ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

HYDRAULIC NETWORK MODELING OF THE EXISTING WATER DISTRIBUTION SYSTEM OF ADDIS ABABA CITY (LEGEDADI SUB SYSTEM AS A CASE STUDY)

BY
DURETI TESSEMA

MARCH 2015
ADDIS ABABA, ETHIOPIA

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Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering, Faculty of Graduate Studies, at Addis Ababa University, Addis Ababa, Ethiopia.

By
Dureti Tessema

Directed by
Dr.Ing. Mebrate Taffese

March, 2015

Department of Civil & Environmental Engineering
Water Supply & Environmental Engineering Stream

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APPROVED BY THE BOARD OF EXAMINERS

Committee Members	**Signature**
1. Mebrate Taffese (PhD) Advisor	
2. Agizew Nigussie Internal examiner	
3. Dr Asie Kemal External examiner	
Esayas G/Youhannes Chairman (Department of Graduate Committee) *Civil & Environmental Engineering*	

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LIST OF ABBREVIATIONS

DN	Nominal Diameter.
l/c/d	Liter Capita Per a Day.
MCM	Million Cubic Meters.
MOPIC	Ministry of Planning and International Cooperation.
PDO	Pressure Dependent Outflow.
P.F	Peak Factor.
S.I-	System International
UFW	Unaccounted for water.
U.S	United States
WSCs	Water Supplies Companies.
ASL	Above Sea Level
WDS	Water Distribution System
WDMs	Water Distribution Models
GUI	Graphical User Interface
EPS	Extended Period Simulations
GIS	Geographic Information System
CAD	Computer Aided Drafting
DBP	Disinfection By-Product formation
NPSH	Net Positive Suction Head
HGL	Hydraulic Grade Line
ORAAMP	Office of the Review of Addis Ababa Master Plan
AA	Addis Ababa
IT	Information Technology
NRW	Non Revenue Water
CSA	Central Statistics Authority
NFF	Need for Fire Flow
USA	United State of America
PVC)	Polyvinyl Chloride Pipe
DCI	Ductile Cast Iron
GI	Galvanized Iron
UTM	Universal Transverse Convertor
WGS	World Geodetic System
^{0}C	Degree Celicius
AAWSA	Addis Ababa Water Supply Authority
WHO	World Health Organization
CT	Collection Tank
GW1	Ground Water 1
GW2	Ground Water 2
GW3	Ground Water 3
BZ	Belay Zeleke
MO	AAWSA Main Office
RK	Ras Kassa
EN	Entoto

TM	Teferi Mekonnen
JM	Jan Meda
KG	Kassa Gebre
AH	Army Hospital
AN	Ankorcha
GR	Gebriel
PH	Police Hospital
RH	Ras Hailu
TR	Terminal Reservoir
PRV	Pressure Reducing Valve
FCV	Flow Control Valve
ESRI	Environmental System Research Institute
N	North
C	Hazen Williams Coefficient
MoWR	Ministry of Water Resource
BPT	Break Pressure Tank
DOH	Department of Health

ABSTRACT

The primary goal of this study is to review the hydraulic performance of the existing distribution system of the city, Addis Ababa, Legedadi subsystem which is aimed to help the city understand its distribution system needs and assist them in long-term planning of water assets.

The scope of the study is to evaluate the performance of the existing drinking water distribution system using hydraulic simulation software in integration with GIS, and recommends the possible remedies to improve the efficiency of the existing system.

The hydraulic simulation software used for this study is Water CAD V8i distributed by Bentley Systems. Bentley Water CAD V8i was selected due to ease of model building and operation and its greater programming capabilities as compared to EPAnet.

Hydraulic modeling of the system is performed by considering the system as a continuous supply system, and the evaluation process adopted the Extended Period Simulation method. The system has been checked for different scenarios and alternatives to deepen our investigation. Considering, the model is calibrated at specific locations and the results with field measurements show reasonable difference, so that we use some fine tuning using Hazen Williams C –value to align with the field data.

As a matter of fact, I have proved that, there is hydraulic inefficiency in the existing water system to serve the city (Legedadi sub system) and to cope with the future demand.

The outputs show that the network is exposed to relatively high and low values of pressure and velocity, which have negative effects on the performance of the network as well as in the water quality of the system. Besides, failure is forecasted in considering the age of pipes for re-installation and maintenance. As a result, Pipes with ages more than 30 years are replaced and over and under sized pipes have been re-sized. Consequently, the Hazen Williams C-value has been totally improved and it enhances the system performance.

The evaluation study of the water hammer in the Addis Ababa distribution system, which has been implemented to investigate the effects of this phenomena shows that the water hammer values increase by increasing the velocity of water in pipes, and the values of shock pressures were within the limits of the shock pressures in water pipes systems.

In the study, the major hydraulic parameters, the variations, and the relations between them and other factors, which control the performance of the water supply networks are considered and discussed in detail during analysis.

To this end, the network is assessed and possible corrections are given for Optimum water supply network even using Darwin Optimum Pipe Network Designer tool so as to at least the system meet the required design criterion as a constraints. Moreover, the Legedadi subsystem has been categorized for 14 optimum Pressure zones with their corresponding Reservoirs (Pumping stations).

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1 INTRODUCTION

1.1 General Background

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 [9].

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 [9].

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 [9].

The next major phase of expansion of the water supply facilities commenced in 1970 with the commissioning of the *Legedadi* Dam and treatment plant, which was located on the Akaki River east of Addis Ababa. The plant's output of 50,000 m^3/day was transmitted via 900 mm pipe line to the Terminal Reservoir on the city's Eastern edge and to Meskel Square in the city's center. To transfer and distribute these additional water additional reservoirs, pumping stations and pipelines were constructed in the eastern and northern areas of the city. These facilities came to be known as the Stage I Water Supply Project.

The third huge water source of Addis Ababa has been explored from Ground Water source; which is the Akaki well field is situated southeast of Akaki town and about 22 km south of Addis Ababa. The well field covers an area of about 16 km^2.

A total of 35 wells are drilled within this area: 25 production wells, four monitoring wells, four wells for water supply to Akaki, one well for isotope sampling, and one deep test well. The Akaki well field was put into operation in 2001. The capacity of the wells is 347 l/s.

Further development of the water supply facilities was pursued during the l980s under the Stage II Water Supply Project [9].

The First phase included expansion at the *Legedadi* treatment plant, construction of a new transmission pipeline into the city, the rehabilitation of the *Gefersa* treatment plant and the construction or upgrading of several reservoirs and pumping stations throughout the city.

The second phase included extensive primary and secondary pipeline installations and improvements to the distribution network. The capacity of the supply facilities, of 150,000 and 30,000 m^3/day respectively for Legedadi and Gefersa were projected to be adequate to serve the need of Addis Ababa up to 1992.

Planning for a Stage III water supply program commenced in the early 1980's, when a reconnaissance study was undertaken of all potential water supply sources located within a 50km radius [9]. In 1991, feasibility studies and preliminary designs were completed for the development of a number of sources to serve the city to the year 2020 [9].

The delay in the implementation of Water Supply Stage Ill-A (WSS Ill-A) project called for an emergency program to fast-track the development of two water supply projects. These are part of the Akaki well field and the Dire dam, which are completed and both are under service. In addition, a program of spring rehabilitation and bore hole drilling has provided improved water supplies to outlying areas of the city not yet serviced by the distribution network Additional programs are underway to reduce leakage losses and to improve operational efficiencies.

According to three principal sources, the city has three main subsystems Namely –*Legedadi*, *Gefersa* and *Akaki* subsystem. The three subsystems have additional ground water well sources apart from their principal sources. This thesis is focused on the *Legedadi* subsystem of its hydraulic network modeling.

Figure 1.1 Project Site Locations

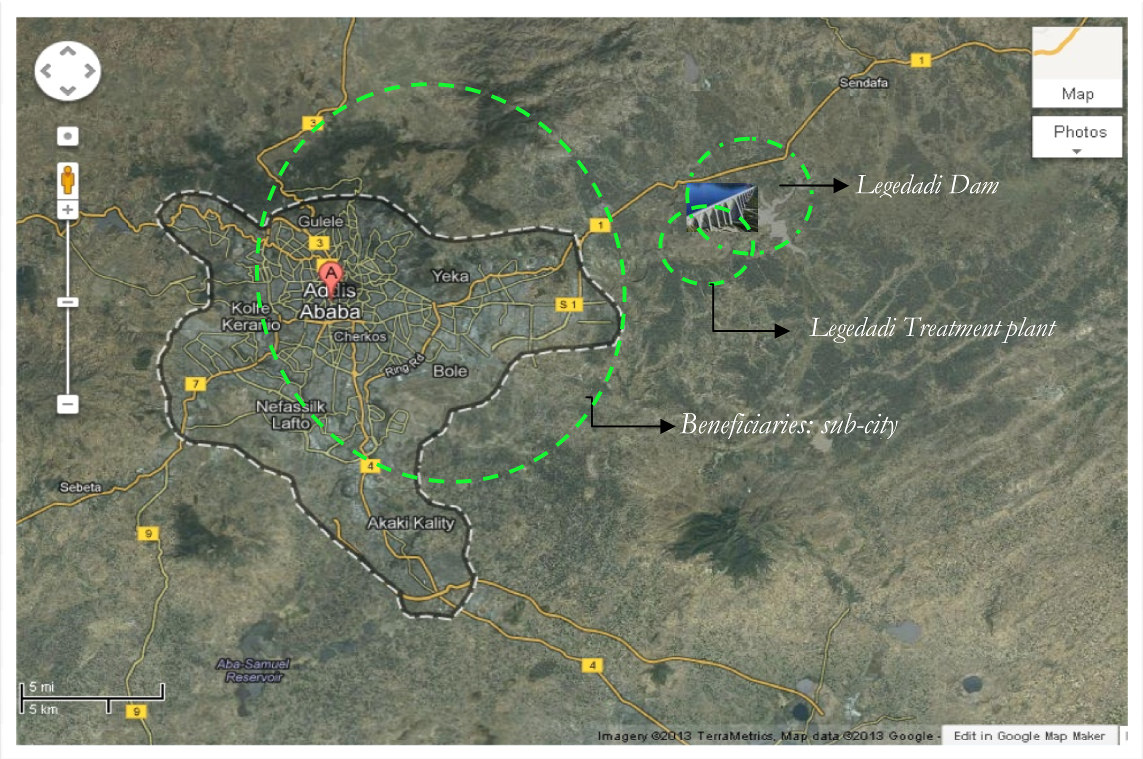
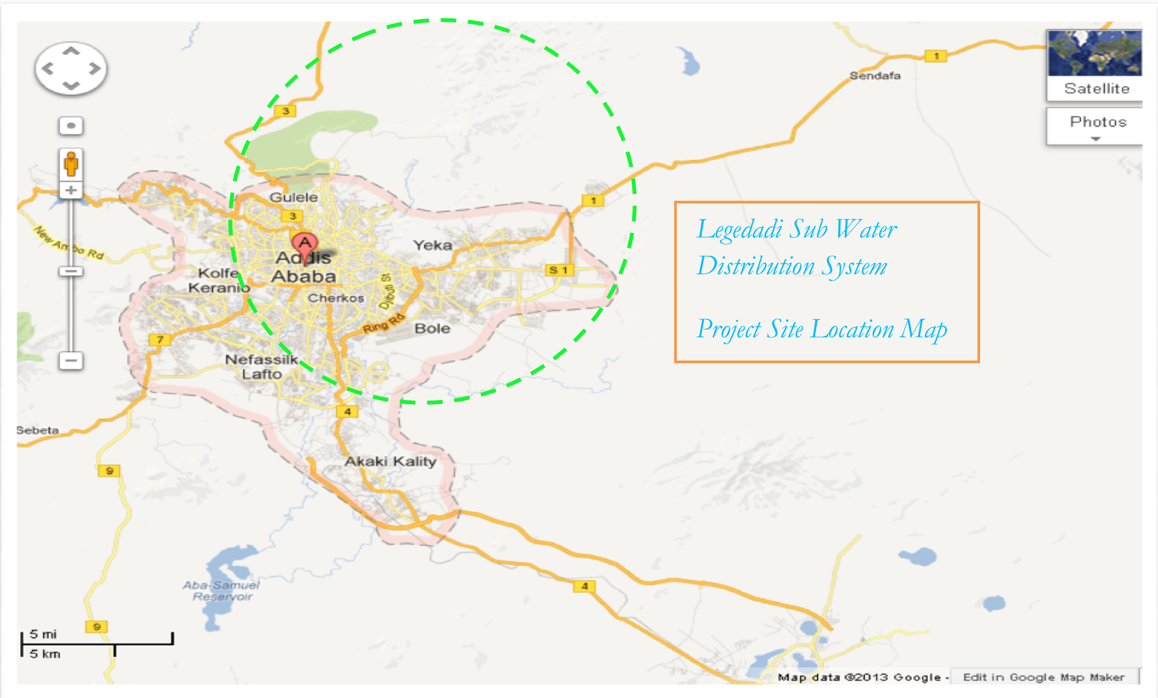


Figure 1.2 Map of Project Site Location



1.2 Problem Statement

Addis Ababa has been suffering from the discontinuous supply of water in the distribution systems. The production of water from the sources is limited and can not satisfy the need of the beneficiaries, especially at peak hour demand there is high scarcity of water. Though the production of water is lesser than the demand of the city, it is possible that to improve the existing water distribution system (network) to produce better pressure head and flow than the existing system output. As a result, here are the major problem statements of this research work.

i. The existing distribution system shows excess and negative pressure heads in the system. Pressure head above 140m & negative pressure are observed in the system. (according to the accepted design criteria in the 1994 Review AWSSA Report) [1].

ii. In addition, the existing distribution system of the city is divided into 13 subsystems, the categorization is only considers the geographical distribution of the city, so that the system requires the pressure zone adjustment within a suitably limited range of pressure. [1].

iii. Since the exiting data management and manipulation is mainly manual and uses local systems. The GIS application and integration with the water system is hardly practicing. Besides, it is important to perceive the system for Darwin Optimizer of water CAD, which predicts the possible optimum pressure and velocity considering the constraints of the distribution network, further, it is fundamental that to identify the nodes having critical scarcity of water.

Thus, the study annotates on *Legedadi* sub system as a case study considering the actual condition of the system. In addition, it is clear that the sub system is upgrading, thus before that it is a critical action to examine the existing system first.

1.3 Objectives of the study

1.3.1 General objective:

The main goal of this study is to evaluate the hydraulic performance of the Addis Ababa water supply networks (*Legedadi* water supply network as a case study) taking into account the effects of local operating conditions.

1.3.2 Specific objectives:

The detailed objectives of the study are the following:

1- Investigate the existing water supply networks and identify the existing water supply problems.
2- Evaluate the hydraulic parameters, and the relations among them and other factors, which control the performance of the water supply networks. Study the hydraulic parameters in the water distribution system (pressure, velocity), with respect to time.
3- Model the existing water supply system as a continuous water supply system- Examine the system for possible Optimum Condition.
4- Integrate the hydraulic water distribution software (Water CAD) with GIS tool.

1.4 Significance of the study

The significance of this paper is to evaluate the hydraulic performance of the water supply networks (Addis Ababa water supply system -*Legedadi* sub system as a case study). This is to analyze the sub distribution service and control its operation using the computer model (Water CAD) analysis with GIS integration, since the city is affected by the intermittent supply of potable water.

The performance of Addis Ababa water supply networks became one of the most critical issues in the water supply sector that requires immediate action as the system repeatedly supplies the discontinuous supply of water.

As the demand on water increases due to the population growth rate, and the increase in per capita consumption, the defect in the performance of the water network led to the negative influence in most of the socioeconomic sectors. This occurs because of the aged pipe system (especially in the old parts of the Addis Ababa City).

Water distribution systems are designed to adequately satisfy the water requirements for a combination of domestic, commercial, industrial, and fire fighting purposes. The system should be capable of meeting the demands placed on it at all times and at satisfactory hydraulic performance [1]. It should enable reliable operation during irregular situations and perform adequately under varying demand loads [2].

In our region the design of water distribution systems is implemented by using universal design factors without taking into account the effects of local conditions, so that the design parameters should be modified to achieve water requirements.

Many sectors of water distribution systems in most parts of Addis Ababa suffer from the deficiency of water supply quantities and sharp deficiency in the pressure, so that to achieve the consumer demand at satisfactory levels, it must improve and increase the efficiencies of the water distribution operating and management systems.

The availability of water makes it possible for pumping water to the consumers at 24 hours with a constant flow rate, if water is not available in sufficient quantities then it should be pumped for shorter time periods at higher flow rate to meet the demand of the consumers, and a storage tank in this case for the entire city is usually provided in order to provide storage where the pumping rate is higher than the demand at night times, and this storage can be used in the case that the pumping rate is below the needed demand , and to equalize the pressure in the network in the cases of pressure increasing.

The water shortage and the conditions of topographic in most of Addis Ababa parts forces to divide the water distribution networks into several pressure zones through which water is pumped alternatively.

This research is part of studies in which researchers study the performance of water distribution systems. This study is to investigate the state of the existing water distribution system (Legedadi water distribution system as a case study) and evaluate the hydraulic performance of the water supply network under varying conditions of supply.

Using multi platform environments, model building is taking place by compiling from different data sources. So that Water CAD is responsible in model management and hydraulic analysis. As a result, results are carefully analyzed and compared with the standard design criterions. The system is also, evaluated for different operation conditions.

Hence, this report could be a significant input for AAWSA to re consider their system and take any necessary measures during upgrading & rehabilitation of the system.

1.5 Study Structure

This research consists of eight chapters including the introduction in chapter one. In chapter two, description of Addis Ababa water resources and the state of the existing water distribution systems.

Chapter three, narrates on literature review, this chapter tries to present some literatures written by other authors which have similar research issues with this research paper.

Chapter four contains details on the Materials and Methods- Model building, elaborates the ways and tools of the thesis that we use to achieve our goal and discusses on the steps taken to construct the model of the existing drinking water distribution system of Addis Ababa city.

Chapter five describes in detail on the integration of GIS with water distribution modeling software, Water CAD, and describes in brief about the importance GIS in water distribution system.

Chapter six, modeling of Addis Ababa water distribution network as continuous supply system, studying a pilot zone of, *Legedadi* sub system, and it elaborates the evaluation process adopted trough the Extended Period Simulation method. Different scenarios and alternatives to deepen our investigation have been conducted and the evaluation of the effects of water hammer phenomena in the system is also the discussed in this chapter.

In chapter seven, results, and findings get from running the hydraulic model is discussed in detail. The hydraulic parameters, the variations, and the relations between them and other factors, which control the performance of the water supply networks, have been analyzed in detail.

In chapter eight, conclusion, and logical recommendations have been given based on the results and findings get from the system hydraulic modeling process.

2 THE EXISTING WATER DISTRIBUTION SYSTEM

2.1 The Major Water Resources of Addis Ababa

The city of Addis Ababa was originally served by a number of springs located at the foot of Entoto mountain ridge together with a series of hand-dug wells. Part of the spring water was treated at the Entoto plant, which was commissioned in 1938 [1].

Currently, the city of Addis Ababa gets its water supply from both surface and ground Water sources.

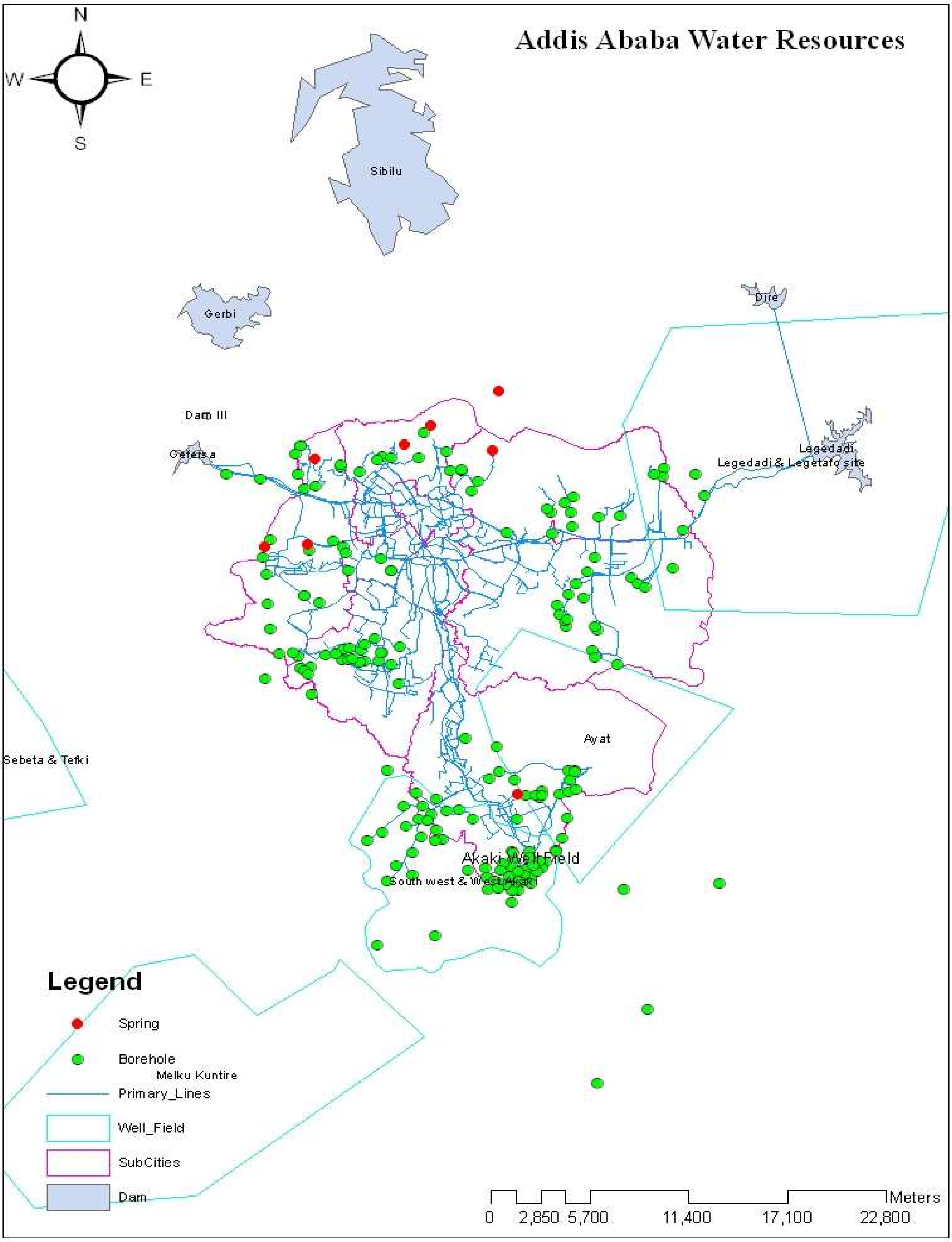
Addis Ababa is at present supplied mainly with surface water from the *Legadadi*, *Dire* and *Gefersa* reservoirs, with additional supplies from groundwater pumped from the ground water source is from Akaki ground water (Akaki well field), springs and wells with in and near Addis Ababa [1].

There are three main surface water dams as source for the surface water supply. These are Gefersa, Legedadi, and Dire. According to the three principal sources, the city has three main subsystems namely: *Legedadi, Gefersa, & Akaki* subsystem [1].

There are two conventional water treatment facilities, namely *Legedadi* and *Gefersa* treatment plants to supply the treated water to the city from the above different sources. The location of the Addis Ababa water supply sources is shown in the figure 2.1below.

At present, the water production of the city looks: *Legadadi* (165,000 m^3/day), *Gefersa* (30,000 m^3/day) and the emergency supply (for some 20-25 years) of the *Akaki* Groundwater field 38,000 m3/day, and other wells and springs located within the city produce 85, 597m3/day, hence the total daily water production is estimated to be 301, 597 m3/day. Out of the total production 65% is from the surface sources and the remaining 35% is from ground water.

Figure 2-1 Addis Ababa Water Resources



2.2 Water supply

Table 2.1: Addis Ababa Water Resources and Production

Source Name	Unit	Years					
		2005	**2006**	**2007**	**2008**	**2009**	**2010**
Legadadi	M3/day	156,389	163,053	164,489	164,966	165,264	165,000
	10^3 M3/year	57,082	59,514	60,038	60,213	60,321	60,225
Gefersa	M3/day	22,782	22,297	23,197	20,596	28,959	30,000
	10^3 M3/year	8,315	8,138	8,467	7,518	10,570	10,950
Akaki wells	M3/day	35,452	36,612	41,035	46,088	46,088	43,000
	10^3 M3/year	12,940	13,363	14,978	16,822	16,822	15,695
City springs& wells	M3/day	4,757	5,052	7,658	10,433	28,249	62,000
	10^3 M3/year	1,736	1,844	2,795	3,808	10,311	22,630
Deep wells	M3/day					1,597	1,597
	10^3 M3/year	-	-	-	-	583	583
Total Production	**M3/day**	**219,380**	**227,014**	**236,379**	**242,083**	**270,157**	**301,597**
	10^3 M3/year	**80,074**	**82,860**	**86,278**	**88,360**	**98,607**	**110,083**

2.3 Water Demand

The indicator for measuring the level of water consumption is the amount of water consumed per capita per day (l/c/d). Water consumption is a function of availability, religion, climate conditions, and affordability. Another indicator used in measuring the level of water consumption is the quality of delivered water. In general, water utilities have to follow WHO standards for domestic water [1].

The existing AAWSA water Supply design criterion for expansion areas are based on the study done under water supply project III [1].

Designing of the water scheme for the future consumption is surely based on the water demand forecast.

The total billed volume of water for the year 2010, as obtained from AAWSA's records, is about 62.35Mm3. About 50.4% is accounted for domestic connected users, consumption of 48% is consumed by non- domestic users and 1.7 % is consumed by public tap users [1].

The Arada branch has the highest percentage of non-domestic consumption about 67%, most likely because it is a high density urbanized area where development of own water source (boreholes) is not possible due to the topography [1].

2.4 Future Potential Water Demand

The population of Addis Ababa will be around 4Million by 2020. The projection was based on the national population census of Ethiopia, 2007. The population growth rate is considered to be 2.1% per annum [1].

Table 2.2 Average daily water demand of Addis Ababa city for different periods

S.No	Year	Water demand (l/c/d)	% of increment
1	1994	98	
2	2002	123	26
3	2006	140	14
4	2011	161	15
5	2020	192	19
6	2025	229	19

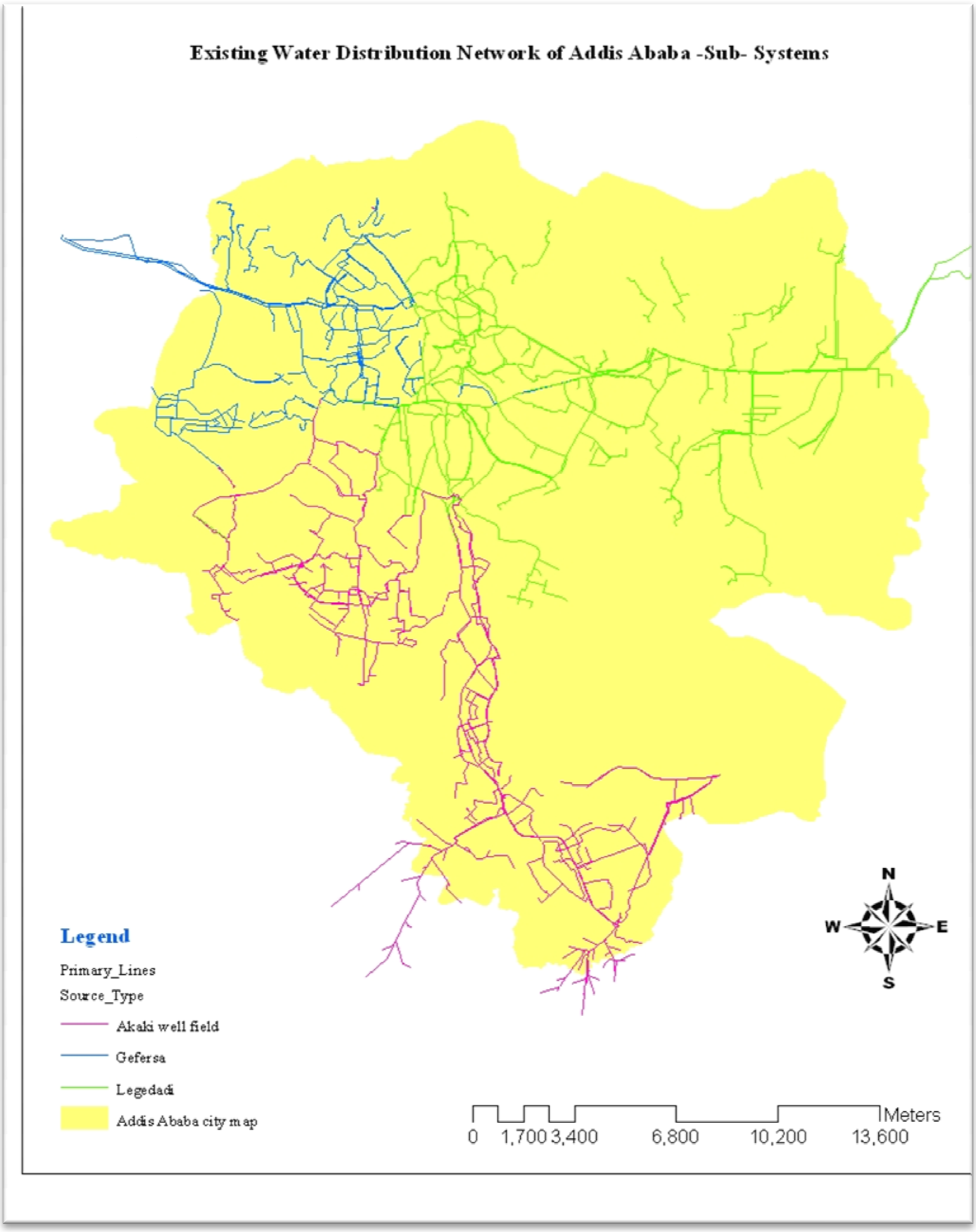
Mode of the supply to the most of the population is house connections, yard connection stand-alone, yard connection common, public fountains. All these mode of supply cover 97% of the town population as per the 1999 CSA publication on Addis Ababa. Less than 3% receive their water in other ways (boreholes, rivers, etc) [1].

The billed water amount is about 63.5% of the total Production and around 36.5 % of produced water is considered to be non revenue water (NRW). Nearly half of the billed volume is consumed by non domestic customers. The existing water supply coverage is estimated at 81% with a supply of an average of 37 l/c/day for domestic customers.

For our study area: Legedadi Pop: 1,636,307.27 according to (CSA, 2007), the existing Water demand per head: 161Lit/cap/day.

Legedadi sub area Total Water demand is: 263,445.47 M3/day and its water production is 165,000M3/day, which is un- reconciled.

Figure 2.2 Location of Addis Ababa water supply network- subsystems.



Gefersa subsystem includes supplies from Gefersa treatment plant to service reservoirs of Rufael , St Paul and Ras Hailu [1].

Legedadi subsystem includes supplies from Legedadi water treatment plant to service reservoirs of Kotebe terminal, Karalo, Ankorcha, Jan meda, Gebriel Palace, Teferi Mekonnen, Entoto, AAWSA Main Office, Belay Zeleke, Police Hospital, army Hospital and Kassa Gebriel and to Pumping station to Urael and Mexico Square [1].

Akaki subsystem includes supplies from Akaki well field to CT, GW1, GW2, GW3, Bole Bulbula service reservoirs and Lebu service reservoirs [1].
The three subsystems have additional ground water well sources apart from their principal sources [1]. The thesis focused on Legedadi sub system.

2.5 Location of the study area

The study area Legedadi subsystem is restricted to Addis Ababa city located between 469302 and 489606 easting (UTM) and 987441 and 1005636 northing (UTM). The total coverage is 240km2, 46% of coverage of Addis Ababa [1].

Figure 2.3 Location map of Legegadi subsystem

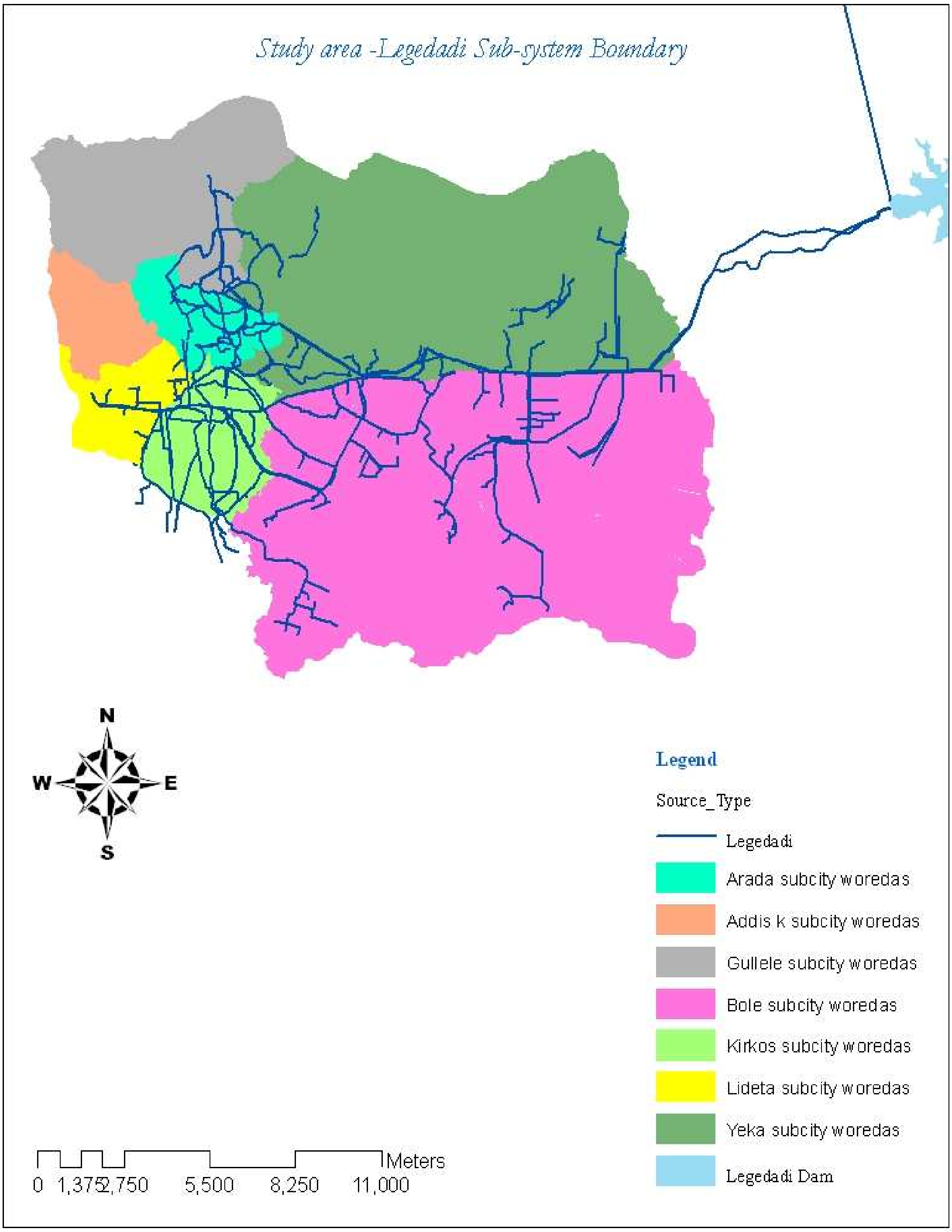


Figure 2.4: Photos of Legedadi Reservoir

2.6 Water Treatment Plant of the study area

2.6.1 Legadadi Treatment Plant

The first stage of *Legadadi* treatment plant was commissioned in 1970 with a capacity of 50,000 m^3/day. It consists of clarifiers followed by rapid sand filtration. The second stage of the plant commissioned in 1985 and with a capacity of 100,000 m^3/day also consists of clarifiers, rapid sand filters and Chlorination. Sludge is disposed of directly to the *Akaki* River [1].

2.7 Transmission Lines

2.7.1 Legadadi Transmission Main

The original *Legadadi* transmission main, of DN 900 mm, was constructed in 1970. With the expansion of the *Legadadi* treatment plant under Stage IIA, additional DN 1,400 mm and DN 1,200 mm transmission mains were laid [1].

2.7.2 Service Reservoirs

At present in *Legedadi* water supply sub system, there are 14 Major Reservoirs are located within the system, having a total capacity of 68,930.00m3. Table **2.3**: presents Service Reservoirs Supplied from *Legedadi* Reservoir [1].

Table 2.3: Water Service Reservoirs Supplied from Legedadi Reservoir

Name	Code	No.	Sub-system served	No. of tanks	Year Built	Construction material	Capacity (m^3)
Belay Zeleke	BZ	1 2	Belay Zeleke	1	1959	Masonry	1000
AAWSA main	MO	1 2	Interconnection	2	1956	Masonry	5000 5000
Ras Kass	RK	1 2	Ras Kassa	2	1963	RC	500 500
Entoto R3 Entoto R2 Entoto R1	R3 R2 R1	1 2 3	Upper Entoto Upper Entoto Upper Entoto	1 1 1	1973 1973 1973	RC RC RC	100 100 100
Entoto	EN	1 2	Entoto	2	1940 1983	Masonry RC	1000 2500
Teferi-Mekonen	TM	1 2 3	Teferi-Mekonen	3	1973 1973 1983	RC	1250 1250 2500
Jan-Meda	JM	1 2 3 4	Jan Meda	4	1973 1973 1983 1983	RC	1250 1250 5000 5000
Kassa Gabre	KG	1 2	Mercato	2	1960 1983	Masonry RC	500 2500
Army Hospital	AH	1 2 3	Lagadadi	3	1963 1963 1983	RC	500 500 5000
Ankorcha	AN	1	Lagadadi	1	1983	RC	5000
Terminal		1 2	Lagadadi	2	- 1969	RC	10,000 10,000
Gebriel	GR	1	Gebriel	1	1960	RC	1000
Ras Kassa upper		1	Ras Kassa	1	-	-	30
Palace		1 2	Gabriel	2	-	-	300 50
Police Hospital	PH	-	Merkato	1	1983	RC	250

Table 2.4: Methods of Supply from Reservoirs

Supplied from reservoir	Supplied to reservoir	Method of Supply	
		Gravity	Pumped
Legadadi Plant	Terminal	X	
Terminal	Jan Meda		X
Janmeda	Teferi mekonen		X
Tefferimekonnen	Entoto		X
Entoto	Entoto R1		X
Entot R1	Entoto R2		X
Entot R2	Entoto R3		X
Janmeda	Gabriel	X	
Janmeda	Awssa Main Office		X
AWSSA main office	Belay Zeleke		X
Police Hospital	Kassa Gabrie		X
Terminal	Angorcha	X	
Terminal	Urael	X	
Teferimekonnen	Ras Kassa		X
Terminal	Mexico Square	X	
Mexcio	Police Hospital		X
Terminal	Police Hospital	X	
Belay Zeleke	Upper Belay Zeleke		X
Mexico	Army Hospital		X
Ras Kassa	Upper Ras Kassa		X

2.8 Pumping Stations

At the commencement of the study an inspection was conducted of all pumping stations. At the time AAWSA was operating a total of 65 pumps in 16 pumping stations [1].

The pumps appear to be in good mechanical condition. There is slight weeping at the glands on the drive shafts; however, this is usually not excessive and can be detected and attended to as part of routine maintenance activities [1].

Table 2-5: Existing Pumps and Pumping Stations in Regular Service

Pumping Station	Code	Pump No	Design (l/s)	Head (M)	Delivery to	Pump position
Terminal	TR	1	313	75	Jan Meda Res	Working
		2	313	75	"	"
		3	313	75	"	Standby
		4	150	75	Jan Meda distribution	Working
		5	150	75	"	"
		6	150	75	"	Standby
		7	4.5	230	Army camp	Working
		8	4.5	230	"	Standby
		9	22	-	"	Working
		10	22	-	Upper Kotebe	Standby
Jan Meda	JM	1	75	57	Teferi Mekonen. Reservoir	Working
		2	75	57	"	"
		3	100	32	AAWSA Main Office Reservoir	"
		4	100	32	"	"
		5	100	32	"	Standby
		6	52	57	Teferi Mekonen	Working
		7	52	57	"	"
		8	52	57	"	Standby
Tefere Mekonnen	TM	1	86	63	Entoto Reservoir	Working
		2	86	63	"	Standby
		3	26	64	Ras Kassa Reservoir	Working
		4	26	64	"	Working
Entoto	EN	1	20	89	Entoto R1	Working
		2	20	89	"	Standby
Entoto R1	R1	1	9	55	Entoto R2	Working
		2	9	55	"	Standby
Entoto R2	R2	1	6	65	Entoto R3	Working
		2	6	65	"	Standby
AAWSA Main Office	MO	1	75	160	Belayzlekie	Working
		2	75	160	"	Standby
Belay Zeleke	BZ	1	5	100	Belayzeleke	Working
		2	5	100	Distribution	"
		3	5	100		Standby
Police Hospital	PH	1	75	98	Kassa Gabri	Working
		2	75	98	"	"
Mexico	MS	1	167	30	PH collect ___	Working

Square PS		2	167	30	"	"
Urael		1	50	38	Gabriel	Working
		2	50	38	"	Standby
		3	50	38	"	"
Rass Kassa	RK	1	8	130	Upper Ras	Working
		2	8	130	Kassa	Working

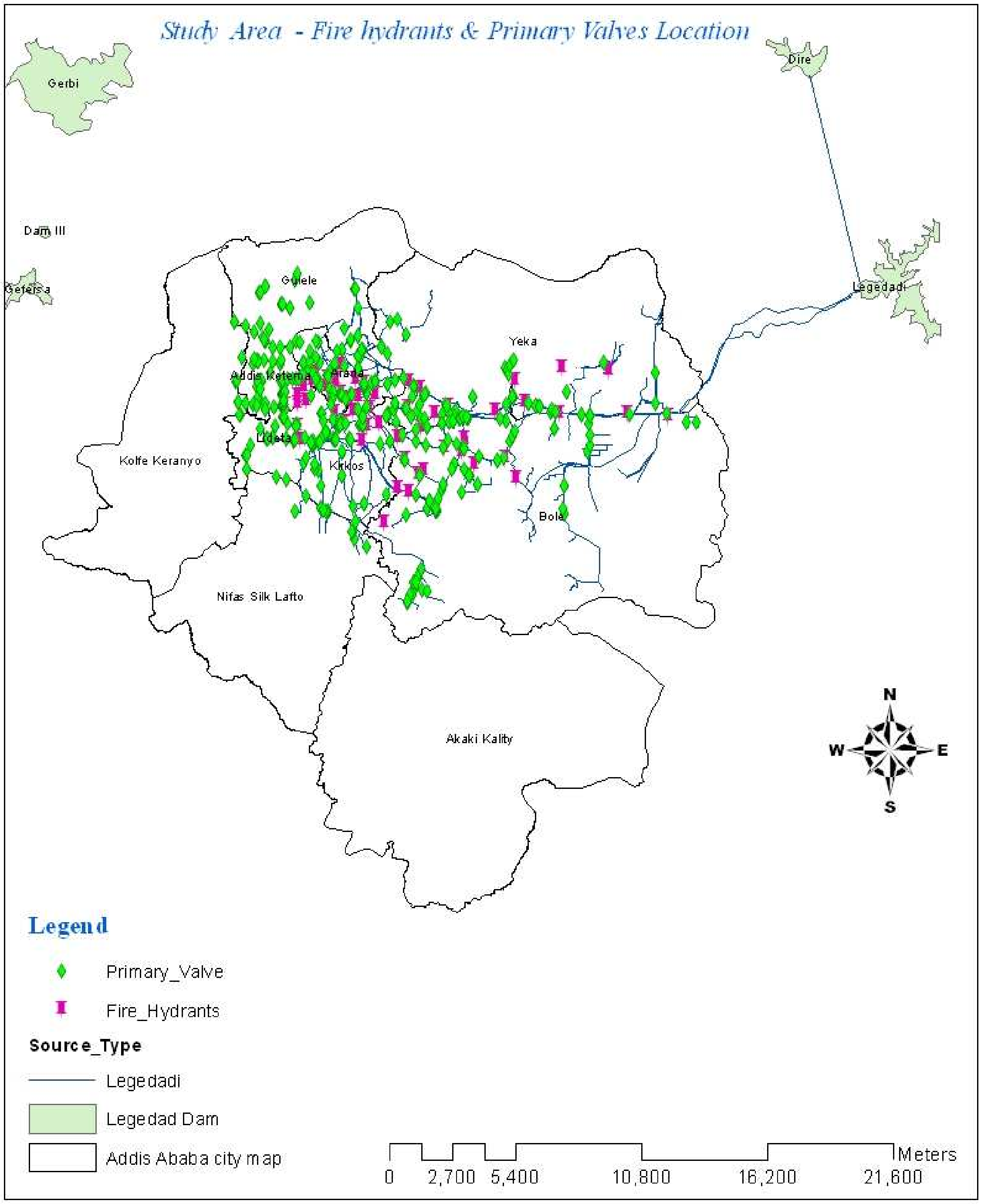
2.9 Fire hydrants in the Legedadi sub-system

Table 2.6: Location of fire hydrants at the Legedadi subsystem

FIRE_HYD ID.No.	X_COORD	Y_COORD	SUB_CITY	BRANCH_Name
28	478743.63	994862.96	Bole	Gurd shoal
29	480044.81	995114.32	Bole	Gurd shoal
30	480489.87	998376.7	Yeka	Gurd shoal
31	480917.35	997482.55	Yeka	Gurd shoal
45	475851.85	997244.22	Yeka	Megengna
47	476446.05	996393.88	Wered 16	Megengna
48	475765.85	995062.71	Wered 17	Megengna
49	475432.84	995993.22	Bole	Megengna
50	477125.1	993057.68	Wered 17	Megengna
51	476374.82	994464.95	Wered 17	Megengna
52	476541.32	994582.28	Wered 17	Megengna
53	475918.82	993677.57	Wered 17	Megengna
54	474894.76	992417.98	Wered 17	Megengna
55	478337.03	995924.74	Wered 17	Megengna
56	477489.88	995553.13	Bole	Megengna
57	478184.73	995383.22	Wered 17	Megengna
58	477375.66	996589.8	Wered 17	Megengna
67	471301.71	998344.24	Addis ketema	Arada
70	471173.56	997721.49	Addis ketema	Arada
71	470624.58	997353.69	Addis ketema	Arada
73	471439.69	998107.99	Addis ketema	Arada
74	471138.24	997404.89	Lideta	Arada
75	471556.73	997489.01	Lideta	Arada
76	470601.98	996930.52	Lideta	Arada
78	471159.69	996460.21	Lideta	Arada
79	471267.36	995847.74	Lideta	Arada
80	474502.77	997784.86	Arada	Arada
81	473559.37	997102.61	Arada	Arada
82	474022.49	998240.78	Arada	Arada
83	474137.41	997911.2	Arada	Arada
85	473655.64	998409.76	Arada	Arada
86	474232.84	997170.31	Arada	Arada
87	473188.71	996617.62	Arada	Arada
88	472441.37	998079.92	Kirkos	Arada
89	472583.16	997742.18	Arada	Arada
90	473008.59	997853.89	Arada	Arada
92	473210.35	997625.03	Arada	Arada

93	473036.89	998978.13	Arada	Arada
94	471940.69	998684.53	Arada	Arada
95	472409.68	998463.93	Arada	Arada
96	472810.78	998422.08	Arada	Arada
97	472779.64	998291.55	Arada	Arada
98	472769.36	997025.58	Arada	Arada
99	474129.34	996476.32	Arada	Arada
100	474683.08	996565.62	Kirkos	Arada
116	476423.76	998032.06	Yeka	Megenagna
127	475953.48	998320.4	Yeka	Megenagna
118	477623.73	997315.17	Yeka	Megenagna
115	477039.9	996994.91	Yeka	Megenagna
119	482386.47	996997.52	Bole	Gurd shoal
120	487038.22	996872.52	Bole	Gurd shoal
121	485317.34	996991	Bole	Gurd shoal
122	484483.08	998785.98	Yeka	Gurd shoal
123	479630.98	997084.74	Yeka	Gurd shoal
124	482470.12	998867.93	Yeka	Gurd shoal
125	480553.37	994271.85	Bole	Gurd shoal
126	473916.79	995836.2	Kirkos	Megenagna

Figure 2.5: Fire hydrants & Primary Valves Location of the Study Area – (Legedadi).



2.10 Distribution System

The existing 13 sub-systems of the Addis Ababa city water scheme can be divided in three groups according to their principal source of water, as : From Gefersa Reservoir: Rufael, Core-Kolifie & St. Paul; From Legadadi Reservoir: Legadadi, Gabriel, Jan Meda, Teferi Mekonnen, Interconnection Merkato, Entoto/Ras Kassa, Belay Zeleke; From Akaki Well Field: Akaki, Sarries, Legedadi West. But, for this study case, we are going to discuss only the distribution systems on the Legedadi sub systems.

