13
P-180	127	J1	J-194	75	ISOPVC	90	6	1.37
P-180	76	J-90	FCV-136	25	JISPVC	105	-0.59	1.21
P-181	8	J-6	J-7	50	JISPVC	105	-0.0083	0
P-181	17	FCV-136	J-13	25	JISPVC	105	-0.59	1.21
P-182	8	J-8	J-9	50	JISPVC	125	0.3	0.15
P-182	77	J-196	FCV-137	65	ISOPVC	125	4.3	1.3
P-183	8	J-10	J-11	50	JISPVC	115	0.097	0.05
P-183	17	FCV-137	J-197	65	ISOPVC	115	4.3	1.3
P-184	15	J-12	J-13	75	JISPVC	105	0.74	0.17
P-185	29	J-296	J-14	40	JISPVC	110	-0.12	0.09
P-185	8	FCV-138	J-32	65	GS	150	-7.6	2.29
P-186	30	J-15	J-16	80	JISPVC	105	0.32	0.06
P-186	9	J-66	FCV-139	65	GS	150	-7.6	2.29
P-187	31	J-7	J-8	50	JISPVC	145	-0.043	0.02
P-187	127	FCV-139	FCV-138	65	GS	150	-7.6	2.29
P-188	35	J-17	J-12	75	JISPVC	105	-2.3	0.52
P-188	427	J321	FCV-140	50	GS	150	-1.2	0.59
P-189	36	J-18	J-19	75	JISPVC	105	-1.8	0.4
P-189	40	FCV-140	J-64	40	GS	150	-1.2	0.92
P-190	36	J-11	J-6	75	JISPVC	105	0.97	0.22
P-190	5	J-144	FCV-141	30	ISOPE	150	0.25	0.36

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-191	41	J-14	J-18	75	JISPVC	105	-0.91	0.21
P-191	245	FCV-141	J334	35	ISOPE	150	0.25	0.26
P-192	42	J-9	J-15	60	JISPVC	125	0.19	0.07
P-192	185	J-292	FCV-142	25	JISPVC	95	-0.21	0.43
P-193	43	J-19	J-17	75	JISPVC	105	-2.1	0.47
P-193	9	FCV-142	J-78	25	JISPVC	135	-0.21	0.43
P-194	84	J-274	J-10	35	JISPVC	115	-0.048	0.05
P-194	184	J-291	FCV-144	25	JISPVC	135	-0.34	0.69
P-195	122	J-13	J-4	45	JISPVC	125	0.12	0.07
P-195	8	FCV-144	J-91	25	JISPVC	135	-0.34	0.69
P-196	7	J-69	FCV-145	35	HDPE	105	1.1	1.17
P-197	408	FCV-145	J-299	40	HDPE	110	1.1	0.9
P-198	10	J-199	FCV-146	40	ISOPVC	90	2.3	1.86
P-199	515	FCV-146	J313	40	ISOPVC	110	2.3	1.86
P-203	68	J-143	J327	63	ISOPE	150	-2.9	0.94
P-204	99	J-151	J-6404	30	ISOPE	150	0.56	0.79
P-205	73	J-6404	J-71	20	ISOPE	150	0.39	1.23
P-206	285	J-194	J310	85	ISOPVC	95	6	1.05
P-211	3	J-34	J-35	100	ISOPVC	95	-16	2.04
P-211	319	J327	FCV-40	40	Ductile Iron	150	2.3	1.84
P-212	14	J-36	J-33	75	ISOPVC	150	10	2.27
P-212	252	J-143	J-6406	30	Ductile Iron	150	0.12	0.17
P-213	23	J-37	J-29	140	ISOPVC	135	-24	1.59
P-213	127	J-67	J-6407	140	GS	125	30	1.92
P-214	103	J-16	J-38	100	ISOPVC	90	-16	2.06
P-214	132	J-6407	J-68	75	GS	125	3	0.68
P-215	181	J-39	J-34	80	ISOPVC	85	-5.3	1.05
P-215	142	J-124	J-6407	80	HDPE	125	-1.3	0.25
P-216	185	J-38	J-40	150	ISOPVC	150	-16	0.93
P-217	235	J-40	J-37	140	ISOPVC	150	-23	1.51
P-219	395	J-35	J-16	100	ISOPVC	150	-16	2.08
P-221	466	J-36	J-34	85	ISOPVC	150	-10	1.79
P-223	174	J-200	J-44	95	ISOPVC	90	-18	2.48
P-224	37	J-46	J-196	150	ISOPVC	125	4.6	0.26
P-225	3	J-199	J-44	125	DCI	90	18	1.44
P-226	18	J-6419	J-48	250	ISOPE	150	1.30E+02	2.56
P-228	102	J-52	J-255	25	GS	100	0.065	0.13
P-229	102	J-53	J-254	25	GS	100	0.11	0.23

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-230	167	J-54	J315	25	GS	150	0.48	0.98
P-234	128	J-6407	J-6415	110	JISPVC	110	25	2.62
P-235	45	J-55	J-54	40	GS	110	0.58	0.46
P-236	299	J-59	J-55	65	GS	115	2	0.61
P-237	130	J303	J-60	15	GS	105	-0.09	0.51
P-238	230	J-60	J-61	25	GS	105	0.42	0.87
P-240	109	J-63	J-253	25	GS	100	0.35	0.71
P-240	4	J-6420	FCV-152	500	Ductile Iron	125	2.00E+02	1.04
P-241	9	J-67	J-134	250	JISPVC	150	-1.20E+02	2.42
P-242	3	FCV-152	J-6419	500	Ductile Iron	125	2.00E+02	1.04
P-243	16	J-6419	J-119	500	Ductile Iron	125	77	0.39
P-246	6,461	source reservoir	J-6420	500	Ductile Iron	125	2.10E+02	1.08
P-247	385	FCV-95	PRV-4	75	ISOPVC	150	-9.3	2.11
P-248	58	PRV-4	J-33	75	ISOPVC	150	-9.3	2.11
P-249	83	J-104	PRV-6	40	JISPVC	95	-2.6	2.04
P-250	52	PRV-6	J-76	40	JISPVC	95	-2.6	2.04
P-251	5	J-76	J-77	90	JISPVC	95	-4.2	0.66
P-251	58	J-177	PRV-7	95	JISPVC	105	-17	2.45
P-252	13	PRV-7	J-200	95	JISPVC	105	-17	2.45
P-253	8	J-73	J-65	50	JISPVC	150	-2.9	1.45
P-253	90	J-29	PRV-8	140	ISOPVC	135	-25	1.65
P-254	9	J-78	J-79	35	JISPVC	125	1.2	1.29
P-254	166	PRV-8	J-30	140	ISOPVC	135	-25	1.65
P-255	9	J-80	J-81	35	JISPVC	125	-2.2	2.29
P-255	50	J-178	PRV-10	110	JISPVC	120	-8.8	0.92
P-256	9	PRV-10	Fire Hydrant (Point)-54	110	JISPVC	120	-8.8	0.92
P-257	206	J-134	PRV-11	250	ISOPE	125	-1.20E+02	2.45
P-258	138	PRV-11	J-48	250	ISOPE	125	-1.20E+02	2.45
P-259	27	J-65	J-41	50	JISPVC	150	-4.2	2.15
P-259	26	J-110	PRV-12	50	ISOPVC	140	3.6	1.81
P-260	31	J-85	J-288	25	JISPVC	105	0.33	0.67
P-260	62	PRV-12	J-42	50	ISOPVC	140	3.6	1.81
P-261	31	J-86	J-273	25	JISPVC	110	0.023	0.05
P-261	32	J-105	PRV-13	40	ISOPVC	105	-0.37	0.3
P-262	55	PRV-13	J-75	40	ISOPVC	105	-0.37	0.3
P-264	37	J-89	J-90	25	JISPVC	105	-0.38	0.78

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-265	38	J-80	J-91	25	JISPVC	125	-0.37	0.76
P-266	39	J-92	J-93	25	JISPVC	105	1.1	2.28
P-267	39	J-94	J-89	25	JISPVC	90	-0.65	1.33
P-268	39	J-95	J-94	25	JISPVC	90	-0.44	0.89
P-269	39	J-96	J-85	25	JISPVC	105	0.53	1.08
P-270	40	J-97	J-96	25	JISPVC	105	0.75	1.53
P-271	40	J-91	J-78	25	JISPVC	125	-0.82	1.68
P-272	40	J-93	J-97	25	JISPVC	105	0.95	1.94
P-273	44	J-6	J-92	25	JISPVC	105	1.3	2.56
P-274	50	J-98	J-99	25	JISPVC	90	0.37	0.75
P-276	53	J-88	J-95	25	JISPVC	95	-0.23	0.46
P-277	54	J-290	J-102	15	JISPVC	150	-0.28	1.61
P-279	69	J-293	J-79	25	JISPVC	125	-0.063	0.13
P-281	78	J-79	J-81	25	JISPVC	125	0.53	1.07
P-283	86	J-105	J-86	25	JISPVC	105	0.31	0.63
P-284	87	J-75	J-106	25	JISPVC	105	0.38	0.78
P-286	94	J-107	J-10	25	JISPVC	105	0.23	0.47
P-289	133	J-107	J-265	25	JISPVC	105	0.23	0.48
P-290	103	J-84	J-15	25	JISPVC	105	0.22	0.45
P-291	104	J-99	J-95	25	JISPVC	95	-0.051	0.1
P-292	126	J-108	J319	25	JISPVC	100	0.099	0.2
P-293	109	J-99	J-287	25	JISPVC	95	0.22	0.44
P-294	122	J-283	J-85	25	JISPVC	105	-0.066	0.13
P-295	122	J-279	J-97	25	JISPVC	100	-0.058	0.12
P-296	123	J-281	J-96	25	JISPVC	105	-0.055	0.11
P-297	124	J-79	J-294	25	JISPVC	105	0.57	1.17
P-298	128	J-98	J-94	25	JISPVC	90	-0.072	0.15
P-299	124	J-275	J-92	25	JISPVC	105	-0.069	0.14
P-300	124	J-276	J-93	25	JISPVC	100	-0.054	0.11
P-306	130	J-14	J-98	25	JISPVC	105	0.68	1.39
P-308	134	J-106	J-268	25	JISPVC	105	0.26	0.52
P-310	165	J-297	J-98	25	JISPVC	105	-0.13	0.27
P-313	198	J-18	J-89	25	JISPVC	105	0.42	0.85
P-317	191	J-102	J-80	40	JISPVC	140	-2.2	1.75
P-320	196	PRV-2	J317	25	JISPVC	115	0.23	0.47
P-323	272	J-258	J-19	25	JISPVC	105	-0.16	0.32
P-324	272	J-18	J-257	25	JISPVC	105	0.27	0.56

Appendix A10 Flex Table: junction Table for improved network at 12:00am

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
2397	2,410.20	Zone - 1	50	467,276.81	998,682.67	0.65	0.2
J-4	2,451.26	Zone - 2	74	468,221.85	998,675.15	0.028	0.2
J-6	2,466.81	Zone - 2	77	468,354.28	998,720.50	0.027	0.3
J-7	2,467.18	Zone - 2	77	468,361.38	998,723.14	0.2	0.3
J-8	2,468.80	Zone - 2	75	468,390.71	998,732.63	0.033	0.4
J-9	2,472.30	Zone - 2	71	468,398.04	998,735.06	0.048	0.3
J-10	2,464.33	Zone - 2	79	468,312.16	998,705.98	0.072	0.2
J-11	2,464.72	Zone - 2	79	468,319.93	998,708.49	0.029	0.4
J-12	2,446.06	Zone - 2	79	468,097.45	998,641.17	0.035	0.2
J-13	2,446.90	Zone - 2	78	468,108.28	998,639.17	0.026	0.2
J-14	2,450.50	Zone - 2	74	467,951.39	998,589.97	0.094	0.2
J-15	2,471.36	Zone - 2	72	468,437.65	998,748.39	0.085	0.2
J-16	2,472.39	Zone - 2	71	468,465.52	998,758.32	0.15	1.8
J-17	2,448.80	Zone - 2	76	468,065.05	998,627.13	0.083	0.2
J-18	2,445.50	Zone - 2	79	467,989.13	998,606.07	0.15	0.2
J-19	2,445.60	Zone - 2	79	468,023.50	998,615.15	0.12	0.2
J-29	2,477.50	Zone - 2	78	468,291.09	999,274.80	0.78	2.9
J-30	2,487.20	Zone - 2	72	468,037.70	999,256.03	0.97	3.5
J-32	2,440.20	Zone - 3	54	468,584.03	997,255.51	1.5	0.5
J-33	2,457.00	Zone - 3	62	468,548.10	997,885.58	0.72	0.9
J-34	2,460.70	Zone - 2	71	468,522.36	998,364.81	0.49	1.3
J-35	2,463.00	Zone - 2	69	468,522.28	998,367.42	0.22	1.5
J-36	2,459.40	Zone - 3	60	468,545.87	997,899.20	0.32	1.1
J-37	2,476.00	Zone - 2	79	468,299.22	999,253.59	0.13	2.6
J-38	2,475.82	Zone - 2	76	468,432.31	998,855.29	0.18	2.1
J-39	2,459.36	Zone - 2	68	468,341.67	998,356.53	0.11	1.1
J-40	2,473.29	Zone - 2	79	468,373.46	999,030.91	0.19	2.3
J-41	2,465.10	Zone - 3	59	468,458.89	997,941.87	0.079	0.7
J-42	2,465.30	Zone - 2	79	468,144.16	998,943.79	0.18	0.3
J-43	2,464.40	Zone - 2	80	468,010.75	998,901.96	0.15	0.2
J-44	2,484.40	Zone - 1	38	467,657.13	998,337.14	0.11	3
J-46	2,495.80	Zone - 1	65	466,778.48	999,516.40	0.06	5.5
J-48	2,498.60	Zone - 1	62	466,767.89	999,521.83	0.29	6.6
J-50	2,503.80	Zone - 1	51	467,491.58	999,234.94	0.0044	4.6
J-51	2,505.20	Zone - 1	56	467,491.92	999,347.36	2.3	5.9
J-52	2,445.87	Zone - 1	35	467,720.62	998,744.66	0.1	0.2
J-53	2,444.61	Zone - 1	23	467,664.61	998,743.21	0.071	0.2

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-54	2,415.00	Zone - 1	13	467,357.74	998,518.43	0.081	0.2
J-55	2,415.00	Zone - 1	49	467,391.98	998,546.94	0.59	0.2
J-56	2,445.60	Zone - 1	12	467,402.05	998,902.65	0.69	0.7
J-57	2,480.50	Zone - 2	61	467,971.74	999,091.22	0.11	1.3
J-59	2,443.30	Zone - 1	23	467,650.74	998,667.08	0.16	0.3
J-60	2,427.70	Zone - 1	43	467,675.58	998,073.91	0.057	0.7
J-61	2,422.12	Zone - 1	15	467,802.39	998,266.38	0.027	0.2
J-63	2,443.78	Zone - 1	19	467,629.95	998,737.03	0.3	0.2
J-64	2,465.10	Zone - 3	57	468,427.95	997,944.71	0.046	0.4
J-65	2,466.60	Zone - 3	55	468,434.16	997,952.59	0.0088	0.5
J-66	2,429.80	Zone - 3	56	468,467.35	997,282.56	0.43	0.2
J-67	2,471.30	Zone - 1	8	466,577.22	999,280.22	76	5.5
J-68	2,463.60	Zone - 1	11	466,741.56	999,084.50	0.078	4.1
J-69	2,420.61	Zone - 1	17	467,838.96	998,241.84	0.092	0.2
J-70	2,461.20	Zone - 1	58	467,785.41	998,733.79	0.21	0.2
J-71	2,403.80	Zone - 3	43	468,266.66	997,263.24	0.24	0.2
J-72	2,451.00	Zone - 3	59	468,317.39	997,831.52	0.75	0.2
J-73	2,465.30	Zone - 3	56	468,427.47	997,956.21	0.078	0.4
J-75	2,485.60	Zone - 2	60	468,193.73	998,764.61	0.078	1.5
J-76	2,481.60	Zone - 2	73	468,333.84	998,353.75	0.048	2.6
J-77	2,480.50	Zone - 2	74	468,335.06	998,357.13	0.0016	2.9
J-78	2,457.60	Zone - 3	8	468,220.61	998,277.37	0.089	0.3
J-79	2,451.00	Zone - 3	14	468,229.25	998,276.23	0.062	0.3
J-80	2,454.80	Zone - 3	12	468,243.73	998,203.04	0.14	0.4
J-81	2,451.00	Zone - 3	19	468,252.48	998,201.72	0.19	0.7
J-84	2,475.94	Zone - 2	70	468,404.94	998,846.51	0.18	0.4
J-85	2,457.22	Zone - 2	39	468,413.30	998,528.89	0.11	0.2
J-86	2,484.30	Zone - 2	59	468,139.11	998,654.41	0.096	0.5
J-88	2,438.07	Zone - 2	67	468,180.42	998,398.92	0.074	0.2
J-89	2,443.46	Zone - 2	71	468,137.79	998,522.03	0.078	0.2
J-90	2,444.34	Zone - 2	72	468,124.77	998,557.05	0.12	0.2
J-91	2,451.60	Zone - 3	14	468,232.99	998,239.64	0.092	0.2
J-92	2,464.54	Zone - 2	62	468,365.69	998,678.94	0.056	0.2
J-93	2,462.96	Zone - 2	52	468,378.10	998,642.34	0.095	0.2
J-94	2,441.66	Zone - 2	67	468,150.18	998,485.28	0.074	0.2
J-95	2,439.71	Zone - 2	66	468,162.01	998,448.29	0.088	0.2
J-96	2,458.79	Zone - 2	41	468,403.20	998,566.81	0.14	0.2
J-97	2,461.03	Zone - 2	44	468,390.57	998,604.33	0.12	0.2
J-98	2,433.69	Zone - 2	75	468,026.61	998,483.54	0.22	0.2