The sub-system primary lines, i.e. those having a diameter greater than or equal to 150 mm, are included in computer model of the existing distribution system utilizing WATERCAD and shown in figure 2.2. A brief description of the sub-systems is given below [1].

a. Belay Zeleke Sub-System

Belay Zeleke is located in one of the highest parts of the city and straddles Belay Zeleke road. The area is supplied by gravity from Belay Zeleke (BZ) reservoir, which is fed by pumping from the AAWSA main office (MO) reservoir. Some of the upper parts of the sub-system have to be supplied by pumping from BZ reservoir [1].

b. Entoto and Upper Entoto Sub-System

This sub-system is situated in the highest part of the city. The area gets water from four reservoirs – Entoto, R1, R2, and R3 – by pumps from Teferi Mekonnen reservoir. From Entoto reservoir pumps feed R1, R1 to R2, and R2 to R3 reservoir [1].

c. Ras Kassa Sub-System

This sub-system is situated in the northeast corner of the city. It is supplied from Rass Kassa (RK) reservoir by gravity and from Teferi Mekonnen reservoir by pumping. The area is mainly residential. Some of the upper parts of the system have to be supplied by pumping from RK reservoir [1].

d. . Teferi Mekonnen Sub-System

Teferi Mekonnen sub-system lies in one of the most important zones, being the site of the university, many Government offices and much commercial activity. The area is supplied by gravity from Teferi Mekonnen reservoir, which is fed by pumping from Janmeda reservoir [1].

e. **Interconnection Sub-System**

This zone straddles Churchill Avenue from the AAWSA MO down to Tikur Anbassa Square. Its name is derived from its being the zone where water from the west can be transferred to supply the east, and vice versa. The area is supplied by gravity from the AAWSA MO, which is fed by pumping from Janmeda reservoir. Largely commercial in nature, this area contains many of the main Government and municipal offices [1].

f. **Mercato Sub-System**

Mercato area, located to the west of the city centre, is a density populated and predominantly commercial zone. It is supplied from Kassa Gebri reservoir, which is fed by pumped supply from the Police Hospital pumping station [1].

g. **Janmeda Sub-System**

This area is supplied by gravity from Janmeda reservoir, which is fed via a DN 900 mm line from Terminal reservoir. In addition, there is also supply from Terminal reservoir via a DN 400 mm line directly to the distribution network. It represents a combination of commercial, institutional and domestic consumers [1].

h. **Gabriel Sub-System**

The area receives water partly from Gabriel reservoir (which is fed by gravity from Janmeda reservoir) and partly from Urael pumping station. The area is primarily domestic. Its two major commercial consumers are the Hilton Hotel and Africa Hall (ECA) [1].

i. Legadadi Sub-System

This is one of the largest of the sub-systems and covers the entire southern half of the city. The area is fed by gravity and utilizes three groups of service reservoirs, namely Terminal, Angorcha and Army Hospital, all of which are fed from Legadadi treatment plant. In addition, there is also supply from Gotera reservoir by pumping directly to the distribution system, the reservoir receiving water by pumping from the Akaki well field. The Police Hospital pumping station also takes water from Legadadi sub-system for Kassa Gebri reservoir. Consumers in this sub-system are domestic, commercial and industrial [1].

3 LITERATURE REVIEW

3.1 Introduction

Several researches have been made to study the behavior of water distribution systems, and to reach an optimal solutions and assumptions in order to improve the hydraulic performance and cost effective of the water supply networks.

Jarrar H (1998) studied the hydraulic performance of water distribution systems under the action of cyclic pumping; the results show that the network under consideration is exposed to relatively high-pressure values throughout. The velocity of the water through the network attained also high values. These high values of pressure and velocity have negative effects on the performance of the network [3].

Earle Brown Dr. Suite 629 Minneapolis, made a study: ’Distribution System Modeling Improves Water Network’. The study shows that Water distribution system modeling has become a key tool in evaluating existing water networks and planning for future development. Modeling can show the weak links in a distribution system. The key part to water system modeling is the use of field data to calibrate the computer model. Field data is gathered by flowing a city fire hydrant and measuring the flow rate, monitoring a nearby hydrant for static and residual pressures, and recording production and storage levels at the time of the test [6].

Genedese,Gallerano and Misiti (1987) were involved in the optimal design of closed hydraulic networks with pumping stations and different flow rate conditions. Their study had two aims in the design of water distribution systems. The first is minimum values of peizometric heads at the nodes. The second is maximum values of velocities in the branches [3].

Perez,Martinez and Vela(1993) suggested a method for optimal design by considering factors other than pipe size. Pressure reducing valves were suggested to reduce the pressure in the down stream pipes [3].

S. *Takahashi, J. G. Saldarriaga, M. C. Vega and F. Herna´ ndez, demonstrated that the* calibration process of water distribution system models allows for accurate and reliable hydraulic analysis results. Thus, calibration is of utmost importance if adequate operation and maintenance model-based procedures are sought. However, in emerging economies, there is a series of factors that make it more difficult to construct accurate models, including very poor information management, unusually high leakages and the presence of a large number of illegal connections. While some of the model variables are assumed to be known under normal circumstances, these factors make it necessary to consider them for calibration as well [8].

The team presents a calibration methodology flexible enough to address such problems allowing the calibration of pipe diameter, roughness and minor losses, and nodal demands and leakages.

Naeeni S (1996) developed a computer program, which enables to obtain the optimum design of various kinds of water distribution networks so that all constraints such as pipe diameters, flow, velocities, and nodal pressures are satisfied [3].

Masri M (1997) studied the optimum design of water distribution networks. A computerized technique was developed for the analysis and optimal design of water distribution networks. The results show that the selection of the hydraulic restrictions should be reasonable and reflects the real capacity of the water distribution system [3].

AL-Abbase R (2000) showed that the optimum design of water distribution systems is a theoretical purpose, and cannot be achieved completely. His study dealt with evaluation the performance of five big sectors in Mosul city. A computerized technique was developed to obtain the optimum design, which achieves the demands of the consumers at lowest cost using the commercial pipes [3].

James, Liggest and Chen (1994) made a study about distribution systems. Data about pressure and flow rate were obtained by continuous monitoring of their system. Transient analysis, time lagged calculations and inverse calculations were applied as a tool for calibration and leak detection [3].

James E.Funk (1994) studied the behavior of water distribution systems during transient operations. He concluded that during transient operations, pressure much higher than steady state values could develop. The causes of transient operation can be a result of pumps stopping or starting, valves opening or closing, and system startup or shut down [3].

Laura Baumberger, Vincent Hart, and Samuel Darkwah showed the Effect of GIS-Based Demand Allocation on Water Distribution System Modeling [8].

Hydraulic models can be used to analyze systems where demand and operating conditions are static or is time varying. The former type of model is a 'steady-state' model, and the latter is referred to as an ‘extended period simulation’ or EPS model. In this analysis, EPS mode was utilized.

Water demand is the driving force behind the hydraulic dynamics of water distribution systems. It is therefore critical to accurately represent demands in hydraulic systems.

The most common method of loading a water distribution model involves the spatial allocation of demands. Most water distribution hydraulic software leverage the spatial analysis abilities of GIS software and use source data types such as geo coded billing meter records, water production data, census tracts, land use zoning, traffic analysis zones, meter routes, and demand density information [7].

The objective of this article is twofold:

1. Compare water demands projected using population information, land use, and customer billing records.

2. Evaluate and discuss the effect of demand allocation techniques on water distribution system modeling.

Water Demand Projection: is the main purpose of water demand projection in the water master planning process is to identify sufficient water supply to meet the projected aggregated demand curve. The projection of water demand through ultimate build-out provides a series of supply targets that must be met in the years to come. The establishment of existing and projected future demands is an early and critical step, and a miscalculation can derail the entire master planning process.

Demands have many uses besides distribution system modeling, including supply planning and setting treatment plant and transmission main capacities; therefore, it is important that demands are consistent with accepted water use characteristics and available data and that they undergo a thorough review process.

In this analysis, water demands were estimated using three methods: population projections, land use information, and water production records [7].

Vairavamoorthy, Akinpelu,Lin and Ali (2000) suggested a new method of design sustainable water distribution systems in developing countries. They developed a modified mathematical modeling tool specifically developed for intermittent water distribution systems. This modified tool combined with optimal design algorithms with the objective of providing an equitable distribution of water at the least cost forms the basis of this new approach. They also develop guidelines for the effective monitoring and management of water quality in intermittent water distribution systems. A modified network analysis program has been developed that incorporates pressure dependent outflow functions to model the demand [3].

Vairavamoorthy and Lumbrs (1998) studied the leakage reduction in water distribution systems depending on optimal valve control. The inclusion of pressure- dependent leakage terms in network analysis allows the application of formal optimization techniques to identify the most effective means of reducing water losses in distribution systems. They describe the development of an optimization method to minimize leakage in water distribution systems through the most effective settings of flow reduction valves [3].

M.Y.Abdel-Latif (2001) assess the hydraulic behavior and evaluate the global performance of Bani Suhila City water distribution network by developing a computer model for a distribution network under actual existing and alternative conditions, especially involving intermittent supply. The performance of the network was evaluated from a hydraulic point view using a systematic, engineering approach, and the results indicated that the performance was adequate and the system provided an acceptable level of service based on pressure considerations [3].

3.2 Basic Principles of Water Distribution System

The objective of water distribution systems is to deliver water of suitable quality to individual users in an adequate amount and at a satisfactory pressure. It should be capable of delivering the maximum instantaneous design flow at a satisfactory pressure [4].

The water distribution networks should meet demands for potable water. If designed correctly, the network of interconnected pipes, storage tanks, pumps, and regulating valves provides adequate pressures, adequate supply, and good water quality throughout the system. If incorrectly designed, some areas may have low pressures, poor fire protection, and even health risks [4].

The water distribution network, which is typically the most expensive component of a water supply system, is continuously subject to environmental and operational stresses which lead to its deterioration. Increased operation and maintenance costs, water losses, reduction in the quality of service and reduction in the quality of water are typical outcomes of this deterioration [4].

3.3 System Configurations

Transmission and distribution systems can be either looped or branched, as the name suggests, in looped systems there may be several different paths that the water can follow to get from the source to a particular customer. In a branched system, also called a tree or dendritic system, the water has only one possible path from the source to a customer [4].

3.3.1 Looped system (Grid Systems)

Looped systems are generally more desirable than branched systems because, coupled with sufficient valving, they can provide an additional level of reliability. In systems such as rural distribution networks, the low density of customers may make interconnecting the branches of the system prohibitive from both monetary and logistical standpoints [4].There are no dead ends in this type of distribution networks. The maintenance operation did not affect the interruption on the whole area as in the branching system, this type of layout is highly desirable because, for any given area on the grid, water can be supplied from more than one direction.

This results in substantially lower head losses than would otherwise occur and, with valves located properly, allows for minimum inconvenience when repairs or maintenance activities are required. The whole area is covered with mains that form the grid system [4].

Most water supply systems are a complex combination of loops and branches, with a trade-off between loops for reliability (redundancy) and branches for infrastructure cost savings [4].

3.3.2 Branching Systems

This type of distribution networks is the most economical system, and common in the developing countries due to its low cost. In this system, when there is need for developing the network, new branches follow that development and new dead ends will be constructed [4].

The branching systems have some disadvantages such as the following: [4]

- The dead ends cause accumulation of sediments, which result in increasing contamination and health risks.
- The maintenance operation upstream of the network will prevent water to reach the downstream due to the interruption of the whole area of maintenance.
- The fluctuating demand causes high-pressure oscillations.

3.3.3 Ring Systems

The mains form a ring around the area under service, secondary pipes connecting the mains and delivering the water to the consumers [4].

3.3.4 Radial Systems

The area under service in the radial system is divided into subareas, and a storage tank is placed in the center of each subarea to supply [4].

3.4 Methods of Water Distribution

3.4.1 Gravity Distribution

This is possible, when the source of supply water is at some elevation above the city , so that sufficient pressure can be maintained in the mains for domestic and fire services . The advantage of this method of distribution is saving power that needed for pumping [4].

3.4.2 Distribution by Pumping Without Storage

In this method of distribution, water is pumped directly into the mains with no other outlet than the water actually consumed. The pumping rate should be sufficient to satisfy the demand. This method is the least desirable way of distribution; the power failure leads to complete interruption in water supply. An advantage of direct pumping is that a large fire service pump may be used which can run up the pressure to any desired amount permitted by the construction of mains [4].

3.4.3 Distribution by means of pumps with storage

In this method an elevated tanks or reservoirs are used to maintain the excess water pumped during periods of low consumption, and these stored quantities of water may be used during the periods of high consumption. This method allows fairly uniform rates of pumping and hence is economical [4].

3.5 Principles of Pipe Network Hydraulics

Flow in a pipe network satisfies two basic principles, conservation of mass, and conservation of energy [4].

3.5.1 Conservation of Mass- Flows Demands

Conservation of mass states that, for a steady state system, the flow into and out of the system must be the same. This principle is a simple one, at any node in the system under incompressible flow conditions; the total volumetric or mass flow in must equal the mass flow out (less the change in storage) [4].

This relationship holds for the entire network and for individual nodes. One mass balance equation is written for each node in the network as [4]:

Separating the total volumetric flow into flows from connecting pipes, demands, and storage, we obtain the following equation [32]:

$$\sum Q_{in}\ \Delta t = \sum Q_{out}\ \Delta t + \Delta V_S$$

Where : $\sum Q_{in}$: the total flow into the node.

$\sum Q_{out}$: the total demand at the node.

ΔV_S : is the change in the storage.

Δt : is the change in time.

The continuity equation at node j can be expressed as following :

$$\sum_{i=1}^{i=NP_{(j)}} Q_{ij} - C_j = 0$$

Where: $\sum Q_{ij}$: is the algebraic sum of the flow rates in the pipes meeting at the node j .

C_j : is the external flow rate at node j.

$NP_{(j)}$: is the number of pipes meeting at junction j.

3.5.2 Conservation of Energy

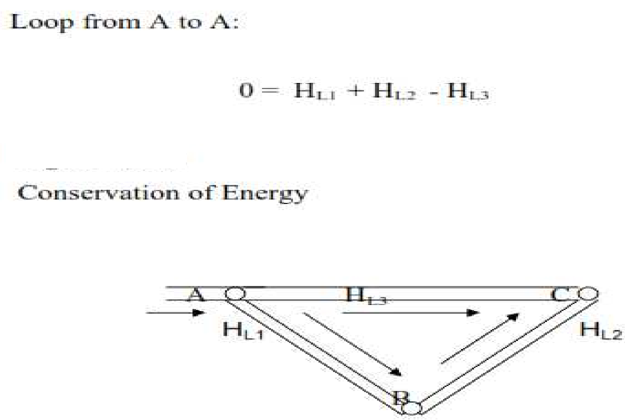
It is the second governing equation that describes the relationship between the energy loss and pipe flow. The head losses through the system must balance at each point.

For pressure networks, this means that the total head loss between any two nodes in the system must be the same regardless of what path is taken between two points [4].

The head loss must be sign consistent with the assumed flow direction (gain head when proceeding opposite the direction of flow, and lose head when proceeding with the flow) [4].

As shown in the figure (3.1) below, the combined head loss around a loop must equal zero in order to achieve the same hydraulic grade that was started with [4].

Figure 3.1 Representation of conservation of Energy



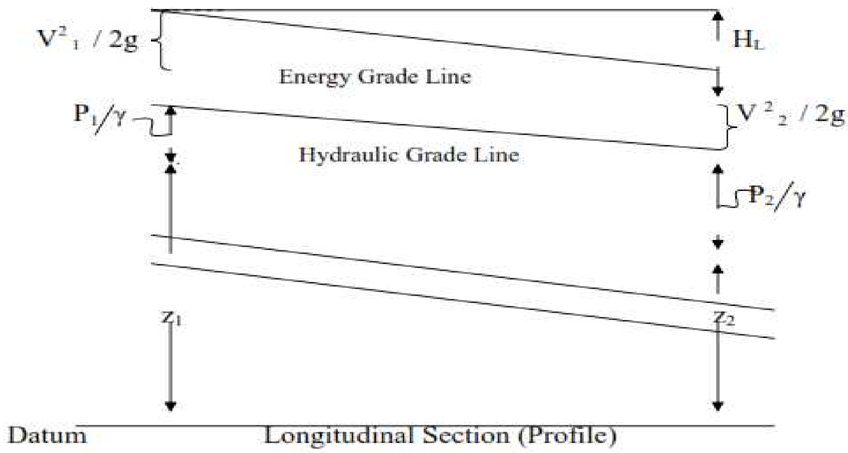
3.6 The Energy Equation

The Energy equation is known as Bernoulli's equation. It consists the pressure head, elevation head, and velocity head. There may be also energy added to the system (such as by a pump), and energy removed from the system (due to friction). The changes in energy are referred to as head gains and head losses [4].

In the hydraulic applications, energy values are often converted into units of energy per unit weight resulting in units of length [4].

Balancing the energy across any two points in the system, the energy equation will be as follow: [4]

The Energy Principle



$$P_1/\gamma + z_1 + V^2{}_1/2g + H_G = P_2/\gamma + z_2 + V^2{}_2/2g + H_L$$

Where : P : is the pressure (Ib/ft^2 or N/m^2)

γ : is the specific weight of the fluid (Ib/ft^3 or N/m^3)

z : is the elevation at the centroid (ft or m)

V : is the fluid velocity (ft/s or m/ s)

g : is gravitational acceleration (ft/s^2 or m/ s^2)

H_G : is the head gain, such as from a pump (ft or m)

H_L : is the combined head loss (ft or m)

3.7 Energy Losses

There is a combination of several factors that cause the energy losses. The main reason of the energy loss is due to internal friction between fluid particles traveling at different velocities. The movement of any fluid through a conduit results in a resistance to flow and this resistance or energy loss is referred to as friction [4].

The other reason causes energy loss is due to localized areas of increased turbulence and disruption of the stream lines such as disruptions from valves and other fittings in a pressure pipe [4]. The rate of losing energy a long a given length is called friction slope .It is usually presented as a unit less value, or in units of length per length (ft/ft , m/m , etc.) [4].

3.8 Friction Losses

Hazen-Williams equation and the Darcy-Weisbach equation are the most commonly methods used for determining head losses in pressure piping systems [4].

The assumptions for a pressure pipe system can be described as the following:

Pressure piping is almost always circular, so the area of flow, wetted perimeter, and the hydraulic radius can all be directly related to diameter [4].

Through a given length of a pipe in a pressure piping system, flow is full, so the friction slope is constant for a certain flow rate. This means that the energy grade and hydraulic grade drop linearly in the direction of flow [4].

- The velocity must be constant, since the flow rate and cross-area are constant. This means that the hydraulic grade line (the sum of the pressure head (P/γ), and the elevation head (z)), and the energy grade line (the sum of the hydraulic grade line and the velocity head (v / 2g)) [4].

Equations that represent the friction losses associated with the flow of a liquid through a given section can all be described by the following general equation [4]:

$$V = KCR^{X}S^{Y}$$

Where: V: mean velocity.

C : flow resistance factor

R : hydraulic radius (A/P_w)

$R_{Circular}$: $\frac{\pi . D^2/4}{\pi . D} = \frac{D}{4}$

P_w : wetted perimeter (ft or m)

A: cross sectional area (ft^2 or m^2)

D : pipe diameter (ft or m)

S : friction slope

x , y : exponents

k : factor to account for empirical constant , unit conversion, etc.

3.8.1 Hazen – Williams's Equation

The most frequently equation used in the design and analysis of water distribution networks, it was developed by the experiment and used only for water with in temperatures normally experienced in potable water systems [4].

$$V = KCR^{0.63}S^{0.54}$$

Where : V : mean velocity (ft/s or m/s)

K : 1.32 for U.S. standard units , or 0.85 for S.I. units

C : Hazen –Williams roughness coefficient.

R : Hydraulic radius of the pipe in meters

S : the dimensionless slope of the energy grade line

3.8.2 Darcy – Weisbach (Colebrook-White) Equation

This equation is a theoretically based equation, and its common use in the analysis of pressure pipe systems. For any flow rate and any incompressible fluid, It can be applied to open channel flow (free-surface flow) [4].

$$V = \sqrt{\frac{8g\ RS}{f}}$$

Where : V : flow velocity (ft/s or m/s)

g : gravitational acceleration (ft/s^2 or m/ s^2)

R : hydraulic radius (ft or m)

f : Darcy-Weisbach friction factor

S : Friction slope

The Darcy – Weisbach friction factor, f, can be found using the Colebrook equation as follows:

$$\frac{1}{\sqrt{f}} = -2 \log \left[\frac{K}{14.8\ R} + \frac{2.51}{R_e \sqrt{f}} \right]$$

Where : K : roughness height (ft or m)

R_e : Reynolds number

Table 3.1: Friction Losses Summary

Equation	Formula	Remarks
Manning's	$V = \frac{1}{n}R^{2/3}S^{1/2}$	This equation is commonly used for open channel flow.
Chezy's (Kutter's)	$V = C\sqrt{RS}$	Widely used in sanitary sewer design and analysis
Hazen-Williams	$V = 0.85CR^{0.63}S^{0.54}$	Commonly used in the design and analysis of pressure pipe systems
Darcy-Weisbach	$V = \sqrt{\frac{8g}{f}RS}$	Can be used for pressured pipe systems and open channel flows.

3.8.3 Reynolds Number

It is an index used to classify flow as either laminar flow (it is a flow characterized by smooth flow lines) or turbulent flow (it is a flow characterized by the formation of eddies within the flow) [4].

$$R_e = \frac{4VR}{\nu}$$

Where: R_e : Reynolds number.

V : Mean velocity (ft/s or m/s)

R : Hydraulic radius (ft or m)

ν : Kinematics viscosity (ft^2/s or m^2/s)

If the number below 2000, flow is laminar. The number is above 4000 the flow is turbulent. Between 2000 and 4000, may be either turbulent or laminar flow [4].

3.9 Minor Losses

Minor losses are a result of localized areas of increased turbulence and are frictional head losses, which cause energy losses within a pipe. A drop in the energy and hydraulic grades caused by valves, meters, and fittings, the value of these minor losses is often negligible relative to friction and for long pipes, and they are often ignored during analysis [4].

Minor head losses (also referred to as local losses) can be associated with the added turbulence that occurs at bends, junctions, meters, and valves, enlargers, reducer. The importance of such losses will depend on the layout of the pipe network and the degree of accuracy required.

The resulting head loss is computed from the following equation:

$$H_m = \frac{K V^2}{2g}$$

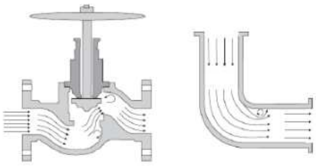
Where : H_m : minor loss (ft or m)

K : minor loss coefficient for the specific fitting .

V : velocity (ft/s or m/s)

g : is gravitational acceleration (ft/s^2 or m/s^2)

Figure 3.2 Minor losses



$$h_m = k_f \frac{V^2}{2g}$$

3.10 Water Hammer

When the velocity of flow in a pipe changes suddenly, surge pressures are generated as some, or all, of the kinetic energy of the fluid is converted to potential energy and stored temporarily via elastic deformation of the system. As the system rebounds and the fluid returns to its original pressure, the stored potential energy is converted to kinetic energy and a surge pressure wave moves through the system. Ultimately, the excess energy associated with the wave is dissipated through frictional losses. This phenomenon, generally known as "water hammer", occurs most commonly when valves are opened or closed suddenly, or when pumps are started or stopped. The excess pressures associated with water hammer can be significant under some circumstances [3].

The maximum pressure surge caused by abruptly stopping the flow in a single pipe is given by :

$$a = \frac{4660}{[\,1 + Kd/Et\,]^{0.5}}$$

Where: k : bulk modulus of the fluid, pounds per square inch

d : internal diameter of the pipe , inches

E : modulus of elasticity of the pipe materials, pounds per square inch.

t : thickness of the pipe wall, inches

The magnitude of the maximum potential water hammer pressure surge as illustrated by the above equation is a function of fluid velocity, and the pipe material. In water distribution systems, water hammer is usually not a problem because flow velocities are typically low, when higher than normal flow velocities are expected, consideration should be given to the use of slow-operating control valves, safety valves, surge tanks, air chambers, and special pump control systems [3].

3.11 Calibration

Calibration: is the process of comparing the model results to field observations and, if necessary, adjusting the data describing the system until model-predicted performance reasonably agrees with measured system performance over a wide range of operating conditions. The process of calibration may include changing system demands, fine-tuning the roughness of pipes, altering pump operating characteristics, and adjusting other model attributes that affect simulation results.

Most model calibration eventually comes down to adjustments in a parameter like the C-factor, according to the equation:

$$C = \frac{k(Q \pm \Delta Q)}{(h_L \pm \Delta h_L)^{0.54}}$$

where
C = Hazen-Williams C-factor
k = factor depending on units and distribution system
Q = estimated flow (gpm, m^3/s)
ΔQ = error in measuring Q (gpm, m^3/s)
h_L = estimated head loss due to friction (ft, m)
Δh_L = error in measuring head loss due to friction (ft, m)

Equation 6.1

3.11.1 C-Factor Sensitivity

If the flows and heads are small, errors in measuring these quantities will be on the same order of magnitude as the quantities themselves, making them of little use in the calibration process. If such data are used, the value of parameters found by calibration will be poor.

For a given distribution system, error in flow is usually not larger than flow measurements so Equation 6.1 can be simplified and the head loss can be related to C-factor by:

$$C = \frac{k}{(h_L \pm \Delta h_L)^{0.54}}$$

3.12 Hydraulic Design Parameters

The main hydraulic parameters in water distribution networks are the pressure and the flow rate, other relevant design factors are the pipe diameters, velocities, and the hydraulic gradients [3].

3.12.1 Pressure

The pressure at nodes depends on the adopted minimum and maximum pressures within the network, topographic circumstances, and the size of the network [3].

The minimum pressure should be maintained to avoid water column separation and to ensure that consumers' demands are provided at all times. The maximum pressure constraints results from service performance requirements such fire needs or the pressure –bearing capacity of the pipes, also limit the leakage in the distribution system, especially that there is a direct relationship between the high pressure and the increasing of leakage value in the system [3].

3.12.2 Flow rate

It is the quantity of water passes within a certain time through a certain section. Velocity is directly proportional to the flow rate. For a known pipe diameter and a known velocity, the flow rate through a section can be estimated. Low velocities affect the proper supply and will be undesirable for hygienic reasons (sediment formation may cause due to the long time of retention). The effect of the velocity on the diameters of pipe system can be observed from the following equation: [3]

$$V = \frac{4Q}{\pi . D^2}$$

$$D = \sqrt{\frac{4Q}{\pi . V}}$$

Where : D : diameter of the pipe (m)
Q : discharge (m^3 /sec)
V : velocity (m/sec)

From the above equation it is clear that the velocity increasing should decrease the diameter value [3].

3.13 Types of simulations

After the basic elements and the network topology are defined, further refinement of the model can be done depending on its intended purpose. There are various types of simulations that a model may perform, depending on what the modeler is trying to observe or predict. The two most basic types are: [4]

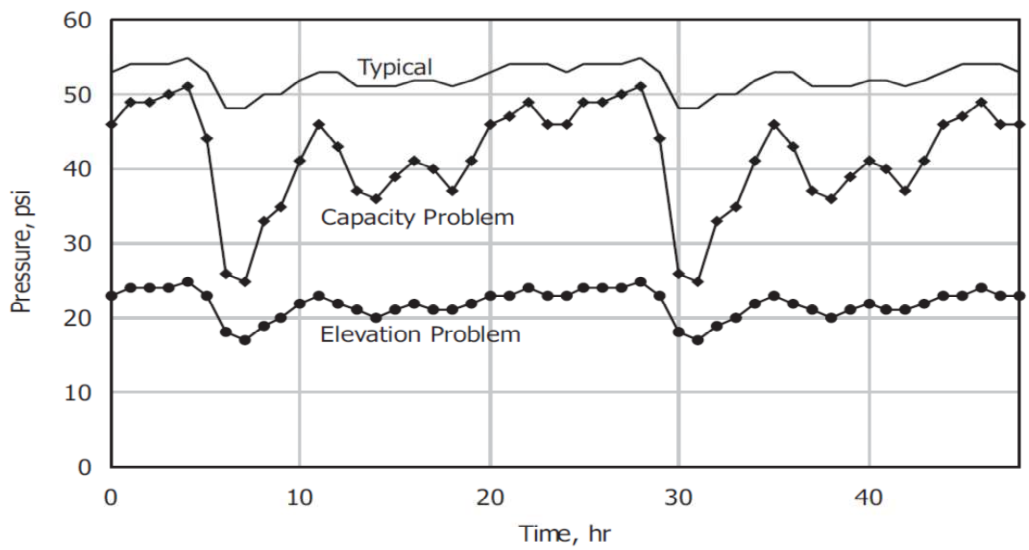
3.13.1 Steady-state simulation

Computes the state of the system (flows, pressures, pump operating attributes, valve position, and so on) assuming that hydraulic demands and boundary conditions do not change with respect to time [4].

3.13.2 Extended-period simulation (EPS)

Determines the quasi-dynamic behavior of a system over a period of time, computing the state of the system as a series of steady-state simulations in which hydraulic demands and boundary conditions do change with respect to time [4].

Figure 3.3 EPS runs showing low pressure due to elevation or system capacity



3.13.2.1.1 Simulation Duration

An extended-period simulation can be run for any length of time, depending on the purpose of the analysis. The most common simulation duration is typically a multiple of 24 hours, because the most recognizable pattern for demands and operations is a daily one [5].

3.13.2.1.2 Hydraulic Time Step

An important decision when running an extended-period simulation is the selection of the hydraulic time step. The time step is the length of time for one steady-state portion of an EPS, and it should be selected such that changes in system hydraulics from one increment to the next are gradual. When junction demands and tank inflow/outflow rates are highly variable, decreasing the time step can improve the accuracy of the simulation [5].

3.14 Scenario Manager

Scenario Manager allows you to calculate multiple "What If?" situations in a single project file. You may wish to try several designs and compare the results, or analyze an existing system using several different demand alternatives and compare the resulting system pressures.

A Scenario is a set of Alternatives, while alternatives are groups of actual model data. Scenario and alternatives are based on a parent/child relationship where a child scenario or alternative inherits data from the parent scenario or alternative. "What If?" situations will involve changing demands and pipe sizes [5].

4 MATERIALS AND METHODS

4.1 Introduction

This chapter discusses on the steps taken to construct the model of the existing drinking water distribution system of the Addis Ababa city.

In 2003 EC , AAWSA selected consultant, THAL Consulting Engineers LTD. THAL and AAWSA have agreed that , THAL to design the Addis Ababa Water Supply scheme , called Water III-A and prepare bid document. The implementation of the project has commenced at the present time [1].

4.2 Data Collection

The most important step in any research study is data collection. In building the model of the distribution network, the secondary data were first gathered regarding all the distribution system parameters. Particular field measurements and visits to the Legedadi sub-system are conducted with AAWSA technical team.

4.2.1 Existing Maps & Records

Any necessary data for model development for the existing system were available and has been gathered from AAWSA especially from Water IIIA design document.

Major Information and data gathered from AAWSA are as follows:

a. System Maps

System maps are typically the most useful documents for gaining an overall understanding of a water distribution system because they illustrate a wide variety of valuable system characteristics. System maps may include such information as:

- Pipe alignment, connectivity, material, diameter, and so on
- The locations of other system components, such as tanks and valves
- Pressure zone boundaries
- Elevations

• Miscellaneous notes or references for tank characteristics

• Background information, such as the locations of roadways, streams, planning zones, and so on

• Other utilities

b. Topographic Maps

We use a topographic map set of lines called contours to indicate elevations of the ground surface. By superimposing a topographic map on a map of the network model, it is possible to interpolate the ground elevations at junction nodes and other locations throughout the system.

c. Electronic Maps and Records

For our model development, the role of electronic maps and records is indispensable.
Computer-Aided Drafting (CAD) drawing to a Geographic Information System (GIS) that combines graphics and data.

A Geographic information system (GIS) is a computer-based tool for mapping and analyzing objects and events that happen on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps (ESRI, 2001).

d. Model Representation

The concept of a network is fundamental to a water distribution model. The network contains all of the various components of the system, and defines how those elements are interconnected. Networks are comprised of nodes, which represent features at specific locations within the system, and links, which define relationships between nodes.

4.3 Introduction to WaterCAD

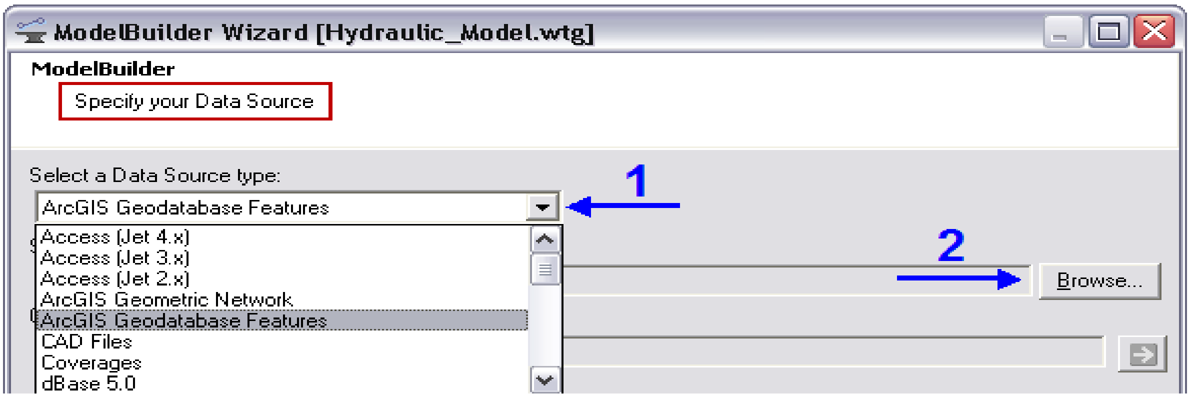
WaterCAD Stand-Alone is powerful, easy-to-use programs that helps civil engineers design and analyze water distribution systems. We use WaterCAD as a major hydraulic analyzing tool in this research work. The following are some of the major steps using for developing a hydraulic model [5].

4.3.1 Building A Model Using Model Builder

For model building the Arc GIS imports Auto Cad files then digitize all the network and the change the file to the shape file, then Water CAD using model builder interface imports directly the shape files at ones file is exported to the are exported to Arc GIS

In the Model Builder, one can select the 'data source type' as shape files, and the very important aspect that the user has to consider during modeling is that all the geospatial data files used during modeling should have the same geographic projection[5].

Figure 4.1: Building a model via importing geospatial data

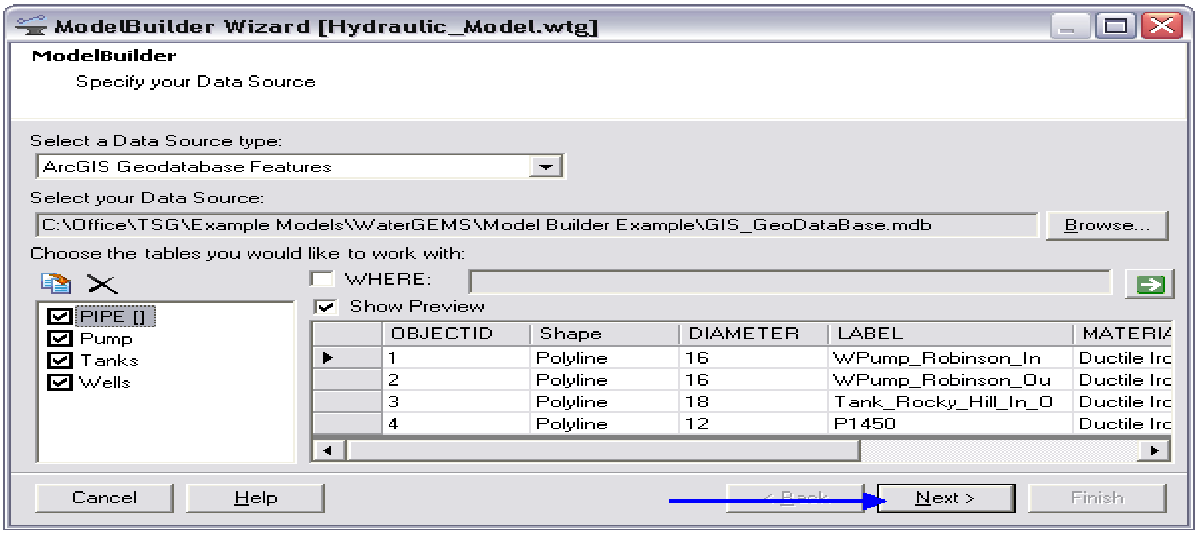


The shapefiles of the water lines, appurtenances, reservoirs and the storage facilities were projected with respect to the coordinate system of WGS. This co-ordinate system was Adindan_UTM_Zone_37N and WGS_1984_UTM_Zone_37N.

Once the shape files are selected the user can preview the attribute tables of each shape file. Next the user needs to specify the co-ordinate unit of the data source. The co-ordinate unit selected was 'meters'.

The Model Builder then executes the build operations evaluating the user defined conditions. Once the model has been built, the user has to edit the network.

Figure 4.2 Water CAD Model Builders



4.3.2 Bentley Water CAD Features

The major pillars evaluated in Water CAD: Hydraulic, Fire-flow, Water-quality, and Operations Modeling [5]

Using WaterCAD, it is also possible to determine automatically determine water availability for fire-protection needs. They can calculate how much flow is available at any hydrant or group of hydrants in the system, based on pressure and flow constraints dictated by local regulations [5].

We can quickly and accurately establish the ability of the water network to provide adequate protection against fires.

Water utilities, municipalities and design engineering firms trust WaterCAD as a reliable, resource-saving, decision-support tool for water infrastructure [5].

a. Comprehensive Scenario Management

Using the WaterCAD we can have unique Scenario Control Center gives full control to configure, run, evaluate, visualize, and compare an unlimited number of scenarios within a single file [5].

Scenario control center consider multiple design, planning, analysis, and operational scenarios to make reliable decisions for their water distribution infrastructure. They can easily set up unlimited modeling scenarios to analyze and compare rehabilitation alternatives for multiple planning horizons, pump control strategies for energy-saving operation, or flushing alternatives for emergency contamination events [5].

b. Results Presentation

- Thematic mapping
- Dynamic, multi-parameter, and multi-scenario
- Graphing
- Contouring
- Advance profiling
- Advanced tabular reporting with FlexTables
- Property-based color coding and symbology
- Property-based annotation

For the hydraulic modeling of the system, I use the secondary data gathered from the line office AAWSA such as node data, pipe data, Tank data, Hydrants data, PRV and Primary valves data [5].

For the pipe data: material type, size and length; for nodal data: demand pattern , nodal demand, & elevation ; Tank data: tank diameter, base elevation, minimum elevation , initial elevation and maximum (overflow) elevation ; Pump information: pump head, discharge and I use 1 point design head based on the available head and discharge data [5]

The valve status data have been collected. The existing valves have several status conditions, that is valves used for the intermittent supply and for throttling [5].

Hazen Williams Coefficients (C) are vary based on the year of construction, because the older the pipe has the smaller C-value, and vice versa is true. The C- values are determined after the calibration of the system [5].

4.4 Hydraulic modeling in Water CAD

4.4.1 Assigning base water demands to each node:

The consumption or use of water, also known as water demand, is the driving force behind the hydraulic dynamics occurring in water distribution systems. Anywhere that water can leave the system represents a point of consumption, including a customer’s faucet, a leaky main, or an open fire hydrant.

Three questions related to water consumption must be answered when building a hydraulic model:

(1) How much water is being used?

(2) Where are the points of consumption located? And

(3) How does the usage change as a function of time?

The three basic demand types described below:

- Customer demand is the water required to meet the non-emergency needs of users in the system. This demand type typically represents the metered portion of the total water consumption.
- Unaccounted-for water (UFW) is the portion of total consumption that is “lost” due to system leakage, theft, unmetered services, or other causes.
- Fire flow demand is a computed system capacity requirement for ensuring adequate protection is provided during fire emergencies.

The following steps outline a typical example of the process the modeler might follow.

1. Allocate average-day demands to nodes.
2. Develop peaking factors for steady-state runs or diurnal curves for EPS runs
3. Estimate fire and other special demands.
4. Project demands under future conditions for planning and design.

4.4.2 Baseline Demands

Determining baseline demands to which a variety of peaking factors and demand multipliers can be applied, or to which new land developments and customers can be added. Baseline demands typically include both customer demands and unaccounted-for water. Usually, the average day demand in the current year is the baseline from which other demand distributions are built.

To assign base demand to each supply node, it is necessary to know the houses around each supply node.

Base Demand for a supply node = (Population served by that node) / (Total Population)* Total water demand of the city per day.

The following are some examples of demand events frequently considered:

• **Average-day demand:** The average rate of demand for an average day (past, present, or future)

• **Maximum-day demand:** The average rate of use on the maximum usage day (past, present, or future)

• **Peak-hour demand:** The average rate of usage during the maximum hour of usage (past, present, or future)

• **Maximum day of record:** The highest average rate of demand for the historical Record

4.4.3 Time Varying Demands

Water usage in municipal water distribution systems is inherently unsteady due to continuously varying demands. In order for an extended period simulation to accurately reflect the dynamics of the real system, these demand fluctuations must be incorporated into the model.

Demand Pattern is a function relating water use to time of day. A diurnal curve is a type of pattern that describes changes in demand over the course of a daily cycle.

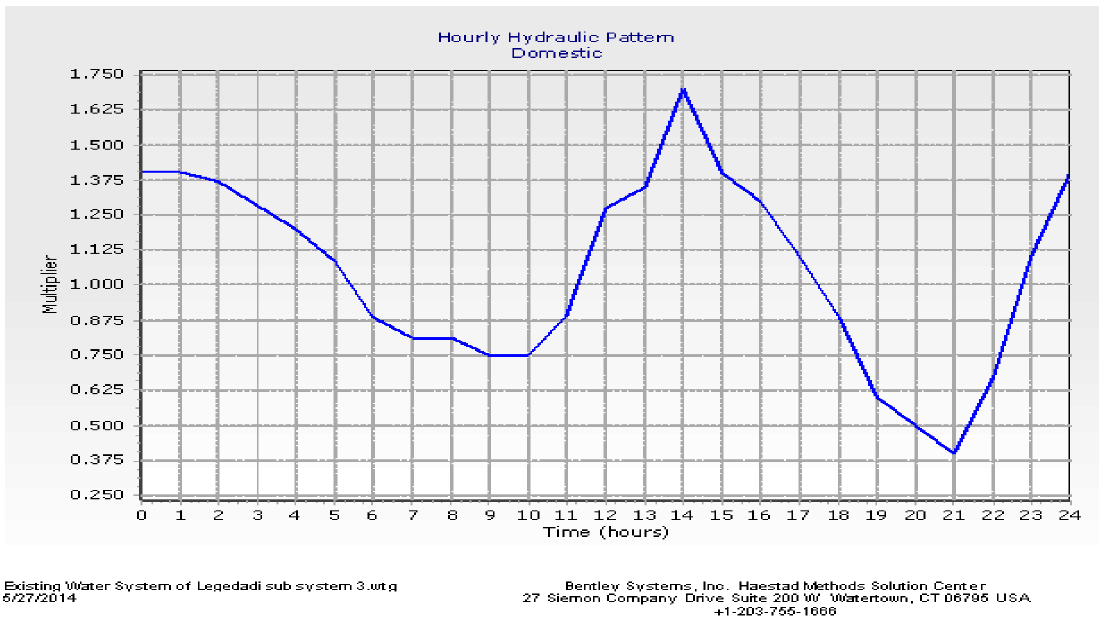
The temporal variations in water usage for municipal water systems typically follow a 24-hour cycle called a diurnal demand pattern. However, system flow experience changes not only on a daily basis, but also weekly and annually.

4.4.3.1 Diurnal Curves

Each city has its own unique level of usage that is a function of recent climatic conditions and the time of day. (Economic growth also influences demands, but its effect occurs over periods longer than the typical modeling time horizon, and it is accounted for using future demand projections.)

Figure 4.3: illustrates a typical diurnal curve for a residential area. There is relatively low usage at night when most people sleep, increased usage during the early morning hours as people wake up and prepare for the day, decreased usage during the middle of the day, and finally, increased usage again in the early evening as people return home.

Figure 4.3: A typical diurnal curve for Addis Ababa city



4.4.3.2 Defining Usage Patterns within a Model

Most, hydraulic models express demands by using a constant baseline demand multiplied by a dimensionless demand pattern factor at each time increment.

A demand multiplier is defined as

$$Mult_i = Q_i / Q_{base}$$

where $Multi_i$ = demand multiplier at the i^{th} time step
Q_i = demand in i^{th} time step (gpm, m^3/s)
Q_{base} = base demand (gpm, m^3/s)

The series of demand pattern multipliers models the diurnal variation in demand and can be reused at nodes with similar usage characteristics.

4.4.3.3 Projecting Future Demands

Water distribution models are created not only to solve the problems of today, but also to prevent problems in the future. With almost any endeavor, the future holds a lot of uncertainty, and demand projection is no exception.

Long-range planning may include the analysis of a system for 5-, 10-, and 20-year time frames. When performing long-term planning analyses, estimating future demands is an important factor influencing the quality of information provided by the model.

Scenario management tools in models help make this process easier. Even the most comprehensive scenario management, however, is just another tool that needs to be applied intelligently to obtain reasonable results.

The water distribution system is designed to cope mainly with the domestic demand. As it is common in Addis Ababa, the consumption for industrial, commercial, and institutional demands is included in the domestic consumption figure to form a total water demand per person and day. According to studies carried out by the AAWSA Consultants (THAL Consulting), in which the predicted future water consumption till the year 2025 was estimated depending on the future domestic consumption, and considering (UFW) and technical losses. Based on the demand determination the per capita demand of the city per head is 161 lit/cap/day for 2011 fiscal year.

4.4.4 Fire Protection Demand

Fire protection demands can represent a huge fraction of the total demand for the system. The NFF should be added to the hourly peak flow on the design of the distribution system. To ensure the supplies of NFF in towns are used mainly hydrants. The good engineering practice in USA requests hydrants in congested streets at distances of 100 m and in residential areas at distances of 200 m. [1] The head should be not lower than 20 psi (136 m) in USA the duration of a fire for design purpose is 2 hour for NFF 160 l/s or less, and 3 hours for NFF 180 – 220 l/s.[1]

The sizes of buildings in Ethiopia are smaller than in the American cities. Considering that big buildings in USA have their own firefighting means and storage provided, considering the much higher risks for fire due to heating and air conditioning installations, higher electrical loads, and taking into account the different economic standards, we may consider the duration for a fire at only 1 hour at an NFF of 100 l/s therefore the additional storage for fire fighting in the operational reservoirs, called “intangible reserve” could be established at 360 m^3 [1].

Lately the City of Addis Ababa has made a first attempt to regularize the firefighting within the city. The recommendations refer to: [1].

Location: at corner of streets to serve two directions and only on road wider than 6 m.

Spacing: according to the population density between 150-500m.between two successive hydrants.

Connections: on mains or distribution pipes equal or higher than DN 150 mm.

Head: pressure in network of 30-50m. The pressure zones provide for higher heads in the peak hour as the difference in topographical levels is 80 m. and AAWSA should be able to supply only buildings not higher than 3-4 floors. During fire occurrence the meaning of “peak hour” could be waived and water diverted to needing areas on the account of regular areas of supply Higher head could be obtained in certain areas by operating the valves. On the other side higher investments in the network, high in any case in a water supply system, could be avoided if the fire brigades are endowed with suitable mobile pumps [1].

Big buildings: These must be prepared with local firefighting facilities (internal hydrants, sprinkler installations, suitable storage reservoirs, etc.) and the plumbing code of practice must be applied [1].

4.4.5 Population Projection

Geometric increase method of population forecasting has been adopted for this research because this method is mostly applicable for growing towns and cities having vast scope of expansion , like Addis Ababa city. It is based on the assumption that the percentage increase in population remains constant.

The formula that has been adopted for population projection is:

$$Pn = Po * (1+K)^{n}$$

Where: Po : Initial population

Pn: Population at n years

n: No of years

K: Percentage (geometric) increase

The population size of Addis Ababa city for different years has been collected from the Central Stastical Agency.

Table 4.1: Census record of population size of Addis Ababa

Year	**1978**	**1984**	**1994**	**2007**
Population	1,167,315	1,423,111	2,112,737	2,739,551

4.5 Calibration

4.5.1 Model Calibration

Model calibration was conducted by comparing the results of the actual element of the model with results generated by the model at the same locations.

To calibrate the model, some junctions accessible and available for flow data measurement are selected and flow measurements are taken using flow measuring instrument.

Figure4.4 Photo of Pressure bar installed on tank inlet pipe

Figure 4.5 Photo of Flow measuring device

Figure 4.6 Photo of Field pressure measurement

Figure 4.7 Photo of Field flow measurement of 900mm

Figure 4.8: Photo of Field flow measurement of 1200mm

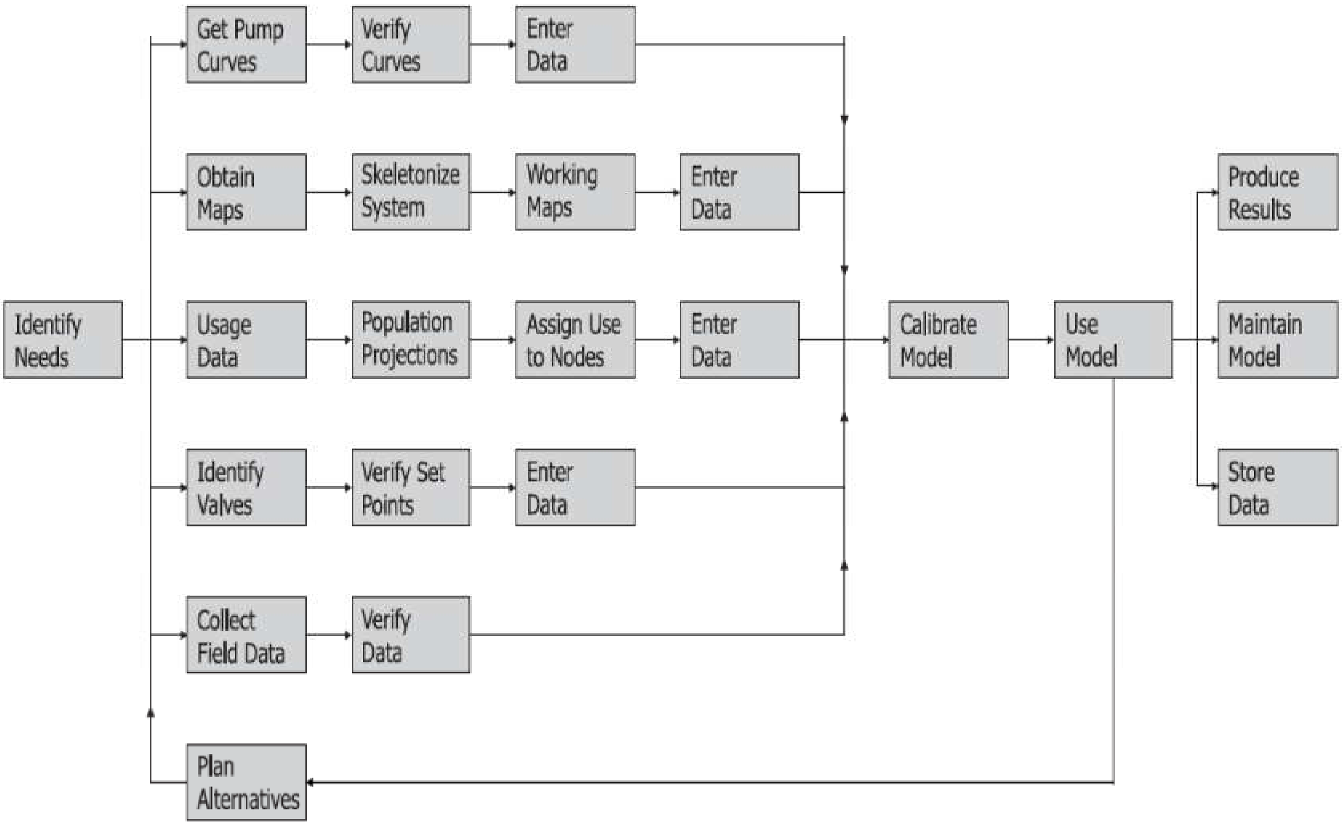
Figure 4.9 : Photo of Tank level measuring gauges

Using the information provided by the AAWSA, the model was calibrated to meet the general calibration criteria for flow and pressure.