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-99	2,434.31	Zone - 2	72	468,058.48	998,445.12	0.17	0.2
J-102	2,441.60	Zone - 3	13	468,303.14	998,021.52	0.27	0.2
J-104	2,450.50	Zone - 3	15	468,200.65	998,344.80	0.039	0.4
J-105	2,481.00	Zone - 2	64	468,220.09	998,682.13	0.052	0.9
J-106	2,481.60	Zone - 2	61	468,110.14	998,740.27	0.25	0.6
J-107	2,474.30	Zone - 2	72	468,283.39	998,795.73	0.19	0.2
J-108	2,446.90	Zone - 1	49	467,724.03	998,582.74	0.093	0.2
J-109	2,472.43	Zone - 2	80	468,347.17	999,013.23	0.071	1.8
J-110	2,475.30	Zone - 2	73	468,227.67	998,972.48	0.092	0.6
J-112	2,473.33	Zone - 2	78	468,308.33	998,999.29	0.029	1.5
J-113	2,476.20	Zone - 2	73	468,271.13	998,987.27	0.041	0.9
J-114	2,442.89	Zone - 1	55	467,774.76	998,748.06	0.07	0.3
J-115	2,444.00	Zone - 1	62	467,785.82	998,587.30	0.11	0.4
J-116	2,441.60	Zone - 1	49	467,655.42	998,579.76	0.38	0.5
J-117	2,482.70	Zone - 2	58	468,022.91	999,107.22	0.16	1.5
J-118	2,485.20	Zone - 2	66	468,097.91	999,038.43	0.3	2.5
J-119	2,505.20	Zone - 1	56	466,786.58	999,529.53	0.008	6.9
J-120	2,505.30	Zone - 1	56	466,791.98	999,526.92	0.63	6.6
J-121	2,508.20	Zone - 2	53	468,034.87	999,252.96	0.11	5.2
J-124	2,463.90	Zone - 1	12	466,679.70	999,070.90	0.077	4
J-126	2,446.30	Zone - 1	57	467,656.88	998,356.03	0.4	0.8
J-127	2,475.57	Zone - 2	75	468,346.49	999,048.25	0.025	0.6
J-128	2,477.20	Zone - 2	73	468,272.64	999,151.61	0.029	1.1
J-129	2,477.20	Zone - 2	73	468,245.28	999,142.58	0.45	0.8
J-130	2,476.60	Zone - 2	74	468,301.10	999,141.82	0.059	0.8
J-131	2,477.84	Zone - 2	73	468,335.35	999,077.97	0.12	0.6
J-132	2,475.50	Zone - 2	77	468,288.44	999,217.52	0.11	1.7
J-133	2,454.50	Zone - 1	19	467,659.47	998,237.64	0.25	0.9
J-134	2,469.40	Zone - 1	10	466,586.29	999,280.11	0.41	5.8
J-135	2,455.80	Zone - 1	4	467,668.70	998,979.16	0.12	0.5
J-136	2,451.00	Zone - 1	8	467,665.56	999,067.44	0.14	0.3
J-137	2,430.00	Zone - 1	35	467,588.16	997,959.76	0.12	1
J-138	2,427.70	Zone - 1	34	467,787.60	997,160.99	4.7	0.5
J-139	2,390.00	Zone - 3	74	468,235.53	996,933.98	0.18	0.2
J-141	2,395.00	Zone - 3	75	468,238.62	997,117.81	0.87	0.2
J-142	2,401.60	Zone - 3	73	468,298.90	997,116.21	0.2	0.2
J-143	2,398.14	Zone - 3	78	468,364.40	997,114.71	0.24	0.2
J-144	2,441.30	Zone - 3	13	468,224.48	998,050.12	0.67	0.2
J-145	2,457.70	Zone - 1	22	467,784.57	998,257.16	0.092	1.4

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-146	2,472.93	Zone - 2	71	468,317.62	999,001.79	0.044	0.3
J-147	2,475.20	Zone - 2	75	468,279.96	998,990.24	0.036	1.2
J-149	2,475.10	Zone - 2	73	468,232.15	998,974.17	0.033	0.7
J-150	2,433.80	Zone - 1	7	467,007.32	998,824.51	2.5	1.7
J-151	2,410.36	Zone - 3	47	468,362.17	997,403.62	0.1	0.2
J-152	2,400.00	Zone - 3	73	468,366.27	997,002.41	0.16	0.2
J-153	2,405.00	Zone - 3	66	468,431.76	997,000.36	0.22	0.2
J-154	2,395.00	Zone - 3	71	468,299.60	997,004.26	0.27	0.2
J-156	2,450.20	Zone - 3	25	468,255.59	997,634.69	0.72	0.2
J-158	2,497.20	Zone - 2	63	468,038.80	999,221.71	0.023	3.3
J-159	2,511.00	Zone - 2	50	468,037.25	999,236.24	0.02	4.6
J-160	2,451.20	Zone - 1	9	467,722.97	998,980.18	0.17	0.3
J-161	2,459.00	Zone - 1	6	467,588.14	998,979.04	0.25	1.3
J-162	2,482.20	Zone - 2	57	467,916.10	998,976.78	0.24	0.4
J-163	2,483.80	Zone - 2	57	467,915.57	999,070.56	0.067	0.8
J-164	2,480.50	Zone - 1	61	467,922.97	999,073.12	0.057	1.1
J-165	2,498.60	Zone - 1	56	467,494.91	999,234.94	0.076	3.4
J-166	2,499.40	Zone - 2	61	468,040.86	999,222.19	0.15	4.4
J-167	2,428.40	Zone - 1	43	467,668.02	998,078.76	0.24	1.2
J-168	2,421.04	Zone - 1	45	467,711.20	998,051.55	0.13	0.5
J-169	2,422.78	Zone - 1	25	467,744.90	997,929.02	0.34	0.2
J-170	2,419.71	Zone - 1	28	467,770.42	997,966.09	0.078	0.2
J-171	2,422.15	Zone - 1	34	467,665.79	997,981.08	0.1	0.3
J-172	2,420.23	Zone - 1	20	467,802.47	998,188.00	0.2	0.3
J-175	2,428.30	Zone - 1	8	467,457.74	998,219.24	0.77	0.6
J-176	2,456.30	Zone - 1	69	467,818.71	998,454.52	0.32	0.7
J-177	2,460.30	Zone - 1	21	467,793.10	998,269.24	0.055	1.7
J-178	2,450.30	Zone - 1	18	467,513.73	999,152.07	0.35	2
J-182	2,456.60	Zone - 1	75	467,843.46	998,346.62	0.065	1.5
J-183	2,501.00	Zone - 1	54	467,486.70	999,234.93	0.32	3.9
J-184	2,412.00	Zone - 3	66	468,487.96	996,937.64	0.093	0.2
J-194	2,473.80	Zone - 2	72	468,202.73	998,361.70	0.052	2.5
J-196	2,555.00	Zone - 1	6	466,810.99	999,498.21	0.2	5.1
J-197	2,495.30	Zone - 1	63	466,892.19	999,451.67	2.2	3.2
J-199	2,483.30	Zone - 1	40	467,657.38	998,339.80	0.027	3.4
J-200	2,480.20	Zone - 1	10	467,831.18	998,329.72	0.1	2.5
J-205	2,506.10	Zone - 1	55	467,560.48	999,348.17	0.89	5.8
J-209	2,455.50	Zone - 1	15	467,442.18	998,070.35	0.44	0.4
J-239	2,470.36	Zone - 1	9	466,760.64	999,087.11	0.78	3.6

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-241	2,516.00	Zone - 1	32	466,877.41	999,345.95	1.5	2
J-245	2,435.00	Zone - 1	7	467,303.24	998,980.89	1.6	0.5
J-246	2,455.50	Zone - 1	4	467,722.05	998,868.69	0.09	0.2
J-247	2,451.10	Zone - 1	9	467,731.79	999,066.44	0.16	0.2
J-248	2,450.00	Zone - 1	8	467,661.83	999,178.96	0.26	0.2
J-249	2,445.50	Zone - 1	13	467,569.66	999,061.53	0.25	0.2
J-250	2,497.00	Zone - 1	58	467,484.76	999,273.18	0.45	3.1
J-251	2,500.00	Zone - 1	31	467,745.59	999,348.06	1.7	1.3
J-252	2,501.30	Zone - 1	53	467,620.30	999,201.25	0.21	1.6
J-253	2,443.50	Zone - 1	15	467,612.68	998,842.72	0.29	0.2
J-254	2,450.20	Zone - 1	17	467,662.34	998,845.41	0.096	0.2
J-255	2,450.64	Zone - 1	30	467,715.04	998,846.66	0.055	0.2
J-256	2,451.30	Zone - 1	46	467,768.36	998,844.81	0.046	0.2
J-257	2,446.78	Zone - 2	72	467,899.32	998,862.91	0.23	0.2
J-258	2,449.95	Zone - 2	73	467,931.26	998,869.95	0.14	0.2
J-259	2,447.00	Zone - 2	77	467,969.17	998,885.60	0.1	0.2
J-260	2,530.00	Zone - 2	10	467,816.09	999,054.49	0.16	0.2
J-261	2,481.20	Zone - 2	58	467,849.04	999,105.86	0.15	0.2
J-262	2,480.30	Zone - 2	60	467,886.56	999,184.25	0.31	0.6
J-263	2,477.50	Zone - 2	64	467,942.11	999,186.04	0.14	0.7
J-264	2,481.60	Zone - 2	59	467,996.32	999,187.29	0.086	0.9
J-265	2,470.42	Zone - 2	73	468,209.96	998,864.59	0.2	0.2
J-268	2,481.00	Zone - 2	58	468,066.71	998,866.60	0.22	0.3
J-273	2,481.60	Zone - 2	61	468,109.38	998,644.66	0.019	0.4
J-274	2,464.00	Zone - 2	80	468,232.96	998,677.41	0.041	0.2
J-275	2,457.21	Zone - 2	69	468,247.66	998,641.10	0.059	0.2
J-276	2,455.24	Zone - 2	59	468,260.32	998,603.28	0.046	0.2
J-277	2,445.00	Zone - 2	71	468,246.54	998,598.31	0.06	0.2
J-278	2,445.00	Zone - 2	70	468,259.49	998,560.56	0.049	0.2
J-279	2,453.35	Zone - 2	52	468,274.51	998,565.39	0.049	0.2
J-280	2,444.20	Zone - 2	65	468,272.78	998,521.43	0.048	0.2
J-281	2,457.20	Zone - 2	42	468,287.29	998,525.84	0.046	0.2
J-282	2,441.60	Zone - 2	64	468,285.13	998,483.95	0.046	0.2
J-283	2,455.40	Zone - 2	41	468,298.22	998,489.84	0.056	0.2
J-284	2,447.35	Zone - 2	57	468,296.25	998,447.74	0.12	0.2
J-285	2,446.90	Zone - 2	78	468,326.41	998,371.73	0.071	0.2
J-287	2,433.47	Zone - 2	70	468,126.84	998,360.10	0.18	0.2
J-288	2,456.43	Zone - 2	39	468,422.07	998,499.18	0.28	0.2
J-289	2,465.20	Zone - 3	59	468,471.76	997,958.56	0.52	0.5

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J-290	2,439.40	Zone - 3	7	468,349.64	997,994.74	0.24	0.2
J-291	2,453.60	Zone - 3	8	468,040.77	998,234.06	0.29	0.2
J-292	2,450.00	Zone - 3	12	468,027.52	998,270.48	0.18	0.2
J-293	2,457.30	Zone - 3	8	468,209.18	998,342.70	0.054	0.2
J-294	2,440.20	Zone - 3	14	468,352.63	998,279.97	0.49	0.2
J-295	2,440.50	Zone - 3	12	467,962.85	998,139.45	0.48	0.2
J-296	2,462.20	Zone - 2	62	467,923.94	998,581.46	0.1	0.2
J-297	2,435.00	Zone - 2	72	467,927.38	998,576.55	0.11	0.2
J-298	2,422.20	Zone - 1	6	467,894.04	997,831.02	0.9	0.2
J-299	2,350.20	Zone - 3	9	467,940.74	997,839.52	0.96	0.2
J-300	2,420.00	Zone - 1	27	467,874.28	997,845.92	0.45	0.2
J-301	2,418.77	Zone - 1	28	467,864.88	997,903.95	0.27	0.2
J-6400	2,414.00	Zone - 3	65	468,490.57	997,111.32	0.67	0.2
J-6404	2,400.18	Zone - 3	54	468,312.96	997,319.48	0.15	0.2
J-6406	2,396.00	Zone - 3	80	468,353.92	997,366.62	0.1	0.2
J-6407	2,464.10	Zone - 1	12	466,651.46	999,180.35	0.38	4.9
J-6415	2,455.80	Zone - 1	10	466,528.52	999,144.04	21	4.2
J-6419	2,507.20	Zone - 1	54	466,773.69	999,538.45	1.1	7
J-6420	2,513.00	Zone - 1	48	466,766.50	999,537.78	8.2	7.4
J1	2,480.50	Zone - 2	74	468,329.25	998,369.96	0.029	3.1
J236	2,464.00	Zone - 1	10	466,722.48	998,965.02	2.2	3.6
J302	2,423.19	Zone - 1	33	467,637.32	997,939.20	0.22	0.3
J303	2,428.00	Zone - 1	39	467,603.86	997,965.91	0.077	0.2
J304	2,425.00	Zone - 1	41	467,791.77	998,000.22	0.11	0.3
J305	2,416.54	Zone - 1	30	467,832.31	998,059.44	0.28	0.2
J306	2,430.20	Zone - 1	32	467,561.37	997,917.54	2.5	0.7
J307	2,424.40	Zone - 1	5	467,433.41	998,076.17	0.99	0.4
J308	2,483.00	Zone - 1	7	467,910.82	998,327.16	0.054	1.8
J309	2,470.20	Zone - 1	16	467,932.31	998,328.79	0.12	0.8
J310	2,471.30	Zone - 1	65	467,918.37	998,345.91	0.12	2.1
J311	2,461.10	Zone - 1	75	467,876.76	998,345.39	0.062	1.9
J312	2,451.60	Zone - 3	12	467,902.15	998,186.94	0.18	0.2
J313	2,440.00	Zone - 1	7	467,155.59	998,411.81	2	1.3
J314	2,443.00	Zone - 1	55	467,347.95	998,488.18	0.52	0.3
J315	2,411.10	Zone - 1	12	467,244.60	998,640.64	0.41	0.2
J317	2,428.60	Zone - 1	8	467,727.12	998,537.40	0.2	0.5
J318	2,453.30	Zone - 1	64	467,818.52	998,616.07	0.19	0.2
J319	2,447.10	Zone - 1	49	467,658.90	998,667.15	0.084	0.2
J320	2,454.40	Zone - 1	66	467,778.73	998,844.73	0.15	0.2