Successful calibration of indicates that the network components are operating correctly, demand is appropriately allocated, and the reservoir levels are correct. Besides, the correct calibration of the residual pressure indicates that the pipe roughness coefficients are set at the appropriate levels, similar to actual conditions.

In Conclusion the major activities in methodology are rotating in the following activities:

Figure 4.10 Flowchart of the overall Modeling Process



5 INTEGRATING GIS WITH HYDRAULIC MODELING

5.1 Introduction

A Geographic Information System (GIS) is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information" [4].

GIS is becoming an increasingly valuable tool for the water distribution modeler both as a source for modeling data and as a decision-support tool. Anderson, Lowry, and although approximately 15 percent of water utilities currently use GIS in their modeling, almost 80 percent plan to use GIS in the future [4].

5.2 GIS Integration with Hydraulic Models

This integration of the hydraulic model and the GIS leads to the following benefits: [4]

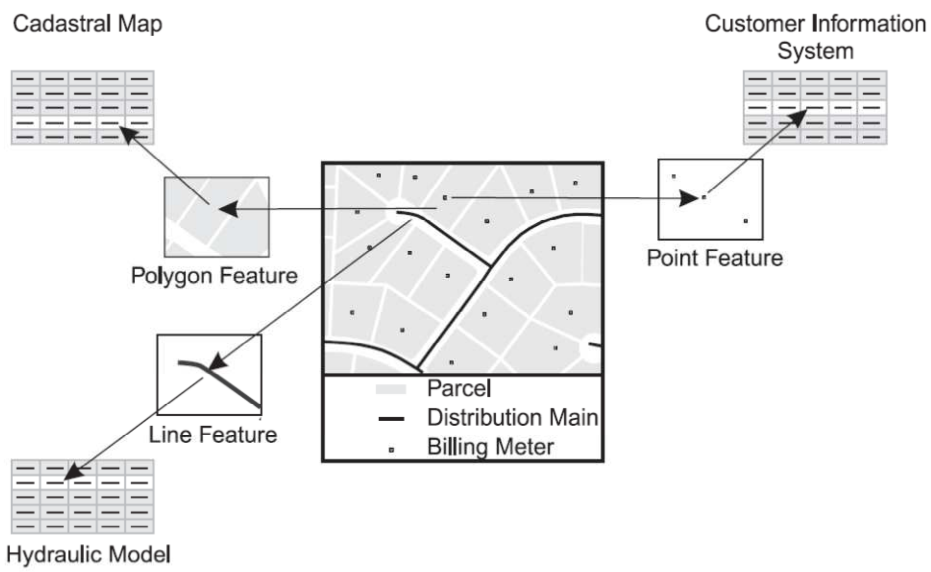
- Time-savings in constructing models
- Ability to integrate disparate land use, demographic, and monitoring data using GIS analysis tools to more accurately predict future system demands.
- Visual, map-based quality control of model inputs.
- Map-based display and analysis of model outputs in combination with other GIS layers.

In addition to being used for map-making; a GIS can be used to perform system analysis, answering questions about: [4].

- Location (using proximity, buffer, or overlay analysis)
- Condition
- Temporal and spatial patterns (trends)
- What-if scenarios (in modeling)

Within a GIS, features (objects on a map) are not simply points and lines; they have attributes (information about the feature) associated with them. In a water distribution system, facilities such as pipes, tanks, and pumps are features possessing attributes [4].

Figure 5.1 Organizing the desktop with GIS centric data management



These tasks will form the basis of GIS applications, and application descriptions prepared as part of the needs assessment include:[4]

- Facility mapping (GIS data maintenance)
- Service request tracking/work management
- Asset management/ reporting
- Field data collection/inspections
- Leak detection (compare master meter to individual account data)
- Link to as-built/intersection drawings (CAD or images)
- Isolation tracing/customer notification
- Demand projections/demographic data
- Planning/construction monitoring
- New connection processing
- Cross-connection
- Well monitoring/water resources analysis

5.3 Database Design

The database design for a GIS developed for a water utility should strive to accomplish three fundamental goals that will enable the GIS to become a strategic asset for the modeling organization:

i. **Cartographically represent the water distribution facilities (assets):** This representation can be used to create map products.
ii. **Inventory the network:** The GIS is often the primary record for geographically distributed assets (that is, assets outside the plant).
iii. **Model the network:** The GIS should be able to model the flow of water in the system and support the integration of hydraulic modeling software.
iv. **Land Bas**e: Water utility GIS must use some type of land base layer as a spatial reference.

The GIS was used to assign elevations to modeling nodes, based on the location of modeling nodes on the plane.

The GIS also was used to assign demands to modeling nodes. (Nodes associated with pumps and tanks were temporarily removed so they would not have demands assigned.) [4].

Geocoding was used to geolocate customer meters to the Topologically Integrated Geographic Encoding and Referencing street centerline file. During geocoding, the GIS matched the address of the customer meter with address ranges in the street centerline file.

Demands were then assigned based on the proximity of the customer meter to a model node. Aggregate demands were computed and then applied to the node [4].

A GIS professional can use a GIS to create a model more efficiently, more accurately, and more cost-effectively than an engineer creating a model input file from scratch inside a traditional modeling environment. Consider the following: [4].

• Because GIS tools can automate the process, model building can be faster and more efficient, especially for large models.

• Because GIS can manage large volumes of data, the model can incorporate more detail.

• Both hydraulic modeling software and GIS have advanced editing tools. The user needs to look at each task and decide if it is better done in the model or the GIS.

• In the ideal case, where GIS data-entry has a consistent spatial reference and a high level of quality control applied, the integrated model should contain better data and should therefore be easier to calibrate and potentially lead to better decision-making.

• Contour interpolations and digital elevation models (DEMs) in the GIS can be used to assign elevations to model nodes automatically.

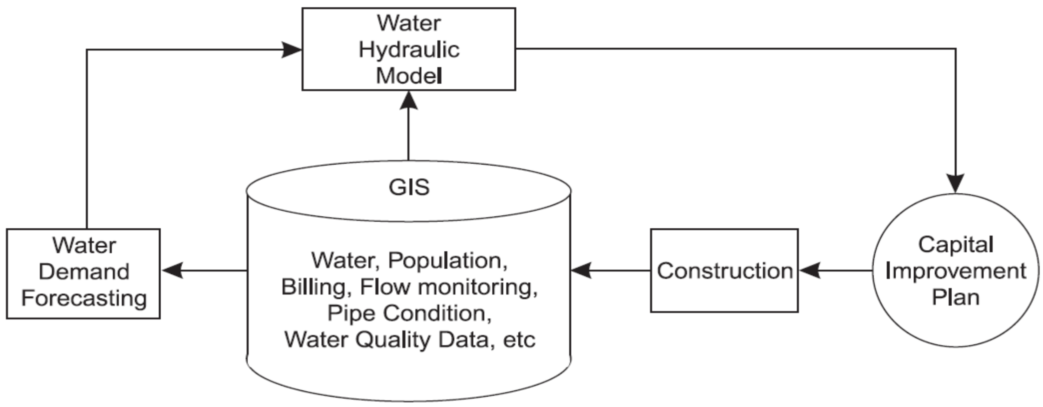
• Digital orthophotos available in the GIS can be overlaid with the model to provide a base map reference.

• Georeferenced customer billing records can be used to generate and allocate water demands for the model.

• If modeling results are returned to the GIS, further analyses can be run, and other users such as planners and developers can manipulate modeling data in conjunction with other GIS data.

By working with GIS professionals to build a water model from a properly constructed GIS, the engineer can spend time evaluating the water system and making engineering decisions [4].

Figure 5.2 Maintaining the hydraulic model



All pipes and other network elements included in the model must be marked appropriately in the GIS. Thus, as pipes, nodes, and associated features and attributes in the GIS are updated over time; these elements can easily be selected again and used to reconstruct the model with current data. Alternatively, the full system can be imported into the model and then reduced by skeletonization [4].

GIS drawbacks in modeling: [4]

a) Database design incompatibilities or omissions:
   - The GIS incorporates identification numbers for system elements that differ from what can be used by the modeler.
   - The GIS lacks critical valve information.
   - The GIS lacks pump performance curve information.
   - The GIS may have many short pipe segments that were introduced to provide full topology, but that would unnecessarily add to the complexity of the model.

Utilities collect and compute water usage data by means of several possible methods, ranging from the highly accurate to the more generalized. Three common techniques are: [4].

- Storing individual customer meter records for each billing period in a customer information system[4]
- Aggregating usage data for larger areas such as meter routes or pressure zones
- Computing water usage estimates based on land-use or population

A GIS is not essential for loading the hydraulic model with water usage data, but it can be used to effectively address each of these use cases and streamline the demand allocation process. Much of the early work in using GIS for modeling focused on accurately placing demands [4].

Typically, the modeling data is maintained in a separate GIS layer created specifically for modeling [4].

Hydraulic modeling results in the enterprise GIS can be used for a number of purposes, including: [4].

- Pressure mapping
- Establishment of water main replacement priorities (when combined with other GIS layers such as soils and repair data)
- Connection permit processing (available capacity can be reviewed and future demands reserved)
- Contaminant isolation/remediation (contaminant is introduced accidentally or intentionally)

5.4 Using Relationships to Trace Networks

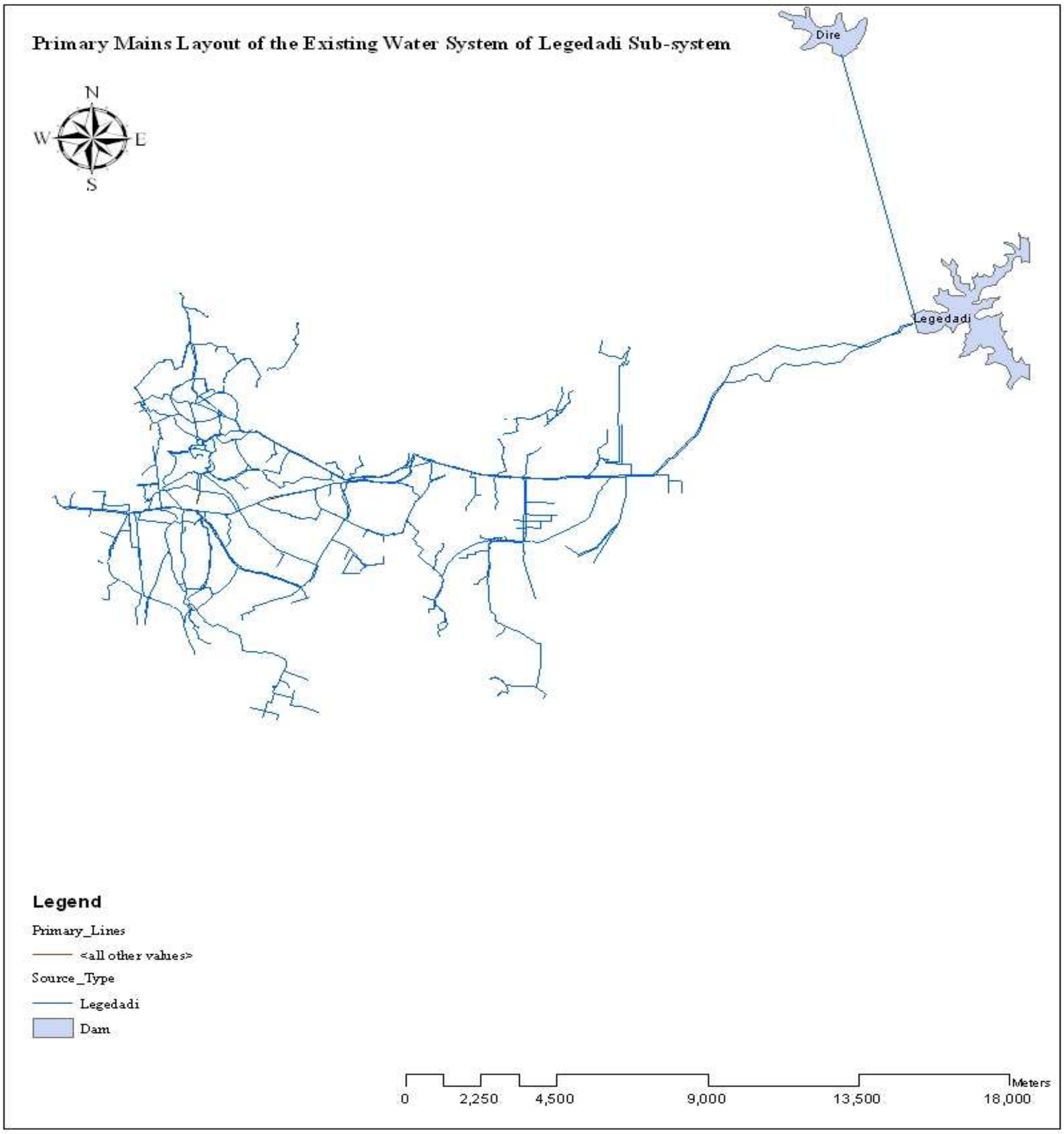
When structured properly, datasets such as those that make up a hydraulic model (pipes and nodes), can be subjected to a process known as network tracing [4].
In network tracing, GIS software uses information on which links are connected to which nodes to allow a system to be traversed. These functions are commonly applied to street networks and utility networks. Examples of this type of analysis include: [4].

- Generating shortest-path driving directions from point one point to another point..
- Indicating the location of a hydrant.
- Identifying the location at which the chlorinated water will enter a stream.
- Indicating the location of a water pipe break and identifying the valves that must be closed to isolate the break.
- Tracing the network to identify segments that are disconnected, either due to inaccurate data or inadvertently closed valves. This analysis can be a great aid in GIS and model input data quality control.

5.5 Addis Ababa Water distribution Network

The Addis Ababa Water Distribution system could be divided into high pressure zone, low pressure zone, and normal pressure zone, which are based on water pressure demands and elevation of different area. The area covered by light orange colour is the entire pressure zone of the test area, called Legedadi pressure zone (shown in Figure 6-3). It has been selected as the test area in this research. All the following statistics shown as maps, tables and graphics are generated from GIS analysis.

Figure 5-3: The Existing Addis Ababa Water Distribution Network-Legedadi Sub-system



These locations can be displayed in the GIS by using color-coding and can be overlaid with other layers to show desirability of monitoring locations in terms of utility land ownership, location of power, and existence of pump stations and valves.

Figure 5-4: Assembly of Water Distribution Network of Addis Ababa City

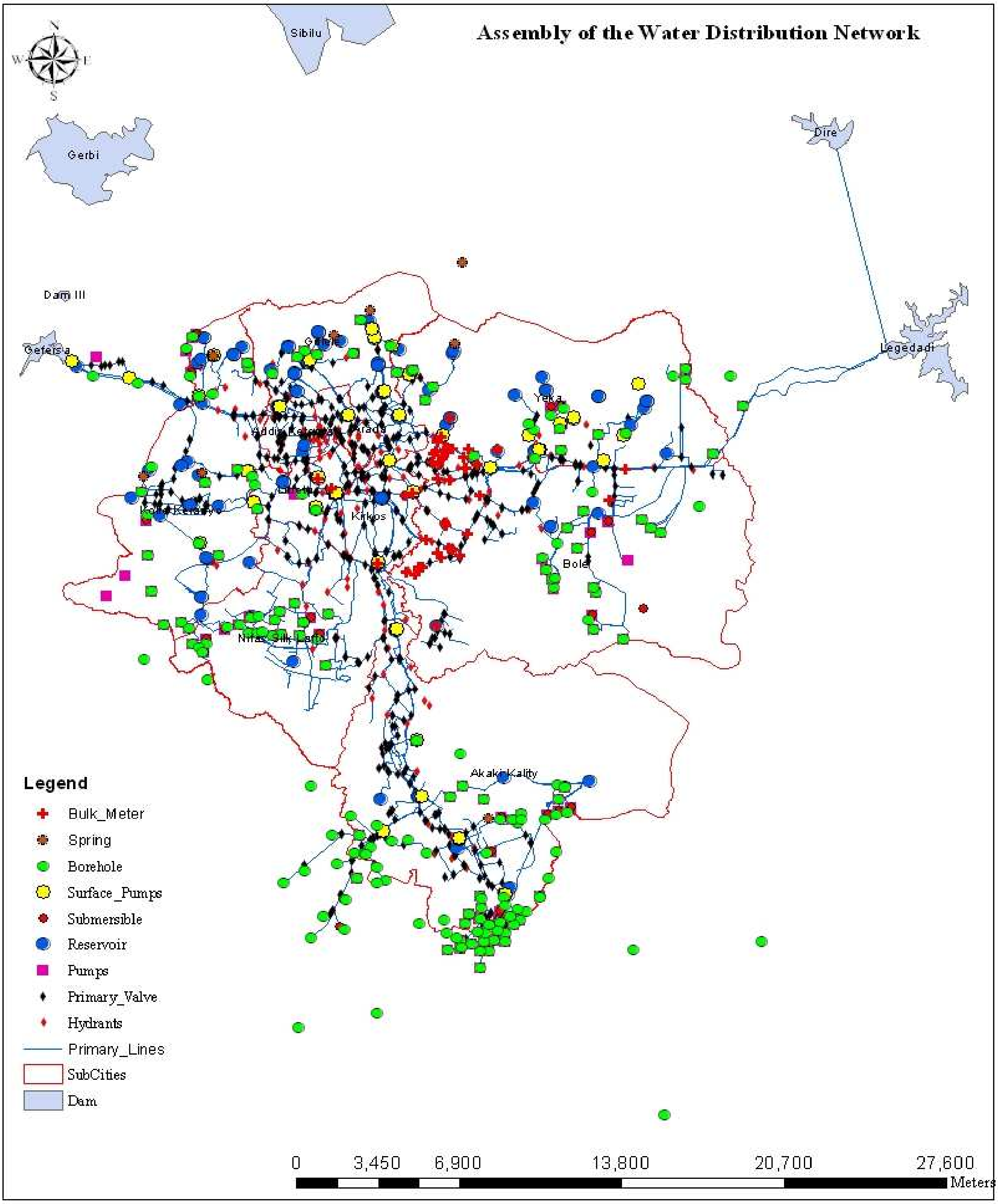


Table 5.1: Compiled Inventory of Asset [1]

BRANCH	WATER SUPPLY							Source type
	Primary line	Sec.line	valve	Pump	Reservoir	Bore hole	Yard Conn	
Addis Ketema	96	233	406	22	29	15	45081	Gefersa
Akaki	119	136	283	56	8	44	15867	Akaki WF
Arada	85	220	1144	10	5	0	42312	Gefersa
Gulele	62	274	824	40	22	11	45444	Gefersa
Gurd Shola	112	333	1123	46	19	27	45682	Legedadi
Megenagna	59	239	963	7	5	59	27640	Legedadi
Mekanisa	65	270	700	42	10	65	51557	Legedadi
Nifas Silk	78	317	871	10	4	2	47945	Legedadi
Total	**676**	**2,022**	**6,314**	**233**	**102**	**223**	**321,528**	
Remark							**July,2010**	

5.5.1 Locating potential sites for facilities

The GIS can be used to identify good locations for water system facility sites. In this case, the GIS is not used as a source of data for modeling but as a way to present alternatives to decision makers.

5.5.2 Locating potential sites for monitoring equipment

In the other hand, how model results can be imported into a GIS and used with other data, such as property ownership and locations of utility-owned buildings, to determine good locations for water quality or pressure monitoring equipment.

5.6 Network Performance Assessment with GIS

5.6.1 Network Failures

A bad water distribution system causes many problems. Like all engineered systems, the wear and tear on a water distribution system may lead to the eventual need to rehabilitate portions of the system such as pipes, pumps, valves and reservoirs.

Failures in any of the components can lead to the collapse of the whole system. Practically and historically, pipeline damage has the greatest impact on system operation. Transmission and distribution pipelines are particularly vulnerable if they are constructed of brittle materials.

Furthermore, the occurrences of pipe failures in water networks cause major technical, economic and socio-economic impacts. So issues on pipeline failures are the target of this section.

One acceptable definition of failure is that a component can no longer perform its intended function. Many reasons lead to pipe failures, for example:

i. Design deficiencies,
ii. Construction problems,
iii. Main's age and
iv. Installation period,
v. Diameter,
vi. Corrosion,
vii. Material,
viii. Other surrounding conditions and water quality and
ix. System pressure in a distribution network.

Except for physical failures, factitious failures exist in a water distribution network, which are caused by operational or management mistakes.

5.6.1.1 Water Leakage

The total amount of water demand largely depends on: customer demand, unaccounted water demand and fire flow demand. Water leakage exists as a major portion in unaccounted water demand [6].

The larger losses are usually from burst pipes, or from the sudden rupture of a joint, whereas smaller losses are from leaking or "weeping" joints, fittings, service pipes, and connections [6].

Practically, major reasons causing bursts in a network are un- predicted pressure fluctuations, fittings, pipes and valves' insufficiency capability of enduring pressure, design, construction or operational mistakes, accumulations of small water losses [6].

Reasons of leaking or weeping problems from various parts of networks are complicated to define, because most of the time they are caused by combined reasons from surroundings, material, age, and corrosion [6].

For instance each material has its own duration year, which is a proper working year for a material, and after this duration, corrosion and other effects happen more easily.

Table 5-2 gives statistical information about common material's duration year [6].

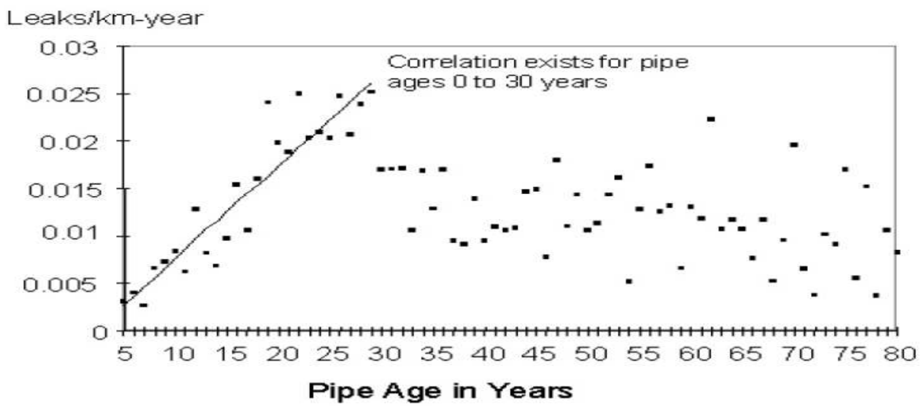
Table 5-2: Material and its duration year

Code No.	Material	Duration (year)
1	Cast iron	30
2	Zinc	10
3	Softened vinyl	15
4	Polyethylene	15
5	Stainless	30
6	Copper	25
7	Plastered cast iron	20

(Source: Jun, 2004)

However, there was a study of leak frequency distributed according to pipe age for grey cast iron pipes studies. The result shows that after some years, in Galvanized Cast Iron case, which is around 80 years old, there is no significant correlation between leak frequency and pipe age See Figure 5-5 [6].

Figure 5-5: Leak frequency versus pipe for GCI water distribution pipes measured over a five year period [6].



Leakage on transmission and distribution mains was defined as a big part for water real losses.

Real loss is an attribute for system Input volume and the relation is:

System Input volume = Water losses+ Authorized consumption (m3/year) [6].

Water losses = Real Losses + Apparent Losses (m3/year)

Water loss is hard to calculate or forecast in water distribution network design, but it is important to assume this amount of water. However, a leakage- free network is not a realizable technical or economic objective, and a low level of water losses cannot be avoided, even in the best operated and maintained systems, where water suppliers pay a lot of attention to water loss control [6].

So minimizing the leakage amount is an important target for water industry, since it is not only an issue related to city's long term planning and environment, but also related with finical and economic issues [6].

5.6.1.2 Red Water

Red water occurs due to corrosion happened on iron or steel pipes in water distribution networks. Corrosion has a cumulative phenomenon, since it reactions occur on the inner surface of a pipe, which lead to chemical deposition process that forms a material build- up along the pipe walls.

The form weakens the pipe wall and lead to the formation of tubercles. The most obvious and immediate impact, however, is that the oxidized iron particles give the water a murky, reddish-brown color. This reduction in the aesthetic of the water prompts numerous customer complaints. The deposited layers in pipes cause actual diameter decreasing and other problems from water quantity and water pressure [6].

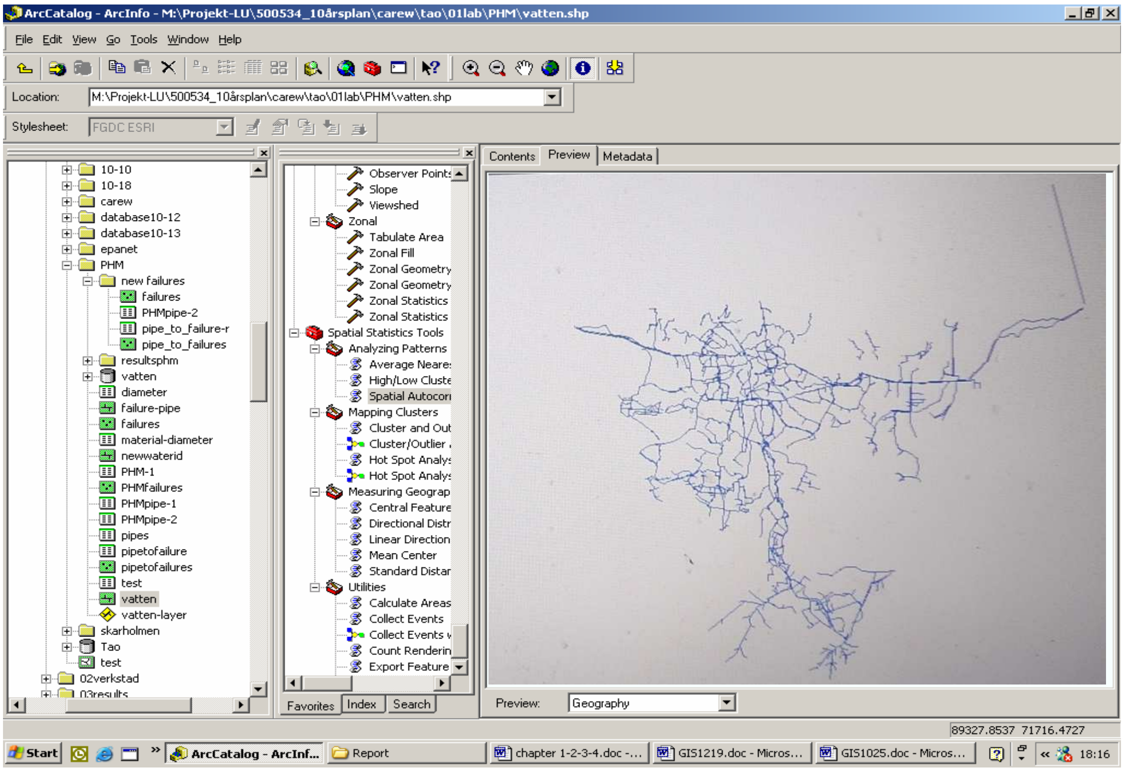
5.7 Water Distribution Network Information

Thirty one water reservoirs and pump stations are located in this area. More information, such as pipe material distribution, pipe installation year distribution and pipe diameter distribution, total length of water mains and total service connections, has been collected by GIS analysis. The aim is to present background information to decision makers.

5.7.1 Network Physical Information

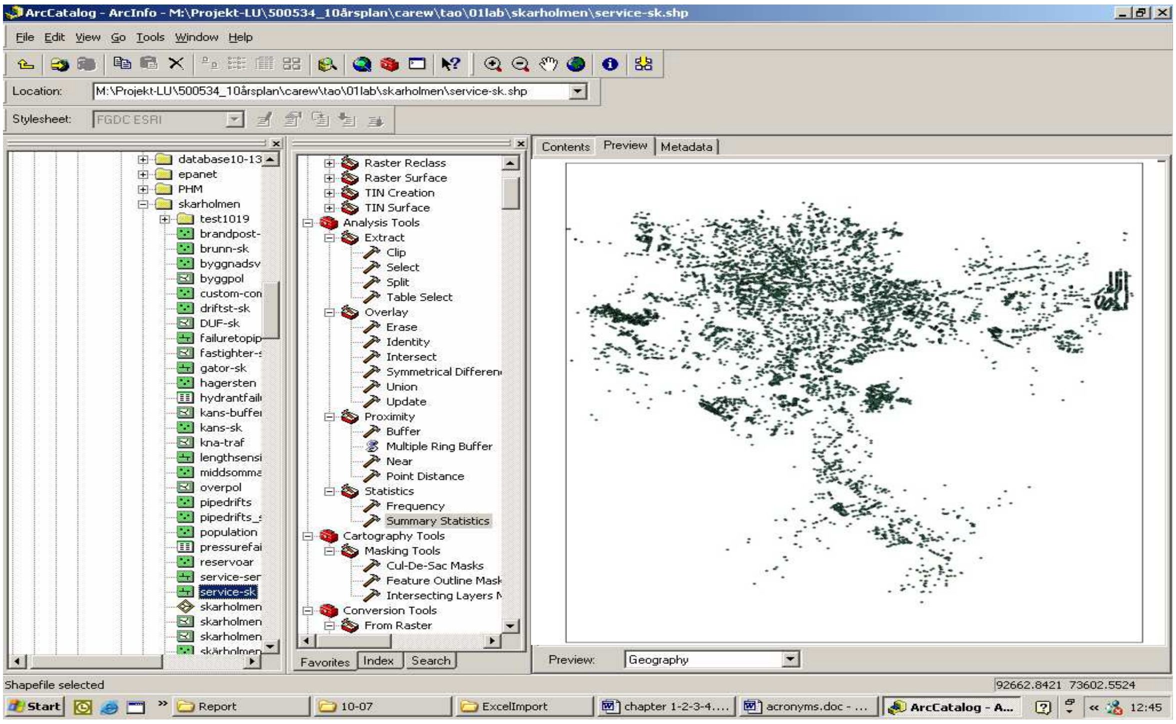
All statistics are extracted from the network shape file (Figure 5.6). In this part, the aim is to analyze the material distribution, installation year distribution and diameter distribution.

Figure 5.6: Addis Ababa Network shape file



Total length of water mains is 382.96 km. And the Total junctions are more than 509. This is abstracted from a shape file, containing service pipe information.

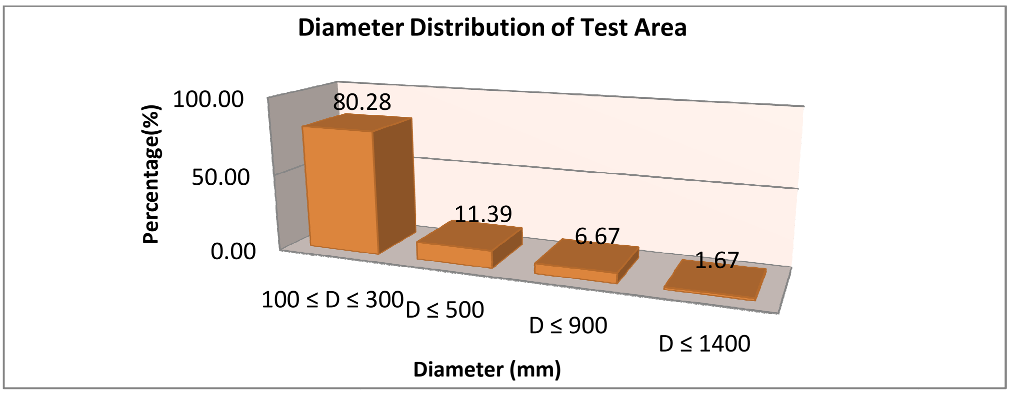
Figure 5.7: Addis Ababa Service information shape file



5.7.1.1 Diameter Distribution

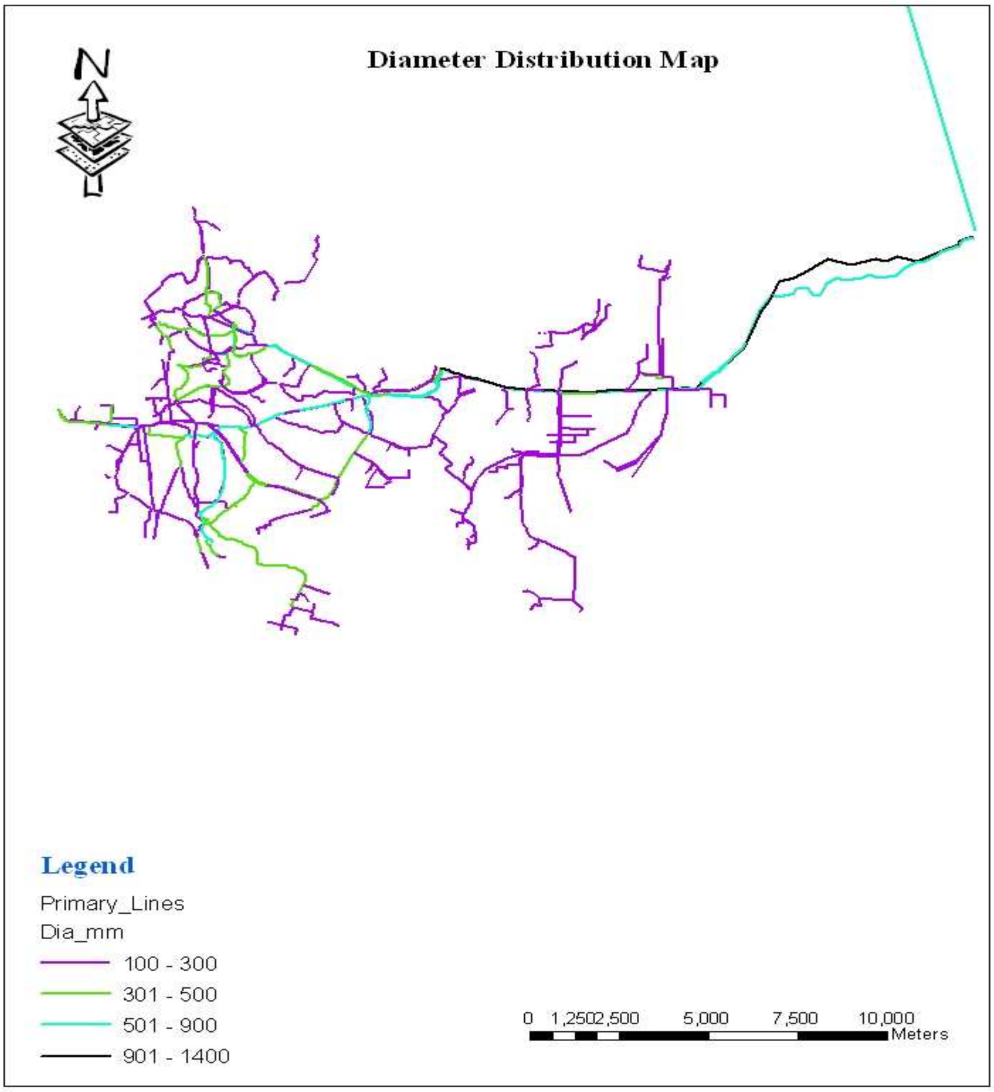
Four diameter groups were defined. These groups are: diameter 100/110 mm < D r ≤ 300/315 mm, diameter ≤ 500 mm, diameter ≤ 900 mm, diameter ≤ 1400 mm, and [1]

Figure 5.8: Diameter Distribution Results



From the results, you can get the following information. Pipes serve as distribution mains are diameter between 100 and 1400 mm. Pipes used for smaller demand water consumers in this network are with diameters smaller than 100 & 150mm. Transmission mains or the beginning parts of distribution pipes have diameters 900 -1400mm. From this information, we can cursorily judge the size and population distribution around this area [1].

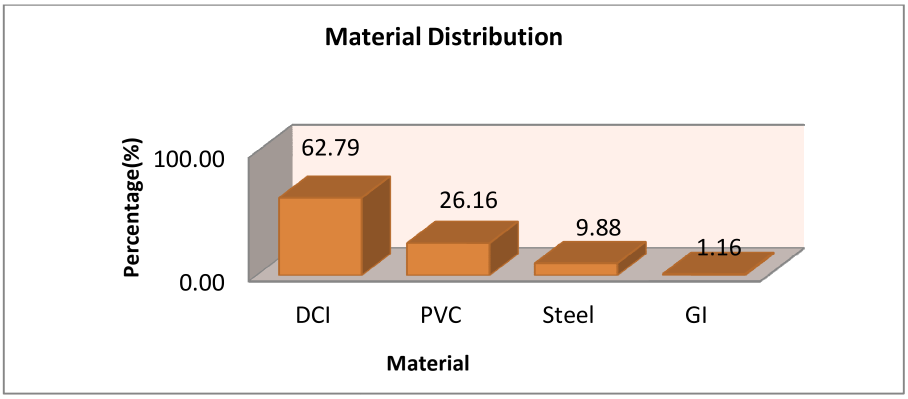
Figure 5.9: Diameter Distribution Map



5.7.1.2 Material Distribution

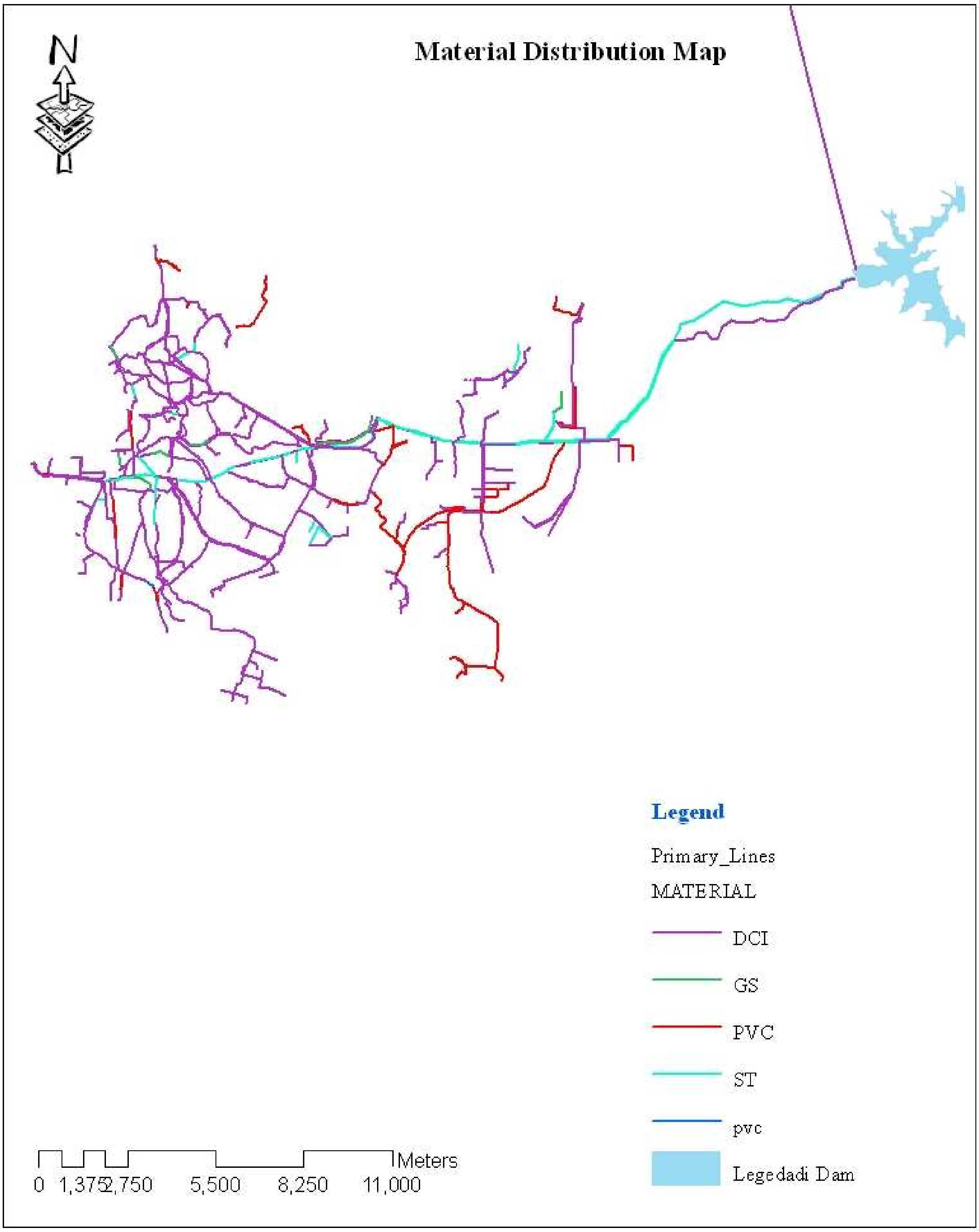
Four material groups have been defined. They are: Ductile Cast Iron (DCI), Steel mains, Polyvinyl Chloride Mains (PVC), and Steel, Galvanized Iron (GI) [1].

Figure 5.10 Material distribution



From figure 6., we can see that DCI (Ductile Cast Iron) is the most common material in this area followed by PVC (Polyvinyl Chloride) Steel and GI (Galvanized Iron) have total of 11.04% . An observation through Arc Map shown that steel pipelines are used mainly for diameter larger than 500 mm, which are transmission mains in this area and for pipes passing through gorges and rivers. PVC material is a new material for water distribution network, which are normally installed after year 1997. [1]

Figure 5.11: The Material Distribution Map



5.7.1.3 Installation Year Distribution

Total 13 groups are defined and each group contains five years [1].

Figure 5.12: Installation Year Distribution

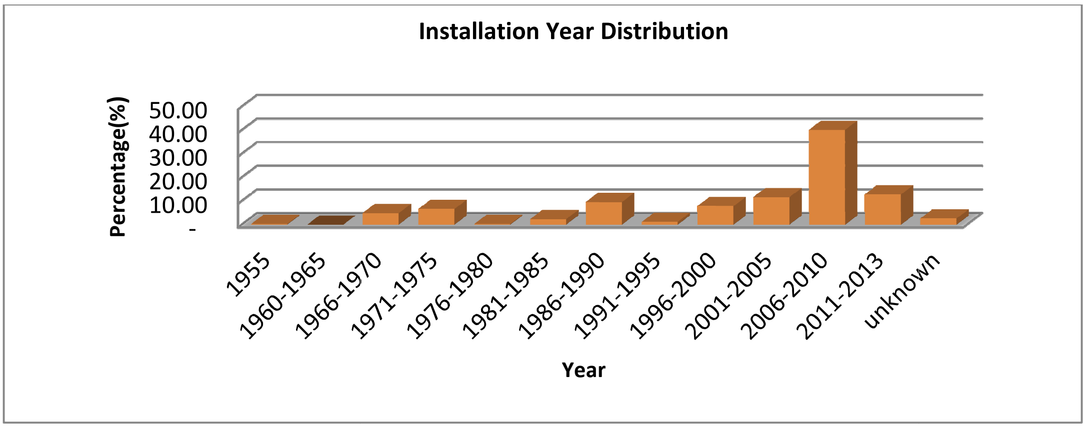
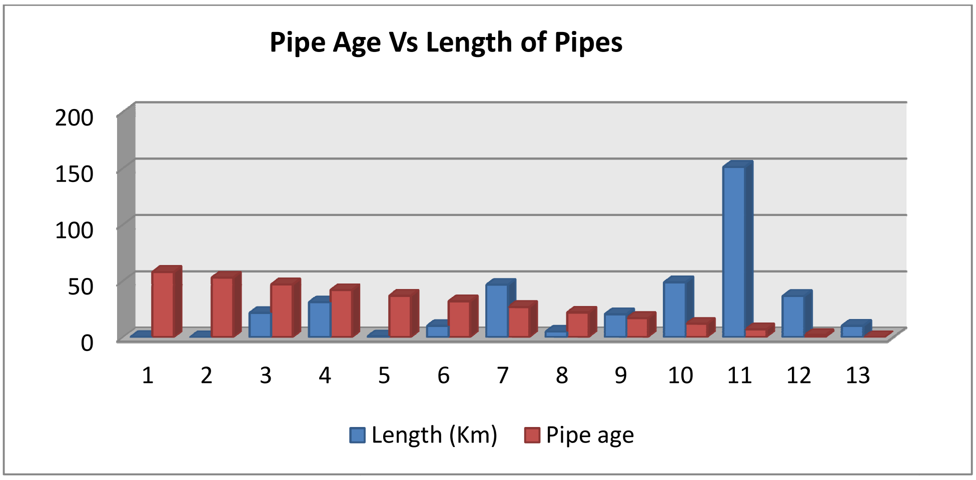


Table 5.3: Installation Year Distribution Statistics

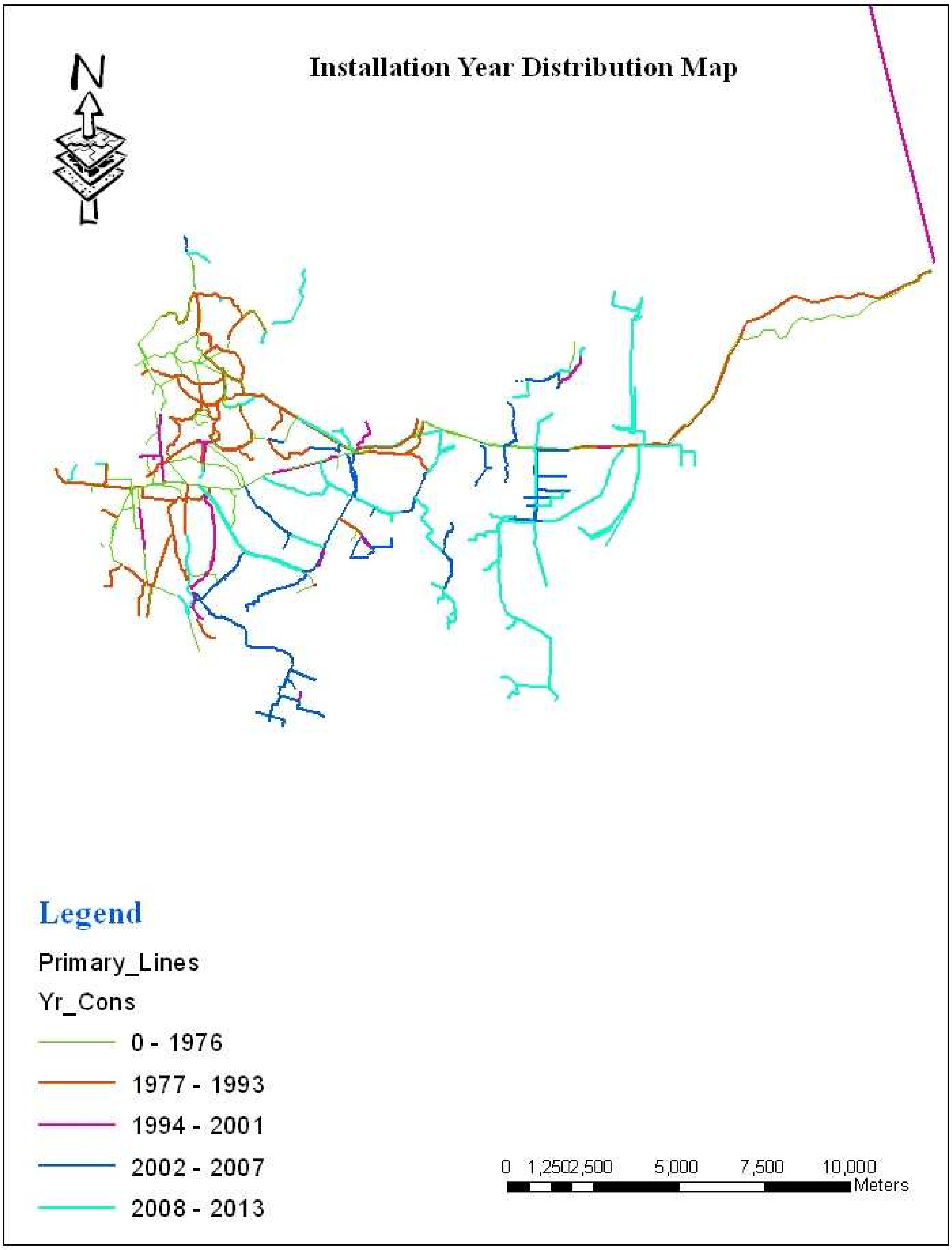
[redacted]			
1955	58	0.31	0.29
1960-1965	53	-	-
1966-1970	47	21.64	4.94
1971-1975	42	31.11	6.69
1976-1980	37	0.87	0.29
1981-1985	32	10.05	2.33
1986-1990	27	46.61	9.59
1991-1995	22	4.96	1.16
1996-2000	17	20.47	7.85
2001-2005	12	8.82	11.63
2006-2010	7	151.25	40.12
2011-2013	2	36.64	12.79
unknown	0	10.22	2.62
Total		**382.96**	**100**

Figure 5.13: Pipe Age vs Length of Pipes



From this distribution statistics, we can see that majority of this network was built during year 2006 to year 2010, which means that the community was developed quite fast during this period. The oldest pipe group has been laid at 1955.

Figure 5.14: Installation Year Distribution Map



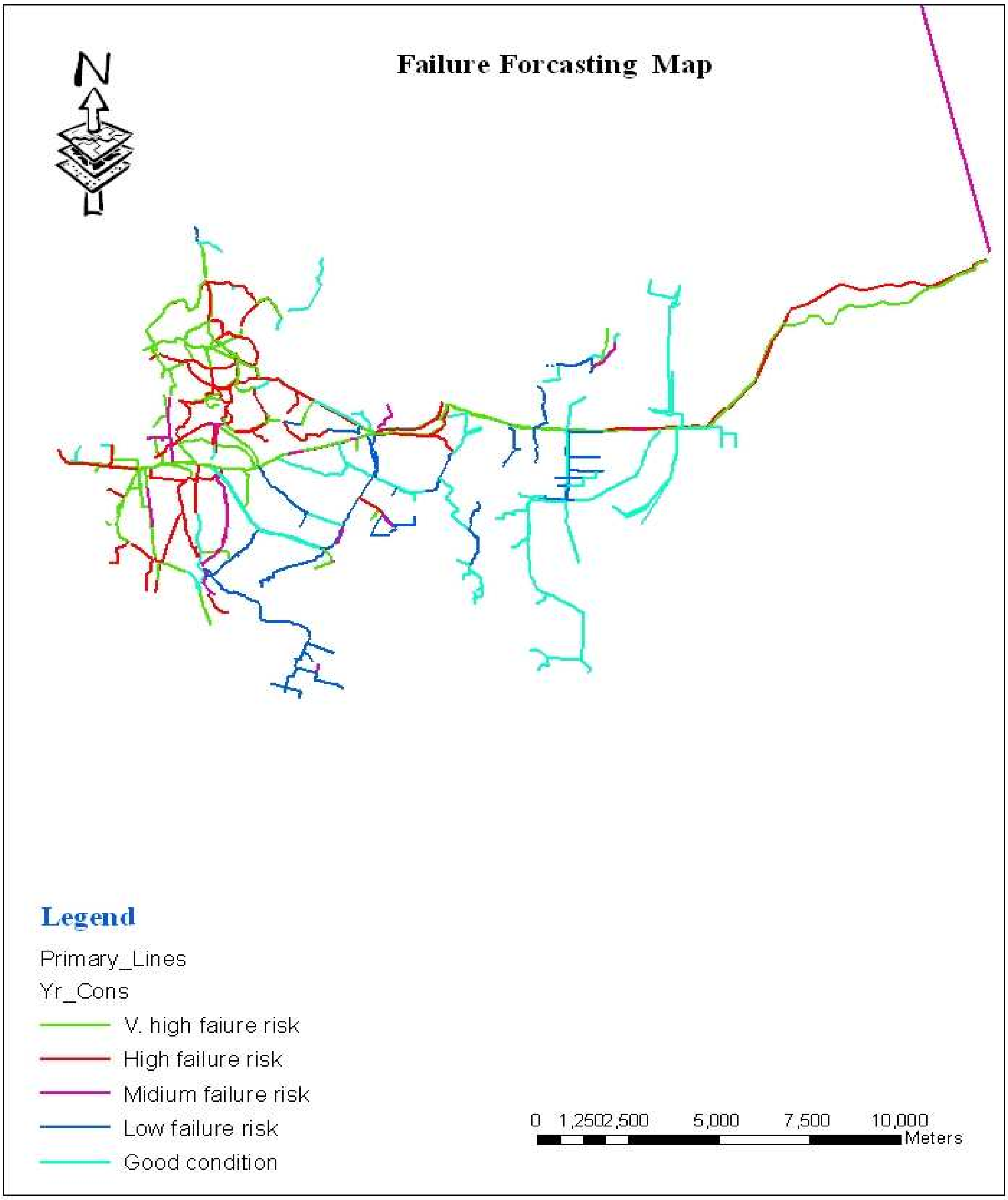
As we collected the information from AAWSA, and observed from the data we can observe the relationship between Material and Installation Year “During 1960s, the majority of the pipes were constructed by ductile cast iron.

Even to the current time as well ductile cast iron pipe is the choice of many water distribution schemes, especially for the transmission mains (Pressure mains). Besides, their joints material or corrosion protections improved from time to time.

From the two graphs, material distribution (Figure 5.11) and installation year distribution (Figure 5-14), it is obvious the majority of water distribution pipelines were constructed during 2006-2010 and (DCI) Main is the major material group for water pipes in this period in addition to PVC.

In Addis Ababa water distribution system especially after the end of 1990s the (PVC) Polyvinyl Chloride Pipe has become more common in material market, due to the low investment cost. Since, DCI pipes and large diameter Steel pipes are imported from the abroad and incurs huge amount of foreign currency, the choice of the water companies and the government as well has become PVC material type for the Service distribution systems.

Figure 5.15 Failure Forecasting Map



5.7.2 Network Rehabilitation

The complex effects of corrosion, wear and tear, and age are eating away the underground infrastructures in all countries around the world. Most of the pipes that have been in the ground for many years are far beyond their expected service life. Rehabilitation is not easy.

Moreover, increased traffic and buildings and the presence of other underground utilities make pipe replacement and rehabilitation both burdensome and expensive. A rehabilitation plan must rely on sound judgments, scientific analysis of current condition in a network.

As has been mention in Advanced Water Distribution Modeling and Management, the rehabilitation works maybe necessary because of:

- The cumulative effect of tuberculation and scaling
- Increased demands due to new customers
- Excessive leakage
- Infrastructure improvements, such as street reconstruction or sewer replacement, in vicinity of distribution system piping
- Water quality problems

Actually rehabilitation works are even more difficult than designing a new system in many situations, because of the conflicts with other buried utilities and many un- predicted problems. Especially in many old cities, there is no enough construction records saved.

It is almost impossible to know underground infrastructure networks situations. Of course, some methods can be used to recover these maps or draft, for instance GPS or Remote Sensing technology.

But comparing with economic and effort investments, it is still a task for long term planning. Currently there are many types of rehabilitation methods, which are suitable for different situations.

- Rehabilitation: Any physical intervention that extends the life of the system and involves changing their condition or specification.
- Relining: the removal of all deposits from inside an existing pipeline, followed by the in situ application of a non-structural lining to provide corrosion protection, such as cement or epoxy mortar (relining is sometimes referred to as scraping and lining, renovation or reconditioning).
- Repair: rectification of local damage.
- Replacement: substitution of a new facility for an existing one where the latter is no longer used for its former objective.

Because the capital costs of a water distribution system combined with the cost of maintaining and repairing the system are often immense, researchers and practitioners are constantly searching for new ways to create more economical and efficient designs for rehabilitation planning. And one of the challenges that the water companies are facing is to find crucial pipelines for rehabilitation with the best methods and most cost saving methodologies.

The groups are operational indicators (rehabilitation, failures and repairs, water losses), quality of service indicators (service, customer complaints), financial indicators (annual costs, annual investments for network mains, tariffs), water resources indicators, and physical indicators. physical assets data – distribution network (transmission and distribution network, water storage, pumping stations), physical assets data - service connection, water volume data, operational data (service pressure, service continuity, water quality monitoring, inspection and maintenance, preventive maintenance, failures, rehabilitation),

It was previously stated that the GIS tools can be used as a stand-alone tool, to assist the engineers in analyzing the evolution of performance of their networks, in establishing diagnosis or in improving their know-how about the behavior of different pipe materials or rehabilitation techniques.

6 HYDRAULIC MODELING OF LEGEDADI SYSTEM

6.1 Hydraulic Modeling of the Distribution Network

6.1.1 Introduction

This section presents the analysis of Addis Ababa City (Legedadi sub- system) water distribution system. The hydraulic modeling was performed to evaluate the adequacy of existing facilities for conveying current and future flows, and to aid in determining improvements that would ensure future viability of the distribution system. This section describes how all the model parameters, scenarios and alternatives necessary to run the model were set.

The mode of supply was varied on various development scenarios towards the aim of improving the water supply to the population.

Pressure is the primary hydraulic parameter analyzed via computer modeling to identify system deficiencies. The target minimum system operating pressure is 30 pounds per square inch (psi) during peak hour demand conditions. During fire flow conditions (fire on a peak day), a residual pressure of 20m must be maintained throughout the system with fire flow storage depleted.

The general methodology of this hydraulic modeling analysis was to examine the current distribution system during various demand and fire flow conditions. According to the above pressure criteria, deficiencies were noted and distribution system improvements proposed.

Further analysis was performed to verify that additional improvements associated with growth of the city meet the minimum distribution system criteria. All distribution system improvements, relating either to the remedy of current deficiencies or the accommodation of future growth, are presented in the Water System Improvements.

6.1.2 Assumptions of the study

In modeling Addis Ababa water distribution system, the following assumptions have been taken into consideration.

- As stated, the existing water distribution system was analyzed and the future demand analysis works are designed on the basis of a computer model utilizing WATERCAD software

- For the purposes of the project, the model was limited to a minimum pipe diameter of DN 150 mm in the distribution network. Diameters of smaller size are considered insignificant in terms of the population supplied.

- The water distribution system is designed to cope mainly with the domestic demand. As it is common in Ethiopia, the consumption for industrial, commercial, and institutional demands are included in the domestic consumption figure to form a total water demand per person per day.

- The demand for each node of consumption was calculated as follows.
  Demand: = No of residence X Water Consumption per capita per day.
- Domestic water demand of the city is assumed to be (161 l/c/day)
- The industrial, commercial and institutional consumption of water are included in the domestic consumption. So that it is assumed to be (66.5l/c/day).
- For unaccounted for water (UFW) calculations and according to studies carried out by the THAL Consulting and AAWSA, their data shows a maximum value of 40% as unaccounted or water. The value of UFW is calculated through meter readings and population projection, shows the range of 30%-40% for domestic consumption and for whole uses of water [1].

- A value of 35% as unaccounted for water has been adopted in the modeling of the system and 30% of the total consumption has been adopted to model the technical loss of water in the system [1].
- Taking in to account that this amount of water is to be pumped in different periods of time for different zones. A study the way of operation, zoning, and changing valves setting in the distribution system is necessary.
- By this procedure, the demand for each node was calculated and analyzed depending on the number of inhabitants for each consumption node, and the period of supplying water.
- Demand: = No of residence X Water Consumption per capita per day.

6.1.3 Demand Pattern of Addis Ababa City

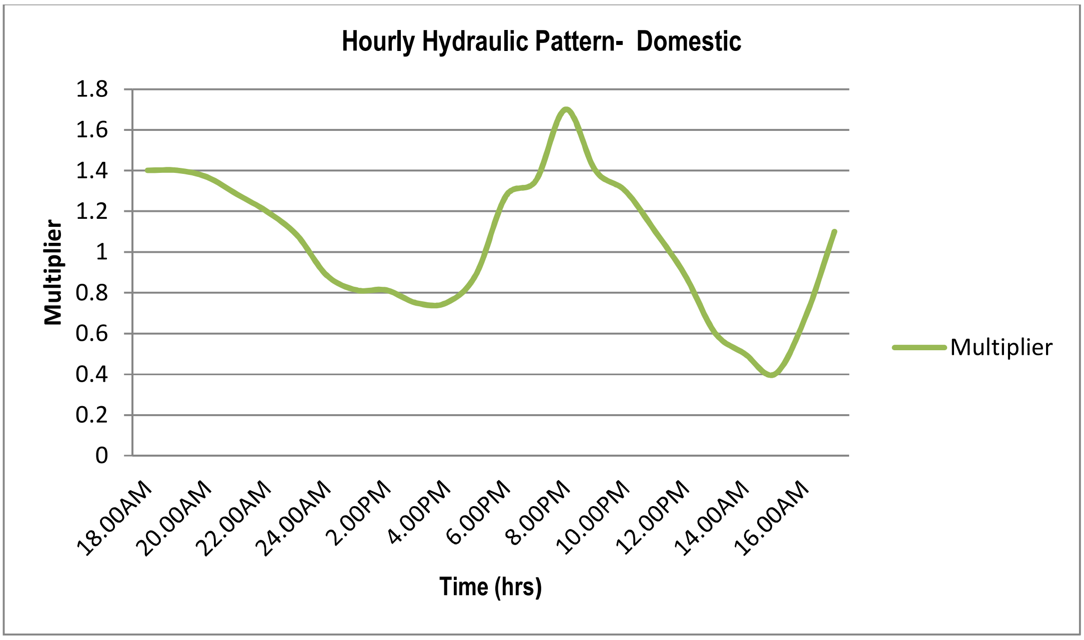
The average demand will be subjected to hourly variations, which mean the demand pattern based on the differences in living standards, industrial water use, Commercial, Public, Fire fighting etc. Since Our type of Simulation that we use for our modeling is the Extended Period Simulation since it is used to evaluate system performance over time.

For such type of simulation, the demand patterns of the city for each node should be identified and the demand variation of each pattern has to be clearly set as well. The major demand patterns of the city are: Residential, Commercial, Industrial, Fire fighting and Public are the major ones. Hence, here are the demand variations with in a day for each type of demand pattern.

- The study also considered the daily distribution of the supply and found as following:

- Low usage	23:00 – 05:00hrs.
- High morning	05:00 – 11:00hrs.
- Moderate	11:00 – 18:00hrs.
- High evening	18:00 – 23:00hrs.

Figure 6.1 Domestic Demand Pattern Curve for Daily Water Consumption of Addis Ababa City



Pattern Detailed Report: Domestic

Element Details			
ID	1481	Notes	
Label	Domestic		

<Pattern Summary>			
Start Time	12:00:00 AM	Pattern Category Type	Hydraulic
Starting Multiplier	1.401	Pattern Format	Continuous

Pattern Curve

Time from Start (hours)	Multiplier
1	1.401
2	1.368
3	1.283
4	1.199
5	1.083
6	0.886
7	0.813
8	0.813
9	0.750
10	0.750
11	0.890
12	1.275
13	1.350
14	1.701
15	1.400
16	1.300
17	1.101
18	0.886
19	0.603
20	0.500
21	0.400
22	0.670
23	1.100
24	1.401

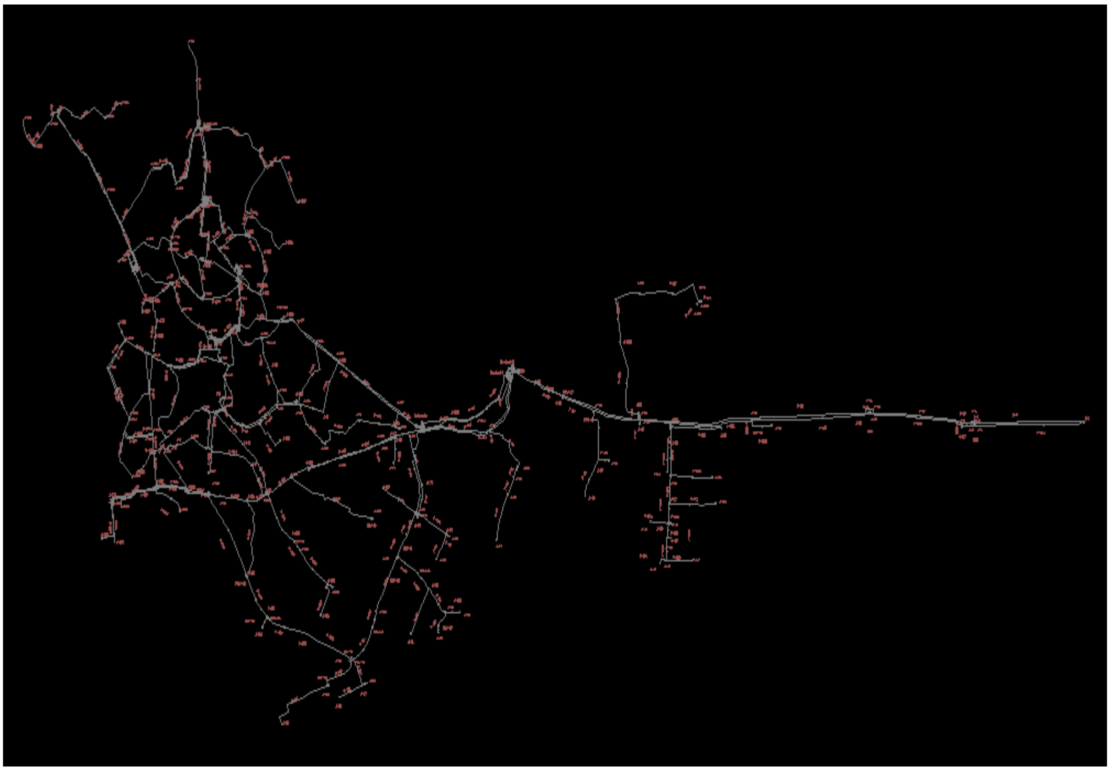
Pattern - Daily Multipliers

	Multiplier
Monday	1.000
Tuesday	1.000
Wednesday	1.000
Thursday	1.000
Friday	1.000
Saturday	1.000
Sunday	1.000

Pattern - Monthly Multipliers

	Multiplier
January	1.000
February	1.000
March	1.000
April	1.000
May	1.000
June	1.000
July	1.000
August	1.000
September	1.000
October	1.000
November	1.000
December	1.000

Figure 6.2：Layout of the Existing water system of Legedadi sub-system



6.1.4 Model Calibration

To calibrate the model, some junctions accessible and available for flow data measurement are selected and flow measurements are taken using flow measuring instrument.

Information recorded included static pressures, flows, residual pressures, reservoir elevations, and the locations of junctions. Using the information provided by the AAWSA, the model was calibrated to meet the general calibration criteria for flow and pressure.

6.1.4.1 Acceptable Level of Calibration

6.1.4.1.1 *Calibration criteria for flow and pressure*

6.1.4.1.1.1 Pressure Criteria

(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

6.1.4.1.1.2 Flow Criteria

(1) Modeled trunk main flows (where the flow is more than 10% of the total demand) should be within ± 5% of the measured flows.

(2) Modeled trunk main flows (where the flow is less than 10% of the total demand) should be within ± 10% of the measured flows.

6.1.5 Hazen-Williams Roughness Coefficients (C- Value)

Many studies show variations in the value of "C" for different materials, wall thickness and pipe age. Thus the value of "C" decreases over time in the case of non-mortar lined cast iron and steel pipes, assuming a given water quality.

As a result, calibration was carried out on some links of the main network and the results are shown in Table 6.2. For the purpose of evaluation of the system the calibrated pipes are part of the main line and were used on the model.

For the pipes having 30 years of operation, "C" diminishes by about 28% and 43% for pipes of DN 1,500 mm and DN 100 mm, respectively.

To this effect, the following roughness coefficients are suggested for existing pipes, depending on age and material and the remaining pipe sections are adjusted for their C-values accordingly:

- New pipes with mortar lining are considered to be C= 130-145.
- All existing PVC pipe: 110-120.
- All existing pipe other than PVC: 90-110.

Table 6.1: Measured Hazen-Williams Coefficients

Construction Year	Diameter of Pipe (mm)	Type of material	Hazen William Coefficient
After 1980	1200-700	DCI STEEL GSI	100
1955-1979	1200-700	DCI STEEL GSI	90
After 1980	600-150	DCI STEEL GSI	90
1955-1979	600-150	DCI STEEL GSI	80
For all PVC pipes			110

As expected, table 6.1 shows that both newer pipes and higher diameter pipes have a better roughness factor. Therefore I have synchronized the field measurement data for sample pipe sections using Hazen Williams Coefficient –C which plays the significant role in calibration process. By varying the value of Hazen William's C until it satisfies the actual field measurement value.

Table 6.2 Sample Flow Measurements on Existing Pipes for Calibration

Sr. No	Transmission main	Length(m)	Dia (mm)	Material	Year of Instal.	Flow corrected against the field measurement (m3/h)	Pressure (m)		Hazen Williams Coefficient -C
							Delivery	Inlet	
1	Leg-Tank to J4	6476.3	1400	Steel	1985	5461.9	12	5	110
2	Leg-Tank to C1a	6890	900	Steel	1985	1803.6	12	5	115
3	ST3 to TR	9526	1200	Steel	1985	4798	10	2	126
4	ST3 to TR	9526	900	Steel	1970	1852	11	2	94
5	TR to JM	7516	900	DCI	1985	2210	73	7	128
6	JM to MO	2741	500	DCI	1985	624	35	5.5	91
7	MO to BZ	2930	300	DCI	1985	247.4	15	1.5	130
8	MO to RH	3710	300	DCI	2003	257	33	12	123

6.2 Need for Fire Flow

- Fire flow analysis, the head condition for the distribution network is at least 138 Kpa.
- In fact, this is the empirical formula for determining the need for fire flow, but in our city case it is so difficult to get the value of these factors and calculate the NFF; since there is no clear data and information [4].

$$NFF = 18FA^{0.5}O(X+P)$$

where NFF = needed fire flow (gpm)
F = class of construction coefficient
A = effective area (ft^2)
O = occupancy factor
X = exposure factor
P = communication factor

- As a result, we have taken the NFF value from the Water III design document adopted for Addis Ababa Water supply scheme which is 100 l/s for 1hr flow therefore the additional storage for fire fighting in the operational reservoirs, called “intangible reserve” could be established at 360 m^3[1].

Cross checking Fire Demand using Empirical Formula:

- Water required for fire protection should be easily available and kept always stored in storage reservoirs
- Estimation of fire demand (NBFU formula)

$$Q_F = 231.6\sqrt{P}(1 - 0.01\sqrt{P})$$

Where, Q_F = is fire demand (m^3/hr); P = Population in 1000's. , P=3Million

Qf= 109Lit/sec

6.3 Design criteria

6.3.1 Pressure and Velocities

The design criteria used in the design of pressure zone boundaries, nodal pressure during the period of peak demand, and optimum velocities of the transfer and distribution mains are as follows:

6.3.1.1 Pressure

The operating pressures in the distribution network according to MoWR Urban Water Supply Design Criterion shall be 15m to 80 ranges.

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

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

The static state pressures in pipelines must be less than the pipe nominal pressure rating. In the case of long mains where water hammer risk is expected, due attention must be given to the pipe material and a proper water hammer analysis carried out.

6.3.2 Velocity & Head loss

According to MoWR Urban Water Supply Design Criterion Water velocities shall be maintained at less than 2 m/sec, except in short sections &for pumps. Velocities in small diameter pipes (<DN100) may need even lower limiting velocities.

A minimum velocity of 0.3 m/sec can be taken, but for looped systems there are also pipelines with sections having velocity <0.1m/sec.

Head loss is related to velocity and pipe roughness. The maximum head loss with therefore be governed by the maximum velocity criterion.

Experience shows that a pipe designed to flow at a velocity between 0.6 and 2 m/sec, depending on diameter, is usually at optimum condition (head loss versus cost). Short sections, particularly at special cases, e.g. at inlet and outlet of pumps, may be designed for higher velocities.

- 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.
- Minimum dynamic head was established at 10 m.
- Maximum velocities of major transmission mains $\leq$ 2.5 m/s.
- Maximum velocities of distribution mains $\leq$ 2 m/s.
- Minimum velocities range 0.1-0.3 m/s within the system.

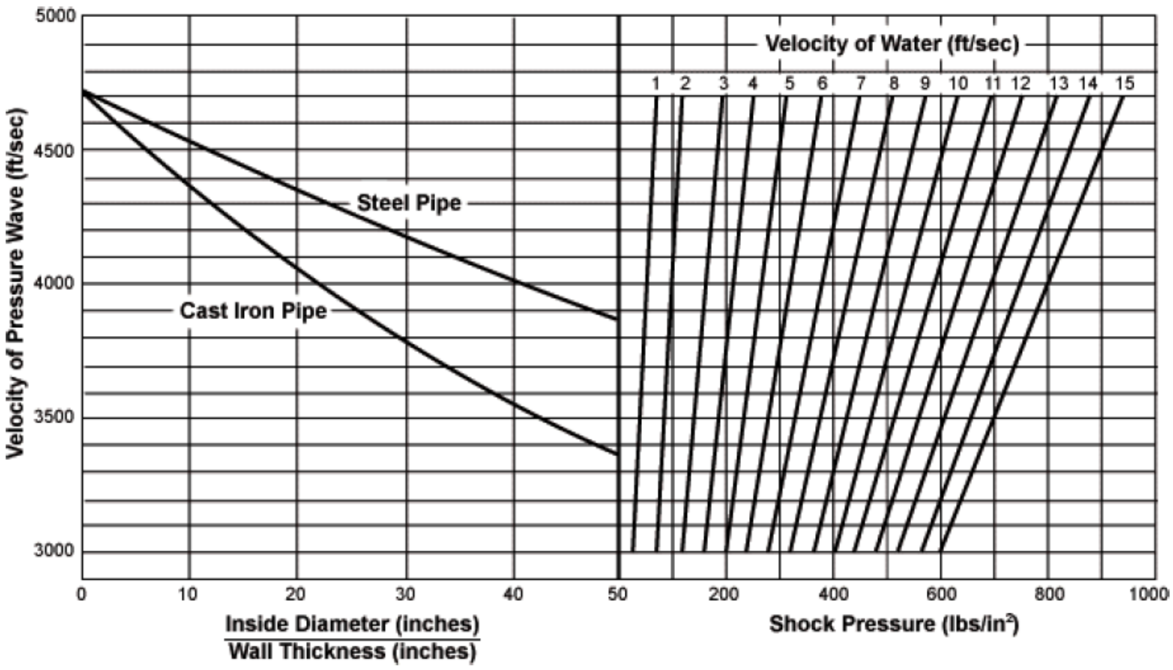
6.3.3 Evaluation of Water Hammer in the Addis Ababa Water System

Water hammer is a series of pulsations of varying magnitude within a pumped liquid. The amplitude and period depend on the velocity of the fluid, as well as on the material, size and strength of the pipe. Shock results from these pulsations when the liquid is suddenly stopped, such as by closing of a valve.

This force is a destructive force that can damage residential or commercial plumbing systems and cause leaking at joints. An evaluation of the water hammer in the Addis Ababa Water distribution system has been implemented to investigate the effects of this force on the system, depending on simple calculation to estimate the maximum shock pressure by using figure 6.9. The factors affecting the water hammer presence in the water systems include.

- Improperly sized supply lines for given peak water flow velocity.
- Excessive system water pressure and lack of pressure reducing apparatus.
- Excessively long straight runs with no bends.
- Lack of expansion tank or other dampening system, such as water hammer arresters.

Chart 6.1 Maximum shock pressure caused by water hammer



- To use Chart 6.1 first it should divide the inside diameter of the pipe by the wall thickness, and
- Enter the figure at this value, then project upward until making an intersection with the curve for either cast iron or steel pipe. This gives the velocity of the pressure wave to the left of the figure. Project this value horizontally to the right to intersect with the water speed line, then project down to get the value for the shock pressure.

As shown in table 6.3, different pipes in the system having different diameters, and velocities were chosen to calculate the shock pressure in the system.

Table 6.3 Maximum shock pressure caused by the water hammer

Pipe-Label	Length (m)	Material	Diameter (mm)	Diameter (in)	Actual Inside Diameter(in)	Wall Thickness (in)	Inside Diameter (in) / Wall Thickness (in)	Velocity of Pressure Wave (ft/sec)	Velocity of Water (m/sec)	Velocity of Water (ft/sec)	Shock Pressure (Ibs/in^2)
P-2	126	DI	900	35.43	35.433	0.8	44.29	3450	5.94	19.49	850
P-428	100	DI	150	5.91	5.906	0.236	25.02	3910	3.62	11.88	610
P-998	36	DI	125	4.92	4.921	0.236	20.85	4020	3.55	11.65	615
P-288	588	Steel	250	9.84	9.843	0.69	14.18	4450	3.28	10.76	620
P-460	2,732	DI	400	15.75	15.748	0.319	49.37	3370	2.87	9.42	440
P-289	1,331	DI	450	17.72	17.717	0.374	47.37	3410	2.87	9.42	445
P-481	63	DI	350	13.78	13.78	0.303	45.48	3415	2.8	9.19	405
P-296	740	DI	450	17.72	17.717	0.374	47.37	3405	2.57	8.43	380
P-50	21	Steel	300	11.81	11.811	0.8	14.73	4470	2.56	8.4	505
P-51	26	Steel	300	11.81	11.811	0.8	14.73	4470	2.56	8.4	505
P-48	24	Steel	300	11.81	11.811	0.8	14.73	4470	2.55	8.37	500
P-49	24	Steel	300	11.81	11.811	0.8	14.73	4470	2.55	8.37	500

As shown in table 6.3 it is obvious that the values of the maximum shock pressure caused by the water hammer is related strongly to the values of water velocity in the system, this mean that the value of the shock pressure and their effect will increase by increasing the water velocity.

Also a considerable note can be observed by making a comparison between the values of the shock pressure for different pipes diameters. It's observed that the value of the shock pressure is equal for different pipes when their velocities are equal. In typical water pipes, shock waves travel at up to 4500 ft/sec, and can exert tremendous instantaneous pressures, sometimes reaching 150 to over 1,000 Psi, and as its shown from the table 6.3, the values of the shock pressures lies within the limits that are common in the water pipes systems[3].

6.3.4 Modeling Scenarios

- One of the many project tools in Bentley Water CAD V8*i* is Scenario Management. Scenarios allow you to calculate multiple "What If?" situations in a single project file. You may wish to try several designs and compare the results, or analyze an existing system using several different demand alternatives and compare the resulting system pressures.

- A Scenario is a set of Alternatives, while alternatives are groups of actual model data Scenario and alternatives are based on a parent/child relationship where a child scenario or alternative inherits data from the parent scenario or alternative.

- The water distribution network in the continuous supply systems should be designed to with stands the range of pressures corresponding to the minimum and maximum supply conditions. Which means: at (average day demand (base demand) , peak hour demand & low flow demand,(night flow demand)

- Here are sample Scenarios & Alternatives for Study the System.

  i. Steady State Simulation Average daily demand alternatives as base scenario
  ii. Extended Period Simulation -Peak hour demand as child scenario
  iii. Firefighting flow demand alternative as child scenario (Peak hou+1hr fire flow)
  iv. Future Water requirement is checked for, 2020.
  v. System conditions are computed over a given duration at a specified time increment
  vi. System behaviors that can be analyzed using an EPS include:
     - How tank levels fluctuate,
     - When pumps are running,
     - Whether valves are open or closed, and
     - How demands change throughout the day.

7 RESULTS AND DISCUSSION

7.1 Results Presentation from Continuous Model

The results of continuous model of Addis Ababa water distribution network discuss the ability of the existing system with the assumed assumptions and development measures such as the availability of water, increasing of demand, reducing the losses and high pressures, to satisfy the requirements of demands, limits of velocities and pressures in order to provide the water by acceptable quantity and quality in the future.

Scenarios and alternatives allow you to create, analyze, and recall an unlimited number of variations of your model. In Bentley WaterCAD V8*i*, scenarios contain alternatives to give you precise control over changes to the model.

7.2 Evaluation of the system in different condition

7.2.1 Steady state Simulation

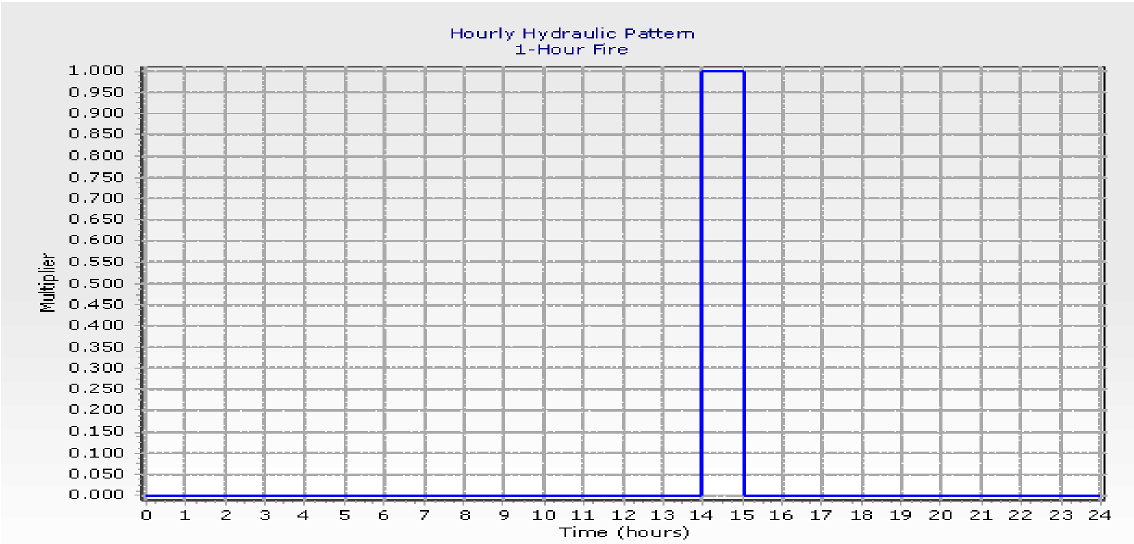
Represent a snapshot in time and are used to determine the operating behavior of a system under static conditions. This type of analysis can be useful in determining the short-term effect of fire flows or average demand conditions on the system.

7.2.2 Extended Period Simulation (EPS)

Extended period simulations (EPS) are used to evaluate system performance over time. This type of analysis allows the user to model tanks filling and draining, regulating valves opening and closing, and pressures and flow rates changing throughout the system in response to varying demand conditions and automatic control strategies formulated by the modeler.

7.2.2.1 Fire flow Demand Scenario

Figure 7.1 Hourly Hydraulic Pattern of 1-Hr Fire flow



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5/5/2014

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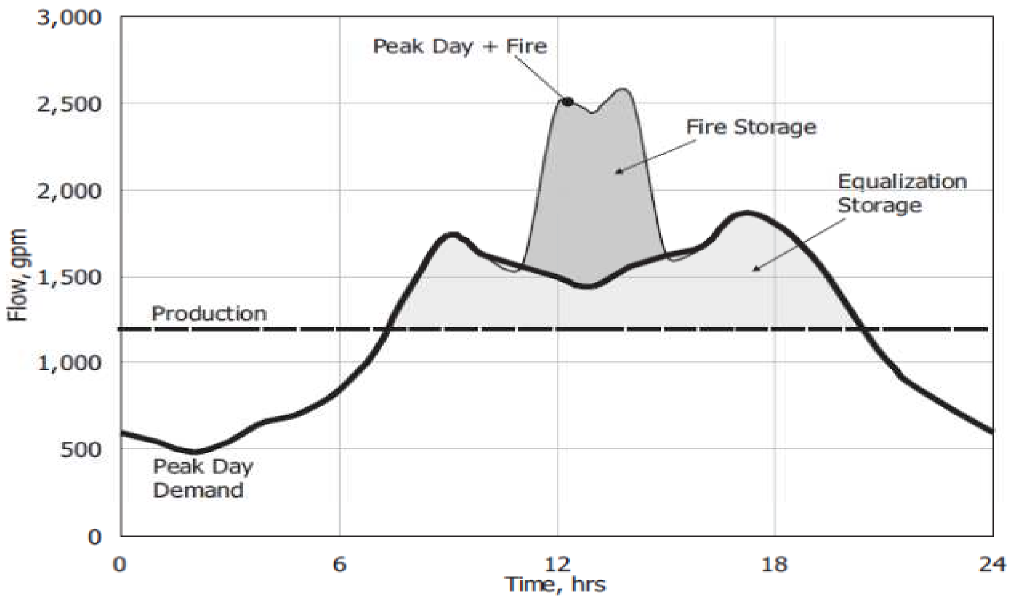
27 Siemon Company Drive Suite 200 W Watertown, CT 06795 USA +1-203-755-1666

Figure 7.2 Demand Pattern of the Day including the Fire Demand



7.2.2.2 Future Water requirement is checked for the existing demand, 2020 and 2025

7.2.2.2.1 Demand Control Center

The Demand Control Center is an editor for manipulating all the demands in your water model. Using the Demand Control Center, you can add new demands, delete existing demands, or modify the values for existing demands using standard SQL select and update queries.

The Demand Control Center provides demand editing capabilities which can:

- Open on all demand nodes, or subset of demand nodes,
- Sort and filter based on demand criteria or zone, add ,edit, and delete individual demands,
- Global Edit demands, Provides access to statistics for the demands listed in the table, and filter elements based on selection set, attribute, predefined query, or zone.

Planning Scenarios- Check the system for future demands 2020/2025

64.7% 0f nodes has negative pressure and couldn't meet the required water demand, hence there is high level of Demand shortfall along the nodes. Refer Appendix A.11

7.2.2.3 Low flow Demand Scenario

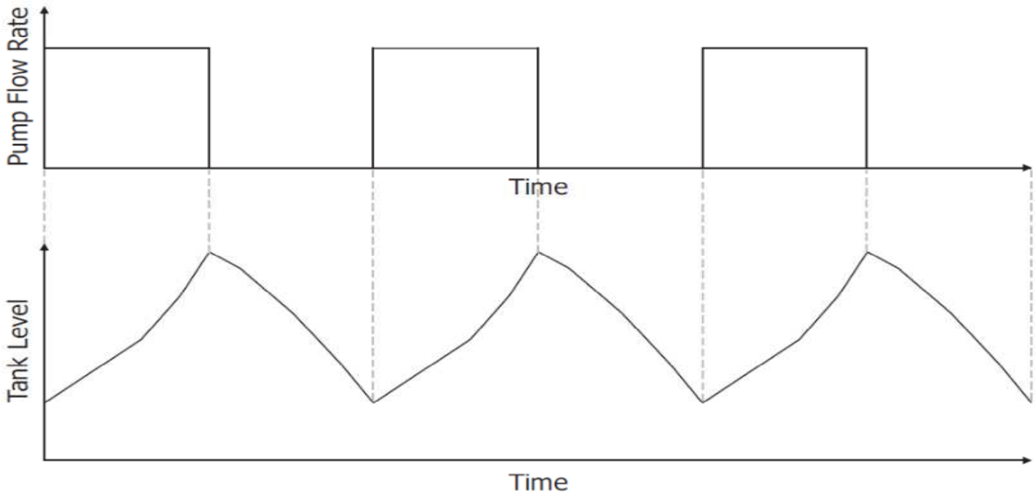
System behaviors that can be analyzed using an EPS include:

- How tank levels fluctuate,
- When pumps are running,
- Whether valves are open or closed, and
- How demands change throughout the day.

7.2.2.4 Indicators of Control Settings

If a pressure switch setting is unknown, tank level charts and pumping logs may provide a clue. As shown in Figure 7.3, pressure switch settings can be determined by looking at tank level charts and correlating them to the times when pumps are placed into or taken out of service. Operations staff can also be helpful in the process of determining pressure switch settings.

Figure 7.3 Correlation between tank levels and pump operation



7.3 Discussion

7.3.1 Findings

In general the analysis shows that the capacity of the existing distribution system is insufficient to supply water from the current source of the town in the required pressure and rate.

For the existing situation of the Addis Ababa water distribution system, (Legedadi subsystem) the following Research Findings have been found:

- *Insufficient availability of water in the systems- un-optimized network performance and insufficient source. For which the demand and the supply of the water is entirely in compatible. Besides, the existing water network can't even serve in its full performance and capacity.*
- *Unstructured network made of old pipes.*
- *Excessive and low service pressures are observed.*
- *Intermittent supply.*
- *No definite Pressure Zoning.*
- *The intermittent supply (Excessive Pumping) is affecting the hydraulic performance of the network and exposes it to high values of pressure and velocities.*
- *There is adverse effect of the intermittent systems on the readings of the customer water meters due to the pushed and sucked air in the network.*
- *Data base management problem-lacks integration.*

Hence for the Modified System –The system calculates pressure zone for the modified system. As a result, nodes entered to their appropriate pressure zone got improved discharge.

The outputs show that the network is exposed to relatively high and low values of pressure and velocity, which have negative effects on the performance of the network.

The comparison of pressure & results and field measurements at specific locations shows a reasonable and small difference.

- The demand nodes which are far away from the sources or booster stations -have been suffering from low pressure values as its shown in table 7.1 and registered for example at the nodes: (J-RK 10, J-112, RK8, B8, RK7, SP26, J-101, J74, J-71)

- The results of the pressure values in the whole system as it is mentioned in the Appendix (A.1, A.3, A.5, A.7, A.9, A.11 & A.13) show the ability of the system to satisfy the needed pressures, In our case all 45% of nodes in the given alternatives experience pressures below and above the design criterion.

- The results of velocities in the continuous system as shown in Appendix (A.2, A.6, A.10, A.12, & A.14) just like the pressure head there are pipes that experiencing unreasonable values of velocities, which are beyond the assumed limits of velocities. Velocities should be with in the allowable limit to avoid stagnation and water quality problems, also to save the pipes from deterioration due to the high velocities.

- The negative sign of the discharges in the pipes as shown in Appendix (A.1, A.3, A.5, A.7, A.9, A.11 & A.13) is an indication to the wrong in assuming direction only.

Here is the summarized Hydraulic Parameters Evaluation and Comparison for the different Scenarios and Alternatives

Table 7.1 Hydraulic Parameters Comparison in different Scenarios

Hydraulic Parameters for Evaluation							
		Pressure (m)			Velocity (m/s)		
S.No	Senario/ Alternatives	Pressure >80m	Pressure <20m	Pressure 20m>P<80m	Velocity> =2.5m/s	Velocity< =0.1m/s	Velocity 0.1m/s<=V >=2.5m/s
1	Base- Avg Day Demand-SSA	7.30%	29.67%	63.02%	0.53%	20.00%	79.47%
2	Low flow Scenario	15.85%	25.50%	58.65%	0.53%	25.66%	73.81%
3	Peak hour (at 14PM) EPS Analsis	1.59%	61.75%	36.66%	5.61%	20.32%	74.07%
4	Peak hour + 1-Hr fire flow-EPS Analsis	0.00%	72.06%	27.94%	12.56%	17.64%	69.80%
5	Peak hour + 1-Hr fire flow+ Future Demand, 2025, EPS Analsis	0.00%	89.97%	10.03%	26.47%	27.80%	45.73%
6	Modified Model-EPS Run	0.00%	45.75%	54.25%	5.86%	17.64%	76.50%

7.3.2 Average Day Demand Findings

User Notifications

Message Id	40004
Scenario	Base- Avg Day Demand
Element Type	Junction
Element Id	183
Label	T12
Time	0
Message	Negative pressure at Junction T12.
Source	Calculation Warnings
Message Id	40004
Scenario	Base- Avg Day Demand
Element Type	Junction
Element Id	367
Label	SP27
Time	0
Message	Negative pressure at Junction SP27.
Source	Calculation Warnings
Message Id	40004
Scenario	Base- Avg Day Demand
Element Type	Junction
Element Id	507
Label	B11
Time	0
Message	Negative pressure at Junction B11.
Source	Calculation Warnings
Message Id	40004
Scenario	Base- Avg Day Demand
Element Type	Junction
Element Id	589
Label	IC7
Time	0
Message	Negative pressure at Junction IC7.
Source	Calculation Warnings

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Table 7.2 Nodes having low values of pressure, Steady state Analysis (-4<=P<=10m)

ID	Label	Elevation (m)	Demand Pattern	Demand (m^3/s)	Hydraulic Grade (m)	Pressure (m H2O)
589	IC7	2,441.00	Domestic	0.008	2,437.60	-3.39
507	B11	2,610.00	Domestic	0.003	2,607.78	-2.22
367	SP27	2,491.00		0.000	2,490.05	-0.95
183	T12	2,512.00	Domestic	0.003	2,511.96	-0.04
136	L117	2,406.00		0.000	2,406.65	0.65
135	L22	2,406.00	Domestic	0.013	2,406.71	0.71
634	J-104	2,615.00		0.000	2,616.04	1.04
186	T13	2,510.00	Domestic	0.003	2,511.39	1.38
443	E4	2,635.00	Domestic	0.014	2,636.49	1.48
421	J-87	2,404.00		0.000	2,406.22	2.22
146	L125	2,404.00		0.000	2,406.56	2.55
217	J-92	2,682.00		0.000	2,685.16	3.16
524	J-86	2,434.00		0.000	2,437.61	3.60
215	J-90	2,637.00		0.000	2,640.86	3.85
145	L124	2,402.00		0.000	2,406.15	4.14
149	L128	2,402.00		0.000	2,406.20	4.19
147	L126	2,402.00		0.000	2,406.34	4.34
629	E12	2,560.00	Domestic	0.006	2,564.37	4.36
140	L119	2,402.00		0.000	2,406.46	4.45
143	L122	2,402.00		0.000	2,406.46	4.45
144	L123	2,402.00		0.000	2,406.46	4.45
445	J-128	2,385.00	Domestic	0.012	2,389.47	4.46
175	J-49	2,507.00		0.000	2,511.88	4.87
470	B7	2,631.00	Domestic	0.002	2,635.89	4.88
171	J-45	2,507.00		0.000	2,512.01	5.00
176	J-50	2,507.00		0.000	2,512.08	5.07
173	J-47	2,507.00		0.000	2,512.09	5.08
190	J-64	2,560.00		0.000	2,565.81	5.79
193	J-67	2,560.00		0.000	2,565.81	5.79
155	J-28	2,460.00		0.000	2,465.97	5.96
159	J-32	2,460.00		0.000	2,465.98	5.97
158	J-31	2,460.00		0.000	2,465.99	5.98
161	J-35	2,460.00		0.000	2,466.01	6.00
165	J-39	2,460.00		0.000	2,466.03	6.02
169	J-43	2,460.00		0.000	2,466.03	6.02
163	J-37	2,460.00		0.000	2,466.04	6.03
168	J-42	2,460.00		0.000	2,466.05	6.03
191	J-65	2,560.00		0.000	2,566.10	6.08
354	T3	2,440.00	Domestic	0.012	2,446.29	6.28
189	J-63	2,560.00		0.000	2,566.46	6.45
154	J-27	2,400.00		0.000	2,406.48	6.47
198	J-72	2,483.00		0.000	2,489.75	6.73
199	J-73	2,483.00		0.000	2,489.75	6.73
201	J-75	2,483.00		0.000	2,489.80	6.79
569	J-114	2,417.00	Domestic	0.005	2,424.55	7.54
522	B10	2,600.00	Domestic	0.043	2,607.82	7.81
332	J-138	2,390.00	Domestic	0.046	2,399.34	9.32
179	E15	2,564.00	Domestic	0.003	2,573.66	9.64

It is obvious from the table (7.2), that the high values of pressure appear at the nodes nearest to the sources of water or booster stations as its shown in the intermittent systems which lead also to conclude that the consumer far away from the supply points will need to be more patient, some high values of pressure are specified at the nodes

(J-RK 10, J-112, RK8, B8, RK7, SP26, J-101, J74, J-71)

Table 7.3 Nodes having high values of Pressure (80>=P<=171.32m)

ID	Label	Elevation (m)	Demand Pattern	Demand (m^3/s)	Hydraulic Grade (m)	Pressure (m H2O)
151	L130	2,402.00		0.000	2,485.31	83.14
148	L127	2,402.00		0.000	2,485.45	83.28
150	L129	2,402.00		0.000	2,485.45	83.28
271	L69	2,283.00	Domestic	0.003	2,366.58	83.41
345	J-120	2,371.00	Domestic	0.006	2,455.75	84.58
246	J-55	2,350.00		0.000	2,435.43	85.26
283	L70	2,280.00	Domestic	0.003	2,366.48	86.30
346	J-121	2,366.00	Domestic	0.006	2,454.73	88.55
194	J-68	2,560.00		0.000	2,657.77	97.58
495	RK10	2,553.00	Domestic	0.001	2,655.11	101.91
428	J-112	2,346.00	Domestic	0.013	2,450.20	103.99
478	RK8	2,538.00	Domestic	0.001	2,644.52	106.30
488	B8	2,636.00	Domestic	0.002	2,743.82	107.60
405	RK7	2,511.00	Domestic	0.001	2,647.87	136.59
424	SP26	2,493.00	Domestic	0.005	2,631.67	138.40
632	J-101	2,545.00		0.000	2,694.59	149.29
200	J-74	2,483.00		0.000	2,654.52	171.17
197	J-71	2,483.00		0.000	2,654.67	171.32

Table 7.4 Links having velocity less than 0.1m/s

ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (m^3/s)	Velocity (m/s)
733	P-5	70	J-4	ST2	1,200.00	Steel	100	0	0
734	P-6	75	ST2	J-5	1,200.00	Steel	100	0	0
743	P-15	49	L22	ST4	1,200.00	Steel	100	0	0
747	P-21	148	L114	AN	600	Steel	100	0	0
775	P-58	71	J-27	L117	1,000.00	Steel	100	0	0
957	P-320	872	L104	J-70	300	DI	100	0	0
1029	P-463	27	J-125	J-126	400	DI	100	0	0
1043	P-478	11	J-116	J-117	200	DI	100	0	0
1142	P-583	730	B10	B9	110	PVC	110	0	0
1198	P-677	900	J-106	J-112	300	DI	90	0	0
1250	P-769	898	J-141	J-137	500	DI	90	0	0
1254	P-775	21	J-135	J-136	150	DI	90	0	0
1327	P-887	172	SP27	J-76	300	DI	100	0	0
810	P-106	16	TM2	J-47	350	Steel	100	0	0
776	P-62	12	J-31	JM3	300	Steel	100	0	0

813	P-108	34	J-46	J-48	400	DI	100	0	0
856	P-165	16	ME2	J-82	400	Steel	120	0	0
855	P-164	18	J-81	ME2	300	Steel	120	0	0
797	P-91	20	J-43	J-39	350	Steel	100	0	0
777	P-63	14	JM3	J-30	250	Steel	100	0	0
771	P-52	30	L127	L129	400	DI	100	0	0
754	P-31	25	L119	L122	1,000.00	Steel	100	0	0
751	P-28	24	L118	L120	900	DI	100	0	0
750	P-27	18	TR3	L118	500	Steel	100	0	0
798	P-92	20	J-40	J-44	250	Steel	100	0	0
800	P-95	12	J-39	JM9	200	Steel	100	0	0
749	P-26	19	L119	TR3	600	Steel	100	0	0
845	P-153	12	J-73	MO2	300	Steel	100	0	0
841	P-148	27	J-72	J-73	300	Steel	100	0	0
846	P-154	11	MO2	J-74	250	Steel	100	0	0
817	P-113	38	J-52	J-51	150	Steel	100	0	0
818	P-115	12	J-50	TM4	150	Steel	100	0	0
801	P-96	15	JM9	J-40	150	Steel	100	0	0
765	P-46	25	L126	TR6	150	Steel	100	0	0
766	P-47	23	TR6	L127	150	Steel	100	0	0
837	P-142	19	J-64	Entoto2	150	Steel	100	0	0
833	P-137	20	J-67	J-64	150	Steel	100	0	0
819	P-116	12	TM4	J-52	125	Steel	100	0	0
838	P-143	33	Entoto2	J-68	125	DI	100	0	0
809	P-104	15	J-46	TM2	300	Steel	100	0	0
781	P-68	12	J-33	J-30	300	Steel	100	0	0
1454	P-650	27	RK	PMP-49	150	DCI	100	0	0
1455	P-651	29	PMP-49	J-101	150	DCI	100	0	0
852	P-162	43	M23	J-81	250	Steel	100	0	0
1340	P-900	409	J-91	L115	150	Steel	90	0	0
1405	P-965	384	J-141	J-130	800	DI	100	-0.002	0
946	P-305	626	L154	J-79	300	DI	100	0	0.01
860	P-174	734	M19	J-78	600	DI	110	-0.002	0.01
1053	P-493	960	T8	T10	150	DI	80	0	0.01
1280	P-823	159	L42	L43	200	DI	110	-0.001	0.02
982	P-350	796	L154	L108	300	Steel	90	0.001	0.02
1325	P-885	778	J-78	M18	300	DI	100	0.002	0.02
978	P-345	127	L155	L154	400	DI	100	0.003	0.03
826	P-126	2,450	T12	SP15	250	DI	100	0.001	0.03
1203	P-704	455	J-84	J-137	500	DI	90	0.007	0.04
1425	P-985	587	T18	T9	200	DI	100	0.001	0.04
857	P-169	20	J-78	ME1	400	Steel	120	0.006	0.04
1329	P-889	854	J-76	SP12	300	DI	120	0.003	0.04
848	P-156	53	MO	J-75	300	DCI	100	0.003	0.04
849	P-157	14	J-75	MO3	300	Steel	100	0.003	0.04
1283	P-826	681	J-79	L156	150	GI	90	0.001	0.05
1153	P-658	812	RK9	RK8	50	PVC	110	0	0.05
851	P-160	1,142	L35	J-79	600	DI	100	0.015	0.05
938	P-290	212	L36	L35	900	Steel	100	0.037	0.06
1248	P-761	461	J-84	J-135	150	Steel	90	0.001	0.06

1271	P-814	102	L153	L37	150	Steel	80	0.001	0.06
977	P-344	456	L35	L155	400	DI	100	0.008	0.06
850	P-158	13	MO3	J-76	250	Steel	100	0.003	0.06
1337	P-898	257	IC7	J-86	400	Steel	90	-0.008	0.07
980	P-347	388	L38	L40	600	DI	110	0.02	0.07
858	P-170	18	ME1	M23	300	Steel	100	0.006	0.08
831	P-135	2,035	B14	SP16	150	DI	100	0.001	0.08
1279	P-822	2,052	L28	L47	200	DI	100	-0.003	0.08
1199	P-584	405	B10	B11	200	DI	90	0.003	0.08
1434	P-994	516	L111	L28	400	DI	100	0.012	0.09

The above 77 pipes in the system has a velocity less than the minimum limits, of minimum velocities which is 0.1-0.3 m/s. Minimum velocities should be avoided from the system to the in order to avoid stagnation and water quality problems. To resolve this problem, maintaining the limits of minimum pressure.