Label	Elevation (m)	Zone	Pressure (m H2O)	X (m)	Y (m)	Demand (L/s)	Concentration (Maximum) (mg/L)
J321	2,436.80	Zone - 3	77	468,221.31	997,546.05	0.98	0.2
J322	2,449.80	Zone - 3	24	468,228.66	997,539.87	0.28	0.2
J323	2,405.20	Zone - 3	7	468,478.52	997,587.41	1.4	0.2
J324	2,433.00	Zone - 3	52	468,410.16	997,492.49	0.43	0.2
J325	2,401.30	Zone - 3	49	468,261.62	997,251.99	0.05	0.2
J327	2,410.00	Zone - 3	67	468,432.14	997,111.30	0.22	0.2
J328	2,466.50	Zone - 2	78	468,200.62	998,772.88	0.083	0.2
J330	2,380.00	Zone - 3	14	468,255.73	997,240.51	0.51	0.2
J332	2,405.00	Zone - 3	41	468,356.13	997,405.07	0.085	0.2
J334	2,445.50	Zone - 3	7	468,364.12	997,900.13	0.22	0.2
J336	2,430.50	Zone - 1	8	467,253.94	998,578.58	0.34	0.6
J337	2,449.60	Zone - 3	22	468,299.06	997,377.69	0.31	0.2
J341	2,458.00	Zone - 1	14	467,570.11	998,260.76	0.38	0.7
J342	2,465.10	Zone - 1	11	466,697.89	999,050.64	0.063	3.9
J343	2,464.00	Zone - 1	12	466,646.21	999,042.49	0.92	3.7
J345	2,474.03	Zone - 2	76	468,299.06	999,004.55	0.013	0.6
J346	2,474.16	Zone - 2	76	468,254.78	998,999.95	0.072	0.7
J347	2,475.58	Zone - 2	75	468,307.55	999,036.75	0.024	0.5
J348	2,477.71	Zone - 2	73	468,293.95	999,063.92	0.043	0.6
J349	2,475.60	Zone - 2	75	468,273.76	999,103.26	0.073	0.5
J350	2,478.30	Zone - 2	74	468,303.39	999,178.33	0.13	1.4

Appendix A11 Flex Table: pipe Table for improved network at 12:00am

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P--18	47	J-124	J343	100	HDPE	125	0.92	0.15
P-1	318	J-81	J-73	25	JISPVC	140	-0.9	1.83
P-2	344	J312	J-80	25	JISPVC	125	-0.18	0.36
P-3	36	J-53	J-63	25	JISPVC	100	0.6	1.22
P-5	56	J-52	J-53	25	JISPVC	100	0.76	1.56
P-7	69	J-108	J-116	25	JISPVC	100	0.46	0.93
P-8	84	J-117	J-264	25	JISPVC	125	0.086	0.18
P-9	97	J-256	J-114	25	JISPVC	100	-0.046	0.09
P-10	142	J-118	J-117	35	JISPVC	150	1.5	1.55
P-12	69	J-51	J-205	500	DCI	120	36	0.21
P-14	500	J-205	J-121	500	DCI	150	35	0.2
P-16	758	J-120	J-51	500	DCI	150	64	0.36
P-16	6	J-121	FCV-96	225	Ductile Iron	110	35	0.89

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-17	27	J-124	J342	50	HDPE	125	0.063	0.03
P-17	11	FCV-96	J-159	225	Ductile Iron	110	35	0.89
P-18	15	J-159	J-166	225	Ductile Iron	110	33	0.83
P-19	88	J-116	J-59	38	HDPE	100	2.5	2.24
P-19	900	J-166	J1	150	Ductile Iron	110	9	0.71
P-20	14	J1	J-77	140	Ductile Iron	95	2.4	0.16
P-21	124	J-68	J236	88	HDPE	125	2.2	0.37
P-23	370	J-59	J-56	38	HDPE	100	0.66	0.58
P-24	174	J-184	J-6400	30	JISPVC	150	-0.093	0.13
P-25	29	J-128	J-129	38	HDPE	140	0.53	0.47
P-25	174	J-6400	J-66	65	JISPVC	150	-5.7	1.73
P-26	40	J-128	J-130	38	HDPE	140	0.34	0.3
P-26	58	J327	J-6400	65	Ductile Iron	150	-5	1.5
P-27	32	J-131	J-127	38	HDPE	140	0.049	0.04
P-27	42	J311	J310	150	Ductile Iron	75	-6.4	0.5
P-28	55	J-37	J-132	38	HDPE	125	1.1	1.01
P-28	22	J308	J309	25	Ductile Iron	75	0.51	1.05
P-29	41	J-127	J347	25	HDPE	140	0.024	0.05
P-30	42	J-132	J350	38	HDPE	140	0.13	0.12
P-31	44	J-131	J348	30	HDPE	140	0.043	0.06
P-32	66	J-130	J349	25	HDPE	140	0.073	0.15
P-32	60	J309	Fire Hydrant (Point)-170	25	JISPVC	85	0.4	0.81
P-33	97	J-132	J-128	38	HDPE	140	0.91	0.8
P-33	209	Fire Hydrant (Point)-170	J-104	25	JISPVC	95	0.4	0.81
P-34	80	J-130	J-131	38	HDPE	140	0.21	0.19
P-35	170	J-129	J346	40	HDPE	140	0.072	0.06
P-36	151	J-129	J345	25	HDPE	140	0.013	0.03
P-37	308	J-133	J-209	38	HDPE	115	0.44	0.39
P-37	23	Fire Hydrant (Point)-54	FCV-56	85	JISPVC	120	-4.7	0.82
P-38	419	J-289	J-39	40	HDPE	140	-0.52	0.46
P-38	11	FCV-56	J-183	85	JISPVC	120	-4.7	0.82
P-39	33	J-109	FCV-31	90	ISOPVC	125	-5.7	0.9
P-40	7	FCV-31	J-40	100	ISOPVC	115	-5.7	0.73
P-44	96	J-136	J-249	40	ISOPE	110	0.25	0.22
P-45	112	J-136	J-248	40	ISOPE	120	0.26	0.23
P-46	1,029	J-137	J-138	100	ISOPE	150	4.7	0.59

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-50	29	J-30	FCV-6	140	ISOPVC	90	-24	1.54
P-51	66	J-142	J-143	63	ISOPE	150	-2.1	0.94
P-51	11	FCV-6	J-166	140	ISOPVC	115	-24	1.54
P-53	124	J-141	J330	15	ISOPE	150	0.51	2.91
P-54	188	J-139	J-141	20	ISOPE	150	-0.18	0.69
P-55	95	J-133	J341	38	ISOPE	90	0.38	0.33
P-57	132	J-145	J-133	38	ISOPE	105	1.1	0.94
P-58	279	J-146	J-9	30	ISOPE	140	-0.044	0.06
P-58	105	J-50	FCV-10	125	Ductile Iron	105	-25	2.03
P-59	8	FCV-10	J-51	125	Ductile Iron	120	-25	2.03
P-60	281	J-149	J-11	38	ISOPE	140	0.76	0.67
P-61	363	J-150	J336	38	ISOPE	100	0.34	0.3
P-62	442	J-68	J-150	38	ISOPE	125	1.6	1.4
P-63	257	J-239	FCV-13	88	ISOPE	125	-0.78	0.13
P-64	243	J323	J-151	28	ISOPE	150	-1.4	2.25
P-64	7	FCV-13	J-134	88	ISOPE	125	-0.78	0.13
P-66	8	J-55	FCV-14	25	Ductile Iron	100	0.65	1.32
P-67	170	FCV-14	2397	35	Ductile Iron	150	0.65	0.67
P-68	99	J322	J-156	28	ISOPVC	150	-0.28	0.46
P-68	45	J-52	FCV-16	25	ISOPVC	100	-0.92	1.88
P-69	112	J-154	J-142	20	ISOPVC	150	-0.27	1.05
P-69	9	FCV-16	J-114	25	[SOPVC	100	-0.92	1.88
P-70	112	J-152	J-143	18	ISOPVC	150	-0.16	0.63
P-70	6	J-70	FCV-17	25	ISOPE	100	0.19	0.39
P-71	141	J-142	J325	15	ISOPVC	150	0.05	0.98
P-71	135	FCV-17	J318	25	ISOPE	100	0.19	0.39
P-72	269	J-43	FCV-18	50	JISPVC	105	2.6	1.33
P-73	6	FCV-18	J-12	50	JISPVC	105	2.6	1.33
P-74	84	J-106	FCV-19	25	JISPVC	105	-0.15	0.3
P-75	17	J-158	J-159	50	ISOPVC	110	-2.5	1.29
P-75	6	FCV-19	J-86	25	JISPVC	105	-0.15	0.3
P-76	6	J-94	FCV-20	25	JISPVC	90	0.049	0.1
P-77	123	FCV-20	J-280	25	JISPVC	130	0.048	0.1
P-78	5	J-89	FCV-21	25	JISPVC	90	0.049	0.1
P-79	123	FCV-21	J-278	25	JISPVC	150	0.049	0.1
P-80	88	J-160	J-247	38	ISOPVC	115	0.16	0.14
P-80	188	J-32	FCV-95	75	ISOPVC	150	-8.1	1.83
P-82	20	J-200	FCV-94	65	ISOPVC	90	0.57	0.17

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-83	112	J-246	J-160	40	ISOPVC	100	-0.09	0.07
P-83	60	FCV-94	J308	50	ISOPVC	90	0.57	0.29
P-84	84	J-136	FCV-91	38	ISOPVC	110	-0.64	0.57
P-85	195	J-260	J-162	38	ISOPPVC	150	-0.16	0.14
P-85	4	FCV-91	J-135	38	ISOPVC	110	-0.64	0.57
P-86	6	J-182	FCV-89	40	ISOPVC	90	2.7	2.11
P-87	106	FCV-89	J-176	53	ISOPVC	110	2.7	1.2
P-88	387	J320	FCV-88	40	ISOPVC	105	-0.55	0.44
P-89	193	J-118	J-158	53	ISOPVC	110	-2.5	1.13
P-89	6	FCV-88	J-176	40	ISOPVC	100	-0.55	0.44
P-90	9	J-126	FCV-86	40	HDPE	100	0.52	0.46
P-91	291	J-75	J-118	40	ISOPVC	120	-0.72	0.63
P-91	349	FCV-86	J314	38	HDPE	105	0.52	0.46
P-92	321	J-285	J-4	25	ISOPVC	140	-0.071	0.14
P-92	6	J-135	FCV-90	38	ISOPVC	110	0.42	0.37
P-93	49	FCV-90	J-160	38	ISOPVC	100	0.41	0.37
P-94	6	J-17	FCV-23	25	JISPVC	105	0.1	0.21
P-95	270	FCV-23	J-259	25	JISPVC	150	0.1	0.21
P-96	42	J-168	J-60	53	ISOPVC	105	-4	1.8
P-96	180	J-107	FCV-27	25	JISPVC	140	-0.21	0.42
P-97	96	J304	J-168	38	ISOPVC	105	-0.11	0.09
P-97	5	FCV-27	J-110	25	JISPVC	140	-0.21	0.42
P-98	44	J-61	J-69	38	ISOPVC	105	0.14	0.12
P-98	5	J-110	FCV-27	25	Ductile Iron	140	0.21	0.42
P-99	180	FCV-27	J-107	25	Ductile Iron	140	0.21	0.42
P-100	51	J-171	J302	38	ISOPVC	105	0.22	0.19
P-100	5	J-110	FCV-27	25	Ductile Iron	140	0.21	0.42
P-101	65	J-172	J-69	38	ISOPVC	105	0.91	0.8
P-101	180	FCV-27	J-107	25	Ductile Iron	140	0.21	0.42
P-102	84	J-168	J-171	38	ISOPVC	105	1.7	1.53
P-102	272	J-6	FCV-28	25	JISPVC	140	-0.29	0.59
P-103	7	FCV-28	J-113	25	JISPVC	140	-0.29	0.6
P-104	112	J-170	J305	38	ISOPVC	105	0.28	0.24
P-104	6	J-156	FCV-41	28	ISOPVC	150	0.31	0.5
P-105	113	J-170	J-301	38	ISOPVC	105	0.27	0.24
P-105	303	FCV-41	J337	28	ISOPVC	150	0.31	0.5
P-106	154	J-169	J-300	38	ISOPVC	105	0.45	0.39
P-106	4	J-64	FCV-44	65	GS	150	-1.1	0.33

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-107	164	J-168	J-172	38	ISOPVC	105	2	1.77
P-107	6	FCV-44	J-65	65	GS	150	-1.1	0.33
P-108	369	J-172	J-298	38	ISOPVC	115	0.9	0.8
P-110	14	J-50	FCV-100	125	DCI	120	18	1.43
P-111	978	FCV-100	J-199	105	DCI	150	18	2.03
P-112	3	J-42	FCV-101	85	ISOPVC	150	2.8	0.49
P-113	137	FCV-101	J-43	85	ISOPVC	150	2.8	0.49
P-114	5	J-149	J-110	65	ISOPVC	125	3.7	1.13
P-114	4	J-90	FCV-102	25	JISPVC	105	0.061	0.12
P-115	9	J-147	J-113	65	ISOPVC	110	4.9	1.46
P-115	124	FCV-102	J-277	25	JISPVC	150	0.06	0.12
P-116	30	J-112	J-147	65	ISOPVC	110	4.9	1.48
P-116	7	J-42	FCV-103	25	GS	140	0.083	0.17
P-117	173	FCV-103	J328	25	GS	140	0.083	0.17
P-118	41	J-113	J-149	65	ISOPVC	140	4.5	1.36
P-118	4	J-109	FCV-104	25	JISPVC	140	0.4	0.81
P-119	41	J-109	J-112	90	ISOPVC	125	5.3	0.83
P-119	172	FCV-104	J-84	25	JISPVC	140	0.39	0.8
P-120	6	J-112	FCV-105	25	JISPVC	140	0.35	0.71
P-121	145	J-115	J-176	38	ISOPVC	105	-1.8	1.57
P-121	273	FCV-105	J-8	25	JISPVC	140	0.35	0.71
P-122	151	J-175	J307	38	ISOPVC	105	0.99	0.87
P-122	201	J-156	FCV-106	28	ISOPVC	150	-1.3	2.14
P-123	161	J-114	J-115	38	ISOPVC	100	-1	0.91
P-123	6	FCV-106	J-72	28	ISOPVC	150	-1.3	2.14
P-124	171	J-72	FCV-107	40	ISOPE	150	-2.1	1.64
P-125	4	FCV-107	J-73	53	ISOPE	150	-2.1	0.94
P-126	6	J-41	FCV-108	75	ISOPVC	150	-4.4	0.99
P-127	436	FCV-108	J-39	85	ISOPVC	140	-4.4	0.77
P-128	130	J-64	FCV-109	15	JISPVC	150	0.084	0.48
P-129	5	FCV-109	J-33	15	JISPVC	150	0.085	0.48
P-130	91	J-41	FCV-110	15	JISPVC	150	0.12	0.67
P-131	7	FCV-110	J-36	15	JISPVC	150	0.12	0.67
P-132	111	J-153	J327	18	ISOPVC	150	-0.22	0.84
P-132	263	J-81	FCV-111	35	JISPVC	105	-2.3	2.42
P-133	5	FCV-111	J-76	35	JISPVC	95	-2.3	2.42
P-134	64	J-78	FCV-112	53	JISPVC	125	-0.4	0.18
P-135	150	J-197	J-241	38	ISOPVC	125	1.5	1.3
P-135	6	FCV-112	J-104	53	JISPVC	95	-0.4	0.18