Actually 0 velocities are expected in the loop kind of water distribution system.

Table 7.5 Links with high velocity value

ID	Label	Length (User Defined) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (m^3/s)	Velocity (m/s)	Headloss Gradient (m/m)	Has User Defined Length?
1460	P-582a	16	B7	J-104	90.0	DI	80.0	0.045	7.10	1.276	False
1479	P-2	126	R-2	LAGADA DI TANK	900.0	Ductile Iron	130.0	3.779	5.94	0.025	False

7.3.3 Peak hour + 1-Hr fire flow

For the Peak hour demand + 1-Hr Fire flow Scenario 72.06% of the demand is not satisfied and 18.72% of the velocities are above 2 m/s. See Appendix A.9 & A.10

7.3.4 Low flow Scenario

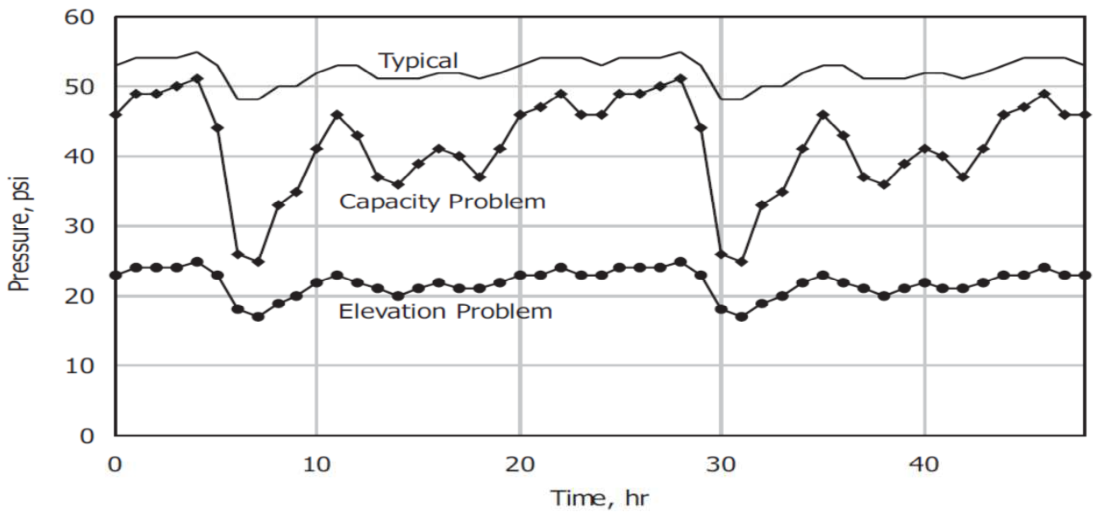
For the Low flow Scenario 25.5 % of the demand is below the allowable pressure limit. And only two pipes (P-2 &P-3) have the velocities above 2m/s, See Appendix A.13 &14

7.3.5 Peak hour + 1-Hr fire flow+ Future Demand, 2020

As we have observed from the result data the existing system hydraulic performance is unable to satisfy the future demand for 2020. 32.62 % of the pipes has high value of velocity above 2m/s and 89.97% of the demands are not satisfied and out of it 64.77% of the nodes have very large negative number, and very high head losses are observed. See Appendix A.11 &12

7.4 System capacity Performance

Figure 7.4 EPS runs showing low pressure due to elevation or system capacity



As per the above figure, we can conclude that as the system's network has the capacity problem, because most nodes in the system have the very sinusoidal pressure modes at the nodes. (Refer Figure 7.4)

7.5 Criticality analysis for the Existing System

The most important function of criticality analysis is the ability of the system to meet demands given a segment outage. A form of this analysis is the case where the shortfalls are determined solely based on connectivity. If the node is connected back to the source, it is assumed the demands are met.

Table 7.6 Criticality Segmentation Results, for the Peak hour +1-Hr fire flow
Criticality Segmentation Results

Segment	Are all demands met?	Is Balanced?	Maximum Allowable Demand Shortfall (%)	System Demanded Volume (L)	System Supplied Volume (L)	System Demand Shortfall (%)	Node with Largest Percent Demand Shortfall	Demand Shortfall at Worst Node (%)	Node with Largest Volume Shortfall	Volume Demanded at Worst Node (L)	Node with the Largest Pressure Shortfall	Pressure Demanded at Worst Node (m H2O)	Pressure Supplied at Worst Node (m H2O)
Criticality Segment – 1	False	True	50.0	192,064,526.6	0.0	100.0	L22	100.0	L47	23,416,710.3	(N/A)	(N/A)	(N/A)
Criticality Segment – 2	True	True	50.0	192,064,526.6	125,543,062.5	34.6	L47	100.0	L47	23,416,710.3	SP26	10.0	-260,168,343.91
Criticality Segment – 3	True	True	50.0	192,064,526.6	125,543,062.5	34.6	L47	100.0	L47	23,416,710.3	SP26	10.0	-260,168,343.91
Criticality Segment – 4	True	True	50.0	192,064,526.6	125,543,062.5	34.6	L47	100.0	L47	23,416,710.3	SP26	10.0	-260,168,343.91

System Demand Shortfall easily detected and shows the degree this shortfall from the criticality analysis**.** Figure 7.4 EPS run showing sample nodes having system capacity problems

7.6 Proposals for the System Operation

7.6.1 Darwin Designer to Optimize the Setup of a Pipe Network

In this lesson, you use Darwin Designer to optimize the setup of a pipe network.

There are three scenarios:

- **Existing System** representing current system conditions
- **Future Condition** representing the system expansion layout
- **Optimization Base** representing the base scenario that Designer will optimize.

7.6.2 Old pipes need to be rehabilitated

By applying possible actions including cleaning pipe, relining pipe, and leaving the pipe as it is (no action or do nothing to a pipe).

From the above table 69% of the Pipes are from 30-40 years , 21.1% of the pipes have 40 -50 years & 9% of the pipes are above 50 years.

Table 7.7: Pipes require Replacement (Year of Construction >=30Years)

Pipe - Id	Shape _Leng(m)	Dia_mm	Material	Yr_Cons	X_Centroid	Y_Centroid	X_Start	Y_Start	Line_Type
P-1	625.24	150	ST	1,955	474386	999769	474114	999614	Distribution
P-2	505.17	200	DCI	1,955	472891	998939	473098	999044	Distribution
P-3	2,163.46	125	GS	1,955	471414	1000911	470714	1001679	Distribution
P-4	2,953.42	150	GS	1,955	471574	1000630	472355	999378	Distribution
P-5	354.61	150	ST	1,955	473872	995522	473993	995655	Distribution
P-6	520.04	125	GS	1,955	472159	999795	472023	1000017	Distribution
P-7	391.05	350	ST	1,955	472751	998618	472767	998450	Distribution
P-8	444.86	300	DCI	1,959	472152	999508	472272	999339	Distribution
P-9	375.65	300	DCI	1,959	471810	999284	471957	999402	Transmission
P-10	1,561.97	900	ST	1,970	485576	996988	486356	997005	Transmission
P-11	1,130.31	900	ST	1,970	486921	997037	487486	997041	Transmission
P-12	2,448.42	900	ST	1,970	483574	996973	482353	997056	Transmission
P-13	2,085.25	1,200	ST	1,970	483700	996987	484739	996983	Distribution
P-14	2,173.96	900	ST	1,970	481313	997370	482353	997057	Distribution
P-15	636.00	150	DCI	1,970	481102	997440	481409	997356	Distribution
P-16	1,100.03	150	ST	1,970	473617	997870	474123	997893	Distribution
P-17	6,698.04	900	DCI	1,970	492358	1000859	489562	1000182	Distribution
P-18	228.07	150	ST	1,970	474654	999965	474667	999855	Distribution
P-19	2,144.67	900	ST	1,970	489064	999243	488599	998299	Distribution
P-20	1,680.03	900	ST	1,970	488045	997667	488599	998299	Transmission
P-21	3,131.79	900	ST	1,970	479366	996838	480300	997702	Transmission
P-22	2,458.30	1,200	ST	1,970	481472	997350	482659	997052	Distribution
P-23	2,298.64	900	ST	1,970	476745	996448	477852	996752	Distribution
P-24	17.48	300	DCI	1,970	481408	997352	481406	997344	Distribution
P-25	567.06	400	ST	1,970	473627	995886	473910	995863	Transmission
P-26	1,613.70	900	ST	1,970	474925	995778	474123	995835	Distribution
P-27	669.80	100	GS	1,970	473555	996718	473849	996571	Distribution
P-28	345.58	100	DCI	1,970	473066	996605	473238	996621	Distribution
P-29	789.23	150	GS	1,970	473055	995821	472778	995998	Transmission
P-30	1,232.62	200	DCI	1,974	473842	1000984	473793	1000372	Distribution
P-31	520.71	150	DCI	1,975	476894	992859	477138	992949	Distribution
P-32	1,275.83	150	DCI	1,975	471723	999625	472102	999148	Distribution
P-33	1,187.25	150	DCI	1,975	473322	999129	473813	998837	Distribution
P-34	1,018.09	150	DCI	1,975	473338	1000038	473074	999662	Distribution
P-35	855.61	200	DCI	1,975	473437	999495	473078	999672	Distribution
P-36	710.51	250	DCI	1,975	473471	1000110	473168	999953	Distribution
P-37	1,195.28	350	DCI	1,975	472632	998815	472392	999126	Distribution
P-38	4,024.86	150	DCI	1,975	472602	1000728	472373	999256	Distribution
P-39	839.45	250	DCI	1,975	473731	999931	473838	1000292	Distribution
P-40	1,198.10	150	DCI	1,975	473641	1002159	473683	1001562	Distribution
P-41	435.70	150	DCI	1,975	475520	997243	475303	997227	Distribution
P-42	488.81	150	DCI	1,975	475502	997252	475359	997440	Transmission
P-43	1,129.39	150	DCI	1,975	473630	1002179	473455	1002702	Distribution
P-44	1,136.70	250	DCI	1,975	473884	990503	473927	989934	Distribution
P-45	516.91	350	DCI	1,975	473549	991837	473402	992457	Transmission
P-46	554.51	300	DCI	1,975	473717	991313	473622	991572	Distribution
P-47	737.86	200	DCI	1,975	472790	992812	473402	992457	Distribution
P-48	1,957.86	300	DCI	1,975	473831	998066	474474	998349	Distribution
P-49	487.00	150	DCI	1,975	475504	997253	475361	997440	Transmission
P-50	1,002.23	200	DCI	1,975	474035	993278	474353	993045	Distribution

P-51	698.74	150	DCI	1,975	476411	997458	476319	997121	Transmission
P-52	948.75	400	DCI	1,975	473816	999846	473771	1000279	Distribution
P-53	2,502.32	250	DCI	1,975	474257	999254	475205	998549	Distribution
P-54	327.47	200	DCI	1,975	472476	998678	472540	998825	Distribution
P-55	1,605.61	250	DCI	1,975	472617	999669	473168	999953	Transmission
P-56	463.36	150	DCI	1,975	472240	999394	472273	999544	Distribution
P-57	1,284.85	450	DCI	1,975	474829	995233	474683	994633	Distribution
P-58	545.88	250	DCI	1,975	477047	993205	476821	993389	Distribution
P-59	431.43	150	DCI	1,975	472486	996142	472402	996215	Distribution
P-60	62.34	150	DCI	1,975	473482	997848	473459	997856	Distribution
P-61	396.84	150	ST	1,975	477845	996539	477849	996737	Distribution
P-62	2,857.32	400	DCI	1,975	479284	996991	480331	997771	Distribution
P-63	1,077.81	125	DCI	1,975	475492	1000863	475072	1000800	Distribution
P-64	321.38	150	DCI	1,975	473974	999536	474114	999614	Distribution
P-65	1,858.80	200	DCI	1,975	474614	996633	475126	995894	Distribution
P-66	1,530.36	200	DCI	1,975	474693	996395	475127	995877	Distribution
P-67	760.15	150	DCI	1,975	475357	997236	475737	997245	Distribution
P-68	556.64	150	DCI	1,975	474270	997088	474480	996954	Distribution
P-69	691.53	350	DCI	1,975	474705	998142	474474	998351	Distribution
P-70	526.39	200	DCI	1,975	472754	998298	472710	998049	Distribution
P-71	666.00	200	DCI	1,975	473805	997632	474040	997702	Distribution
P-72	289.11	200	DCI	1,975	473759	997963	473901	997948	Distribution
P-73	3.84	150	DCI	1,975	475122	995880	475120	995879	Distribution
P-74	3.79	150	DCI	1,975	475122	995878	475121	995877	Distribution
P-75	17.13	150	DCI	1,975	475124	995884	475119	995880	Distribution
P-76	35.24	150	DCI	1,975	475128	995878	475139	995868	Distribution
P-77	11.44	150	DCI	1,975	475127	995888	475124	995885	Distribution
P-78	1,116.37	350	DCI	1,975	474561	998842	474474	998349	Distribution
P-79	42.71	350	DCI	1,975	474523	998384	474512	998403	Distribution
P-80	152.94	300	DCI	1,975	476614	997830	476573	997765	Distribution
P-81	681.05	250	DCI	1,975	474228	999478	473967	999696	Distribution
P-82	424.78	125	ST	1,976	478324	994405	478415	994597	Distribution
P-83	154.94	100	DCI	1,984	480170	997754	480164	997677	Distribution
P-84	2,186.30	150	GS	1,984	479441	997008	480195	997676	Distribution
P-85	1,099.26	1,200	ST	1,985	486905	997074	486356	997045	Distribution
P-86	1,620.34	1,200	ST	1,985	485546	997027	484739	996983	Distribution
P-87	1,740.94	1,200	ST	1,985	488068	997624	488633	998280	Distribution
P-88	6,476.27	1,400	ST	1,985	492257	1001347	489580	1000172	Distribution
P-89	2,929.84	300	DCI	1,985	471606	1000606	472379	999371	Distribution
P-90	1,920.77	500	DCI	1,985	473215	999077	472408	999318	Distribution
P-91	2,143.36	900	DCI	1,985	477568	997320	476648	997869	Distribution
P-92	1,001.16	900	ST	1,985	487965	997626	488328	997919	Transmission
P-93	431.05	1,200	ST	1,985	488791	998433	488880	998629	Transmission
P-94	2,741.17	900	DCI	1,985	475489	998485	476648	997869	Transmission
P-95	1,204.88	400	DCI	1,985	473817	1000902	473676	1001485	Transmission
P-96	1,645.49	400	DCI	1,985	474035	999774	473845	1000297	Distribution
P-97	805.37	500	DCI	1,985	474418	998969	474041	998853	Distribution
P-98	2,527.68	900	DCI	1,985	479740	996778	480328	997719	Transmission
P-99	1,704.72	1,200	ST	1,985	489177	999428	488880	998629	Transmission

From the above table 69% of the Pipes are from 30-40 years , 21.1% of the pipes have 40 -50 years & 9% of the pipes are above 50 years.

7.6.3 Existing pipes need to re-size:

Existing pipes need to re-size are:

Table 7.8 Existing pipes need to re-size are:

ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Revised Diameter (mm)	Material	Hazen-Williams C	Flow (m³/s)	Velocity (m/s)
965	P-582a	15	B7	J-104	90	150	Ductile Iron	80	0.077	12.07
941	P-2	126	R-2	LAGA TANK	900	950	Ductile Iron	130	2.932	4.61
937	P-428	100	J-27	J-138	150	200	Ductile Iron	100	0.078	4.39
936	P-998	36	L2	L3	125	150	Ductile Iron	100	-0.053	4.31
915	P-288	588	L116	L36	250	300	Steel	90	0.201	4.1
914	P-460	2,732	L130	J-127	400	450	Ductile Iron	100	0.442	3.52
844	P-289	1,331	L116	L46	450	500	Ductile Iron	90	0.563	3.54
836	P-481	63	J-132	J-131	350	400	Ductile Iron	100	0.355	3.69
834	P-296	740	L47	L46	450	500	Ductile Iron	90	-0.5	3.14
821	P-671	1,195	J-143	J-108	200	250	PVC	110	0.087	2.76
820	P-710	90	R1	E4	100	150	PVC	110	0.024	3.1
817	P-48	24	L128	TR5	300	200	Steel	100	0.221	3.12
816	P-787	377	G2	G1	150	200	Ductile Iron	100	-0.053	3.02
815	P-785	716	J-144	J-113	150	200	Ductile Iron	100	-0.054	3.04
805	P-485	667	J-131	J-119	300	350	Ductile Iron	90	0.189	2.68
803	P-647	19	PMP-47	J-101	75	150	Galvani Iron	90	0.074	16.69
802	P-646	622	J-101	RK10	75	150	Galvani Iron	90	0.011	2.39
767	P-118	13	TM3	J-51	125	160	Steel	100	0.205	16.67
1479	P-330	819	L19	L18	200	250	Ductile Iron	110	0.073	2.33
1460	P-100	13	JM7	J-41	150	200	Steel	100	0.1	5.63
1457	P-98	14	JM8	J-44	150	200	Steel	100	0.1	5.64
1453	P-252	20	UR1	J-55	200	250	Steel	100	0.114	3.63
1451	P-466	1,165	J-123	J-124	150	200	Ductile Iron	100	-0.041	2.32
1449	P-141	16	Entoto1	J-68	125	150	Steel	100	0.046	3.76
1438	P-152	12	MO1	J-71	250	300	Steel	100	0.2	4.07
1262	P-475	783	J-116	J-130	500	550	Ductile Iron	100	-0.484	2.46
1261	P-474	629	J-115	J-116	500	550	Ductile Iron	100	-0.48	2.45
1259	P-117	13	J-49	TM3	150	200	Steel	100	0.205	11.58
1216	P-804	942	PG	G1	200	250	Ductile Iron	100	0.094	3.01
1207	P-473	860	J-120	J-115	300	350	Ductile Iron	90	-0.208	2.94
1171	P-97	13	J-43	JM8	200	250	Steel	100	0.1	3.17
1148	P-251	16	C45	UR1	250	300	Steel	100	0.114	2.32
1128	P-139	1,259	J-68	R1	150	200	Ductile Iron	100	-0.054	3.05
1081	P-830	377	RK20	RK15	100	150	Galvani Iron	90	-0.022	2.84
1080	P-649	24	PMP-48	B8	100	150	Ductile Iron	90	0.057	7.32
1048	P-653	34	PMP-50	B8	100	150	Steel	100	0.057	7.32
1046	P-111	40	J-50	J-49	200	250	Steel	100	0.205	6.51
1041	P-110	43	TM	J-50	200	250	Steel	100	0.205	6.51
1040	P-529	1,551	L13	L8	200	250	Ductile Iron	120	0.128	4.08
1039	P-721	180	RK20	RK21	100	150	Galvani Iron	90	0.02	2.51
1032	P-530	646	L8	L9	150	200	PVC	120	0.11	6.2
1027	P-585	2,910	B7	SP26	150	200	Galvani Iron	90	0.109	6.14
1014	P-113	38	J-52	J-51	150	200	Steel	100	-0.1	5.66

7.6.4 Pipes having zero velocity –zero flow

Table 7.9 Pipes having zero velocity –zero flow

ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen - Williams C	Has Check Valve ?	Flow (m³/s)	Velocity (m/s)
733	P-5	70	J-4	ST2	1,200.0	Steel	100.0	False	0.000	0.00
734	P-6	75	ST2	J-5	1,200.0	Steel	100.0	False	0.000	0.00
743	P-15	49	L22	ST4	1,200.0	Steel	100.0	False	0.000	0.00
775	P-58	71	J-27	L117	1,000.0	Steel	100.0	False	0.000	0.00
957	P-320	872	L104	J-70	300.0	Ductile Iron	100.0	False	0.000	0.00
1029	P-463	27	J-125	J-126	400.0	Ductile Iron	100.0	False	0.000	0.00
1043	P-478	11	J-116	J-117	200.0	Ductile Iron	100.0	False	0.000	0.00
1142	P-583	730	B10	B9	110.0	PVC	110.0	False	0.000	0.00
1198	P-677	900	J-106	J-112	300.0	Ductile Iron	130.0	False	0.000	0.00
1250	P-769	898	J-141	J-137	500.0	Ductile Iron	130.0	False	0.000	0.00
1254	P-775	21	J-135	J-136	150.0	Ductile Iron	130.0	False	0.000	0.00
1327	P-887	172	SP27	J-76	300.0	Ductile Iron	100.0	False	0.000	0.00
776	P-62	12	J-31	JM3	300.0	Steel	100.0	False	0.000	0.00
810	P-106	16	TM2	J-47	350.0	Steel	100.0	False	0.000	0.00
856	P-165	16	ME2	J-82	400.0	Steel	120.0	False	0.000	0.00
813	P-108	34	J-46	J-48	400.0	Ductile Iron	100.0	False	0.000	0.00
781	P-68	12	J-33	J-30	300.0	Steel	100.0	False	0.000	0.00
777	P-63	14	JM3	J-30	250.0	Steel	100.0	False	0.000	0.00
855	P-164	18	J-81	ME2	300.0	Steel	120.0	False	0.000	0.00
797	P-91	20	J-43	J-39	350.0	Steel	100.0	False	0.000	0.00
852	P-162	43	M23	J-81	250.0	Steel	100.0	False	0.000	0.00
754	P-31	25	L119	L122	1,000.0	Steel	100.0	False	0.000	0.00
749	P-26	19	L119	TR3	600.0	Steel	100.0	False	0.000	0.00
771	P-52	30	L127	L129	400.0	Ductile Iron	100.0	False	0.000	0.00
800	P-95	12	J-39	JM9	200.0	Steel	100.0	False	0.000	0.00
845	P-153	12	J-73	MO2	300.0	Steel	100.0	False	0.000	0.00
841	P-148	27	J-72	J-73	300.0	Steel	100.0	False	0.000	0.00
750	P-27	18	TR3	L118	500.0	Steel	100.0	False	0.000	0.00
765	P-46	25	L126	TR6	150.0	Steel	100.0	False	0.000	0.00
766	P-47	23	TR6	L127	150.0	Steel	100.0	False	0.000	0.00
846	P-154	11	MO2	J-74	250.0	Steel	100.0	False	0.000	0.00
818	P-115	12	J-50	TM4	150.0	Steel	100.0	False	0.000	0.00
801	P-96	15	JM9	J-40	150.0	Steel	100.0	False	0.000	0.00
837	P-142	19	J-64	Entoto2	150.0	Steel	100.0	False	0.000	0.00
833	P-137	20	J-67	J-64	150.0	Steel	100.0	False	0.000	0.00
819	P-116	12	TM4	J-52	125.0	Steel	100.0	False	0.000	0.00
838	P-143	33	Entoto2	J-68	125.0	Ductile Iron	100.0	False	0.000	0.00
1454	P-650	27	RK	PMP-49	150.0	Ductile Iron	100.0	False	0.000	0.00
809	P-104	15	J-46	TM2	300.0	Steel	100.0	False	0.000	0.00
1340	P-900	409	J-91	L115	150.0	Steel	140.0	False	0.000	0.00
1280	P-823	159	L42	L43	200.0	Ductile Iron	110.0	False	0.000	0.00
982	P-350	796	L154	L108	300.0	Steel	140.0	False	0.002	0.03
1325	P-885	778	J-78	M18	300.0	Ductile Iron	100.0	False	0.003	0.04
826	P-126	2,450	T12	SP15	250.0	Ductile Iron	100.0	False	0.002	0.05
857	P-169	20	J-78	ME1	400.0	Steel	120.0	False	0.009	0.08
1283	P-826	681	J-79	L156	150.0	Galvanized iron	120.0	False	0.001	0.08
1417	P-977	587	T15	T1	150.0	Ductile Iron	100.0	False	0.000	0.01

1452	P-648	23	T-14	PMP-48	200.0	Ductile Iron	100.0	False	0.000	0.00
874	P-190	474	E14	R3	100.0	Ductile Iron	130.0	False	0.000	0.00
1450	P-645	21	RK	PMP-47	200.0	Galvanized iron	140.0	False	0.000	0.00
1276	P-819	1,291	L153	L46	250.0	Ductile Iron	100.0	False	0.000	0.00
1206	P-708	157	E3	R2	100.0	Ductile Iron	130.0	False	0.000	0.00
873	P-188	22	R2	J-92	100.0	Ductile Iron	100.0	False	0.000	0.00
1214	P-719	307	RK	RK13	250.0	Ductile Iron	130.0	False	0.000	0.00
1456	P-652	29	T-14	PMP-50	100.0	Steel	100.0	False	0.000	0.00
1208	P-711	262	E1	R3	75.0	Galvanized iron	120.0	False	0.000	0.00
1205	P-706	281	R3	E2	50.0	PVC	110.0	False	0.000	0.00
847	P-155	3,031	J-74	T-14	300.0	Ductile Iron	100.0	False	0.000	0.00
1217	P-722	62	B7	T-14	250.0	Ductile Iron	130.0	False	0.000	0.00

For the above pipes case, there is no flow along those pipes at the peak hour, 14hr due the high demand, but the system shows improvement.

7.6.5 PRV Recommendation for those nodes having very high pressure beyond the allowable limit

Figure: 7.5 Recommended PRV Location for the lower service areas

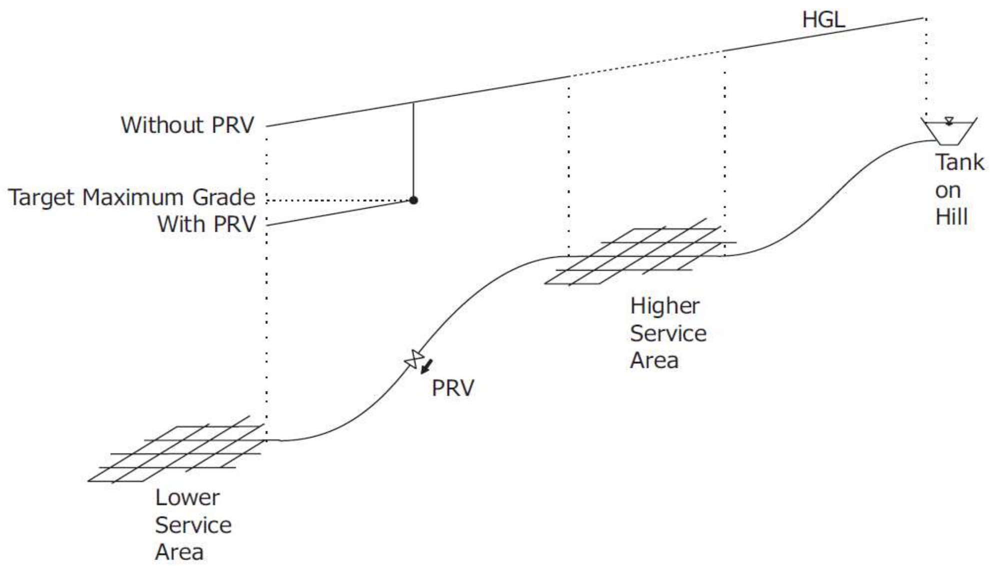


Table 7.10 Existing nodes with very high pressure

ID	Label	Elevation (m)	Demand Pattern	Demand (m^3/s)	Hydraulic Grade (m)	Pressure (m H2O)
197	J-71	2,483.00	Fire Demand	0.000	2,654.69	171.34
200	J-74	2,483.00	Fire Demand	0.000	2,654.54	171.20
405	RK7	2,511.00	Domestic	0.001	2,660.27	148.97
424	SP26	2,493.00	Domestic & Fire Demand	0.007	2,635.16	141.87
632	J-101	2,545.00	Fire Demand	0.000	2,671.84	126.59
478	RK8	2,538.00	Domestic	0.001	2,656.82	118.58
495	RK10	2,553.00	Domestic	0.001	2,670.73	117.49
428	J-112	2,346.00	Domestic & Fire Demand	0.018	2,446.21	100.01
398	RK22	2,431.00	Domestic	0.021	2,528.27	97.07
346	J-121	2,366.00	Domestic & Fire Demand	0.008	2,454.72	88.55
194	J-68	2,560.00	Fire Demand	0.000	2,646.73	86.56
345	J-120	2,371.00	Domestic & Fire Demand	0.008	2,456.63	85.46
283	L70	2,280.00	Domestic	0.004	2,362.85	82.68
488	B8	2,636.00	Domestic & Fire Demand	0.003	2,718.29	82.13

Thus, it is recommendable that nodes with very high pressures should incorporate PRV in the line except for the nodes of fire demand. (Rk7, Rk8, Rk10, Rk22, L70)

7.6.6 Managing very low pressure nodes

Low pressure (negative pressure) nodes, can be managed by using the Flow Control Valves (FCV)

7.6.7 Developing or optimizing pressure zone boundaries

7.6.7.1 Pressure Zones

Given the topographical layout of Legedadi Sub system, and the configuration of the existing distribution network, the task of dividing the study area into pressure zones is one of the significant tasks of this research work.

Allocating nodes to their appropriate pressure zoning would give the chance to the nodes getting better flow and pressure head. As a result, the system shows better improvement.

Construction of a workable model to simulate the city's distribution system, creating a key tool for its operation and management. In the pressure zoning, the software Water CAD that we use is highly responsible for categorizing the system. Formulation of a scheme for optimal division of the existing and future network into feasible pressure zones complying with sound technical and economic considerations.

Figure 7.6 Optimized pressure zone boundaries for the Legedadi Subsystem

The boundaries of the 14 pressure zones proposed for Legedadi sub-system were delineated. The network analysis identified and confirmed the preferred locations for reservoirs and pumping stations.

There are some areas where the static heads are in excess of the design value of 80 m; these include river valleys where very few or no housing units exist and the zoned recreational green areas. There are also a few areas where the static heads are slightly less than 20 m; these areas include small hills where little or no development has occurred.

Table 7.11: Pressure zone boundaries of Legedadi Sub-system

Pressure Zone	Nodes <Count>	Isolation Elements	Pipes	Boundary Pipes	Length (m)	Fluid Volume (L)
Pressure Zone – 1	171	17	233	9	182,092	56,758,161.60
Pressure Zone – 2	10	4	15	0	8,582	167,448.70
Pressure Zone – 3	11	4	14	1	9,602	430,659.40
Pressure Zone – 4	5	2	7	0	2,914	17,118.40
Pressure Zone – 5	39	15	57	1	21,531	1,604,311.50
Pressure Zone – 6	1	0	0	2	0	0
Pressure Zone – 7	1	0	0	1	0	0
Pressure Zone – 8	4	3	6	0	1,444	44,015.20
Pressure Zone – 9	2	1	2	1	868	61,049.10
Pressure Zone – 10	4	1	4	0	1,033	5,511.90
Pressure Zone – 11	4	2	5	0	621	6,690.90
Pressure Zone – 12	11	4	15	0	7,536	299,118.80
Pressure Zone – 13	2	2	3	0	79	4,673.50
Pressure Zone – 14	2	2	3	0	1,707	14,446.00

Table 7.12 Allocations of Reservoirs (Pumps), EPS Analysis, and Continuous Model

[redacted]		
Pressure Zone – 1	TR4	Pump
Pressure Zone – 1	TR5	Pump
Pressure Zone – 1	TR6	Pump
Pressure Zone – 1	UR1	Pump
Pressure Zone – 1	ME1	Pump
Pressure Zone – 1	ME2	Pump
Pressure Zone – 1	TP1	Pump
Pressure Zone – 1	TR2	Pump
Pressure Zone – 1	TR3	Pump
Pressure Zone – 1	JM3	Pump
Pressure Zone – 1	JM5	Pump

Pressure Zone – 1	JM4	Pump
Pressure Zone – 1	JM2	Pump
Pressure Zone – 1	JM1	Pump
Pressure Zone – 1	JM9	Pump
Pressure Zone – 1	JM8	Pump
Pressure Zone – 1	JM7	Pump
Pressure Zone – 2	PMP-49	Pump
Pressure Zone – 2	PMP-47	Pump
Pressure Zone – 2	TM4	Pump
Pressure Zone – 2	TM3	Pump
Pressure Zone – 3	PMP-50	Pump
Pressure Zone – 3	PMP-48	Pump
Pressure Zone – 3	MO1	Pump
Pressure Zone – 3	MO2	Pump
Pressure Zone – 4	PMP-47	Pump
Pressure Zone – 4	PMP-49	Pump
Pressure Zone – 5	MO2	Pump
Pressure Zone – 5	MO1	Pump
Pressure Zone – 5	MO3	Pump
Pressure Zone – 5	TM1	Pump
Pressure Zone – 5	TM2	Pump
Pressure Zone – 5	TM3	Pump
Pressure Zone – 5	TM4	Pump
Pressure Zone – 5	JM1	Pump
Pressure Zone – 5	JM2	Pump
Pressure Zone – 5	JM9	Pump
Pressure Zone – 5	JM8	Pump
Pressure Zone – 5	JM7	Pump
Pressure Zone – 5	JM3	Pump
Pressure Zone – 5	JM4	Pump
Pressure Zone – 5	JM5	Pump
Pressure Zone – 8	R1(1)	Pump
Pressure Zone – 8	Entoto1	Pump
Pressure Zone – 8	Entoto2	Pump
Pressure Zone – 9	MO3	Pump
Pressure Zone – 10	R2(1)	Pump
Pressure Zone – 11	R2(1)	Pump
Pressure Zone – 11	R1(1)	Pump
Pressure Zone – 12	Entoto2	Pump
Pressure Zone – 12	Entoto1	Pump
Pressure Zone – 12	TM1	Pump
Pressure Zone – 12	TM2	Pump
Pressure Zone – 13	ME2	Pump
Pressure Zone – 13	ME1	Pump
Pressure Zone – 14	PMP-50	Pump
Pressure Zone – 14	PMP-48	Pump

- Using Controls- Closing &opening of valves that are control the system from entrance of water from other sources & Check for intermittent supply, operating the pumps for different conditions.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

For the existing situation of Addis Ababa water distribution system, (Legedadi subsystem) the following conclusions have been made from the analysis result and findings.

- There is insufficient availability of water in the systems.
- Unstructured network made of old pipes.
- Excessive and low service pressures are observed.
- Intermittent supply, which is directly connected to the state of unavailability of water.
- No definite Pressure Zoning.
- The intermittent service is most of the water distribution systems of Addis Ababa.
- The intermittent supply affects the hydraulic performance of the network and exposes it to high values of pressure and velocities; which results adverse effect on the readings of the customer water meters due to the pushed and sucked air in the network.
- Original installation date missing for pipes and elements of the system with no trace to follow.
- Data base management problem-lacks integration.

In the modified system, the network runs for the Darwin Optimizer scenario for the modified pressure zone, then the system hydraulic parameters are drastically improved, therefore additional nodes and links are entered in the required allowable design criterion range especially for the critical hydraulic parameters. (Pressure & Velocity) (See table 7.1).

8.2 Recommendations

This study has found out the very crucial findings which are very important for the overall operation of Addis Ababa water distribution system. Finally, the researcher has tried to recommend some of the very important issues so as to improve the hydraulic performance of the water system.

1. Improve database management:

   It's highly advisable that developing a geo database for the whole system is an essential action for the existing system. Because, Geographic Information System is capable enough to build a reasonable management planning and rehabilitation plans for urban water distribution networks. Hence, it is more advisable that as the system hydraulic operation is to be integrated with GIS application.

2. Accurate demand allocation for each nodes using GIS tools. Using land use map of the city (Cadastral map).
3. The existing demand of the city does not satisfied, as the water production from the sources is less in amount than the need of the city -the system requires upgrading. Additional sources with their acceptable hydraulic structures should be supplemented to the system.
4. The system requires, rehabilitation, old pipes need replacement.
5. Under sized and over sized pipes should be re-sized.
6. As we have observed the existing system is highly expensive since about half of the city population is satisfied from the pumping system. Source development should consider the operation cost the distribution system. Gravity method is more advisable, it reduces operation cost and system durability. Since, excessive pumping affect the system hydraulic performance.
7. Some Pumps require capacity upgrading, because their capacity is clearly seen in the tank filling situation in the tank level data.

8. Nodes with zero flow (negatives) can also be managed through pumping to these nodes from the nodes having sufficient flow.
9. Apply Physical loss (Leakage) reduction strategies.
10. More local studies are recommended. This is to understand how the water systems in our region perform under the local conditions of operation and management.
11. Install PRVs to overcome the problems of high pressures and Surge tanks & ARVs to control Water Hammer Problem, especially at the pumping stations (Pressurized Lines).
12. Lowering of UFW.
13. Locate the fire protection nodes at the location where it satisfies the required pressure.
14. For transmission or gravity mains working at static pressures higher than pump capacities or pipe pressure ratings, require break pressure tanks and/or additional booster stations should be considered.
15. Consider the water demand for construction activities conducted in the city.
16. The city should work on the water harvesting strategies at house hold level.
17. Reduce NRW supply.
18. Implementing water conservation strategies such as: Water recycling strategies- Using backwash water for different purpose, such as toilet flushing, gardening, etc rather using clean potable water.

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APPENDICES

A. SAMPLES OF REFERENCE MATERIALS -(TABLES)

B. SAMPLES OF REFERENCE MATERIALS- (FIGURES)

APPENDICES

A. SAMPLES OF REFERENCE MATERIALS -(TABLES)

B. SAMPLES OF REFERENCE MATERIALS- (FIGURES)

STEADY STATE SIMULATION (SSS)

Appendix A.1 Nodes Steady State Analysis Results at Average Day Demand

Flex Table: Junction Table

ID	Label	Elevation (m)	Demand Pattern	Demand (m^3/s)	Hydraulic Grade (m)	Pressure (m H2O)
129	C1	2,410.00	Fixed	0.000	2,421.59	11.56
130	C1a	2,410.00	Fixed	0.000	2,421.58	11.56
131	J-4	2,410.00	Fixed	0.000	2,422.18	12.15
132	J-5	2,410.00	Fixed	0.000	2,422.05	12.02
133	J-6	2,400.00	Fixed	0.000	2,418.57	18.53
134	J-7	2,400.00	Fixed	0.000	2,418.49	18.46
135	L22	2,406.00	Fixed	0.013	2,406.71	0.71
136	L117	2,406.00	Fixed	0.000	2,406.65	0.65
137	L114	2,375.00	Fixed	0.006	2,400.94	25.89
138	L20	2,351.00	Fixed	0.057	2,399.63	48.53
139	L118	2,402.00	Fixed	0.000	2,475.89	73.75
140	L119	2,402.00	Fixed	0.000	2,406.46	4.45
141	L120	2,402.00	Fixed	0.000	2,475.89	73.75
142	L121	2,402.00	Fixed	0.000	2,475.89	73.74
143	L122	2,402.00	Fixed	0.000	2,406.46	4.45
144	L123	2,402.00	Fixed	0.000	2,406.46	4.45
145	L124	2,402.00	Fixed	0.000	2,406.15	4.14
146	L125	2,404.00	Fixed	0.000	2,406.56	2.55
147	L126	2,402.00	Fixed	0.000	2,406.34	4.34
148	L127	2,402.00	Fixed	0.000	2,485.45	83.28
149	L128	2,402.00	Fixed	0.000	2,406.20	4.19
150	L129	2,402.00	Fixed	0.000	2,485.45	83.28
151	L130	2,402.00	Fixed	0.000	2,485.31	83.14
152	J-131	2,427.00	Fixed	0.001	2,463.20	36.13
153	J-124	2,420.00	Fixed	0.022	2,458.28	38.20
154	J-27	2,400.00	Fixed	0.000	2,406.48	6.47
155	J-28	2,460.00	Fixed	0.000	2,465.97	5.96
156	J-29	2,460.00	Fixed	0.000	2,499.82	39.74
157	J-30	2,460.00	Fixed	0.000	2,499.92	39.84
158	J-31	2,460.00	Fixed	0.000	2,465.99	5.98
159	J-32	2,460.00	Fixed	0.000	2,465.98	5.97
160	J-33	2,460.00	Fixed	0.000	2,499.92	39.84
161	J-35	2,460.00	Fixed	0.000	2,466.01	6.00
162	J-36	2,460.00	Fixed	0.000	2,521.56	61.44
163	J-37	2,460.00	Fixed	0.000	2,466.04	6.03
164	J-38	2,460.00	Fixed	0.000	2,521.76	61.64
165	J-39	2,460.00	Fixed	0.000	2,466.03	6.02
166	J-40	2,460.00	Fixed	0.000	2,533.48	73.33
167	J-41	2,460.00	Fixed	0.000	2,533.42	73.27
168	J-42	2,460.00	Fixed	0.000	2,466.05	6.03
169	J-43	2,460.00	Fixed	0.000	2,466.03	6.02
170	J-44	2,460.00	Fixed	0.000	2,533.48	73.33
171	J-45	2,507.00	Fixed	0.000	2,512.01	5.00

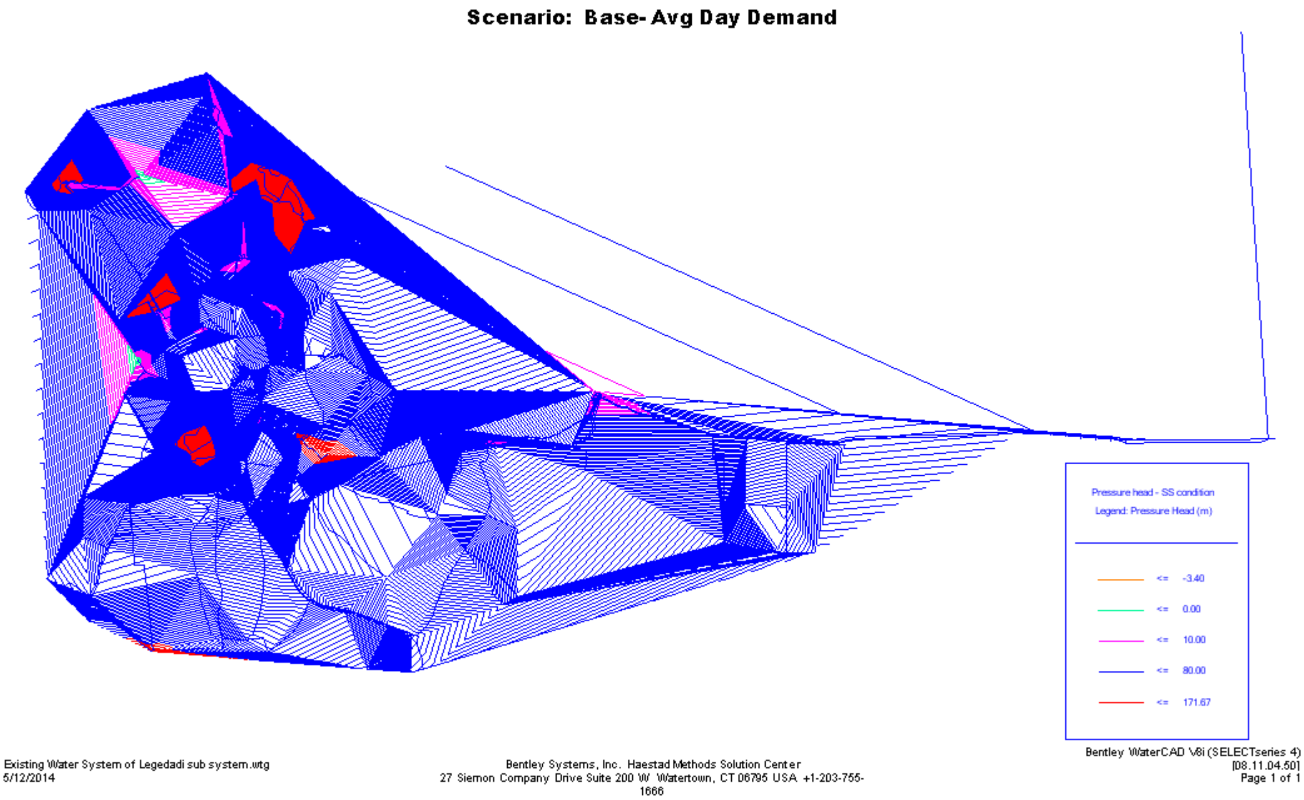
172	J-46	2,507.00	Fixed	0.000	2,569.49	62.37
173	J-47	2,507.00	Fixed	0.000	2,512.09	5.08
174	J-48	2,507.00	Fixed	0.000	2,569.49	62.37
175	J-49	2,507.00	Fixed	0.000	2,511.88	4.87
176	J-50	2,507.00	Fixed	0.000	2,512.08	5.07
177	J-51	2,507.00	Fixed	0.000	2,579.05	71.90
178	J-52	2,507.00	Fixed	0.000	2,579.05	71.90
179	E15	2,564.00	Fixed	0.003	2,573.66	9.64
180	J-133	2,432.00	Fixed	0.001	2,464.94	32.88
181	J-132	2,433.00	Fixed	0.001	2,464.44	31.37
182	T7	2,473.00	Fixed	0.007	2,508.33	35.26
183	T12	2,512.00	Fixed	0.003	2,511.96	-0.04
184	T9	2,459.00	Fixed	0.008	2,507.97	48.87
185	SP15	2,490.00	Fixed	0.001	2,511.94	21.90
186	T13	2,510.00	Fixed	0.003	2,511.39	1.38
187	T1	2,469.00	Fixed	0.005	2,507.49	38.42
188	B14	2,536.00	Fixed	0.048	2,547.59	11.57
189	J-63	2,560.00	Fixed	0.000	2,566.46	6.45
190	J-64	2,560.00	Fixed	0.000	2,565.81	5.79
191	J-65	2,560.00	Fixed	0.000	2,566.10	6.08
192	SP16	2,490.00	Fixed	0.001	2,547.36	57.24
193	J-67	2,560.00	Fixed	0.000	2,565.81	5.79
194	J-68	2,560.00	Fixed	0.000	2,657.77	97.58
195	L35	2,345.00	Fixed	0.001	2,374.21	29.16
196	SP17	2,476.00	Fixed	0.013	2,488.85	12.82
197	J-71	2,483.00	Fixed	0.000	2,654.67	171.32
198	J-72	2,483.00	Fixed	0.000	2,489.75	6.73
199	J-73	2,483.00	Fixed	0.000	2,489.75	6.73
200	J-74	2,483.00	Fixed	0.000	2,654.52	171.17
201	J-75	2,483.00	Fixed	0.000	2,489.80	6.79
202	J-76	2,483.00	Fixed	0.000	2,533.78	50.68
204	J-78	2,352.00	Fixed	0.000	2,373.92	21.88
205	J-79	2,340.00	Fixed	0.000	2,374.20	34.13
206	M23	2,352.00	Fixed	0.006	2,413.91	61.79
207	J-81	2,352.00	Fixed	0.000	2,413.91	61.79
208	J-82	2,352.00	Fixed	0.000	2,373.93	21.89
209	M18	2,345.00	Fixed	0.002	2,373.92	28.86
211	M19	2,345.00	Fixed	0.002	2,373.92	28.86
215	J-90	2,637.00	Fixed	0.000	2,640.86	3.85
216	E13	2,637.00	Fixed	0.003	2,688.22	51.11
217	J-92	2,682.00	Fixed	0.000	2,685.16	3.16
218	E14	2,682.00	Fixed	0.003	2,750.74	68.60
243	L37	2,349.00	Fixed	0.001	2,374.16	25.11
244	L112	2,350.00	Fixed	0.013	2,396.24	46.15
245	C45	2,350.00	Fixed	0.000	2,396.20	46.11
246	J-55	2,350.00	Fixed	0.000	2,435.43	85.26
247	J-118	2,423.00	Fixed	0.002	2,441.07	18.03
256	L28	2,325.00	Fixed	0.008	2,366.56	41.47
257	L116	2,332.00	Fixed	0.001	2,395.84	63.71
258	L46	2,335.00	Fixed	0.008	2,375.98	40.90
259	L36	2,336.00	Fixed	0.001	2,374.22	38.14

260	L40	2,347.00	Fixed	0.005	2,374.13	27.08
261	L41	2,326.00	Fixed	0.010	2,374.07	47.97
262	L44	2,311.00	Fixed	0.005	2,371.93	60.81
263	L47	2,317.00	Fixed	0.261	2,366.73	49.63
265	L45	2,305.00	Fixed	0.055	2,366.29	61.17
267	L42	2,300.00	Fixed	0.005	2,372.14	72.00
269	L154	2,340.00	Fixed	0.001	2,374.20	34.13
270	L113	2,351.00	Fixed	0.002	2,373.68	22.63
271	L69	2,283.00	Fixed	0.003	2,366.58	83.41
276	L81	2,292.00	Fixed	0.002	2,365.08	72.93
277	L104	2,320.00	Fixed	0.002	2,361.98	41.90
278	L83	2,316.00	Fixed	0.025	2,362.66	46.56
279	J-70	2,352.00	Fixed	0.000	2,373.81	21.77
281	L27	2,339.00	Fixed	0.032	2,390.99	51.89
282	L24	2,351.00	Fixed	0.008	2,399.12	48.02
283	L70	2,280.00	Fixed	0.003	2,366.48	86.30
284	L19	2,327.00	Fixed	0.007	2,398.73	71.59
285	L18	2,332.00	Fixed	0.014	2,387.86	55.75
286	J-80	2,345.00	Fixed	0.000	2,396.97	51.86
287	L26	2,342.00	Fixed	0.017	2,391.24	49.14
296	L155	2,340.00	Fixed	0.001	2,374.20	34.14
297	L38	2,349.00	Fixed	0.004	2,374.14	25.09
298	L108	2,345.00	Fixed	0.001	2,374.20	29.14
332	J-138	2,390.00	Fixed	0.046	2,399.34	9.32
339	J-127	2,387.00	Fixed	0.170	2,441.70	54.59
340	J-123	2,376.00	Fixed	0.013	2,446.03	69.88
341	J-125	2,418.00	Fixed	0.100	2,438.00	19.96
342	J-126	2,418.00	Fixed	0.023	2,458.06	39.98
343	J-129	2,411.00	Fixed	0.008	2,461.02	49.92
344	J-122	2,386.00	Fixed	0.008	2,455.41	69.27
345	J-120	2,371.00	Fixed	0.006	2,455.75	84.58
346	J-121	2,366.00	Fixed	0.006	2,454.73	88.55
347	J-115	2,405.00	Fixed	0.005	2,459.74	54.63
348	J-130	2,425.00	Fixed	0.001	2,464.89	39.81
349	J-116	2,405.00	Fixed	0.002	2,462.01	56.89
350	J-117	2,406.00	Fixed	0.002	2,432.32	26.27
351	J-84	2,410.00	Fixed	0.000	2,441.91	31.85
352	J-134	2,411.00	Fixed	0.001	2,441.56	30.50
353	J-119	2,431.00	Fixed	0.002	2,449.37	18.33
354	T3	2,440.00	Fixed	0.012	2,446.29	6.28
355	T11	2,410.00	Fixed	0.008	2,461.01	50.91
356	T4	2,435.00	Fixed	0.006	2,463.31	28.25
357	T8	2,472.00	Fixed	0.007	2,508.26	36.19
358	T10	2,472.00	Fixed	0.005	2,508.26	36.19
359	T5	2,455.00	Fixed	0.005	2,507.82	52.71
360	T6	2,460.00	Fixed	0.006	2,497.25	37.17
361	IC5	2,437.00	Fixed	0.004	2,488.53	51.43
362	IC1	2,472.00	Fixed	0.004	2,488.67	16.64
363	IC2	2,463.00	Fixed	0.008	2,488.34	25.29
364	IC3	2,450.00	Fixed	0.018	2,488.12	38.04
365	IC4	2,432.00	Fixed	0.007	2,487.98	55.87

366	IC6	2,465.00	Fixed	0.004	2,488.80	23.76
367	SP27	2,491.00	Fixed	0.000	2,490.05	-0.95
378	L23	2,352.00	Fixed	0.027	2,395.28	43.19
379	L160	2,334.00	Fixed	0.014	2,382.93	48.83
380	L16	2,327.00	Fixed	0.014	2,382.48	55.37
381	L13	2,387.00	Fixed	0.020	2,408.58	21.53
382	L8	2,340.00	Fixed	0.005	2,405.59	65.46
383	L9	2,332.00	Fixed	0.006	2,404.91	72.77
384	L7	2,363.00	Fixed	0.005	2,405.21	42.13
385	L11	2,382.00	Fixed	0.041	2,410.11	28.05
386	L5	2,362.00	Fixed	0.005	2,407.39	45.30
387	L6	2,365.00	Fixed	0.005	2,407.33	42.24
388	L3	2,360.00	Fixed	0.013	2,402.47	42.38
389	L4	2,360.00	Fixed	0.011	2,402.42	42.33
390	L10	2,392.00	Fixed	0.015	2,409.94	17.91
397	T19	2,430.00	Fixed	0.006	2,464.46	34.39
398	RK22	2,431.00	Fixed	0.015	2,466.78	35.71
403	J-144	2,364.00	Fixed	0.025	2,420.01	55.90
405	RK7	2,511.00	Fixed	0.001	2,647.87	136.59
412	G4	2,351.00	Fixed	0.007	2,411.72	60.59
413	L156	2,347.00	Fixed	0.001	2,374.17	27.11
421	J-87	2,404.00	Fixed	0.000	2,406.22	2.22
422	L31	2,320.00	Fixed	0.007	2,365.01	44.92
424	SP26	2,493.00	Fixed	0.005	2,631.67	138.40
425	RK20	2,500.00	Fixed	0.002	2,532.95	32.88
426	RK15	2,522.00	Fixed	0.001	2,536.27	14.24
427	J-143	2,423.00	Fixed	0.005	2,438.58	15.55
428	J-112	2,346.00	Fixed	0.013	2,450.20	103.99
431	B9	2,582.00	Fixed	0.003	2,634.72	52.62
435	L2	2,360.00	Fixed	0.017	2,399.39	39.31
438	J-106	2,355.00	Fixed	0.014	2,422.18	67.05
440	E1	2,734.00	Fixed	0.003	2,745.40	11.38
441	L30	2,320.00	Fixed	0.007	2,365.58	45.48
443	E4	2,635.00	Fixed	0.014	2,636.49	1.48
444	L33	2,325.00	Fixed	0.007	2,398.26	73.12
445	J-128	2,385.00	Fixed	0.012	2,389.47	4.46
447	B4	2,593.00	Fixed	0.024	2,618.40	25.35
448	J-109	2,385.00	Fixed	0.004	2,433.23	48.13
452	E3	2,673.00	Fixed	0.004	2,684.40	11.38
453	L105	2,308.00	Fixed	0.011	2,359.55	51.45
458	J-141	2,432.00	Fixed	0.002	2,464.89	32.82
459	L29	2,317.00	Fixed	0.007	2,364.08	46.98
463	RK21	2,490.00	Fixed	0.008	2,532.20	42.11
464	J-108	2,353.00	Fixed	0.002	2,402.97	49.87
467	J-110	2,417.00	Fixed	0.008	2,435.88	18.84
469	E2	2,708.00	Fixed	0.001	2,744.26	36.18
470	B7	2,631.00	Fixed	0.002	2,635.89	4.88
478	RK8	2,538.00	Fixed	0.001	2,644.52	106.30
479	L15	2,360.00	Fixed	0.009	2,401.75	41.67
485	E16	2,547.00	Fixed	0.005	2,563.89	16.86
488	B8	2,636.00	Fixed	0.002	2,743.82	107.60

490	RK14	2,523.00	Fixed	0.001	2,538.37	15.33
493	L79	2,292.00	Fixed	0.005	2,363.43	71.29
495	RK10	2,553.00	Fixed	0.001	2,655.11	101.91
501	L1	2,356.00	Fixed	0.014	2,389.69	33.62
504	J-142	2,424.00	Fixed	0.005	2,438.16	14.13
505	L109	2,345.00	Fixed	0.001	2,418.96	73.81
506	J-107	2,379.00	Fixed	0.029	2,402.72	23.67
507	B11	2,610.00	Fixed	0.003	2,607.78	-2.22
509	G2	2,343.00	Fixed	0.031	2,405.66	62.54
522	B10	2,600.00	Fixed	0.043	2,607.82	7.81
524	J-86	2,434.00	Fixed	0.000	2,437.61	3.60
528	J-91	2,360.00	Fixed	0.000	2,400.09	40.01
543	J-113	2,403.00	Fixed	0.006	2,456.79	53.68
547	G1	2,364.00	Fixed	0.015	2,419.16	55.05
550	B1	2,706.00	Fixed	0.007	2,724.04	18.00
552	RK9	2,588.00	Fixed	0.004	2,644.63	56.52
554	J-137	2,390.00	Fixed	0.001	2,441.91	51.81
559	L32	2,325.00	Fixed	0.007	2,398.52	73.37
562	RK13	2,520.00	Fixed	0.004	2,532.56	12.53
565	J-105	2,358.00	Fixed	0.016	2,422.52	64.39
566	J-111	2,397.00	Fixed	0.005	2,437.77	40.69
567	J-135	2,390.00	Fixed	0.001	2,441.88	51.77
568	J-136	2,390.00	Fixed	0.001	2,444.67	54.56
569	J-114	2,417.00	Fixed	0.005	2,424.55	7.54
570	L157	2,339.00	Fixed	0.004	2,373.74	34.67
571	L153	2,345.00	Fixed	0.001	2,374.17	29.11
572	L34	2,345.00	Fixed	0.001	2,374.21	29.15
573	L43	2,303.00	Fixed	0.005	2,372.14	69.00
574	L82	2,311.00	Fixed	0.005	2,368.23	57.12
576	L84	2,321.00	Fixed	0.005	2,362.31	41.23
586	SP12	2,463.00	Fixed	0.003	2,533.77	70.63
589	IC7	2,441.00	Fixed	0.008	2,437.60	-3.39
590	L115	2,370.00	Fixed	0.006	2,400.09	30.03
591	L14	2,377.00	Fixed	0.009	2,404.15	27.10
592	L12	2,385.00	Fixed	0.040	2,409.22	24.18
611	B13	2,595.00	Fixed	0.004	2,621.45	26.40
612	J-139	2,373.00	Fixed	0.013	2,438.51	65.38
613	J-140	2,365.00	Fixed	0.009	2,439.42	74.27
614	G3	2,358.00	Fixed	0.022	2,425.36	67.23
615	G5	2,367.00	Fixed	0.015	2,412.33	45.24
616	G6	2,402.00	Fixed	0.006	2,416.63	14.60
617	T15	2,497.00	Fixed	0.011	2,507.80	10.78
618	T14	2,492.00	Fixed	0.011	2,509.98	17.94
619	T16	2,447.00	Fixed	0.012	2,498.34	51.24
620	T17	2,454.00	Fixed	0.012	2,465.45	11.43
621	T18	2,459.00	Fixed	0.005	2,507.99	48.89
625	L110	2,306.00	Fixed	0.006	2,366.65	60.53
626	L111	2,324.00	Fixed	0.006	2,366.58	42.50
629	E12	2,560.00	Fixed	0.006	2,564.37	4.36
632	J-101	2,545.00	Fixed	0.000	2,694.59	149.29
634	J-104	2,615.00	Fixed	0.000	2,616.04	1.04

Figure B.1 Pressure Map of Nodes for Avg Day Demand, Steady State Analysis



Appendix A.2 Links Steady State Analysis Results at Average Day Demand

ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Flow (m^3/s)	Velocity (m/s)	Head loss Gradient (m/m)
730	P-2	2,592	LAGADA DI TANK	C1a	900	Steel	115	FALSE	0.501	0.79	0.001
731	P-3	49	C1a	C1	700	Steel	100	FALSE	-0.137	0.36	0
732	P-4	2,238	LAGADA DI TANK	J-4	1400	Steel	110	FALSE	1.499	0.97	0.001
733	P-5	70	J-4	ST2	1200	Steel	100	FALSE	0	0	0
734	P-6	75	ST2	J-5	1200	Steel	100	FALSE	0	0	0
735	P-7	200	J-5	C1	1400	Steel	100	FALSE	1.499	0.97	0.001
736	P-8	225	J-5	J-4	1000	Steel	100	FALSE	-1.499	1.91	0.004
737	P-9	78	ST3	J-6	1200	Steel	100	FALSE	-1.054	0.93	0.001
738	P-10	1,892	J-6	C1	1200	Steel	100	FALSE	-1.362	1.2	0.002
739	P-11	1,912	C1a	J-6	900	Steel	100	FALSE	0.639	1	0.002
740	P-12	88	ST3	J-7	1200	DCI	100	FALSE	0.856	0.76	0.001
741	P-13	7,581	J-7	L22	1200	Steel	100	FALSE	1.211	1.07	0.001
742	P-14	156	L22	TR2	900	Steel	100	FALSE	1.333	2.1	0.006
743	P-15	49	L22	ST4	1200	Steel	100	FALSE	0	0	0
744	P-16	279	J-7	J-6	1000	Steel	100	FALSE	-0.947	1.21	0.002
745	P-17	162	L22	TR1	900	Steel	100	FALSE	0.258	0.41	0
746	P-19	51	TR1	L117	1000	Steel	100	FALSE	0.725	0.92	0.001
747	P-21	148	L114	AN	600	Steel	100	FALSE	0	0	0
748	P-22	1,585	L114	L20	600	DI	100	FALSE	0.157	0.56	0.001
749	P-26	19	L119	TR3	600	Steel	100	FALSE	0	0	0
750	P-27	18	TR3	L118	500	Steel	100	FALSE	0	0	0
751	P-28	24	L118	L120	900	DI	100	FALSE	0	0	0
752	P-29	18	L120	L121	900	DI	100	FALSE	0.35	0.55	0.001
753	P-30	7,550	L121	Jan Meda	900	DI	120	FALSE	0.699	1.1	0.001
754	P-31	25	L119	L122	1000	Steel	100	FALSE	0	0	0
755	P-32	22	L122	L123	1000	Steel	100	FALSE	-0.35	0.45	0
756	P-34	19	L122	TR2	600	Steel	100	FALSE	0.35	1.24	0.004
757	P-36	19	TR2	L120	500	Steel	100	FALSE	0.35	1.78	0.009
758	P-35	18	L123	TP1	500	Steel	100	FALSE	0.349	1.78	0.009
759	P-37	20	TP1	L121	500	Steel	100	FALSE	0.349	1.78	0.009
760	P-38	81	TR2	L125	150	Steel	100	FALSE	-0.005	0.27	0.001
761	P-40	24	TR1	L125	500	Steel	100	FALSE	0.285	1.45	0.006
762	P-39	39	L125	L126	500	Steel	100	FALSE	0.268	1.36	0.005
763	P-41	27	L126	L128	500	Steel	100	FALSE	0.268	1.36	0.005
764	P-43	32	L128	L124	500	Steel	100	FALSE	0.134	0.68	0.001
765	P-46	25	L126	TR6	150	Steel	100	FALSE	0	0	0
766	P-47	23	TR6	L127	150	Steel	100	FALSE	0	0	0

767	P-48	24	L128	TR5	300	Steel	100	FALSE	0.134	1.89	0.018
768	P-49	24	TR5	L129	300	Steel	100	FALSE	0.134	1.89	0.018
769	P-50	21	L124	TR4	300	Steel	100	FALSE	0.134	1.9	0.018
770	P-51	26	TR4	L130	300	Steel	100	FALSE	0.134	1.9	0.018
771	P-52	30	L127	L129	400	DI	100	FALSE	0	0	0
772	P-53	33	L129	L130	400	DI	100	FALSE	0.134	1.06	0.004
773	P-56	81	L123	J-27	1000	Steel	100	FALSE	-0.699	0.89	0.001
774	P-57	60	J-27	TR2	1000	Steel	100	FALSE	-0.745	0.95	0.001
775	P-58	71	J-27	L117	1000	Steel	100	FALSE	0	0	0
776	P-62	12	J-31	JM3	300	Steel	100	FALSE	0	0	0
777	P-63	14	JM3	J-30	250	Steel	100	FALSE	0	0	0
778	P-65	13	J-31	J-32	600	Steel	100	FALSE	0.177	0.63	0.001
779	P-66	13	J-32	J-28	600	Steel	100	FALSE	0.089	0.31	0
780	P-67	12	J-29	J-33	300	Steel	100	FALSE	-0.088	1.25	0.008
781	P-68	12	J-33	J-30	300	Steel	100	FALSE	0	0	0
782	P-69	12	J-32	JM4	300	Steel	100	FALSE	0.088	1.25	0.008
783	P-70	14	JM4	J-33	250	Steel	100	FALSE	0.088	1.8	0.02
784	P-71	13	J-28	JM5	300	Steel	100	FALSE	0.089	1.26	0.008
785	P-72	14	JM5	J-29	250	Steel	100	FALSE	0.089	1.81	0.02
786	P-75	16	J-35	J-31	600	Steel	100	FALSE	0.177	0.63	0.001
787	P-77	20	Jan Meda	J-37	600	Steel	100	FALSE	0.323	1.14	0.003
788	P-78	16	J-37	J-35	600	Steel	100	FALSE	0.251	0.89	0.002
789	P-80	14	J-38	J-36	250	Steel	100	FALSE	0.073	1.48	0.014
790	P-79	13	J-37	JM1	300	Steel	100	FALSE	0.073	1.03	0.006
791	P-81	15	JM1	J-38	250	Steel	100	FALSE	0.073	1.48	0.014
792	P-82	13	J-35	JM2	300	Steel	100	FALSE	0.073	1.04	0.006
793	P-83	14	JM2	J-36	250	Steel	100	FALSE	0.073	1.49	0.014
794	P-84	1,782	J-36	TM	400	DI	100	FALSE	0.146	1.16	0.005
795	P-88	23	Jan Meda	J-42	350	Steel	100	FALSE	0.067	0.7	0.002
796	P-89	17	J-42	J-43	350	Steel	100	FALSE	0.034	0.35	0.001
797	P-91	20	J-43	J-39	350	Steel	100	FALSE	0	0	0
798	P-92	20	J-40	J-44	250	Steel	100	FALSE	0	0	0
799	P-93	18	J-44	J-41	250	Steel	100	FALSE	0.034	0.68	0.003
800	P-95	12	J-39	JM9	200	Steel	100	FALSE	0	0	0
801	P-96	15	JM9	J-40	150	Steel	100	FALSE	0	0	0
802	P-97	13	J-43	JM8	200	Steel	100	FALSE	0.034	1.07	0.01
803	P-98	14	JM8	J-44	150	Steel	100	FALSE	0.034	1.9	0.041
804	P-99	13	J-42	JM7	200	Steel	100	FALSE	0.034	1.07	0.01
805	P-100	13	JM7	J-41	150	Steel	100	FALSE	0.034	1.91	0.041
806	P-101	1,730	J-41	TM	250	DI	100	FALSE	0.067	1.37	0.012
807	P-102	85	TM	J-47	400	Steel	100	FALSE	0.096	0.77	0.002
808	P-103	34	J-47	J-45	400	Steel	100	FALSE	0.096	0.77	0.002

809	P-104	15	J-46	TM2	300	Steel	100	FALSE	0	0	0
810	P-106	16	TM2	J-47	350	Steel	100	FALSE	0	0	0
811	P-105	14	J-45	TM1	350	Steel	100	FALSE	0.096	1	0.005
812	P-107	15	TM1	J-48	300	Steel	100	FALSE	0.096	1.36	0.01
813	P-108	34	J-46	J-48	400	DI	100	FALSE	0	0	0
814	P-109	1,246	J-48	EN	400	DI	100	FALSE	0.096	0.77	0.002
815	P-110	43	TM	J-50	200	Steel	100	FALSE	0.023	0.74	0.005
816	P-111	40	J-50	J-49	200	Steel	100	FALSE	0.023	0.74	0.005
817	P-113	38	J-52	J-51	150	Steel	100	FALSE	0	0	0
818	P-115	12	J-50	TM4	150	Steel	100	FALSE	0	0	0
819	P-116	12	TM4	J-52	125	Steel	100	FALSE	0	0	0
820	P-117	13	J-49	TM3	150	Steel	100	FALSE	0.023	1.32	0.021
821	P-118	13	TM3	J-51	125	Steel	100	FALSE	0.023	1.9	0.05
822	P-119	1,056	J-51	E15	200	DI	100	FALSE	0.023	0.74	0.005
823	P-120	1,435	E15	RK	150	DI	100	FALSE	0.021	1.17	0.016
824	P-122	1,075	Jan Meda	J-132	350	DI	100	FALSE	0.054	0.56	0.002
825	P-123	59	TM	T12	400	DI	100	FALSE	0.154	1.23	0.006
826	P-126	2,450	T12	SP15	250	DI	100	FALSE	0.001	0.03	0
827	P-127	135	T12	T13	400	DI	100	FALSE	0.132	1.05	0.004
828	P-130	25	EN	J-63	400	DI	100	FALSE	0.073	0.58	0.001
829	P-131	1,885	J-63	B14	200	DI	100	FALSE	0.034	1.07	0.01
830	P-132	27	J-63	J-65	200	Steel	100	FALSE	0.04	1.26	0.014
831	P-135	2,035	B14	SP16	150	DI	100	FALSE	0.001	0.08	0
832	P-136	22	J-65	J-67	150	Steel	100	FALSE	0.018	1.04	0.013
833	P-137	20	J-67	J-64	150	Steel	100	FALSE	0	0	0
834	P-139	1,259	J-68	R1	150	DI	100	FALSE	0.018	1.04	0.013
835	P-140	18	J-67	Entoto1	150	Steel	100	FALSE	0.018	1.04	0.013
836	P-141	16	Entoto1	J-68	125	Steel	100	FALSE	0.018	1.5	0.032
837	P-142	19	J-64	Entoto2	150	Steel	100	FALSE	0	0	0
838	P-143	33	Entoto2	J-68	125	DI	100	FALSE	0	0	0
839	P-145	556	MO	SP17	350	DI	100	FALSE	0.057	0.59	0.002
840	P-146	38	MO	J-72	400	Steel	100	FALSE	0.071	0.57	0.001
841	P-148	27	J-72	J-73	300	Steel	100	FALSE	0	0	0
842	P-150	26	J-71	J-74	300	Steel	100	FALSE	0.071	1.01	0.006
843	P-151	12	J-72	MO1	300	Steel	100	FALSE	0.071	1.01	0.006
844	P-152	12	MO1	J-71	250	Steel	100	FALSE	0.071	1.45	0.014
845	P-153	12	J-73	MO2	300	Steel	100	FALSE	0	0	0
846	P-154	11	MO2	J-74	250	Steel	100	FALSE	0	0	0
847	P-155	3,031	J-74	T-14	300	DI	100	FALSE	0.071	1.01	0.006
848	P-156	53	MO	J-75	300	DCI	100	FALSE	0.003	0.04	0
849	P-157	14	J-75	MO3	300	Steel	100	FALSE	0.003	0.04	0
850	P-158	13	MO3	J-76	250	Steel	100	FALSE	0.003	0.06	0

851	P-160	1,142	L35	J-79	600	DI	100	FALSE	0.015	0.05	0
852	P-162	43	M23	J-81	250	Steel	100	FALSE	0	0	0
853	P-161	991	J-79	J-82	500	DI	100	FALSE	0.053	0.27	0
854	P-163	45	J-82	J-78	500	DI	100	FALSE	0.053	0.27	0
855	P-164	18	J-81	ME2	300	Steel	120	FALSE	0	0	0
856	P-165	16	ME2	J-82	400	Steel	120	FALSE	0	0	0
857	P-169	20	J-78	ME1	400	Steel	120	FALSE	0.006	0.04	0
858	P-170	18	ME1	M23	300	Steel	100	FALSE	0.006	0.08	0
860	P-174	734	M19	J-78	600	DI	110	FALSE	-0.002	0.01	0
869	P-184	32	R1	J-90	150	DCI	100	FALSE	0.01	0.57	0.004
870	P-185	14	J-90	R1(1)	125	Steel	100	FALSE	0.01	0.82	0.011
871	P-186	17	R1(1)	E13	100	Steel	100	FALSE	0.01	1.29	0.032
872	P-187	410	E13	R2	125	DI	90	FALSE	0.007	0.58	0.007
873	P-188	22	R2	J-92	100	DCI	100	FALSE	0.006	0.72	0.011
874	P-190	474	E14	R3	100	GI	90	FALSE	0.003	0.38	0.004
875	P-189	16	J-92	R2(1)	100	Steel	100	FALSE	0.006	0.72	0.011
876	P-191	16	R2(1)	E14	80	Steel	100	FALSE	0.006	1.13	0.032
913	P-250	16	L112	C45	300	Steel	100	FALSE	0.048	0.68	0.003
914	P-251	16	C45	UR1	250	Steel	100	FALSE	0.048	0.98	0.007
915	P-252	20	UR1	J-55	200	Steel	100	FALSE	0.048	1.53	0.019
935	P-287	457	L112	L116	900	Steel	90	FALSE	0.428	0.67	0.001
936	P-289	1,331	L116	L46	450	DI	90	FALSE	0.317	1.99	0.015
937	P-288	588	L116	L36	250	Steel	90	FALSE	0.11	2.24	0.037
938	P-290	212	L36	L35	900	Steel	100	FALSE	0.037	0.06	0
939	P-293	1,064	L40	L41	400	DI	110	FALSE	0.015	0.12	0
940	P-294	2,499	L37	L44	300	DI	110	FALSE	0.029	0.41	0.001
941	P-296	740	L47	L46	450	DI	90	FALSE	-0.288	1.81	0.013
942	P-299	562	L44	L45	200	DI	90	FALSE	0.03	0.96	0.01
944	P-301	461	L44	L42	200	DI	90	FALSE	-0.006	0.18	0
946	P-305	626	L154	J-79	300	DI	100	FALSE	0	0.01	0
947	P-306	1,009	J-79	L113	300	DI	100	FALSE	0.02	0.28	0.001
948	P-307	2,859	L113	L69	300	DI	100	FALSE	0.046	0.65	0.002
953	P-316	704	L81	L83	250	DI	110	FALSE	0.037	0.76	0.003
954	P-317	941	L83	L104	250	DI	90	FALSE	0.013	0.27	0.001
955	P-318	57	L113	J-70	300	DI	100	FALSE	-0.045	0.63	0.002
956	P-319	47	J-70	J-78	300	DI	100	FALSE	-0.045	0.63	0.002
957	P-320	872	L104	J-70	300	DI	100	FALSE	0	0	0
959	P-323	2,008	L112	L27	250	DI	110	FALSE	0.032	0.66	0.003
960	P-324	800	L20	L24	200	DI	110	FALSE	0.008	0.27	0.001
961	P-325	54	L69	L70	300	DI	110	FALSE	0.043	0.61	0.002
962	P-326	885	L70	L81	300	DI	110	FALSE	0.04	0.56	0.002
964	P-328	771	L20	L19	400	DI	100	FALSE	0.065	0.52	0.001

965	P-330	819	L19	L18	200	DI	110	FALSE	0.043	1.37	0.013
966	P-332	563	J-80	L112	900	Steel	90	FALSE	0.522	0.82	0.001
967	P-333	2,077	J-80	L26	200	DI	100	FALSE	0.017	0.53	0.003
977	P-344	456	L35	L155	400	DI	100	FALSE	0.008	0.06	0
978	P-345	127	L155	L154	400	DI	100	FALSE	0.003	0.03	0
979	P-346	616	L37	L38	600	DI	110	FALSE	0.031	0.11	0
980	P-347	388	L38	L40	600	DI	110	FALSE	0.02	0.07	0
981	P-348	407	L155	L38	200	DI	110	FALSE	0.004	0.13	0
982	P-350	796	L154	L108	300	Steel	90	FALSE	0.001	0.02	0
1014	P-428	100	J-27	J-138	150	DI	100	FALSE	0.046	2.58	0.071
1027	P-460	2,732	L130	J-127	400	DI	100	FALSE	0.268	2.13	0.016
1028	P-461	1,458	J-127	J-125	400	DI	90	FALSE	0.089	0.71	0.003
1029	P-463	27	J-125	J-126	400	DI	100	FALSE	0	0	0
1030	P-464	556	J-126	J-124	350	DI	90	FALSE	-0.023	0.24	0
1031	P-465	1,365	J-125	J-123	150	DI	90	FALSE	-0.011	0.6	0.006
1032	P-466	1,165	J-123	J-124	150	DI	100	FALSE	-0.016	0.92	0.011
1033	P-467	1,370	J-124	J-129	350	DI	100	FALSE	-0.061	0.64	0.002
1034	P-468	689	J-129	J-131	350	DI	100	FALSE	-0.079	0.82	0.003
1035	P-469	1,107	J-129	J-122	150	DI	90	FALSE	0.01	0.56	0.005
1036	P-470	473	J-122	J-123	150	DI	90	FALSE	0.021	1.16	0.02
1037	P-471	478	J-122	J-120	250	DI	100	FALSE	-0.015	0.3	0.001
1038	P-472	654	J-120	J-121	150	DI	100	FALSE	0.006	0.33	0.002
1039	P-473	860	J-120	J-115	300	DI	90	FALSE	-0.058	0.82	0.005
1040	P-474	629	J-115	J-116	500	DI	100	FALSE	-0.216	1.1	0.004
1041	P-475	783	J-116	J-130	500	DI	100	FALSE	-0.218	1.11	0.004
1042	P-476	393	J-118	J-117	200	Steel	100	FALSE	0.052	1.65	0.022
1043	P-478	11	J-116	J-117	200	DI	100	FALSE	0	0	0
1044	P-479	143	J-130	J-133	800	DI	100	FALSE	-0.221	0.44	0
1045	P-480	44	J-133	J-132	350	DI	100	FALSE	0.158	1.64	0.011
1046	P-481	63	J-132	J-131	350	DI	100	FALSE	0.21	2.19	0.02
1047	P-483	526	J-118	J-134	150	Steel	90	FALSE	-0.004	0.22	0.001
1048	P-485	667	J-131	J-119	300	DI	90	FALSE	0.13	1.84	0.021
1049	P-487	1,366	J-119	T3	200	DI	80	FALSE	0.012	0.38	0.002
1050	P-488	407	J-119	J-118	200	DI	100	FALSE	0.049	1.57	0.02
1051	P-490	1,287	T9	T8	250	DI	90	FALSE	-0.007	0.14	0
1052	P-491	1,223	T12	T10	200	DI	100	FALSE	0.018	0.56	0.003
1053	P-493	960	T8	T10	150	DI	80	FALSE	0	0.01	0
1054	P-494	260	T10	T5	150	DI	90	FALSE	0.005	0.31	0.002
1055	P-495	84	T8	T7	250	DI	90	FALSE	-0.014	0.29	0.001
1056	P-496	865	T7	T1	250	DI	90	FALSE	0.015	0.31	0.001
1057	P-499	1,131	T1	T6	150	DI	90	FALSE	0.013	0.76	0.009
1058	P-500	761	T6	T7	250	DI	90	FALSE	-0.067	1.36	0.015

1059	P-501	530	IC5	IC1	200	DI	80	FALSE	-0.004	0.12	0
1060	P-502	166	IC1	SP17	350	DI	90	FALSE	-0.04	0.41	0.001
1061	P-503	359	IC1	IC2	350	DI	80	FALSE	0.032	0.34	0.001
1062	P-504	234	IC2	IC3	300	DI	90	FALSE	0.025	0.35	0.001
1063	P-505	204	IC3	IC4	200	DI	90	FALSE	0.007	0.22	0.001
1064	P-506	213	SP17	IC6	200	DI	90	FALSE	0.004	0.12	0
1065	P-507	1,642	T6	SP27	500	DI	100	FALSE	0.24	1.22	0.004
1066	P-508	57	SP27	MO	500	DI	100	FALSE	0.24	1.22	0.004
1076	P-524	637	L20	L23	200	DI	100	FALSE	0.027	0.87	0.007
1077	P-525	483	L18	L160	150	DI	90	FALSE	0.014	0.81	0.01
1078	P-526	640	L18	L16	150	DI	100	FALSE	0.014	0.81	0.008
1079	P-528	2,122	L13	L22	900	Steel	94	FALSE	0.393	0.62	0.001
1080	P-529	1,551	L13	L8	200	DI	120	FALSE	0.017	0.53	0.002
1081	P-530	646	L8	L9	150	PVC	120	FALSE	0.006	0.32	0.001
1082	P-531	376	L8	L7	150	PVC	120	FALSE	0.005	0.31	0.001
1083	P-532	4,151	J-7	L11	900	Steel	90	FALSE	0.592	0.93	0.002
1084	P-534	1,210	L11	L5	350	DI	100	FALSE	0.065	0.68	0.002
1085	P-535	757	L5	L6	250	PVC	120	FALSE	0.005	0.11	0
1086	P-536	839	L5	L3	250	PVC	120	FALSE	0.054	1.11	0.006
1087	P-537	173	L3	L4	250	PVC	120	FALSE	0.011	0.22	0
1088	P-538	1,085	L11	L10	350	DI	100	FALSE	0.015	0.16	0
1100	P-554	1,097	T11	T19	150	DI	100	FALSE	-0.008	0.48	0.003
1101	P-555	717	T19	T4	150	DI	100	FALSE	0.006	0.33	0.002
1102	P-556	30	J-133	T19	150	DI	100	FALSE	0.02	1.14	0.016
1108	P-666	864	J-110	J-109	150	DI	90	FALSE	0.007	0.42	0.003
1115	P-852	226	L31	L30	150	DI	100	FALSE	-0.007	0.42	0.002
1116	P-654	373	RK7	RK10	50	PVC	110	FALSE	-0.001	0.7	0.019
1128	P-585	2,910	B7	SP26	150	GI	90	FALSE	0.005	0.28	0.001
1134	P-673	618	J-107	J-106	150	GI	80	FALSE	-0.023	1.33	0.032
1139	P-831	177	RK15	RK14	100	GI	90	FALSE	-0.005	0.68	0.012
1142	P-583	730	B10	B9	110	PVC	110	FALSE	0	0	0
1144	P-634	154	J-142	J-143	400	Steel	80	FALSE	-0.083	0.66	0.003
1148	P-671	1,195	J-143	J-108	200	PVC	110	FALSE	0.067	2.12	0.03
1149	P-660	701	RK8	RK7	50	PVC	110	FALSE	-0.001	0.33	0.005
1153	P-658	812	RK9	RK8	50	PVC	110	FALSE	0	0.05	0
1164	P-685	98	G1	J-144	150	Steel	80	FALSE	-0.012	0.66	0.009
1165	P-672	404	J-108	J-107	150	DI	90	FALSE	0.003	0.18	0.001
1171	P-830	377	RK20	RK15	100	GI	90	FALSE	-0.005	0.58	0.009
1173	P-576	1,649	B8	B1	100	PVC	110	FALSE	0.007	0.84	0.012
1175	P-854	247	L30	L29	125	GI	100	FALSE	0.007	0.61	0.006
1177	P-678	938	J-112	J-113	350	DI	90	FALSE	-0.109	1.13	0.007
1183	P-849	420	L33	L32	200	DI	100	FALSE	-0.007	0.24	0.001

1184	P-686	1,044	J-144	L109	100	GI	90	FALSE	0.001	0.18	0.001
1195	P-758	470	L1	L2	125	DI	100	FALSE	-0.014	1.18	0.021
1198	P-677	900	J-106	J-112	300	DI	90	FALSE	0	0	0
1199	P-584	405	B10	B11	200	DI	90	FALSE	0.003	0.08	0
1202	P-703	384	J-143	J-84	400	Steel	80	FALSE	-0.154	1.23	0.009
1203	P-704	455	J-84	J-137	500	DI	90	FALSE	0.007	0.04	0
1205	P-706	281	R3	E2	50	PVC	110	FALSE	0.001	0.64	0.016
1206	P-708	157	E3	R2	100	DI	90	FALSE	-0.004	0.49	0.006
1207	P-710	90	R1	E4	100	PVC	110	FALSE	0.014	1.82	0.05
1208	P-711	262	E1	R3	75	GI	90	FALSE	-0.003	0.6	0.013
1209	P-712	293	EN	E16	100	GI	90	FALSE	0.005	0.58	0.009
1210	P-718	358	RK10	RK9	75	GI	90	FALSE	0.004	0.93	0.029
1211	P-713	769	RK	RK14	100	GI	90	FALSE	0.006	0.78	0.015
1212	P-716	1,101	RK21	RK13	150	DI	90	FALSE	-0.002	0.13	0
1213	P-717	1,945	RK13	RK22	150	DI	50	FALSE	0.015	0.86	0.034
1214	P-719	307	RK	RK13	250	DI	15	FALSE	0.023	0.47	0.057
1215	P-720	1,122	RK13	RK21	150	DI	90	FALSE	0.002	0.13	0
1216	P-721	180	RK20	RK21	100	GI	90	FALSE	0.003	0.39	0.004
1217	P-722	62	B7	T-14	250	DI	80	FALSE	-0.084	1.7	0.028
1218	P-723	659	B7	B9	125	GI	90	FALSE	0.003	0.28	0.002
1237	P-749	482	J-142	J-86	400	Steel	80	FALSE	0.052	0.41	0.001
1238	P-750	580	J-86	J-110	200	DI	90	FALSE	0.016	0.5	0.003
1239	P-751	611	J-86	J-110	250	DI	90	FALSE	0.028	0.56	0.003
1240	P-752	904	J-110	J-109	250	DI	90	FALSE	0.028	0.57	0.003
1241	P-753	1,101	J-109	J-105	250	DI	90	FALSE	0.054	1.09	0.01
1242	P-754	165	J-105	J-106	300	DI	90	FALSE	0.037	0.53	0.002
1243	P-755	833	J-108	J-79	200	DI	90	FALSE	0.059	1.88	0.035
1244	P-756	899	J-108	J-107	150	DI	90	FALSE	0.002	0.12	0
1245	P-757	361	J-142	J-111	300	DI	90	FALSE	0.026	0.37	0.001
1246	P-759	838	J-111	J-109	200	DI	90	FALSE	0.022	0.69	0.005
1247	P-760	1,487	J-84	J-112	350	DI	90	FALSE	-0.096	1	0.006
1248	P-761	461	J-84	J-135	150	Steel	90	FALSE	0.001	0.06	0
1249	P-764	195	J-135	J-134	150	Steel	90	FALSE	0.005	0.3	0.002
1250	P-769	898	J-141	J-137	500	DI	90	FALSE	0	0	0
1251	P-770	18	J-137	J-135	150	DI	90	FALSE	0.006	0.32	0.002
1252	P-771	766	J-119	J-136	300	DI	90	FALSE	0.067	0.95	0.006
1253	P-773	468	J-136	J-84	300	DI	90	FALSE	0.066	0.94	0.006
1254	P-775	21	J-135	J-136	150	DI	90	FALSE	0	0	0
1255	P-778	378	J-117	J-114	200	Steel	100	FALSE	0.05	1.58	0.021
1256	P-781	108	J-114	PG	200	Steel	100	FALSE	0.073	2.32	0.042
1257	P-783	1,063	J-114	J-120	150	DI	100	FALSE	-0.028	1.6	0.029
1258	P-784	490	J-120	J-122	150	DI	100	FALSE	0.004	0.21	0.001

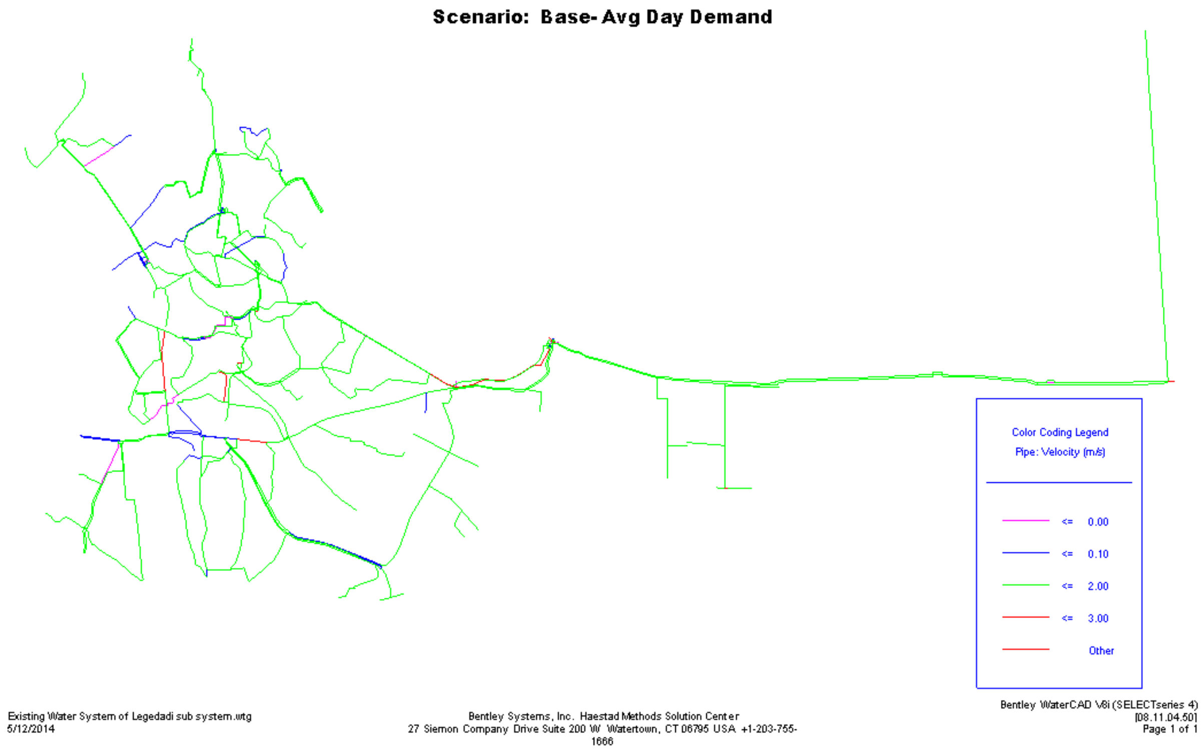
1259	P-785	716	J-144	J-113	150	DI	100	FALSE	-0.038	2.16	0.051
1260	P-786	521	J-113	J-115	400	DI	100	FALSE	-0.153	1.22	0.006
1261	P-787	377	G2	G1	150	DI	100	FALSE	-0.031	1.78	0.036
1262	P-804	942	PG	G1	200	DI	100	FALSE	0.009	0.29	0.001
1263	P-806	378	L38	L157	200	DI	110	FALSE	0.011	0.35	0.001
1264	P-807	1,877	L157	L42	200	DI	110	FALSE	0.01	0.31	0.001
1265	P-808	829	L157	L37	150	Steel	80	FALSE	-0.003	0.14	0.001
1266	P-805	290	L36	L153	600	DI	110	FALSE	0.071	0.25	0
1267	P-809	84	L153	L37	600	DI	110	FALSE	0.063	0.22	0
1268	P-810	139	L35	L34	400	DI	100	FALSE	0.013	0.1	0
1269	P-811	174	L153	L34	200	DI	100	FALSE	-0.004	0.13	0
1270	P-813	177	L34	L153	200	DI	100	FALSE	0.004	0.13	0
1271	P-814	102	L153	L37	150	Steel	80	FALSE	0.001	0.06	0
1272	P-815	207	L34	L153	200	Steel	90	FALSE	0.003	0.11	0
1273	P-816	2,048	L153	L47	200	DI	100	FALSE	0.019	0.62	0.004
1274	P-817	1,236	L47	L45	350	DI	100	FALSE	0.024	0.25	0
1275	P-818	2,068	L153	L47	200	DI	100	FALSE	0.019	0.62	0.004
1276	P-819	1,291	L153	L46	250	DI	100	FALSE	-0.021	0.43	0.001
1277	P-820	619	L30	L28	250	DI	100	FALSE	-0.022	0.46	0.002
1278	P-821	2,787	L19	L32	400	DI	100	FALSE	0.015	0.12	0
1279	P-822	2,052	L28	L47	200	DI	100	FALSE	-0.003	0.08	0
1280	P-823	159	L42	L43	200	DI	110	FALSE	-0.001	0.02	0
1282	P-825	1,457	L43	L41	150	DI	100	FALSE	-0.005	0.3	0.001
1283	P-826	681	J-79	L156	150	GI	90	FALSE	0.001	0.05	0
1284	P-827	2,150	L113	L82	200	DI	100	FALSE	0.016	0.51	0.003
1285	P-828	385	L82	L79	125	Steel	100	FALSE	0.011	0.9	0.012
1286	P-829	490	L83	L79	150	DI	100	FALSE	-0.006	0.33	0.002
1293	P-838	944	L83	L84	200	DI	90	FALSE	0.005	0.16	0
1308	P-868	505	L104	L105	150	DI	100	FALSE	0.011	0.6	0.005
1325	P-885	778	J-78	M18	300	DI	100	FALSE	0.002	0.02	0
1327	P-887	172	SP27	J-76	300	DI	100	FALSE	0	0	0
1329	P-889	854	J-76	SP12	300	DI	120	FALSE	0.003	0.04	0
1337	P-898	257	IC7	J-86	400	Steel	90	FALSE	-0.008	0.07	0
1338	P-897	611	L114	L115	900	Steel	90	FALSE	0.544	0.86	0.001
1339	P-899	2,300	L115	J-80	900	Steel	90	FALSE	0.538	0.85	0.001
1340	P-900	409	J-91	L115	150	Steel	90	FALSE	0	0	0
1341	P-901	2,182	J-87	J-128	150	GI	90	FALSE	0.012	0.7	0.008
1342	P-902	1,423	L14	L114	900	Steel	90	FALSE	0.707	1.11	0.002
1343	P-903	699	L15	L14	150	DI	100	FALSE	-0.009	0.5	0.003
1344	P-904	727	L11	L12	900	Steel	94	FALSE	0.47	0.74	0.001
1345	P-905	626	L12	L13	900	Steel	94	FALSE	0.43	0.68	0.001
1405	P-965	384	J-141	J-130	800	DI	100	FALSE	-0.002	0	0

1406	P-966	794	B7	B13	200	DI	60	FALSE	0.028	0.89	0.018
1407	P-967	464	B13	B4	200	DI	90	FALSE	0.024	0.77	0.007
1408	P-968	984	J-127	J-139	150	DI	100	FALSE	0.009	0.49	0.003
1409	P-969	996	J-139	J-140	150	DI	100	FALSE	-0.004	0.25	0.001
1410	P-970	868	J-140	J-123	150	DI	100	FALSE	-0.014	0.77	0.008
1411	P-971	520	J-55	G3	200	DI	100	FALSE	0.048	1.53	0.019
1412	P-972	1,005	G3	G1	200	DI	100	FALSE	0.026	0.83	0.006
1413	P-973	928	G4	G5	200	DI	90	FALSE	-0.007	0.22	0.001
1414	P-974	768	G5	G6	200	DI	90	FALSE	-0.022	0.7	0.006
1415	P-975	374	G6	PG	200	DI	90	FALSE	-0.029	0.91	0.009
1416	P-976	431	T13	T15	150	DI	100	FALSE	0.014	0.81	0.008
1417	P-977	587	T15	T1	150	DI	100	FALSE	0.003	0.18	0.001
1418	P-978	427	T13	T14	400	DI	100	FALSE	0.114	0.91	0.003
1419	P-979	604	T14	T7	400	DI	100	FALSE	0.103	0.82	0.003
1420	P-980	589	J-29	T16	500	DI	100	FALSE	0.177	0.9	0.003
1421	P-981	497	T16	T6	500	DI	100	FALSE	0.166	0.84	0.002
1422	P-982	539	Jan Meda	T17	800	DI	100	FALSE	0.412	0.82	0.001
1423	P-983	442	T17	J-133	800	DI	100	FALSE	0.4	0.8	0.001
1424	P-984	520	T10	T18	200	DI	100	FALSE	0.007	0.22	0.001
1425	P-985	587	T18	T9	200	DI	100	FALSE	0.001	0.04	0
1431	P-991	1,335	L28	L110	400	DI	110	FALSE	-0.016	0.13	0
1432	P-992	636	L110	L47	400	DI	110	FALSE	-0.022	0.17	0
1433	P-993	1,489	L47	L111	400	DI	100	FALSE	0.017	0.14	0
1434	P-994	516	L111	L28	400	DI	100	FALSE	0.012	0.09	0
1437	P-997	43	L125	J-87	150	GI	90	FALSE	0.012	0.7	0.008
1438	P-998	36	L2	L3	125	DI	100	FALSE	-0.031	2.53	0.085
1441	P-636	99	J-65	E12	150	DI	100	FALSE	0.021	1.2	0.017
1442	P-637	1,784	E12	B14	150	DCI	100	FALSE	0.015	0.86	0.009
1447	P-643	16	L117	FCV-1	900	Steel	100	FALSE	0.725	1.14	0.002
1448	P-644	1,046	FCV-1	L14	900	Steel	90	FALSE	0.725	1.14	0.002
1449	P-646	622	J-101	RK10	75	GI	90	FALSE	0.006	1.41	0.063
1450	P-645	21	RK	PMP-47	75	GI	90	FALSE	0.006	1.41	0.063
1451	P-647	19	PMP-47	J-101	75	GI	90	FALSE	0.006	1.41	0.063
1452	P-648	23	T-14	PMP-48	100	DI	90	FALSE	0.004	0.56	0.008
1453	P-649	24	PMP-48	B8	100	DI	90	FALSE	0.004	0.56	0.008
1454	P-650	27	RK	PMP-49	150	DCI	100	FALSE	0	0	0
1455	P-651	29	PMP-49	J-101	150	DCI	100	FALSE	0	0	0
1456	P-652	29	T-14	PMP-50	100	Steel	100	FALSE	0.004	0.56	0.007
1457	P-653	34	PMP-50	B8	100	Steel	100	FALSE	0.004	0.56	0.007
1460	P-582a	15	B7	J-104	90	DI	80	FALSE	0.045	7.1	1.276
1461	P-582	1,161	J-104	B10	250	DI	90	FALSE	0.045	0.92	0.007
1478	P-1	9,149	R-1	LAGA.TANK	600	DI	130	FALSE	0.253	0.89	0.001
1479	P-2	126	R-2	LAGA.TANK	900	DI	130	FALSE	3.779	5.94	0.025