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-136	7	J-88	FCV-113	25	JISPVC	95	0.12	0.24
P-137	8	J-163	J-164	38	ISOPVC	125	-0.62	0.55
P-137	119	FCV-113	J-284	25	JISPVC	95	0.12	0.24
P-138	5	J-95	FCV-114	25	JISPVC	95	0.046	0.09
P-139	111	J320	J-70	40	ISOPVC	100	0.4	0.32
P-139	124	FCV-114	J-282	25	JISPVC	90	0.046	0.09
P-140	5	J-141	FCV-115	35	ISOPE	150	-1.6	1.62
P-141	15	J-145	J-177	85	JISPVC	105	-13	2.28
P-141	55	FCV-115	J-142	35	ISOPE	150	-1.6	1.62
P-142	50	J306	J-137	53	JISPVC	105	-2.5	1.13
P-144	143	J-137	J-167	80	JISPVC	105	-7.3	1.45
P-144	5	J-183	FCV-117	65	ISOPVC	120	0.45	0.13
P-145	213	J-167	J-145	100	JISPVC	105	-12	1.5
P-145	33	FCV-117	J-250	65	ISOPVC	120	0.45	0.13
P-146	150	J-252	FCV-118	38	ISOPVC	120	-0.21	0.19
P-147	3	J-50	J-165	50	JISPVC	120	1.9	0.99
P-147	4	FCV-118	J-165	38	ISOPVC	120	-0.21	0.19
P-148	5	J-183	J-50	85	JISPVC	120	-5.4	0.96
P-148	6	J-165	FCV-119	38	ISOPVC	120	1.7	1.46
P-149	350	FCV-119	J-251	38	ISOPVC	140	1.7	1.46
P-150	639	J-150	FCV-120	38	ISOPVC	140	-1.3	1.15
P-151	225	J-56	J-161	50	JISPVC	100	-1.6	0.81
P-151	10	FCV-120	J-178	38	ISOPVC	120	-1.3	1.15
P-152	218	J-66	J324	40	JISPVC	150	0.43	0.34
P-152	18	J-161	FCV-121	65	JISPVC	110	-3	0.91
P-153	224	J-126	J-116	50	JISPVC	110	2.5	1.26
P-153	174	FCV-121	J-178	65	JISPVC	120	-3	0.91
P-154	4	J-161	FCV-122	38	ISOPVC	110	1.2	1.04
P-155	78	FCV-122	J-135	38	ISOPVC	110	1.2	1.04
P-156	33	J311	J-182	65	JISPVC	90	6.3	1.9
P-156	9	J-56	FCV-123	150	GS	100	1.6	0.09
P-157	69	J-182	PRV-2	50	JISPVC	90	3.6	1.82
P-157	185	FCV-123	J-245	40	GS	100	1.6	1.25
P-158	118	PRV-2	J-126	50	JISPVC	90	3.4	1.72
P-160	3	J-119	FCV-125	475	DCI	125	64	0.36
P-161	3	FCV-125	J-120	475	DCI	125	64	0.36
P-162	6	J-115	FCV-126	25	JISPVC	100	0.63	1.29
P-163	84	J-144	J-102	65	JISPVC	140	-1.4	0.41
P-163	56	FCV-126	J-108	25	JISPVC	100	0.63	1.29

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-164	278	J-295	J-144	40	JISPVC	140	-0.48	0.38
P-164	6	J-177	FCV-128	40	ISOPVC	105	1.8	1.55
P-165	5	Fire Hydrant (Point)-12	J-196	35	JISPVC	125	-0.1	0.1
P-165	353	FCV-128	J-175	40	ISOPVC	105	1.8	1.55
P-166	12	J-48	J-46	75	JISPVC	110	4	0.91
P-166	4	J-60	FCV-129	65	ISOPVC	105	-4.3	1.29
P-167	52	J-164	J-57	75	JISPVC	125	-0.98	0.22
P-167	5	FCV-129	J-167	65	ISOPVC	105	-4.3	1.29
P-168	54	J-57	J-117	75	JISPVC	125	-1.2	0.28
P-168	5	J-171	FCV-130	38	ISOPVC	105	1.4	1.25
P-169	4	J-71	FCV-39	25	JISPVC	150	0.085	0.17
P-169	90	FCV-130	J-169	38	ISOPVC	105	1.4	1.25
P-170	179	FCV-39	J332	50	JISPVC	150	0.085	0.04
P-170	9	J-169	FCV-131	38	ISOPVC	105	0.63	0.55
P-171	36	FCV-131	J-170	38	ISOPVC	105	0.62	0.55
P-172	3	FCV-40	J-151	65	JISPVC	150	2	0.59
P-172	137	J-261	FCV-132	40	ISOPVC	125	-0.15	0.14
P-173	31	FCV-132	J-162	40	ISOPVC	125	-0.15	0.14
P-174	33	J-162	FCV-133	40	ISOPVC	125	-0.55	0.49
P-175	86	FCV-133	J-163	40	ISOPVC	125	-0.55	0.49
P-176	7	J-164	FCV-134	40	ISOPVC	125	0.31	0.27
P-177	110	FCV-134	J-262	40	ISOPVC	125	0.31	0.27
P-178	8	J-57	FCV-135	40	GS	125	0.14	0.11
P-179	92	FCV-135	J-263	40	GS	125	0.14	0.11
P-180	127	J1	J-194	75	ISOPVC	90	6.5	1.48
P-180	76	J-90	FCV-136	25	JISPVC	105	-0.5	1.03
P-181	8	J-6	J-7	50	JISPVC	105	0.054	0.03
P-181	17	FCV-136	J-13	25	JISPVC	105	-0.5	1.03
P-182	8	J-8	J-9	50	JISPVC	125	0.17	0.09
P-182	77	J-196	FCV-137	65	ISOPVC	125	3.7	1.1
P-183	8	J-10	J-11	50	JISPVC	115	0.12	0.06
P-183	17	FCV-137	J-197	65	ISOPVC	115	3.7	1.1
P-184	15	J-12	J-13	75	JISPVC	105	0.63	0.14
P-185	29	J-296	J-14	50	JISPVC	110	-0.1	0.05
P-185	8	FCV-138	J-32	65	GS	150	-6.6	1.99
P-186	30	J-15	J-16	80	JISPVC	105	0.21	0.04
P-186	9	J-66	FCV-139	65	GS	150	-6.6	1.99
P-187	31	J-7	J-8	50	JISPVC	145	-0.15	0.07
P-187	127	FCV-139	FCV-138	65	GS	150	-6.6	1.99

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-188	35	J-17	J-12	75	JISPVC	105	-1.9	0.44
P-188	427	J321	FCV-140	40	GS	150	-0.98	0.78
P-189	36	J-18	J-19	75	JISPVC	105	-1.5	0.34
P-189	40	FCV-140	J-64	40	GS	150	-0.98	0.78
P-190	36	J-11	J-6	75	JISPVC	105	0.85	0.19
P-190	5	J-144	FCV-141	28	ISOPE	150	0.22	0.35
P-191	41	J-14	J-18	75	JISPVC	105	-0.77	0.17
P-191	245	FCV-141	J334	28	ISOPE	150	0.22	0.35
P-192	42	J-9	J-15	60	JISPVC	125	0.078	0.03
P-192	185	J-292	FCV-142	25	JISPVC	95	-0.18	0.36
P-193	43	J-19	J-17	75	JISPVC	105	-1.8	0.4
P-193	9	FCV-142	J-78	25	JISPVC	135	-0.18	0.36
P-194	84	J-274	J-10	35	JISPVC	115	-0.041	0.04
P-194	184	J-291	FCV-144	25	JISPVC	135	-0.29	0.59
P-195	122	J-13	J-4	45	JISPVC	125	0.099	0.06
P-195	8	FCV-144	J-91	25	JISPVC	135	-0.29	0.59
P-196	7	J-69	FCV-145	25	HDPE	105	0.96	1.95
P-197	408	FCV-145	J-299	25	HDPE	140	0.96	1.95
P-198	10	J-199	FCV-146	38	ISOPVC	90	2	1.75
P-199	515	FCV-146	J313	38	ISOPVC	110	2	1.75
P-203	68	J-143	J327	65	ISOPE	150	-2.6	0.78
P-204	99	J-151	J-6404	28	ISOPE	150	0.47	0.77
P-205	73	J-6404	J-71	20	ISOPE	150	0.33	1.29
P-206	285	J-194	J310	85	ISOPVC	95	6.5	1.14
P-211	3	J-34	J-35	100	ISOPVC	95	-14	1.83
P-211	319	J327	FCV-40	40	Ductile Iron	150	2	1.56
P-212	14	J-36	J-33	75	ISOPVC	150	8.7	1.97
P-212	252	J-143	J-6406	30	Ductile Iron	150	0.1	0.14
P-213	23	J-37	J-29	140	ISOPVC	135	-22	1.42
P-213	127	J-67	J-6407	140	GS	125	26	1.72
P-214	103	J-16	J-38	100	ISOPVC	90	-15	1.85
P-214	132	J-6407	J-68	75	GS	125	3.9	0.88
P-215	181	J-39	J-34	85	ISOPVC	85	-5	0.88
P-215	142	J-124	J-6407	100	HDPE	125	-1.1	0.18
P-216	185	J-38	J-40	150	ISOPVC	150	-15	0.96
P-217	235	J-40	J-37	140	ISOPVC	150	-21	1.34
P-219	395	J-35	J-16	100	ISOPVC	150	-15	1.86
P-221	466	J-36	J-34	85	ISOPVC	150	-8.9	1.57
P-223	174	J-200	J-44	85	ISOPVC	90	-15	2.72