Existing Water System of Legedadi sub system.wtg

Bentley WaterCAD V8i (SELECTseries 4)

Figure B.2 Velocity Map of Links for Avg Day Demand, Steady State Analysis



Appendix A.3 Flex Table: Tank Steady State Analysis Results at Average Day Demand

ID	Label	Elevation (Base) (m)	Elevation (Minimum) (m)	Elevation (Initial) (m)	Elevation (Maximum) (m)	Volume (Inactive) (ML)	Diameter (m)	Flow (Out net) (m^3/s)	Hydraulic Grade (m)
642	LAGADADI TANK	2,422.00	2,423.00	2,426.80	2,428.00	0.00	3.05	-2.031	2,426.80
643	ST2	2,410.00	2,410.00	2,421.12	2,423.00	0.00	3.05	0.000	2,421.12
644	ST4	2,404.00	2,404.20	2,406.70	2,409.20	0.00	8.00	0.000	2,406.70
645	TR2	2,404.00	2,404.20	2,406.50	2,409.20	0.00	50.00	-0.593	2,406.50
646	ST3	2,400.00	2,418.00	2,418.55	2,420.00	0.00	3.05	-0.198	2,418.55
647	TR1	2,404.00	2,404.20	2,406.70	2,409.20	0.00	50.00	0.752	2,406.70
648	AN	2,387.00	2,387.00	2,387.10	2,395.00	0.00	28.00	0.000	2,387.10
649	Jan Meda	2,462.10	2,462.10	2,466.10	2,470.10	0.00	28.00	0.157	2,466.10
650	TM	2,508.30	2,508.30	2,512.30	2,514.30	0.00	32.00	0.060	2,512.30
651	EN	2,563.50	2,563.50	2,566.50	2,571.80	0.00	14.00	-0.018	2,566.50
652	RK	2,548.00	2,548.00	2,550.00	2,553.00	0.00	12.00	0.015	2,550.00
653	R1	2,639.00	2,639.00	2,641.00	2,646.20	0.00	21.00	0.006	2,641.00
654	MO	2,486.50	2,486.50	2,489.80	2,490.20	0.00	60.00	-0.109	2,489.80
655	T-14	2,635.60	2,635.60	2,637.60	2,639.60	0.00	17.00	0.021	2,637.60
658	R2	2,683.40	2,683.40	2,685.40	2,687.40	0.00	6.00	0.002	2,685.40
659	R3	2,746.80	2,746.80	2,748.80	2,750.80	0.00	6.00	0.001	2,748.80
665	PG	2,419.50	2,419.50	2,420.00	2,424.00	0.00	16.00	-0.035	2,420.00

Appendix A.4 Flex Table: Pump Table Steady State Analysis Results at Average Day Demand

ID	Label	Pump Definition	Status (Initial)	Hydraulic Grade (Suction) (m)	Hydraulic Grade (Discharge) (m)	Flow (Total) (m^3/s)	Pump Head (m)
674	TR3	Pump Terminal (1,2,3)	Off	2,406.46	2,475.89	0.000	0.00
675	TR2	Pump Terminal (1,2,3)	On	2,406.39	2,476.06	0.350	69.67
676	TP1	Pump Terminal (1,2,3)	On	2,406.30	2,476.06	0.349	69.76
677	TR6	Pump Terminal (4,5,6)	Off	2,406.34	2,485.45	0.000	0.00
678	TR5	Pump Terminal (4,5,6)	On	2,405.77	2,485.89	0.134	80.12
679	TR4	Pump Terminal (4,5,6)	On	2,405.78	2,485.77	0.134	80.00
680	JM3	Pump Jan Meda 3,4,5 (To AAWSA)	Off	2,465.99	2,499.92	0.000	0.00
681	JM4	Pump Jan Meda 3,4,5 (To AAWSA)	On	2,465.88	2,500.21	0.088	34.33
682	JM5	Pump Jan Meda 3,4,5 (To AAWSA)	On	2,465.87	2,500.11	0.089	34.24
683	JM1	Pump Jan Meda 1,2 (To Tel. Mek.)	On	2,465.96	2,521.98	0.073	56.02
684	JM2	Pump Jan Meda 1,2 (To Tel. Mek.)	On	2,465.93	2,521.76	0.073	55.83
685	JM9	Pump Jan Meda 7,8,9 (To Tef.Mek.)	Off	2,466.03	2,533.48	0.000	0.00
686	JM8	Pump Jan Meda 7,8,9 (To Tef.Mek.)	On	2,465.91	2,534.04	0.034	68.14
687	JM7	Pump Jan Meda 7,8,9 (To Tef.Mek.)	On	2,465.91	2,533.97	0.034	68.05
688	TM2	Pump Tefere Mekonnen 1,2 (to Entoto)	Off	2,512.09	2,569.49	0.000	0.00
689	TM1	Pump Tefere Mekonnen 1,2 (to Entoto)	On	2,511.95	2,569.64	0.096	57.69
690	TM4	Pump Tefere Mekonnen 3,4 (To Rass Kassa)	Off	2,512.08	2,579.05	0.000	0.00
691	TM3	Pump Tefere Mekonnen 3,4 (To Rass Kassa)	On	2,511.62	2,579.71	0.023	68.09
692	Entoto1	Pump Entoto (to R1)	On	2,565.57	2,658.30	0.018	92.73
693	Entoto2	Pump Entoto (to R1)	Off	2,565.81	2,657.77	0.000	0.00
694	MO1	Pump AAWSA Main (1,2)	On	2,489.68	2,654.83	0.071	165.14
695	MO2	Pump AAWSA Main (1,2)	Off	2,489.75	2,654.52	0.000	0.00
696	MO3	Pump AAWSA Main (3)	On	2,489.80	2,533.78	0.003	43.98
697	ME2	Pump Mexico 2	Off	2,373.93	2,413.91	0.000	0.00
698	ME1	Pump Mexico 1	On	2,373.92	2,413.91	0.006	39.99
701	R1(1)	Pump R1	On	2,640.71	2,688.76	0.010	48.05
702	R2(1)	Pump R2	On	2,684.99	2,751.26	0.006	66.27
712	UR1	Pump Urael	On	2,396.09	2,435.82	0.048	39.73
720	PMP-47	RK	On	2,548.66	2,695.79	0.006	147.12
721	PMP-48	BZ	On	2,637.42	2,744.01	0.004	106.60
722	PMP-49	RK	Off	2,550.00	2,694.59	0.000	0.00
723	PMP-50	BZ	On	2,637.40	2,744.05	0.004	106.64

Existing Water System of Legedadi sub system.wtg

Bentley WaterCAD V8i (SELECTseries 4)

EXTENDED PERIOD SIMULATION (EPS)

Appendix A.5 Nodes EPS Analysis Results at Peak Hour Demand

Flex Table: Junction Table (Existing Water System of Legedadi sub system.wtg) Current Time: 14.000 hours

ID	Label	Elevation (m)	Demand Pattern	Demand (m^3/s)	Hydraulic Grade (m)	Pressure (m H2O)
129	C1	2,410.00		0.000	2,422.45	12.42
130	C1a	2,410.00		0.000	2,422.44	12.42
131	J-4	2,410.00		0.000	2,423.08	13.05
132	J-5	2,410.00		0.000	2,422.93	12.91
133	J-6	2,400.00		0.000	2,419.23	19.19
134	J-7	2,400.00		0.000	2,419.14	19.10
135	L22	2,406.00	Domestic	0.020	2,404.89	-1.11
136	L117	2,406.00		0.000	2,404.60	-1.40
137	L114	2,375.00	Domestic	0.009	2,391.01	15.98
138	L20	2,351.00	Domestic	0.088	2,388.06	36.98
139	L118	2,402.00		0.000	2,473.69	71.54
140	L119	2,402.00		0.000	2,404.81	2.81
141	L120	2,402.00		0.000	2,473.69	71.54
142	L121	2,402.00		0.000	2,473.68	71.53
143	L122	2,402.00		0.000	2,404.81	2.81
144	L123	2,402.00		0.000	2,404.81	2.81
145	L124	2,402.00		0.000	2,403.60	1.59
146	L125	2,404.00		0.000	2,404.44	0.44
147	L126	2,402.00		0.000	2,404.00	2.00
148	L127	2,402.00		0.000	2,458.31	56.20
149	L128	2,402.00		0.000	2,403.70	1.69
150	L129	2,402.00		0.000	2,458.31	56.20
151	L130	2,402.00		0.000	2,458.01	55.90
152	J-131	2,427.00	Domestic	0.002	2,458.37	31.31
153	J-124	2,420.00	Domestic	0.035	2,446.11	26.06
154	J-27	2,400.00		0.000	2,404.84	4.83
155	J-28	2,460.00		0.000	2,463.61	3.61
156	J-29	2,460.00		0.000	2,498.15	38.07
157	J-30	2,460.00		0.000	2,498.24	38.16
158	J-31	2,460.00		0.000	2,463.63	3.62
159	J-32	2,460.00		0.000	2,463.62	3.61
160	J-33	2,460.00		0.000	2,498.24	38.16
161	J-35	2,460.00		0.000	2,463.64	3.64
162	J-36	2,460.00		0.000	2,518.10	57.98
163	J-37	2,460.00		0.000	2,463.67	3.67
164	J-38	2,460.00		0.000	2,518.31	58.19
165	J-39	2,460.00		0.000	2,463.67	3.66
166	J-40	2,460.00		0.000	2,530.61	70.47
167	J-41	2,460.00		0.000	2,530.55	70.41
168	J-42	2,460.00		0.000	2,463.68	3.67
169	J-43	2,460.00		0.000	2,463.67	3.66
170	J-44	2,460.00		0.000	2,530.61	70.47
171	J-45	2,507.00		0.000	2,508.07	1.07
172	J-46	2,507.00		0.000	2,570.90	63.77

173	J-47	2,507.00		0.000	2,508.14	1.13
174	J-48	2,507.00		0.000	2,570.90	63.77
175	J-49	2,507.00		0.000	2,507.87	0.87
176	J-50	2,507.00		0.000	2,508.08	1.08
177	J-51	2,507.00		0.000	2,574.64	67.51
178	J-52	2,507.00		0.000	2,574.64	67.51
179	E15	2,564.00	Domestic	0.004	2,569.15	5.13
180	J-133	2,432.00	Domestic	0.002	2,461.56	29.50
181	J-132	2,433.00	Domestic	0.002	2,460.63	27.58
182	T7	2,473.00	Domestic	0.011	2,503.45	30.39
183	T12	2,512.00	Domestic	0.005	2,507.86	-4.14
184	T9	2,459.00	Domestic	0.013	2,502.18	43.09
185	SP15	2,490.00	Domestic	0.002	2,507.80	17.77
186	T13	2,510.00	Domestic	0.005	2,507.12	-2.88
187	T1	2,469.00	Domestic	0.008	2,502.25	33.18
188	B14	2,536.00	Domestic	0.074	2,525.97	-10.01
189	J-63	2,560.00	Domestic	0.000	2,568.40	8.38
190	J-64	2,560.00		0.000	2,567.48	7.47
191	J-65	2,560.00		0.000	2,567.79	7.77
192	SP16	2,490.00	Domestic	0.002	2,525.45	35.38
193	J-67	2,560.00		0.000	2,567.48	7.47
194	J-68	2,560.00	Domestic	0.000	2,657.72	97.52
195	L35	2,345.00	Domestic	0.002	2,324.89	-20.07
196	SP17	2,476.00	Domestic	0.020	2,487.99	11.96
197	J-71	2,483.00		0.000	2,653.24	169.89
198	J-72	2,483.00		0.000	2,490.07	7.06
199	J-73	2,483.00		0.000	2,490.07	7.06
200	J-74	2,483.00		0.000	2,653.09	169.74
201	J-75	2,483.00		0.000	2,490.13	7.11
202	J-76	2,483.00		0.000	2,534.09	50.98
204	J-78	2,352.00		0.000	2,324.18	-27.77
205	J-79	2,340.00		0.000	2,324.81	-15.16
206	M23	2,352.00	Domestic	0.009	2,364.15	12.13
207	J-81	2,352.00		0.000	2,364.15	12.13
208	J-82	2,352.00		0.000	2,324.20	-27.74
209	M18	2,345.00	Domestic	0.002	2,324.17	-20.79
211	M19	2,345.00	Domestic	0.002	2,324.18	-20.78
215	J-90	2,637.00		0.000	2,639.79	2.78
216	E13	2,637.00	Domestic	0.005	2,685.36	48.27
217	J-92	2,682.00		0.000	-2,200,074.14	-2,198,319.19
218	E14	2,682.00		0.000	2,682.00	0.00
243	L37	2,349.00	Domestic	0.002	2,324.79	-24.16
244	L112	2,350.00	Domestic	0.020	2,379.63	29.57
245	C45	2,350.00		0.000	2,379.51	29.45
246	J-55	2,350.00		0.000	2,393.43	43.34
247	J-118	2,423.00	Domestic	0.002	2,429.15	6.14
256	L28	2,325.00	Domestic	0.012	2,309.51	-15.46
257	L116	2,332.00	Domestic	0.002	2,378.64	46.55
258	L46	2,335.00	Domestic	0.012	2,331.29	-3.71
259	L36	2,336.00	Domestic	0.002	2,324.90	-11.08
260	L40	2,347.00	Domestic	0.008	2,324.73	-22.22
261	L41	2,326.00	Domestic	0.015	2,324.59	-1.41
262	L44	2,311.00	Domestic	0.007	2,320.15	9.13

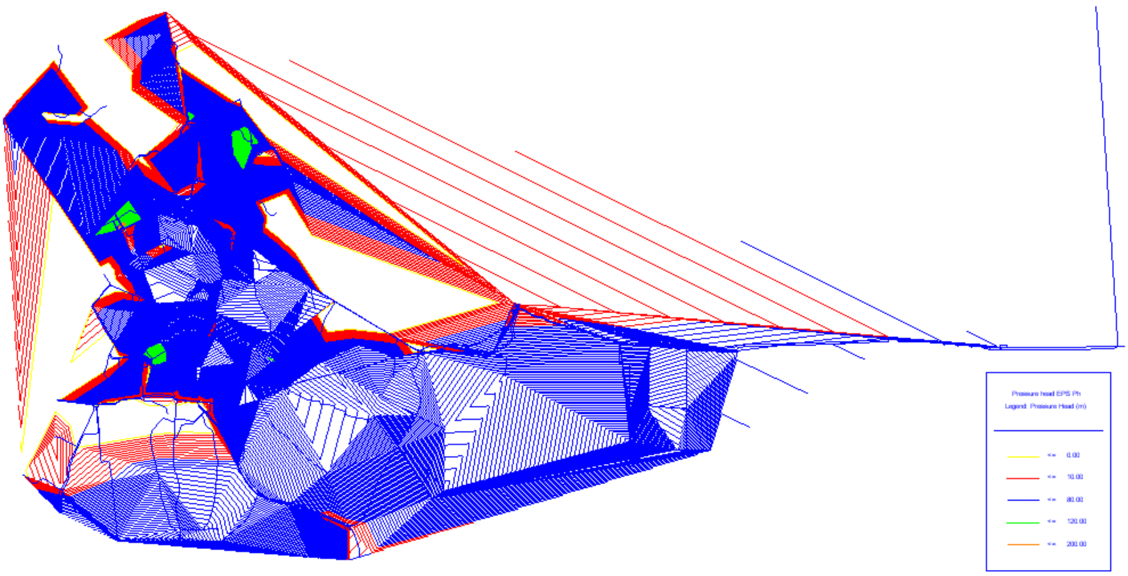
263	L47	2,317.00	Domestic	0.405	2,309.91	-7.08
265	L45	2,305.00	Domestic	0.085	2,308.78	3.77
267	L42	2,300.00	Domestic	0.007	2,320.54	20.50
269	L154	2,340.00	Domestic	0.002	2,324.85	-15.12
270	L113	2,351.00	Domestic	0.004	2,323.63	-27.32
271	L69	2,283.00	Domestic	0.005	2,307.64	24.59
276	L81	2,292.00	Domestic	0.003	2,304.27	12.25
277	L104	2,320.00	Domestic	0.004	2,297.29	-22.66
278	L83	2,316.00	Domestic	0.039	2,298.81	-17.15
279	J-70	2,352.00		0.000	2,323.93	-28.01
281	L27	2,339.00	Domestic	0.050	2,367.80	28.74
282	L24	2,351.00	Domestic	0.013	2,386.90	35.83
283	L70	2,280.00	Domestic	0.005	2,307.42	27.36
284	L19	2,327.00	Domestic	0.011	2,386.04	58.92
285	L18	2,332.00	Domestic	0.022	2,361.56	29.50
286	J-80	2,345.00	Domestic	0.000	2,381.38	36.31
287	L26	2,342.00	Domestic	0.026	2,368.49	26.43
296	L155	2,340.00	Domestic	0.001	2,324.85	-15.12
297	L38	2,349.00	Domestic	0.006	2,324.75	-24.21
298	L108	2,345.00	Domestic	0.002	2,324.84	-20.12
332	J-138	2,390.00	Domestic	0.071	2,388.77	-1.23
339	J-127	2,387.00	Domestic	0.263	2,367.80	-19.16
340	J-123	2,376.00	Domestic	0.019	2,404.03	27.98
341	J-125	2,418.00	Domestic	0.155	2,360.55	-57.34
342	J-126	2,418.00	Domestic	0.036	2,445.62	27.56
343	J-129	2,411.00	Domestic	0.012	2,453.07	41.98
344	J-122	2,386.00	Domestic	0.012	2,442.45	56.34
345	J-120	2,371.00	Domestic	0.009	2,444.03	72.88
346	J-121	2,366.00	Domestic	0.009	2,441.73	75.58
347	J-115	2,405.00	Domestic	0.007	2,451.83	46.73
348	J-130	2,425.00	Domestic	0.002	2,461.46	36.38
349	J-116	2,405.00	Domestic	0.003	2,456.07	50.97
350	J-117	2,406.00	Domestic	0.003	2,424.93	18.89
351	J-84	2,410.00		0.000	2,424.15	14.12
352	J-134	2,411.00	Domestic	0.002	2,425.22	14.19
353	J-119	2,431.00	Domestic	0.002	2,437.48	6.46
354	T3	2,440.00	Domestic	0.019	2,430.55	-9.43
355	T11	2,410.00	Domestic	0.013	2,452.71	42.62
356	T4	2,435.00	Domestic	0.009	2,457.87	22.83
357	T8	2,472.00	Domestic	0.011	2,503.21	31.15
358	T10	2,472.00	Domestic	0.008	2,502.51	30.45
359	T5	2,455.00	Domestic	0.008	2,501.51	46.41
360	T6	2,460.00	Domestic	0.009	2,495.84	35.77
361	IC5	2,437.00	Domestic	0.006	2,487.28	50.18
362	IC1	2,472.00	Domestic	0.006	2,487.58	15.55
363	IC2	2,463.00	Domestic	0.012	2,486.84	23.79
364	IC3	2,450.00	Domestic	0.027	2,486.34	36.27
365	IC4	2,432.00	Domestic	0.011	2,486.04	53.93
366	IC6	2,465.00	Domestic	0.006	2,487.89	22.84
367	SP27	2,491.00	Domestic	0.000	2,490.32	-0.68
378	L23	2,352.00	Domestic	0.042	2,378.26	26.21
379	L160	2,334.00	Domestic	0.022	2,350.45	16.42
380	L16	2,327.00	Domestic	0.022	2,349.44	22.40

381	L13	2,387.00	Domestic	0.030	2,406.60	19.56
382	L8	2,340.00	Domestic	0.009	2,399.87	59.75
383	L9	2,332.00	Domestic	0.009	2,398.35	66.22
384	L7	2,363.00	Domestic	0.009	2,399.02	35.95
385	L11	2,382.00	Domestic	0.064	2,408.22	26.16
386	L5	2,362.00	Domestic	0.009	2,402.10	40.02
387	L6	2,365.00	Domestic	0.009	2,401.96	36.88
388	L3	2,360.00	Domestic	0.020	2,391.01	30.95
389	L4	2,360.00	Domestic	0.017	2,390.90	30.84
390	L10	2,392.00	Domestic	0.023	2,407.85	15.82
397	T19	2,430.00	Domestic	0.009	2,460.47	30.41
398	RK22	2,431.00		0.000	2,431.00	0.00
403	J-144	2,364.00	Domestic	0.039	2,348.77	-15.20
405	RK7	2,511.00		0.000	2,511.00	0.00
412	G4	2,351.00		0.000	2,351.00	0.00
413	L156	2,347.00	Domestic	0.001	2,324.73	-22.23
421	J-87	2,404.00		0.000	2,403.69	-0.31
422	L31	2,320.00	Domestic	0.012	2,306.02	-13.95
424	SP26	2,493.00		0.000	2,493.00	0.00
425	RK20	2,500.00		0.000	2,500.00	0.00
426	RK15	2,522.00		0.000	2,522.00	0.00
427	J-143	2,423.00	Domestic	0.007	2,418.03	-4.96
428	J-112	2,346.00	Domestic	0.020	2,436.26	90.08
431	B9	2,582.00		0.000	2,582.00	0.00
435	L2	2,360.00	Domestic	0.026	2,384.09	24.05
438	J-106	2,355.00	Domestic	0.022	2,386.98	31.92
440	E1	2,734.00		0.000	2,734.00	0.00
441	L30	2,320.00	Domestic	0.012	2,307.30	-12.67
443	E4	2,635.00	Domestic	0.022	2,629.78	-5.21
444	L33	2,325.00	Domestic	0.012	2,384.98	59.86
445	J-128	2,385.00	Domestic	0.019	2,365.97	-18.99
447	B4	2,593.00		0.000	2,593.00	0.00
448	J-109	2,385.00	Domestic	0.006	2,407.69	22.65
452	E3	2,673.00		0.000	2,673.00	0.00
453	L105	2,308.00	Domestic	0.016	2,291.82	-16.15
458	J-141	2,432.00	Domestic	0.002	2,461.46	29.40
459	L29	2,317.00	Domestic	0.012	2,303.92	-13.05
463	RK21	2,490.00		0.000	2,490.00	0.00
464	J-108	2,353.00	Domestic	0.004	2,360.79	7.78
467	J-110	2,417.00	Domestic	0.012	2,412.70	-4.29
469	E2	2,708.00		0.000	2,708.00	0.00
470	B7	2,631.00		0.000	2,631.00	0.00
478	RK8	2,538.00		0.000	2,538.00	0.00
479	L15	2,360.00	Domestic	0.014	2,393.24	33.18
485	E16	2,547.00	Domestic	0.007	2,562.60	15.57
488	B8	2,636.00		0.000	2,636.00	0.00
490	RK14	2,523.00		0.000	2,523.00	0.00
493	L79	2,292.00	Domestic	0.008	2,300.55	8.53
495	RK10	2,553.00	Domestic	0.000	2,553.00	0.00
501	L1	2,356.00	Domestic	0.022	2,362.23	6.22
504	J-142	2,424.00	Domestic	0.007	2,417.18	-6.81
505	L109	2,345.00	Domestic	0.002	2,346.40	1.40
506	J-107	2,379.00	Domestic	0.045	2,358.81	-20.15

507	B11	2,610.00	Domestic	0.000	2,610.00	0.00
509	G2	2,343.00	Domestic	0.049	2,315.24	-27.70
522	B10	2,600.00	Domestic	0.000	2,600.00	0.00
524	J-86	2,434.00		0.000	2,416.08	-17.88
528	J-91	2,360.00		0.000	2,388.96	28.90
543	J-113	2,403.00	Domestic	0.009	2,446.45	43.36
547	G1	2,364.00	Domestic	0.024	2,345.62	-18.34
550	B1	2,706.00		0.000	2,706.00	0.00
552	RK9	2,588.00		0.000	2,588.00	0.00
554	J-137	2,390.00	Domestic	0.002	2,424.15	34.08
559	L32	2,325.00	Domestic	0.012	2,385.56	60.44
562	RK13	2,520.00		0.000	2,520.00	0.00
565	J-105	2,358.00	Domestic	0.025	2,387.57	29.51
566	J-111	2,397.00	Domestic	0.007	2,416.41	19.37
567	J-135	2,390.00	Domestic	0.002	2,424.20	34.13
568	J-136	2,390.00	Domestic	0.002	2,429.07	38.99
569	J-114	2,417.00	Domestic	0.007	2,421.57	4.56
570	L157	2,339.00	Domestic	0.006	2,323.90	-15.07
571	L153	2,345.00	Domestic	0.002	2,324.82	-20.14
572	L34	2,345.00	Domestic	0.002	2,324.88	-20.08
573	L43	2,303.00	Domestic	0.007	2,320.54	17.51
574	L82	2,311.00	Domestic	0.008	2,311.37	0.37
576	L84	2,321.00	Domestic	0.008	2,298.03	-22.93
586	SP12	2,463.00	Domestic	0.005	2,534.06	70.92
589	IC7	2,441.00	Domestic	0.013	2,416.06	-24.89
590	L115	2,370.00	Domestic	0.009	2,388.96	18.92
591	L14	2,377.00	Domestic	0.014	2,398.65	21.61
592	L12	2,385.00	Domestic	0.062	2,407.25	22.20
611	B13	2,595.00		0.000	2,595.00	0.00
612	J-139	2,373.00	Domestic	0.020	2,366.73	-6.26
613	J-140	2,365.00	Domestic	0.014	2,376.10	11.08
614	G3	2,358.00	Domestic	0.034	2,365.66	7.64
615	G5	2,367.00		0.000	2,367.00	0.00
616	G6	2,402.00		0.000	2,402.00	0.00
617	T15	2,497.00	Domestic	0.017	2,502.24	5.23
618	T14	2,492.00	Domestic	0.017	2,505.36	13.33
619	T16	2,447.00	Domestic	0.018	2,496.78	49.68
620	T17	2,454.00	Domestic	0.018	2,462.51	8.49
621	T18	2,459.00	Domestic	0.008	2,502.17	43.09
625	L110	2,306.00	Domestic	0.009	2,309.72	3.72
626	L111	2,324.00	Domestic	0.009	2,309.57	-14.40
629	E12	2,560.00	Domestic	0.009	2,563.89	3.89
620	T17	2,454.00	Domestic	0.018	2,462.51	8.49
621	T18	2,459.00	Domestic	0.008	2,502.17	43.09
625	L110	2,306.00	Domestic	0.009	2,309.72	3.72
626	L111	2,324.00	Domestic	0.009	2,309.57	-14.4
629	E12	2,560.00	Domestic	0.009	2,563.89	3.89
632	J-101	2,545.00		0	-6,917,655.46	-6,906,261.24

Figure B.3 Pressure Map of Nodes for Peak Hour Demand Scenario, EPS Analysis

Scenario: Peak Hour Demand



Existing Water System of Legedadi sub system.wtg
5/12/2014

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W Watertown, CT 06795 USA +1-203-755-1666

Bentley WaterCAD V8i (SELECTseries 4)
[08.11.04.50]
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Appendix A.6 Links EPS Analysis Results at Peak Hour Demand

FlexTable: Pipe Table (Existing Water System of Legedadi sub system.wtg), Current Time: 14 hours-(Peak our demand)

ID	Label	Length (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Flow (m³/s)	Velocity (m/s)	Headloss Gradient (m/m)
730	P-2	6,890	LAGADADI TANK	C1a	900.0	Steel	115.0	False	0.519	0.82	0.001
731	P-3	10	C1a	C1	700.0	Steel	100.0	False	-0.142	0.37	0.000
732	P-4	6,360	LAGADADI TANK	J-4	1,400.0	Steel	110.0	False	1.552	1.01	0.001
733	P-5	20	J-4	ST2	1,200.0	Steel	100.0	False	0.000	0.00	0.000
734	P-6	20	ST2	J-5	1,200.0	Steel	100.0	False	0.000	0.00	0.000
735	P-7	528	J-5	C1	1,400.0	Steel	100.0	False	1.552	1.01	0.001
736	P-8	30	J-5	J-4	1,000.0	Steel	100.0	False	-1.552	1.98	0.005
737	P-9	20	ST3	J-6	1,200.0	Steel	100.0	False	-1.026	0.91	0.001
738	P-10	1,964	J-6	C1	1,200.0	Steel	100.0	False	-1.409	1.25	0.002
739	P-11	1,964	C1a	J-6	900.0	Steel	100.0	False	0.661	1.04	0.002
740	P-12	88	ST3	J-7	1,200.0	DCI	100.0	False	0.979	0.87	0.001
741	P-13	9,526	J-7	L22	1,200.0	Steel	100.0	False	1.342	1.19	0.001
742	P-14	35	L22	TR2	900.0	Steel	100.0	False	0.475	0.75	0.001
743	P-15	10	L22	ST4	1,200.0	Steel	100.0	False	0.000	0.00	0.000
744	P-16	40	J-7	J-6	1,000.0	Steel	100.0	False	-1.045	1.33	0.002
745	P-17	35	L22	TR1	900.0	Steel	100.0	False	1.222	1.92	0.005
746	P-19	40	TR1	L117	1,000.0	Steel	100.0	False	1.158	1.47	0.003
747	P-21	148	L114	AN	600.0	Steel	100.0	False	0.000	0.00	0.000
748	P-22	1,585	L114	L20	600.0	DI	100.0	False	0.244	0.86	0.002
749	P-26	19	L119	TR3	600.0	Steel	100.0	False	0.000	0.00	0.000
750	P-27	18	TR3	L118	500.0	Steel	100.0	False	0.000	0.00	0.000
751	P-28	24	L118	L120	900.0	DI	100.0	False	0.000	0.00	0.000
752	P-29	18	L120	L121	900.0	DI	100.0	False	0.353	0.55	0.001
753	P-30	7,550	L121	Jan Meda	900.0	DI	120.0	False	0.705	1.11	0.001
754	P-31	7	L119	L122	1,000.0	Steel	100.0	False	0.000	0.00	0.000
755	P-32	5	L122	L123	1,000.0	Steel	100.0	False	-0.353	0.45	0.000
756	P-34	19	L122	TR2	600.0	Steel	100.0	False	0.353	1.25	0.004
757	P-36	19	TR2	L120	500.0	Steel	100.0	False	0.353	1.80	0.009
758	P-35	19	L123	TP1	500.0	Steel	100.0	False	0.352	1.80	0.009
759	P-37	20	TP1	L121	500.0	Steel	100.0	False	0.352	1.80	0.009
760	P-38	50	TR2	L125	150.0	Steel	100.0	False	0.014	0.81	0.008
761	P-40	24	TR1	L125	500.0	Steel	100.0	False	0.401	2.04	0.011
762	P-39	39	L125	L126	500.0	Steel	100.0	False	0.397	2.02	0.011
763	P-41	27	L126	L128	500.0	Steel	100.0	False	0.397	2.02	0.011
764	P-43	33	L128	L124	500.0	Steel	100.0	False	0.199	1.01	0.003
765	P-46	25	L126	TR6	150.0	Steel	100.0	False	0.000	0.00	0.000
766	P-47	23	TR6	L127	150.0	Steel	100.0	False	0.000	0.00	0.000
767	P-48	24	L128	TR5	300.0	Steel	100.0	False	0.198	2.80	0.037
768	P-49	24	TR5	L129	300.0	Steel	100.0	False	0.198	2.80	0.037
769	P-50	21	L124	TR4	300.0	Steel	100.0	False	0.199	2.81	0.037
770	P-51	26	TR4	L130	300.0	Steel	100.0	False	0.199	2.81	0.037
771	P-52	30	L127	L129	400.0	DI	100.0	False	0.000	0.00	0.000
772	P-53	33	L129	L130	400.0	DI	100.0	False	0.198	1.58	0.009
773	P-56	22	L123	J-27	1,000.0	Steel	100.0	False	-0.705	0.90	0.001
774	P-57	16	J-27	TR2	1,000.0	Steel	100.0	False	-0.776	0.99	0.001
775	P-58	20	J-27	L117	1,000.0	Steel	100.0	False	0.000	0.00	0.000
776	P-62	9	J-31	JM3	300.0	Steel	100.0	False	0.000	0.00	0.000
777	P-63	10	JM3	J-30	250.0	Steel	100.0	False	0.000	0.00	0.000
778	P-65	19	J-31	J-32	600.0	Steel	100.0	False	0.170	0.60	0.001

779	P-66	19	J-32	J-28	600.0	Steel	100.0	False	0.085	0.30	0.000
780	P-67	16	J-29	J-33	300.0	Steel	100.0	False	-0.085	1.20	0.008
781	P-68	19	J-33	J-30	300.0	Steel	100.0	False	0.000	0.00	0.000
782	P-69	12	J-32	JM4	300.0	Steel	100.0	False	0.085	1.20	0.008
783	P-70	15	JM4	J-33	250.0	Steel	100.0	False	0.085	1.73	0.019
784	P-71	13	J-28	JM5	300.0	Steel	100.0	False	0.085	1.21	0.008
785	P-72	14	JM5	J-29	250.0	Steel	100.0	False	0.085	1.74	0.019
786	P-75	16	J-35	J-31	600.0	Steel	100.0	False	0.170	0.60	0.001
787	P-77	20	Jan Meda	J-37	600.0	Steel	100.0	False	0.321	1.13	0.003
788	P-78	16	J-37	J-35	600.0	Steel	100.0	False	0.246	0.87	0.002
789	P-80	14	J-38	J-36	250.0	Steel	100.0	False	0.075	1.53	0.015
790	P-79	13	J-37	JM1	300.0	Steel	100.0	False	0.075	1.06	0.006
791	P-81	16	JM1	J-38	250.0	Steel	100.0	False	0.075	1.53	0.015
792	P-82	13	J-35	JM2	300.0	Steel	100.0	False	0.076	1.07	0.006
793	P-83	14	JM2	J-36	250.0	Steel	100.0	False	0.076	1.54	0.015
794	P-84	1,782	J-36	TM	400.0	DI	100.0	False	0.151	1.20	0.005
795	P-88	23	Jan Meda	J-42	350.0	Steel	100.0	False	0.069	0.72	0.003
796	P-89	17	J-42	J-43	350.0	Steel	100.0	False	0.035	0.36	0.001
797	P-91	20	J-43	J-39	350.0	Steel	100.0	False	0.000	0.00	0.000
798	P-92	20	J-40	J-44	250.0	Steel	100.0	False	0.000	0.00	0.000
799	P-93	18	J-44	J-41	250.0	Steel	100.0	False	0.035	0.70	0.004
800	P-95	12	J-39	JM9	200.0	Steel	100.0	False	0.000	0.00	0.000
801	P-96	15	JM9	J-40	150.0	Steel	100.0	False	0.000	0.00	0.000
802	P-97	13	J-43	JM8	200.0	Steel	100.0	False	0.035	1.10	0.011
803	P-98	14	JM8	J-44	150.0	Steel	100.0	False	0.035	1.95	0.043
804	P-99	13	J-42	JM7	200.0	Steel	100.0	False	0.035	1.11	0.011
805	P-100	13	JM7	J-41	150.0	Steel	100.0	False	0.035	1.96	0.043
806	P-101	1,730	J-41	TM	250.0	DI	100.0	False	0.069	1.41	0.013
807	P-102	85	TM	J-47	400.0	Steel	100.0	False	0.086	0.69	0.002
808	P-103	34	J-47	J-45	400.0	Steel	100.0	False	0.086	0.69	0.002
809	P-104	15	J-46	TM2	300.0	Steel	100.0	False	0.000	0.00	0.000
810	P-106	16	TM2	J-47	350.0	Steel	100.0	False	0.000	0.00	0.000
811	P-105	14	J-45	TM1	350.0	Steel	100.0	False	0.086	0.89	0.004
812	P-107	15	TM1	J-48	300.0	Steel	100.0	False	0.086	1.22	0.008
813	P-108	34	J-46	J-48	400.0	DI	100.0	False	0.000	0.00	0.000
814	P-109	1,246	J-48	EN	400.0	DI	100.0	False	0.086	0.69	0.002
815	P-110	43	TM	J-50	200.0	Steel	100.0	False	0.024	0.75	0.005
816	P-111	40	J-50	J-49	200.0	Steel	100.0	False	0.024	0.75	0.005
817	P-113	38	J-52	J-51	150.0	Steel	100.0	False	0.000	0.00	0.000
818	P-115	12	J-50	TM4	150.0	Steel	100.0	False	0.000	0.00	0.000
819	P-116	12	TM4	J-52	125.0	Steel	100.0	False	0.000	0.00	0.000
820	P-117	12	J-49	TM3	150.0	Steel	100.0	False	0.024	1.34	0.021
821	P-118	13	TM3	J-51	125.0	Steel	100.0	False	0.024	1.93	0.051
822	P-119	1,056	J-51	E15	200.0	DI	100.0	False	0.024	0.75	0.005
823	P-120	1,437	E15	RK	150.0	DI	100.0	False	0.019	1.10	0.015
824	P-122	1,075	Jan Meda	J-132	350.0	DI	100.0	False	0.075	0.78	0.003
825	P-123	63	TM	T12	400.0	DI	100.0	False	0.179	1.43	0.008
826	P-126	2,449	T12	SP15	250.0	DI	100.0	False	0.002	0.04	0.000
827	P-127	130	T12	T13	400.0	DI	100.0	False	0.151	1.20	0.005
828	P-130	25	EN	J-63	400.0	DI	100.0	False	0.104	0.83	0.003
829	P-131	1,885	J-63	B14	200.0	DI	100.0	False	0.052	1.66	0.023
830	P-132	27	J-63	J-65	200.0	Steel	100.0	False	0.052	1.66	0.022
831	P-135	2,035	B14	SP16	150.0	DI	100.0	False	0.002	0.12	0.000
832	P-136	22	J-65	J-67	150.0	Steel	100.0	False	0.019	1.08	0.014
833	P-137	20	J-67	J-64	150.0	Steel	100.0	False	0.000	0.00	0.000
834	P-139	1,244	J-68	R1	150.0	DI	100.0	False	0.019	1.08	0.014
835	P-140	18	J-67	Entoto1	150.0	Steel	100.0	False	0.019	1.08	0.014
836	P-141	16	Entoto1	J-68	125.0	Steel	100.0	False	0.019	1.55	0.034
837	P-142	19	J-64	Entoto2	150.0	Steel	100.0	False	0.000	0.00	0.000

838	P-143	33	Entoto2	J-68	125.0	DI	100.0	False	0.000	0.00	0.000
839	P-145	556	MO	SP17	350.0	DI	100.0	False	0.088	0.91	0.004
840	P-146	38	MO	J-72	400.0	Steel	100.0	False	0.073	0.58	0.001
841	P-148	28	J-72	J-73	300.0	Steel	100.0	False	0.000	0.00	0.000
842	P-150	27	J-71	J-74	300.0	Steel	100.0	False	0.073	1.03	0.006
843	P-151	12	J-72	MO1	300.0	Steel	100.0	False	0.073	1.03	0.006
844	P-152	12	MO1	J-71	250.0	Steel	100.0	False	0.073	1.48	0.014
845	P-153	12	J-73	MO2	300.0	Steel	100.0	False	0.000	0.00	0.000
846	P-154	11	MO2	J-74	250.0	Steel	100.0	False	0.000	0.00	0.000
847	P-155	3,031	J-74	T-14	300.0	DI	100.0	False	0.073	1.03	0.006
848	P-156	41	MO	J-75	300.0	DCI	100.0	False	0.005	0.07	0.000
849	P-157	20	J-75	MO3	300.0	Steel	100.0	False	0.005	0.07	0.000
850	P-158	18	MO3	J-76	250.0	Steel	100.0	False	0.005	0.10	0.000
851	P-160	1,142	L35	J-79	600.0	DI	100.0	False	0.042	0.15	0.000
852	P-162	37	M23	J-81	250.0	Steel	100.0	False	0.000	0.00	0.000
853	P-161	954	J-79	J-82	500.0	DI	100.0	False	0.083	0.42	0.001
854	P-163	45	J-82	J-78	500.0	DI	100.0	False	0.083	0.42	0.001
855	P-164	17	J-81	ME2	300.0	Steel	120.0	False	0.000	0.00	0.000
856	P-165	12	ME2	J-82	400.0	Steel	120.0	False	0.000	0.00	0.000
857	P-169	13	J-78	ME1	400.0	Steel	120.0	False	0.009	0.07	0.000
858	P-170	16	ME1	M23	300.0	Steel	100.0	False	0.009	0.12	0.000
860	P-174	734	M19	J-78	600.0	DI	110.0	False	-0.002	0.01	0.000
869	P-184	32	R1	J-90	150.0	DCI	100.0	False	0.010	0.59	0.005
870	P-185	19	J-90	R1(1)	125.0	Steel	100.0	False	0.010	0.85	0.011
871	P-186	20	R1(1)	E13	100.0	Steel	100.0	False	0.010	1.33	0.034
872	P-187	410	E13	R2	125.0	DI	90.0	False	0.006	0.48	0.005
873	P-188	22	R2	J-92	100.0	DCI	100.0	False	0.000	0.00	0.000
874	P-190	472	E14	R3	100.0	GI	90.0	False	0.000	0.00	0.000
875	P-189	16	J-92	R2(1)	100.0	Steel	100.0	False	0.002	0.26	0.000
876	P-191	19	R2(1)	E14	80.0	Steel	100.0	False	0.002	0.41	0.000
913	P-250	63	L112	C45	300.0	Steel	100.0	False	0.083	1.18	0.007
914	P-251	17	C45	UR1	250.0	Steel	100.0	False	0.083	1.69	0.018
915	P-252	19	UR1	J-55	200.0	Steel	100.0	False	0.083	2.64	0.053
935	P-287	457	L112	L116	900.0	Steel	90.0	False	0.689	1.08	0.002
936	P-289	1,331	L116	L46	450.0	DI	90.0	False	0.507	3.19	0.036
937	P-288	588	L116	L36	250.0	Steel	90.0	False	0.180	3.66	0.091
938	P-290	213	L36	L35	900.0	Steel	100.0	False	0.079	0.12	0.000
939	P-293	1,064	L40	L41	400.0	DI	110.0	False	0.023	0.18	0.000
940	P-294	2,498	L37	L44	300.0	DI	110.0	False	0.043	0.61	0.002
941	P-296	738	L47	L46	450.0	DI	90.0	False	-0.453	2.85	0.029
942	P-299	562	L44	L45	200.0	DI	90.0	False	0.044	1.41	0.020
944	P-301	461	L44	L42	200.0	DI	90.0	False	-0.008	0.26	0.001
946	P-305	626	L154	J-79	300.0	DI	100.0	False	0.006	0.08	0.000
947	P-306	995	J-79	L113	300.0	DI	100.0	False	0.031	0.43	0.001
948	P-307	2,859	L113	L69	300.0	DI	100.0	False	0.071	1.01	0.006
953	P-316	704	L81	L83	250.0	DI	110.0	False	0.058	1.18	0.008
954	P-317	940	L83	L104	250.0	DI	90.0	False	0.020	0.41	0.002
955	P-318	57	L113	J-70	300.0	DI	100.0	False	-0.069	0.98	0.005
956	P-319	47	J-70	J-78	300.0	DI	100.0	False	-0.069	0.98	0.005
957	P-320	873	L104	J-70	300.0	DI	100.0	False	0.000	0.00	0.000
959	P-323	2,008	L112	L27	250.0	DI	110.0	False	0.050	1.02	0.006
960	P-324	800	L20	L24	200.0	DI	110.0	False	0.013	0.41	0.001
961	P-325	76	L69	L70	300.0	DI	110.0	False	0.066	0.94	0.004
962	P-326	856	L70	L81	300.0	DI	110.0	False	0.061	0.87	0.004
964	P-328	770	L20	L19	400.0	DI	100.0	False	0.101	0.80	0.003
965	P-330	607	L19	L18	200.0	DI	110.0	False	0.067	2.13	0.030
966	P-332	563	J-80	L112	900.0	Steel	90.0	False	0.842	1.32	0.003
967	P-333	2,077	J-80	L26	200.0	DI	100.0	False	0.026	0.83	0.006
977	P-344	455	L35	L155	400.0	DI	100.0	False	0.017	0.13	0.000

978	P-345	127	L155	L154	400.0	DI	100.0	False	0.010	0.08	0.000
979	P-346	616	L37	L38	600.0	DI	110.0	False	0.048	0.17	0.000
980	P-347	345	L38	L40	600.0	DI	110.0	False	0.031	0.11	0.000
981	P-348	407	L155	L38	200.0	DI	110.0	False	0.005	0.16	0.000
982	P-350	796	L154	L108	300.0	Steel	90.0	False	0.002	0.03	0.000
1014	P-428	100	J-27	J-138	150.0	DI	100.0	False	0.071	4.00	0.161
1027	P-460	2,732	L130	J-127	400.0	DI	100.0	False	0.397	3.16	0.033
1028	P-461	1,458	J-127	J-125	400.0	DI	90.0	False	0.128	1.02	0.005
1029	P-463	20	J-125	J-126	400.0	DI	100.0	False	0.000	0.00	0.000
1030	P-464	562	J-126	J-124	350.0	DI	90.0	False	-0.036	0.37	0.001
1031	P-465	1,365	J-125	J-123	150.0	DI	90.0	False	-0.027	1.50	0.032
1032	P-466	1,165	J-123	J-124	150.0	DI	100.0	False	-0.032	1.79	0.036
1033	P-467	1,369	J-124	J-129	350.0	DI	100.0	False	-0.102	1.06	0.005
1034	P-468	689	J-129	J-131	350.0	DI	100.0	False	-0.127	1.32	0.008
1035	P-469	1,107	J-129	J-122	150.0	DI	90.0	False	0.014	0.79	0.010
1036	P-470	473	J-122	J-123	150.0	DI	90.0	False	0.044	2.49	0.081
1037	P-471	478	J-122	J-120	250.0	DI	100.0	False	-0.033	0.68	0.003
1038	P-472	654	J-120	J-121	150.0	DI	100.0	False	0.009	0.51	0.004
1039	P-473	860	J-120	J-115	300.0	DI	90.0	False	-0.083	1.18	0.009
1040	P-474	629	J-115	J-116	500.0	DI	100.0	False	-0.303	1.54	0.007
1041	P-475	783	J-116	J-130	500.0	DI	100.0	False	-0.306	1.56	0.007
1042	P-476	393	J-118	J-117	200.0	Steel	100.0	False	0.035	1.11	0.011
1043	P-478	11	J-116	J-117	200.0	DI	100.0	False	0.000	0.00	0.000
1044	P-479	143	J-130	J-133	800.0	DI	100.0	False	-0.310	0.62	0.001
1045	P-480	44	J-133	J-132	350.0	DI	100.0	False	0.218	2.27	0.021
1046	P-481	63	J-132	J-131	350.0	DI	100.0	False	0.292	3.03	0.036
1047	P-483	526	J-118	J-134	150.0	Steel	90.0	False	0.012	0.69	0.007
1048	P-485	667	J-131	J-119	300.0	DI	90.0	False	0.163	2.30	0.031
1049	P-487	1,366	J-119	T3	200.0	DI	80.0	False	0.019	0.59	0.005
1050	P-488	407	J-119	J-118	200.0	DI	100.0	False	0.049	1.57	0.020
1051	P-490	1,287	T9	T8	250.0	DI	90.0	False	-0.014	0.28	0.001
1052	P-491	1,222	T12	T10	200.0	DI	100.0	False	0.022	0.68	0.004
1053	P-493	960	T8	T10	150.0	DI	80.0	False	0.003	0.17	0.001
1054	P-494	260	T10	T5	150.0	DI	90.0	False	0.008	0.48	0.004
1055	P-495	84	T8	T7	250.0	DI	90.0	False	-0.028	0.56	0.003
1056	P-496	868	T7	T1	250.0	DI	90.0	False	0.019	0.38	0.001
1057	P-499	1,131	T1	T6	150.0	DI	90.0	False	0.010	0.59	0.006
1058	P-500	761	T6	T7	250.0	DI	90.0	False	-0.054	1.11	0.010
1059	P-501	530	IC5	IC1	200.0	DI	80.0	False	-0.006	0.18	0.001
1060	P-502	169	IC1	SP17	350.0	DI	90.0	False	-0.062	0.64	0.002
1061	P-503	359	IC1	IC2	350.0	DI	80.0	False	0.050	0.52	0.002
1062	P-504	234	IC2	IC3	300.0	DI	90.0	False	0.038	0.54	0.002
1063	P-505	205	IC3	IC4	200.0	DI	90.0	False	0.011	0.34	0.001
1064	P-506	213	SP17	IC6	200.0	DI	90.0	False	0.006	0.18	0.000
1065	P-507	1,642	T6	SP27	500.0	DI	100.0	False	0.208	1.06	0.003
1066	P-508	57	SP27	MO	500.0	DI	100.0	False	0.208	1.06	0.003
1076	P-524	637	L20	L23	200.0	DI	100.0	False	0.042	1.35	0.015
1077	P-525	483	L18	L160	150.0	DI	90.0	False	0.022	1.26	0.023
1078	P-526	640	L18	L16	150.0	DI	100.0	False	0.022	1.26	0.019
1079	P-528	2,661	L13	L22	900.0	Steel	94.0	False	0.375	0.59	0.001
1080	P-529	1,548	L13	L8	200.0	DI	120.0	False	0.026	0.82	0.004
1081	P-530	646	L8	L9	150.0	PVC	120.0	False	0.009	0.49	0.002
1082	P-531	376	L8	L7	150.0	PVC	120.0	False	0.009	0.48	0.002
1083	P-532	5,178	J-7	L11	900.0	Steel	90.0	False	0.682	1.07	0.002
1084	P-534	1,209	L11	L5	350.0	DI	100.0	False	0.101	1.05	0.005
1085	P-535	754	L5	L6	250.0	PVC	120.0	False	0.009	0.17	0.000
1086	P-536	839	L5	L3	250.0	PVC	120.0	False	0.084	1.72	0.013
1087	P-537	173	L3	L4	250.0	PVC	120.0	False	0.017	0.34	0.001
1088	P-538	1,084	L11	L10	350.0	DI	100.0	False	0.023	0.24	0.000