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-224	37	J-46	J-196	140	ISOPVC	125	4	0.26
P-225	3	J-199	J-44	125	DCI	90	16	1.27
P-226	18	J-6419	J-48	240	ISOPE	150	1.10E+02	2.38
P-228	102	J-52	J-255	25	GS	100	0.055	0.11
P-229	102	J-53	J-254	25	GS	100	0.096	0.2
P-230	167	J-54	J315	25	GS	150	0.41	0.83
P-234	128	J-6407	J-6415	100	JISPVC	125	21	2.69
P-235	45	J-55	J-54	15	GS	125	0.49	2.78
P-236	299	J-59	J-55	65	GS	115	1.7	0.52
P-237	130	J303	J-60	15	GS	105	-0.077	0.43
P-238	230	J-60	J-61	15	GS	105	0.17	0.94
P-240	109	J-63	J-253	25	GS	100	0.29	0.6
P-240	4	J-6420	FCV-152	500	Ductile Iron	125	1.70E+02	0.98
P-241	9	J-67	J-134	250	JISPVC	150	-1.00E+02	2.26
P-242	3	FCV-152	J-6419	500	Ductile Iron	125	1.70E+02	0.98
P-243	16	J-6419	J-119	500	Ductile Iron	125	64	0.36
P-246	6,461	source reservoir	J-6420	50	Ductile Iron	125	1.80E+02	1.02
P-247	385	FCV-95	PRV-4	75	ISOPVC	150	-8.1	1.83
P-248	58	PRV-4	J-33	75	ISOPVC	150	-8.1	1.83
P-249	83	J-104	PRV-6	40	JISPVC	95	-0.048	0.04
P-250	52	PRV-6	J-76	40	JISPVC	95	-0.048	0.04
P-251	5	J-76	J-77	90	JISPVC	95	-2.4	0.38
P-251	58	J-177	PRV-7	85	JISPVC	105	-15	2.6
P-252	13	PRV-7	J-200	85	JISPVC	105	-15	2.6
P-253	8	J-73	J-65	50	JISPVC	150	-3	1.55
P-253	90	J-29	PRV-8	140	ISOPVC	135	-23	1.47
P-254	9	J-78	J-79	35	JISPVC	125	0.16	0.17
P-254	166	PRV-8	J-30	140	ISOPVC	135	-23	1.47
P-255	9	J-80	J-81	35	JISPVC	125	-2.6	2.69
P-255	50	J-178	PRV-10	85	JISPVC	120	-4.7	0.83
P-256	9	PRV-10	Fire Hydrant (Point)-54	85	JISPVC	120	-4.7	0.82
P-257	206	J-134	PRV-11	240	ISOPE	125	-1.00E+02	2.29
P-258	138	PRV-11	J-48	240	ISOPE	125	-1.00E+02	2.29
P-259	27	J-65	J-41	53	JISPVC	150	-4.2	1.89
P-259	26	J-110	PRV-12	53	ISOPVC	140	3	1.37
P-260	31	J-85	J-288	25	JISPVC	105	0.28	0.57

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-260	62	PRV-12	J-42	53	ISOPVC	140	3	1.37
P-261	31	J-86	J-273	25	JISPVC	110	0.019	0.04
P-261	32	J-105	PRV-13	40	ISOPVC	105	-0.31	0.28
P-262	55	PRV-13	J-75	40	ISOPVC	105	-0.31	0.28
P-264	37	J-89	J-90	25	JISPVC	105	-0.33	0.66
P-265	38	J-80	J-91	25	JISPVC	125	0.4	0.82
P-266	39	J-92	J-93	25	JISPVC	105	0.95	1.94
P-267	39	J-94	J-89	25	JISPVC	90	-0.55	1.13
P-268	39	J-95	J-94	25	JISPVC	90	-0.37	0.76
P-269	39	J-96	J-85	25	JISPVC	105	0.45	0.92
P-270	40	J-97	J-96	25	JISPVC	105	0.64	1.3
P-271	40	J-91	J-78	25	JISPVC	125	0.023	0.05
P-272	40	J-93	J-97	25	JISPVC	105	0.81	1.65
P-273	44	J-6	J-92	25	JISPVC	105	1.1	2.17
P-274	50	J-98	J-99	25	JISPVC	90	0.31	0.63
P-276	53	J-88	J-95	25	JISPVC	95	-0.19	0.39
P-277	54	J-290	J-102	15	JISPVC	150	-0.24	1.36
P-279	69	J-293	J-79	25	JISPVC	125	-0.054	0.11
P-281	78	J-79	J-81	25	JISPVC	125	-0.44	0.9
P-283	86	J-105	J-86	25	JISPVC	105	0.26	0.53
P-284	87	J-75	J-106	25	JISPVC	105	0.33	0.67
P-286	94	J-107	J-10	25	JISPVC	105	0.24	0.48
P-289	133	J-107	J-265	25	JISPVC	105	0.2	0.41
P-290	103	J-84	J-15	25	JISPVC	105	0.21	0.44
P-291	104	J-99	J-95	25	JISPVC	95	-0.043	0.09
P-292	126	J-108	J319	25	JISPVC	100	0.084	0.17
P-293	109	J-99	J-287	25	JISPVC	95	0.18	0.37
P-294	122	J-283	J-85	25	JISPVC	105	-0.056	0.11
P-295	122	J-279	J-97	25	JISPVC	100	-0.049	0.1
P-296	123	J-281	J-96	25	JISPVC	105	-0.046	0.09
P-297	124	J-79	J-294	25	JISPVC	105	0.49	0.99
P-298	128	J-98	J-94	25	JISPVC	90	-0.061	0.12
P-299	124	J-275	J-92	25	JISPVC	105	-0.059	0.12
P-300	124	J-276	J-93	25	JISPVC	100	-0.046	0.09
P-306	130	J-14	J-98	25	JISPVC	105	0.58	1.18
P-308	134	J-106	J-268	25	JISPVC	105	0.22	0.44
P-310	165	J-297	J-98	25	JISPVC	105	-0.11	0.23
P-313	198	J-18	J-89	25	JISPVC	105	0.36	0.72
P-317	191	J-102	J-80	40	JISPVC	140	-1.9	1.49

Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
P-320	196	PRV-2	J317	25	JISPVC	115	0.2	0.4
P-323	272	J-258	J-19	25	JISPVC	105	-0.14	0.28
P-324	272	J-18	J-257	25	JISPVC	105	0.23	0.47

Appendix A12 Flex Table: PRV Table for improved network at 12:00am

Label	Elevation (m)	Diameter (Valve) (mm)	Flow (L/s)	Hydraulic Grade (From) (m)	Hydraulic Grade (To) (m)	Zone	Setting Type
PRV-2	2,439.00	50	0.2	2,520.55	2,439.00	Zone - 1	Pressure
PRV-4	2,459.93	50	8.1	2,516.94	2,516.94	Zone - 3	Pressure
PRV-6	2,465.40	50	0.048	2,554.93	2,465.40	Zone - 2	Pressure
PRV-7	2,477.50	50	15	2,488.85	2,488.85	Zone - 1	Pressure
PRV-8	2,486.55	50	23	2,556.95	2,556.95	Zone - 2	Pressure
PRV-10	2,469.25	50	4.7	2,554.71	2,469.25	Zone - 1	Pressure
PRV-11	2,483.96	50	1.00E+02	2,557.92	2,483.96	Zone - 1	Pressure
PRV-12	2,471.47	50	3	2,547.11	2,547.11	Zone - 2	Pressure
PRV-13	2,477.70	50	-0.31	2,545.72	2,545.72	Zone - 2	Pressure

Appendix A13graph for sample junction during peak hour