1100	P-554	1,097	T11	T19	150.0	DI	100.0	False	-0.013	0.74	0.007
1101	P-555	717	T19	T4	150.0	DI	100.0	False	0.009	0.52	0.004
1102	P-556	30	J-133	T19	150.0	DI	100.0	False	0.031	1.77	0.036
1108	P-666	864	J-110	J-109	150.0	DI	90.0	False	0.011	0.60	0.006
1115	P-852	226	L31	L30	150.0	DI	100.0	False	-0.012	0.65	0.006
1116	P-654	377	RK7	RK10	50.0	PVC	110.0	False	-0.002	1.09	0.044
1128	P-585	2,909	B7	SP26	150.0	GI	90.0	False	0.008	0.44	0.003
1134	P-673	618	J-107	J-106	150.0	GI	80.0	False	-0.029	1.62	0.046
1139	P-831	0	RK15	RK14	100.0	GI	90.0	False	-0.022	2.74	0.151
1142	P-583	699	B10	B9	110.0	PVC	110.0	False	0.000	0.00	0.000
1144	P-634	154	J-142	J-143	400.0	Steel	80.0	False	-0.121	0.96	0.006
1148	P-671	1,195	J-143	J-108	200.0	PVC	110.0	False	0.086	2.74	0.048
1149	P-660	703	RK8	RK7	50.0	PVC	110.0	False	-0.001	0.51	0.010
1153	P-658	812	RK9	RK8	50.0	PVC	110.0	False	0.000	0.08	0.000
1164	P-685	97	G1	J-144	150.0	Steel	80.0	False	-0.024	1.34	0.032
1165	P-672	404	J-108	J-107	150.0	DI	90.0	False	0.010	0.55	0.005
1171	P-830	371	RK20	RK15	100.0	GI	90.0	False	-0.020	2.59	0.142
1173	P-576	1,647	B8	B1	100.0	PVC	110.0	False	0.010	1.30	0.027
1175	P-854	247	L30	L29	125.0	GI	100.0	False	0.012	0.94	0.014
1177	P-678	938	J-112	J-113	350.0	DI	90.0	False	-0.138	1.43	0.011
1183	P-849	420	L33	L32	200.0	DI	100.0	False	-0.012	0.37	0.001
1184	P-686	1,042	J-144	L109	100.0	GI	90.0	False	0.002	0.28	0.002
1195	P-758	470	L1	L2	125.0	DI	100.0	False	-0.022	1.83	0.047
1198	P-677	900	J-106	J-112	300.0	DI	90.0	False	0.000	0.00	0.000
1199	P-584	404	B10	B11	200.0	DI	90.0	False	0.004	0.13	0.000
1202	P-703	384	J-143	J-84	400.0	Steel	80.0	False	-0.214	1.70	0.016
1203	P-704	455	J-84	J-137	500.0	DI	90.0	False	-0.005	0.02	0.000
1205	P-706	281	R3	E2	50.0	PVC	110.0	False	0.000	0.00	0.000
1206	P-708	157	E3	R2	100.0	DI	90.0	False	0.000	0.00	0.000
1207	P-710	90	R1	E4	100.0	PVC	110.0	False	0.022	2.82	0.113
1208	P-711	262	E1	R3	75.0	GI	90.0	False	0.000	0.00	0.000
1209	P-712	293	EN	E16	100.0	GI	90.0	False	0.007	0.91	0.020
1210	P-718	358	RK10	RK9	75.0	GI	90.0	False	0.006	1.44	0.066
1211	P-713	769	RK	RK14	100.0	GI	90.0	False	0.000	0.00	0.000
1212	P-716	1,101	RK21	RK13	150.0	DI	90.0	False	0.003	0.18	0.002
1213	P-717	1,945	RK13	RK22	150.0	DI	50.0	False	0.024	1.34	0.075
1214	P-719	307	RK	RK13	250.0	DI	15.0	False	0.000	0.00	0.000
1215	P-720	1,122	RK13	RK21	150.0	DI	90.0	False	-0.003	0.18	0.002
1216	P-721	180	RK20	RK21	100.0	GI	90.0	False	0.018	2.29	0.108
1217	P-722	62	B7	T-14	250.0	DI	80.0	False	0.000	0.00	0.000
1218	P-723	659	B7	B9	125.0	GI	90.0	False	0.005	0.43	0.000
1237	P-749	482	J-142	J-86	400.0	Steel	80.0	False	0.075	0.60	0.002
1238	P-750	580	J-86	J-110	200.0	DI	90.0	False	0.023	0.72	0.006
1239	P-751	611	J-86	J-110	250.0	DI	90.0	False	0.040	0.81	0.006
1240	P-752	903	J-110	J-109	250.0	DI	90.0	False	0.040	0.81	0.006
1241	P-753	1,101	J-109	J-105	250.0	DI	90.0	False	0.075	1.54	0.018
1242	P-754	165	J-105	J-106	300.0	DI	90.0	False	0.050	0.71	0.004
1243	P-755	833	J-108	J-79	200.0	DI	90.0	False	0.067	2.12	0.043
1244	P-756	899	J-108	J-107	150.0	DI	90.0	False	0.006	0.36	0.002
1245	P-757	361	J-142	J-111	300.0	DI	90.0	False	0.038	0.54	0.002
1246	P-759	839	J-111	J-109	200.0	DI	90.0	False	0.031	0.98	0.010
1247	P-760	1,487	J-84	J-112	350.0	DI	90.0	False	-0.118	1.23	0.008
1248	P-761	461	J-84	J-135	150.0	Steel	90.0	False	-0.001	0.07	0.000
1249	P-764	195	J-135	J-134	150.0	Steel	90.0	False	-0.010	0.57	0.005
1250	P-769	898	J-141	J-137	500.0	DI	90.0	False	0.000	0.00	0.000
1251	P-770	18	J-137	J-135	150.0	DI	90.0	False	-0.007	0.38	0.003
1252	P-771	766	J-119	J-136	300.0	DI	90.0	False	0.092	1.31	0.011
1253	P-773	468	J-136	J-84	300.0	DI	90.0	False	0.090	1.28	0.011
1254	P-775	21	J-135	J-136	150.0	DI	90.0	False	0.000	0.00	0.000

1255	P-778	379	J-117	J-114	200.0	Steel	100.0	False	0.032	1.00	0.009
1256	P-781	108	J-114	PG	200.0	Steel	100.0	False	0.048	1.52	0.019
1257	P-783	1,063	J-114	J-120	150.0	DI	100.0	False	-0.024	1.34	0.021
1258	P-784	490	J-120	J-122	150.0	DI	100.0	False	0.009	0.48	0.003
1259	P-785	716	J-144	J-113	150.0	DI	100.0	False	-0.065	3.66	0.136
1260	P-786	521	J-113	J-115	400.0	DI	100.0	False	-0.212	1.68	0.010
1261	P-787	376	G2	G1	150.0	DI	100.0	False	-0.049	2.76	0.081
1262	P-804	942	PG	G1	200.0	DI	100.0	False	0.000	0.00	0.000
1263	P-806	378	L38	L157	200.0	DI	110.0	False	0.016	0.53	0.002
1264	P-807	1,878	L157	L42	200.0	DI	110.0	False	0.015	0.46	0.002
1265	P-808	829	L157	L37	150.0	Steel	80.0	False	-0.004	0.21	0.001
1266	P-805	290	L36	L153	600.0	DI	110.0	False	0.098	0.35	0.000
1267	P-809	84	L153	L37	600.0	DI	110.0	False	0.095	0.34	0.000
1268	P-810	139	L35	L34	400.0	DI	100.0	False	0.018	0.14	0.000
1269	P-811	174	L153	L34	200.0	DI	100.0	False	-0.006	0.18	0.000
1270	P-813	177	L34	L153	200.0	DI	100.0	False	0.006	0.18	0.000
1271	P-814	102	L153	L37	150.0	Steel	80.0	False	0.002	0.09	0.000
1272	P-815	207	L34	L153	200.0	Steel	90.0	False	0.005	0.15	0.000
1273	P-816	2,046	L153	L47	200.0	DI	100.0	False	0.028	0.90	0.007
1274	P-817	1,234	L47	L45	350.0	DI	100.0	False	0.040	0.42	0.001
1275	P-818	2,070	L153	L47	200.0	DI	100.0	False	0.028	0.90	0.007
1276	P-819	1,291	L153	L46	250.0	DI	100.0	False	-0.042	0.85	0.005
1277	P-820	604	L30	L28	250.0	DI	100.0	False	-0.035	0.71	0.004
1278	P-821	2,787	L19	L32	400.0	DI	100.0	False	0.023	0.18	0.000
1279	P-822	2,055	L28	L47	200.0	DI	100.0	False	-0.004	0.13	0.000
1280	P-823	159	L42	L43	200.0	DI	110.0	False	-0.001	0.02	0.000
1282	P-825	1,455	L43	L41	150.0	DI	100.0	False	-0.008	0.45	0.003
1283	P-826	691	J-79	L156	150.0	GI	90.0	False	0.001	0.07	0.000
1284	P-827	2,150	L113	L82	200.0	DI	100.0	False	0.025	0.79	0.006
1285	P-828	385	L82	L79	125.0	Steel	100.0	False	0.017	1.39	0.028
1286	P-829	490	L83	L79	150.0	DI	100.0	False	-0.009	0.51	0.004
1293	P-838	944	L83	L84	200.0	DI	90.0	False	0.008	0.25	0.001
1308	P-868	505	L104	L105	150.0	DI	100.0	False	0.016	0.93	0.011
1325	P-885	778	J-78	M18	300.0	DI	100.0	False	0.002	0.03	0.000
1327	P-887	173	SP27	J-76	300.0	DI	100.0	False	0.000	0.00	0.000
1329	P-889	854	J-76	SP12	300.0	DI	120.0	False	0.005	0.07	0.000
1337	P-898	257	IC7	J-86	400.0	Steel	90.0	False	-0.013	0.10	0.000
1338	P-897	611	L114	L115	900.0	Steel	90.0	False	0.877	1.38	0.003
1339	P-899	2,300	L115	J-80	900.0	Steel	90.0	False	0.868	1.36	0.003
1340	P-900	409	J-91	L115	150.0	Steel	90.0	False	0.000	0.00	0.000
1341	P-901	2,182	J-87	J-128	150.0	GI	90.0	False	0.019	1.08	0.017
1342	P-902	1,423	L14	L114	900.0	Steel	90.0	False	1.130	1.78	0.005
1343	P-903	700	L15	L14	150.0	DI	100.0	False	-0.014	0.78	0.008
1344	P-904	906	L11	L12	900.0	Steel	94.0	False	0.493	0.78	0.001
1345	P-905	781	L12	L13	900.0	Steel	94.0	False	0.431	0.68	0.001
1405	P-965	384	J-141	J-130	800.0	DI	100.0	False	-0.002	0.00	0.000
1406	P-966	794	B7	B13	200.0	DI	60.0	False	0.043	1.37	0.037
1407	P-967	464	B13	B4	200.0	DI	90.0	False	0.037	1.19	0.021
1408	P-968	984	J-127	J-139	150.0	DI	100.0	False	0.005	0.27	0.001
1409	P-969	996	J-139	J-140	150.0	DI	100.0	False	-0.015	0.86	0.009
1410	P-970	868	J-140	J-123	150.0	DI	100.0	False	-0.030	1.68	0.032
1411	P-971	520	J-55	G3	200.0	DI	100.0	False	0.083	2.64	0.053
1412	P-972	1,005	G3	G1	200.0	DI	100.0	False	0.049	1.55	0.020
1413	P-973	928	G4	G5	200.0	DI	90.0	False	-0.011	0.34	0.000
1414	P-974	768	G5	G6	200.0	DI	90.0	False	-0.034	1.09	0.013
1415	P-975	374	G6	PG	200.0	DI	90.0	False	0.000	0.00	0.000
1416	P-976	431	T13	T15	150.0	DI	100.0	False	0.017	0.95	0.011
1417	P-977	587	T15	T1	150.0	DI	100.0	False	0.000	0.02	0.000
1418	P-978	427	T13	T14	400.0	DI	100.0	False	0.129	1.03	0.004

1419	P-979	604	T14	T7	400.0	DI	100.0	False	0.112	0.89	0.003
1420	P-980	590	J-29	T16	500.0	DI	100.0	False	0.170	0.87	0.002
1421	P-981	495	T16	T6	500.0	DI	100.0	False	0.152	0.77	0.002
1422	P-982	539	Jan Meda	T17	800.0	DI	100.0	False	0.580	1.15	0.002
1423	P-983	442	T17	J-133	800.0	DI	100.0	False	0.561	1.12	0.002
1424	P-984	520	T10	T18	200.0	DI	100.0	False	0.008	0.24	0.001
1425	P-985	586	T18	T9	200.0	DI	100.0	False	-0.001	0.03	0.000
1431	P-991	1,334	L28	L110	400.0	DI	110.0	False	-0.024	0.19	0.000
1432	P-992	638	L110	L47	400.0	DI	110.0	False	-0.034	0.27	0.000
1433	P-993	1,492	L47	L111	400.0	DI	100.0	False	0.027	0.21	0.000
1434	P-994	516	L111	L28	400.0	DI	100.0	False	0.018	0.14	0.000
1437	P-997	43	L125	J-87	150.0	GI	90.0	False	0.019	1.08	0.017
1438	P-998	36	L2	L3	125.0	DI	100.0	False	-0.048	3.93	0.192
1441	P-636	99	J-65	E12	150.0	DI	100.0	False	0.033	1.87	0.039
1442	P-637	1,783	E12	B14	150.0	DCI	100.0	False	0.024	1.34	0.021
1447	P-643	16	L117	FCV-1	900.0	Steel	100.0	False	1.158	1.82	0.005
1448	P-644	1,046	FCV-1	L14	900.0	Steel	90.0	False	1.158	1.82	0.006
1449	P-646	622	J-101	RK10	75.0	GI	90.0	False	0.010	2.18	0.143
1450	P-645	21	RK	PMP-47	75.0	GI	90.0	False	0.000	0.00	0.000
1451	P-647	19	PMP-47	J-101	75.0	GI	90.0	False	0.006	1.46	0.065
1452	P-648	23	T-14	PMP-48	100.0	DI	90.0	False	0.000	0.00	0.000
1453	P-649	24	PMP-48	B8	100.0	DI	90.0	False	0.007	0.87	0.026
1454	P-650	27	RK	PMP-49	150.0	DCI	100.0	False	0.000	0.00	0.000
1455	P-651	29	PMP-49	J-101	150.0	DCI	100.0	False	0.003	0.18	0.000
1456	P-652	29	T-14	PMP-50	100.0	Steel	100.0	False	0.000	0.00	0.000
1457	P-653	34	PMP-50	B8	100.0	Steel	100.0	False	0.007	0.87	0.018
1460	P-582a	16	B7	J-104	90.0	DI	80.0	False	0.070	11.00	3.137
1461	P-582	1,161	J-104	B10	250.0	DI	90.0	False	0.070	1.43	0.017
1478	P-1	0	R-1	LAG TANK	600.0	DI	130.0	False	0.238	0.84	0.001
1479	P-2	0	R-2	LAG TANK	900.0	DI	130.0	False	2.932	4.61	0.016

Figure B.4 Velocity Map of Links for Peak Hour Demand Scenario, EPS Analysis

Scenario: Peak Hour Demand

Existing Water System of Legedadi sub system.wtg
5/12/2014

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W Watertown, CT 06795 USA +1-203-755-1666

Bentley WaterCAD V8i (SELECTseries 4)
[08.11.04.50]
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Appendix A.7 Tank Condition EPS Analysis Results at Peak Hour Demand

Flex Table: Tank Table (Existing Water System of Legedadi sub system.wtg), Current Time: 14.000 hours

ID	Label	Elevation (Base) (m)	Elevation (Minimum) (m)	Elevation (Initial) (m)	Elevation (Maximum) (m)	Volume (Inactive) (ML)	Diameter (m)	Flow (Out net) (m^3/s)	Hydraulic Grade (m)
642	LAGADA DI TANK	2,422.00	2,423.00	2,426.80	2,428.00	0.00	3.05	-1.099	2,428.00
643	ST2	2,410.00	2,410.00	2,421.12	2,423.00	0.00	3.05	0.000	2,421.12
644	ST4	2,404.00	2,404.20	2,406.70	2,409.20	0.00	8.00	0.000	2,406.70
645	TR2	2,404.00	2,404.20	2,406.50	2,409.20	0.00	50.00	0.315	2,404.86
646	ST3	2,400.00	2,418.00	2,418.55	2,420.00	0.00	3.05	-0.046	2,419.21
647	TR1	2,404.00	2,404.20	2,406.70	2,409.20	0.00	50.00	0.337	2,404.71
648	AN	2,387.00	2,387.00	2,387.10	2,395.00	0.00	28.00	0.000	2,387.10
649	Jan Meda	2,462.10	2,462.10	2,466.10	2,470.10	0.00	28.00	0.339	2,463.73
650	TM	2,508.30	2,508.30	2,512.30	2,514.30	0.00	32.00	0.069	2,508.30
651	EN	2,563.50	2,563.50	2,566.50	2,571.80	0.00	14.00	0.025	2,568.47
652	RK	2,548.00	2,548.00	2,550.00	2,553.00	0.00	12.00	0.036	2,548.00
653	R1	2,639.00	2,639.00	2,641.00	2,646.20	0.00	21.00	0.014	2,639.94
654	MO	2,486.50	2,486.50	2,489.80	2,490.20	0.00	60.00	-0.043	2,490.13
655	T-14	2,635.60	2,635.60	2,637.60	2,639.60	0.00	17.00	0.071	2,635.60
658	R2	2,683.40	2,683.40	2,685.40	2,687.40	0.00	6.00	0.002	2,683.40
659	R3	2,746.80	2,746.80	2,748.80	2,750.80	0.00	6.00	0.008	2,746.80
665	PG	2,419.50	2,419.50	2,420.00	2,424.00	0.00	16.00	-0.003	2,419.50

Appendix A.8 Pump Definition EPS Analysis Results at Peak Hour Demand

ID	Label	Pump Definition	Status (Initial)	Hydraulic Grade (Suction) (m)	Hydraulic Grade (Discharge) (m)	Flow (Total) (m^3/s)	Pump Head (m)
674	TR3	Pump Terminal (1,2,3)	Off	2,404.81	2,473.69	0.000	0.00
675	TR2	Pump Terminal (1,2,3)	On	2,404.74	2,473.86	0.353	69.12
676	TP1	Pump Terminal (1,2,3)	On	2,404.65	2,473.86	0.352	69.20
677	TR6	Pump Terminal (4,5,6)	Off	2,404.00	2,458.31	0.000	0.00
678	TR5	Pump Terminal (4,5,6)	On	2,402.80	2,459.22	0.198	56.41
679	TR4	Pump Terminal (4,5,6)	On	2,402.82	2,458.98	0.199	56.16
680	JM3	Pump Jan Meda 3,4,5 (To AAWSA)	Off	2,463.63	2,498.24	0.000	0.00
681	JM4	Pump Jan Meda 3,4,5 (To AAWSA)	On	2,463.52	2,498.50	0.085	34.98
682	JM5	Pump Jan Meda 3,4,5 (To AAWSA)	On	2,463.51	2,498.41	0.085	34.90
683	JM1	Pump Jan Meda 1,2 (To Tel. Mek.)	On	2,463.59	2,518.54	0.075	54.95
684	JM2	Pump Jan Meda 1,2 (To Tel. Mek.)	On	2,463.56	2,518.30	0.076	54.74
685	JM9	Pump Jan Meda 7,8,9 (To Tef.Mek.)	Off	2,463.67	2,530.61	0.000	0.00
686	JM8	Pump Jan Meda 7,8,9 (To Tef.Mek.)	On	2,463.53	2,531.21	0.035	67.68
687	JM7	Pump Jan Meda 7,8,9 (To Tef.Mek.)	On	2,463.54	2,531.13	0.035	67.59
688	TM2	Pump Tefere Mekonnen 1,2 (to Entoto)	Off	2,508.14	2,570.90	0.000	0.00
689	TM1	Pump Tefere Mekonnen 1,2 (to Entoto)	On	2,508.02	2,571.02	0.086	63.00
690	TM4	Pump Tefere Mekonnen 3,4 (To Rass Kassa)	Off	2,508.08	2,574.64	0.000	0.00
691	TM3	Pump Tefere Mekonnen 3,4 (To Rass Kassa)	On	2,507.61	2,575.32	0.024	67.71
692	Entoto1	Pump Entoto (to R1)	On	2,567.24	2,658.27	0.019	91.04
693	Entoto2	Pump Entoto (to R1)	Off	2,567.48	2,657.72	0.000	0.00
694	MO1	Pump AAWSA Main (1,2)	On	2,490.01	2,653.40	0.073	163.40
695	MO2	Pump AAWSA Main (1,2)	Off	2,490.07	2,653.09	0.000	0.00
696	MO3	Pump AAWSA Main (3)	On	2,490.13	2,534.09	0.005	43.96
697	ME2	Pump Mexico 2	Off	2,324.20	2,364.15	0.000	0.00
698	ME1	Pump Mexico 1	On	2,324.18	2,364.16	0.009	39.98
701	R1(1)	Pump R1	On	2,639.63	2,685.95	0.010	46.32
702	R2(1)	Pump R2	On	-2,200,074.14	-2,199,990.16	0.002	83.97
712	UR1	Pump Urael	On	2,379.22	2,394.51	0.083	15.29
720	PMP-47	RK	On	-6,917,799.93	-6,917,654.24	0.006	145.69
721	PMP-48	BZ	On	-7,315,667.56	-7,315,598.07	0.007	69.49
722	PMP-49	RK	Off	-3,457,553.66	-6,917,655.46	0.000	0.00
723	PMP-50	BZ	On	-7,315,667.56	-7,315,598.07	0.007	69.49

FIRE FLOW DEMAND SCENARIO

Appendix A.9: Node EPS Analysis Results at Peak Hour + 1-Hr Fire flow Results

Flex Table: Junction Table (Existing Water System of Legedadi sub system.wtg)

ID	Label	Elevation (m)	Demand Pattern	Demand (m^3/s)	Hydraulic Grade (m)	Pressure (m H2O)
129	C1	2,410.00		0.000	2,422.82	12.79
130	C1a	2,410.00		0.000	2,422.82	12.79
131	J-4	2,410.00		0.000	2,423.41	13.38
132	J-5	2,410.00		0.000	2,423.27	13.25
133	J-6	2,400.00		0.000	2,419.82	19.78
134	J-7	2,400.00		0.000	2,419.72	19.68
135	L22	2,406.00	D	0.022	2,405.18	-0.81
136	L117	2,406.00		0.000	2,404.83	-1.16
137	L114	2,375.00	D	0.010	2,387.89	12.86
138	L20	2,351.00	D	0.096	2,384.38	33.32
139	L118	2,402.00	D & F	0.100	2,468.37	66.24
140	L119	2,402.00		0.000	2,405.12	3.11
141	L120	2,402.00	D & F	0.100	2,468.37	66.24
142	L121	2,402.00	D & F	0.100	2,468.37	66.24
143	L122	2,402.00		0.000	2,405.12	3.11
144	L123	2,402.00		0.000	2,405.12	3.11
145	L124	2,402.00		0.000	2,403.61	1.61
146	L125	2,404.00		0.000	2,404.64	0.64
147	L126	2,402.00		0.000	2,404.11	2.10
148	L127	2,402.00		0.000	2,447.47	45.38
149	L128	2,402.00		0.000	2,403.73	1.73
150	L129	2,402.00		0.000	2,447.47	45.38
151	L130	2,402.00		0.000	2,447.11	45.02
152	J-131	2,427.00	D	0.002	2,455.18	28.13
153	J-124	2,420.00	D	0.038	2,437.52	17.49
154	J-27	2,400.00		0.000	2,405.15	5.14
155	J-28	2,460.00		0.000	2,463.67	3.66
156	J-29	2,460.00		0.000	2,498.05	37.98
157	J-30	2,460.00		0.000	2,498.15	38.07
158	J-31	2,460.00		0.000	2,463.68	3.68
159	J-32	2,460.00		0.000	2,463.67	3.66
160	J-33	2,460.00		0.000	2,498.15	38.07
161	J-35	2,460.00		0.000	2,463.70	3.69
162	J-36	2,460.00		0.000	2,518.11	58.00
163	J-37	2,460.00		0.000	2,463.73	3.72
164	J-38	2,460.00		0.000	2,518.32	58.21
165	J-39	2,460.00		0.000	2,463.30	3.29
166	J-40	2,460.00	F	0.100	2,463.57	3.56
167	J-41	2,460.00	F	0.100	2,464.52	4.51
168	J-42	2,460.00		0.000	2,463.38	3.38
169	J-43	2,460.00		0.000	2,463.30	3.29
170	J-44	2,460.00	F	0.100	2,464.07	4.07
171	J-45	2,507.00		0.000	2,508.07	1.07
172	J-46	2,507.00		0.000	2,571.26	64.13
173	J-47	2,507.00		0.000	2,508.14	1.13
174	J-48	2,507.00		0.000	2,571.26	64.13
175	J-49	2,507.00		0.000	2,484.89	-22.07

176	J-50	2,507.00		0.000	2,496.12	-10.86
177	J-51	2,507.00	F	0.100	1,247.37	-1,257.09
178	J-52	2,507.00	F	0.100	1,235.63	-1,268.81
179	E15	2,564.00	D	0.005	1,247.11	-1,314.24
180	J-133	2,432.00	D	0.002	2,459.75	27.70
181	J-132	2,433.00	D	0.002	2,458.48	25.43
182	T7	2,473.00	D	0.012	2,503.04	29.98
183	T12	2,512.00	D	0.005	2,507.81	-4.18
184	T9	2,459.00	D	0.014	2,501.45	42.37
185	SP15	2,490.00	D	0.002	2,507.75	17.71
186	T13	2,510.00	D	0.005	2,507.00	-2.99
187	T1	2,469.00	D	0.009	2,501.69	32.62
188	B14	2,536.00	D	0.081	2,518.18	-17.78
189	J-63	2,560.00		0.000	2,568.75	8.73
190	J-64	2,560.00		0.000	2,565.75	5.74
191	J-65	2,560.00		0.000	2,567.33	7.31
192	SP16	2,490.00	D	0.002	2,517.56	27.51
193	J-67	2,560.00		0.000	2,565.75	5.74
194	J-68	2,560.00	F	0.100	2,517.58	-42.33
195	L35	2,345.00	D	0.002	2,305.97	-38.95
196	SP17	2,476.00	D	0.022	2,487.61	11.58
197	J-71	2,483.00	F	0.100	2,322.35	-160.33
198	J-72	2,483.00		0.000	2,489.80	6.78
199	J-73	2,483.00		0.000	2,489.80	6.78
200	J-74	2,483.00	F	0.100	2,322.07	-160.60
201	J-75	2,483.00		0.000	2,489.54	6.53
202	J-76	2,483.00		0.000	2,515.41	32.34
204	J-78	2,352.00		0.000	2,305.08	-46.82
205	J-79	2,340.00		0.000	2,305.83	-34.10
206	M23	2,352.00	D	0.009	2,345.05	-6.93
207	J-81	2,352.00		0.000	2,345.05	-6.93
208	J-82	2,352.00		0.000	2,305.11	-46.79
209	M18	2,345.00	D	0.003	2,305.07	-39.85
211	M19	2,345.00	D	0.003	2,305.08	-39.84
215	J-90	2,637.00		0.000	2,639.80	2.80
216	E13	2,637.00	D	0.005	2,685.13	48.03
217	J-92	2,682.00		0.000	-2,413,242.87	-2,411,058.64
218	E14	2,682.00	D	0.000	2,682.00	0.00
243	L37	2,349.00	D	0.002	2,305.86	-43.05
244	L112	2,350.00	D	0.022	2,373.47	23.42
245	C45	2,350.00		0.000	2,373.26	23.21
246	J-55	2,350.00	F	0.100	2,353.55	3.54
247	J-118	2,423.00	D	0.003	2,421.15	-1.84
256	L28	2,325.00	D	0.013	2,288.66	-36.27
257	L116	2,332.00	D	0.002	2,372.27	40.19
258	L46	2,335.00	D	0.013	2,314.79	-20.17
259	L36	2,336.00	D	0.002	2,305.98	-29.96
260	L40	2,347.00	D	0.009	2,305.79	-41.13
261	L41	2,326.00	D	0.016	2,305.62	-20.34
262	L44	2,311.00	D	0.008	2,300.54	-10.44
263	L47	2,317.00	D	0.444	2,289.13	-27.82
265	L45	2,305.00	D	0.093	2,287.71	-17.26
267	L42	2,300.00	D	0.008	2,300.97	0.96
269	L154	2,340.00	D	0.002	2,305.90	-34.03
270	L113	2,351.00	D	0.004	2,304.43	-46.48
271	L69	2,283.00	D	0.005	2,285.46	2.45
276	L81	2,292.00	D	0.004	2,281.46	-10.52
277	L104	2,320.00	D	0.004	2,273.18	-46.73
278	L83	2,316.00	D	0.043	2,274.98	-40.93

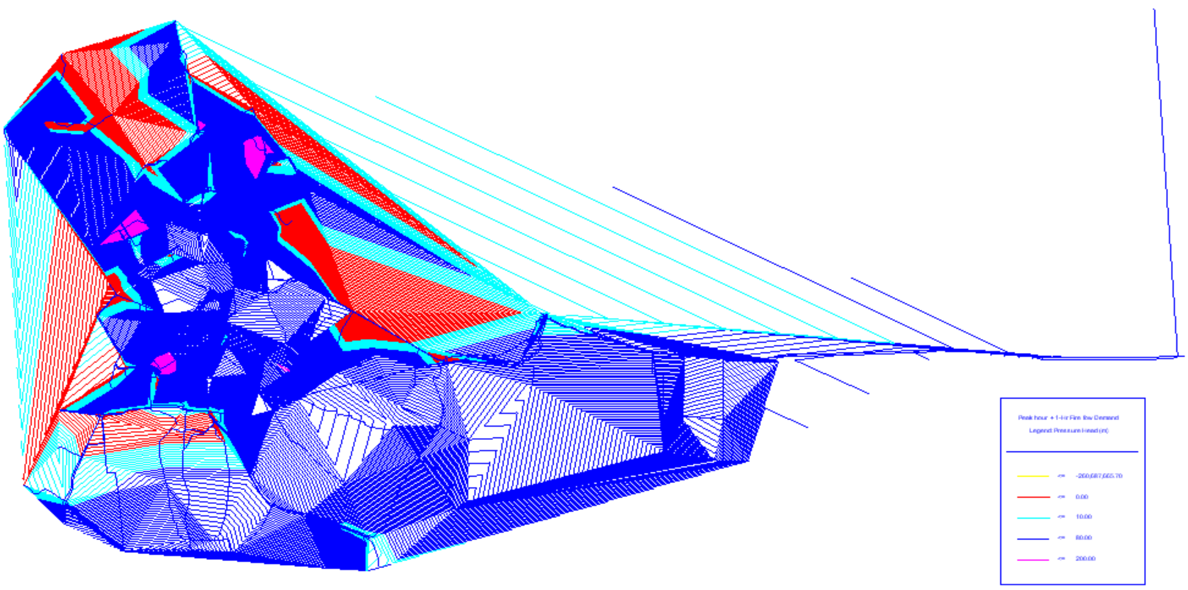
279	J-70	2,352.00		0.000	2,304.79	-47.12
281	L27	2,339.00	D	0.055	2,359.44	20.40
282	L24	2,351.00	D	0.014	2,383.01	31.95
283	L70	2,280.00	D	0.005	2,285.19	5.18
284	L19	2,327.00	D	0.012	2,381.99	54.88
285	L18	2,332.00	D	0.024	2,352.94	20.90
286	J-80	2,345.00		0.000	2,375.69	30.63
287	L26	2,342.00	D	0.029	2,360.40	18.36
296	L155	2,340.00	D	0.001	2,305.91	-34.02
297	L38	2,349.00	D	0.006	2,305.81	-43.11
298	L108	2,345.00	D	0.002	2,305.89	-39.03
332	J-138	2,390.00	D	0.078	2,386.08	-3.91
339	J-127	2,387.00	D	0.289	2,336.98	-49.92
340	J-123	2,376.00	D	0.021	2,368.68	-7.30
341	J-125	2,418.00	D	0.170	2,327.98	-89.84
342	J-126	2,418.00	D	0.039	2,436.94	18.90
343	J-129	2,411.00	D	0.013	2,446.70	35.63
344	J-122	2,386.00	D	0.013	2,393.81	7.79
345	J-120	2,371.00	D & F	0.110	2,394.04	22.99
346	J-121	2,366.00	D & F	0.110	2,156.20	-209.38
347	J-115	2,405.00	D	0.008	2,436.72	31.66
348	J-130	2,425.00	D	0.002	2,459.52	34.45
349	J-116	2,405.00	D	0.004	2,446.80	41.71
350	J-117	2,406.00	D	0.004	2,420.46	14.43
351	J-84	2,410.00		0.000	2,402.07	-7.91
352	J-134	2,411.00	D	0.002	2,406.78	-4.22
353	J-119	2,431.00	D	0.003	2,426.82	-4.17
354	T3	2,440.00	D	0.020	2,418.60	-21.36
355	T11	2,410.00	D	0.014	2,449.25	39.17
356	T4	2,435.00	D	0.010	2,455.38	20.34
357	T8	2,472.00	D	0.012	2,502.74	30.68
358	T10	2,472.00	D	0.009	2,501.80	29.74
359	T5	2,455.00	D	0.009	2,500.61	45.52
360	T6	2,460.00	D	0.010	2,495.73	35.65
361	IC5	2,437.00	D	0.006	2,486.77	49.67
362	IC1	2,472.00	D	0.006	2,487.13	15.10
363	IC2	2,463.00	D	0.013	2,486.25	23.20
364	IC3	2,450.00	D	0.030	2,485.66	35.58
365	IC4	2,432.00	D	0.012	2,485.30	53.19
366	IC6	2,465.00	D	0.006	2,487.49	22.45
367	SP27	2,491.00		0.000	2,490.34	-0.66
378	L23	2,352.00	D	0.047	2,372.76	20.72
379	L160	2,334.00	D	0.024	2,339.76	5.75
380	L16	2,327.00	D	0.024	2,338.56	11.54
381	L13	2,387.00	D	0.033	2,406.16	19.12
382	L8	2,340.00	D	0.009	2,274.25	-65.62
383	L9	2,332.00	F	0.110	2,107.47	-224.08
384	L7	2,363.00	D	0.009	2,273.24	-89.58
385	L11	2,382.00	D	0.070	2,407.85	25.79
386	L5	2,362.00	D	0.009	2,400.59	38.51
387	L6	2,365.00	D	0.009	2,400.42	35.35
388	L3	2,360.00	D	0.022	2,387.43	27.38
389	L4	2,360.00	D	0.018	2,387.30	27.25
390	L10	2,392.00	D	0.026	2,407.41	15.38
397	T19	2,430.00	D	0.010	2,458.47	28.41
398	RK22	2,431.00	D	0.000	2,431.00	0.00
403	J-144	2,364.00	D	0.043	2,358.22	-5.77
405	RK7	2,511.00	D	0.000	2,511.00	0.00
412	G4	2,351.00	D	0.012	2,398.56	47.47

413	L156	2,347.00	D	0.001	2,305.74	-41.18
421	J-87	2,404.00		0.000	2,403.75	-0.25
422	L31	2,320.00	D	0.013	2,284.52	-35.41
424	SP26	2,493.00	D & F	0.000	2,493.00	0.00
425	RK20	2,500.00	D	0.000	2,500.00	0.00
426	RK15	2,522.00	D	0.000	2,522.00	0.00
427	J-143	2,423.00	D	0.008	2,395.43	-27.51
428	J-112	2,346.00	D & F	0.122	2,407.94	61.81
431	B9	2,582.00	D	0.000	2,582.00	0.00
435	L2	2,360.00	D	0.028	2,379.22	19.19
438	J-106	2,355.00	D	0.024	2,361.21	6.19
440	E1	2,734.00	D	0.000	2,734.00	0.00
441	L30	2,320.00	D	0.013	2,286.03	-33.90
443	E4	2,635.00	D	0.024	2,627.90	-7.09
444	L33	2,325.00	D	0.013	2,380.73	55.62
445	J-128	2,385.00	D	0.021	2,359.00	-25.95
447	B4	2,593.00	D	0.000	2,593.00	0.00
448	J-109	2,385.00	D	0.006	2,383.93	-1.07
452	E3	2,673.00	D	0.000	2,673.00	0.00
453	L105	2,308.00	D	0.018	2,266.69	-41.23
458	J-141	2,432.00	D	0.003	2,459.52	27.46
459	L29	2,317.00	D	0.013	2,282.03	-34.90
463	RK21	2,490.00	D	0.000	2,490.00	0.00
464	J-108	2,353.00	D	0.004	2,337.37	-15.60
467	J-110	2,417.00	D	0.013	2,389.45	-27.49
469	E2	2,708.00	D	0.000	2,708.00	0.00
470	B7	2,631.00	D	0.000	2,631.00	0.00
478	RK8	2,538.00	D	0.000	2,538.00	0.00
479	L15	2,360.00	D	0.015	2,391.00	30.94
485	E16	2,547.00	D	0.008	2,561.90	14.87
488	B8	2,636.00	D & F	0.000	2,636.00	0.00
490	RK14	2,523.00	D	0.000	2,523.00	0.00
493	L79	2,292.00	D	0.009	2,277.05	-14.92
495	RK10	2,553.00	D	0.000	2,553.00	0.00
501	L1	2,356.00	D	0.025	2,353.29	-2.71
504	J-142	2,424.00	D	0.008	2,394.47	-29.47
505	L109	2,345.00	D	0.002	2,355.41	10.39
506	J-107	2,379.00	D	0.049	2,334.11	-44.80
507	B11	2,610.00	D	0.000	2,610.00	0.00
509	G2	2,343.00	D	0.053	2,321.62	-21.33
522	B10	2,600.00	D	0.000	2,600.00	0.00
524	J-86	2,434.00		0.000	2,393.23	-40.69
528	J-91	2,360.00		0.000	2,385.29	25.24
543	J-113	2,403.00	D	0.010	2,428.53	25.48
547	G1	2,364.00	D	0.026	2,357.68	-6.31
550	B1	2,706.00	D	0.000	2,706.00	0.00
552	RK9	2,588.00	D	0.000	2,588.00	0.00
554	J-137	2,390.00	D	0.002	2,402.09	12.06
559	L32	2,325.00	D	0.013	2,381.42	56.31
562	RK13	2,520.00	D	0.000	2,520.00	0.00
565	J-105	2,358.00	D	0.027	2,361.83	3.82
566	J-111	2,397.00	D	0.008	2,393.60	-3.39
567	J-135	2,390.00	D	0.002	2,402.34	12.31
568	J-136	2,390.00	D	0.002	2,411.27	21.22
569	J-114	2,417.00	D	0.008	2,420.10	3.10
570	L157	2,339.00	D	0.006	2,304.82	-34.11
571	L153	2,345.00	D	0.002	2,305.89	-39.03
572	L34	2,345.00	D	0.002	2,305.95	-38.97
573	L43	2,303.00	D	0.008	2,300.97	-2.03

574	L82	2,311.00	D	0.009	2,289.89	-21.07
576	L84	2,321.00	D	0.009	2,274.06	-46.85
586	SP12	2,463.00	D & F	0.105	2,508.39	45.30
589	IC7	2,441.00	D	0.014	2,393.21	-47.70
590	L115	2,370.00	D	0.010	2,385.29	15.26
591	L14	2,377.00	D	0.015	2,397.42	20.38
592	L12	2,385.00	D	0.068	2,406.83	21.79
611	B13	2,595.00	D	0.000	2,595.00	0.00
612	J-139	2,373.00	D	0.022	2,333.89	-39.03
613	J-140	2,365.00	D	0.016	2,341.37	-23.58
614	G3	2,358.00	D	0.038	2,352.51	-5.48
615	G5	2,367.00	D	0.026	2,400.21	33.14
616	G6	2,402.00	D	0.011	2,411.69	9.67
617	T15	2,497.00	D	0.019	2,501.65	4.64
618	T14	2,492.00	D	0.019	2,505.09	13.06
619	T16	2,447.00	D	0.020	2,496.66	49.56
620	T17	2,454.00	D	0.020	2,461.53	7.51
621	T18	2,459.00	D	0.009	2,501.44	42.35
625	L110	2,306.00	D	0.010	2,288.91	-17.05
626	L111	2,324.00	D	0.010	2,288.72	-35.21
629	E12	2,560.00	D	0.010	2,562.74	2.73
632	J-101	2,545.00	D & F	0.000	2,545.00	0.00
634	J-104	2,615.00		0.000	-260,689,753.65	-260,167,262.78

Figure B.5 Pressure Map of Nodes for Peak hour + 1-Hr Fire Flow demand Scenario, EPS Analysis

Scenario: Peak hour + 1- Hr Fire flow



Existing Water System of Legedadi sub system 2.wtg
5/13/2014

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W Watertown, CT 06795 USA +1-203-755-1666

Bentley WaterCAD V8i (SELECTseries 4)
[08.11.04.50]
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Appendix A.10 Links EPS Analysis Result at Peak Hour +1Hr Fire flow Demand Results

Flex Table: Pipe Table (Existing Water System of Legedadi sub system.wtg)

ID	Label	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Flow (m^3/s)	Velocity (m/s)	Headloss Gradient (m/m)	Length (User Defined) (m)
730	P-2	LAGA TANK	C1a	900	Steel	115	FALSE	0.5	0.79	0.001	6,890
731	P-3	C1a	C1	700	Steel	100	FALSE	-0.137	0.36	0	10
732	P-4	LAGA TANK	J-4	1,400.00	Steel	110	FALSE	1.494	0.97	0.001	6,360
733	P-5	J-4	ST2	1,200.00	Steel	100	FALSE	0	0	0	20
734	P-6	ST2	J-5	1,200.00	Steel	100	FALSE	0	0	0	20
735	P-7	J-5	C1	1,400.00	Steel	100	FALSE	1.494	0.97	0.001	528
736	P-8	J-5	J-4	1,000.00	Steel	100	FALSE	-1.494	1.9	0.004	30
737	P-9	ST3	J-6	1,200.00	Steel	100	FALSE	-0.937	0.83	0.001	20
738	P-10	J-6	C1	1,200.00	Steel	100	FALSE	-1.357	1.2	0.002	1,964
739	P-11	C1a	J-6	900	Steel	100	FALSE	0.637	1	0.002	1,964
740	P-12	ST3	J-7	1,200.00	DCI	100	FALSE	1.014	0.9	0.001	88
741	P-13	J-7	L22	1,200.00	Steel	100	FALSE	1.357	1.2	0.002	9,526
742	P-14	L22	TR2	900	Steel	100	FALSE	0.27	0.42	0	35
743	P-15	L22	ST4	1,200.00	Steel	100	FALSE	0	0	0	10
744	P-16	J-7	J-6	1,000.00	Steel	100	FALSE	-1.057	1.35	0.002	40
745	P-17	L22	TR1	900	Steel	100	FALSE	1.342	2.11	0.006	35
746	P-19	TR1	L117	1,000.00	Steel	100	FALSE	1.304	1.66	0.003	40
747	P-21	L114	AN	600	Steel	100	FALSE	0	0	0	148
748	P-22	L114	L20	600	DI	100	FALSE	0.268	0.95	0.002	1,585
749	P-26	L119	TR3	600	Steel	100	FALSE	0	0	0	19
750	P-27	TR3	L118	500	Steel	100	FALSE	0	0	0	18
751	P-28	L118	L120	900	DI	100	FALSE	-0.1	0.16	0	24
752	P-29	L120	L121	900	DI	100	FALSE	0.182	0.29	0	18
753	P-30	L121	Jan Meda	900	DI	120	FALSE	0.464	0.73	0.001	7,550
754	P-31	L119	L122	1,000.00	Steel	100	FALSE	0	0	0	7
755	P-32	L122	L123	1,000.00	Steel	100	FALSE	-0.382	0.49	0	5
756	P-34	L122	TR2	600	Steel	100	FALSE	0.382	1.35	0.004	19
757	P-36	TR2	L120	500	Steel	100	FALSE	0.382	1.95	0.01	19
758	P-35	L123	TP1	500	Steel	100	FALSE	0.382	1.94	0.01	19
759	P-37	TP1	L121	500	Steel	100	FALSE	0.382	1.94	0.01	20
760	P-38	TR2	L125	150	Steel	100	FALSE	0.016	0.92	0.011	50
761	P-40	TR1	L125	500	Steel	100	FALSE	0.446	2.27	0.014	24
762	P-39	L125	L126	500	Steel	100	FALSE	0.442	2.25	0.014	39
763	P-41	L126	L128	500	Steel	100	FALSE	0.442	2.25	0.014	27
764	P-43	L128	L124	500	Steel	100	FALSE	0.221	1.13	0.004	33
765	P-46	L126	TR6	150	Steel	100	FALSE	0	0	0	25
766	P-47	TR6	L127	150	Steel	100	FALSE	0	0	0	23
767	P-48	L128	TR5	300	Steel	100	FALSE	0.221	3.12	0.045	24
768	P-49	TR5	L129	300	Steel	100	FALSE	0.221	3.12	0.045	24
769	P-50	L124	TR4	300	Steel	100	FALSE	0.221	3.13	0.045	21
770	P-51	TR4	L130	300	Steel	100	FALSE	0.221	3.13	0.045	26
771	P-52	L127	L129	400	DI	100	FALSE	0	0	0	30
772	P-53	L129	L130	400	DI	100	FALSE	0.221	1.76	0.011	33
773	P-56	L123	J-27	1,000.00	Steel	100	FALSE	-0.764	0.97	0.001	22

774	P-57	J-27	TR2	1,000.00	Steel	100	FALSE	-0.842	1.07	0.002	16
775	P-58	J-27	L117	1,000.00	Steel	100	FALSE	0	0	0	20
776	P-62	J-31	JM3	300	Steel	100	FALSE	0	0	0	9
777	P-63	JM3	J-30	250	Steel	100	FALSE	0	0	0	10
778	P-65	J-31	J-32	600	Steel	100	FALSE	0.172	0.61	0.001	19
779	P-66	J-32	J-28	600	Steel	100	FALSE	0.086	0.3	0	19
780	P-67	J-29	J-33	300	Steel	100	FALSE	-0.086	1.21	0.008	16
781	P-68	J-33	J-30	300	Steel	100	FALSE	0	0	0	19
782	P-69	J-32	JM4	300	Steel	100	FALSE	0.086	1.21	0.008	12
783	P-70	JM4	J-33	250	Steel	100	FALSE	0.086	1.74	0.019	15
784	P-71	J-28	JM5	300	Steel	100	FALSE	0.086	1.22	0.008	13
785	P-72	JM5	J-29	250	Steel	100	FALSE	0.086	1.75	0.019	14
786	P-75	J-35	J-31	600	Steel	100	FALSE	0.172	0.61	0.001	16
787	P-77	Jan Meda	J-37	600	Steel	100	FALSE	0.323	1.14	0.003	20
788	P-78	J-37	J-35	600	Steel	100	FALSE	0.247	0.87	0.002	16
789	P-80	J-38	J-36	250	Steel	100	FALSE	0.075	1.53	0.015	14
790	P-79	J-37	JM1	300	Steel	100	FALSE	0.075	1.06	0.006	13
791	P-81	JM1	J-38	250	Steel	100	FALSE	0.075	1.53	0.015	16
792	P-82	J-35	JM2	300	Steel	100	FALSE	0.076	1.07	0.006	13
793	P-83	JM2	J-36	250	Steel	100	FALSE	0.076	1.54	0.015	14
794	P-84	J-36	TM	400	DI	100	FALSE	0.151	1.2	0.006	1,782
795	P-88	Jan Meda	J-42	350	Steel	100	FALSE	0.2	2.08	0.018	23
796	P-89	J-42	J-43	350	Steel	100	FALSE	0.1	1.04	0.005	17
797	P-91	J-43	J-39	350	Steel	100	FALSE	0	0	0	20
798	P-92	J-40	J-44	250	Steel	100	FALSE	-0.1	2.04	0.025	20
799	P-93	J-44	J-41	250	Steel	100	FALSE	-0.1	2.03	0.025	18
800	P-95	J-39	JM9	200	Steel	100	FALSE	0	0	0	12
801	P-96	JM9	J-40	150	Steel	100	FALSE	0	0	0	15
802	P-97	J-43	JM8	200	Steel	100	FALSE	0.1	3.19	0.076	13
803	P-98	JM8	J-44	150	Steel	100	FALSE	0.1	5.67	0.307	14
804	P-99	J-42	JM7	200	Steel	100	FALSE	0.1	3.18	0.075	13
805	P-100	JM7	J-41	150	Steel	100	FALSE	0.1	5.66	0.306	13
806	P-101	J-41	TM	250	DI	100	FALSE	-0.1	2.03	0.025	1,730
807	P-102	TM	J-47	400	Steel	100	FALSE	0.085	0.68	0.002	85
808	P-103	J-47	J-45	400	Steel	100	FALSE	0.085	0.68	0.002	34
809	P-104	J-46	TM2	300	Steel	100	FALSE	0	0	0	15
810	P-106	TM2	J-47	350	Steel	100	FALSE	0	0	0	16
811	P-105	J-45	TM1	350	Steel	100	FALSE	0.085	0.89	0.004	14
812	P-107	TM1	J-48	300	Steel	100	FALSE	0.085	1.21	0.008	15
813	P-108	J-46	J-48	400	DI	100	FALSE	0	0	0	34
814	P-109	J-48	EN	400	DI	100	FALSE	0.085	0.68	0.002	1,246
815	P-110	TM	J-50	200	Steel	100	FALSE	0.205	6.51	0.283	43
816	P-111	J-50	J-49	200	Steel	100	FALSE	0.205	6.51	0.283	40
817	P-113	J-52	J-51	150	Steel	100	FALSE	-0.1	5.66	0.306	38
818	P-115	J-50	TM4	150	Steel	100	FALSE	0	0	0	12
819	P-116	TM4	J-52	125	Steel	100	FALSE	0	0	0	12
820	P-117	J-49	TM3	150	Steel	100	FALSE	0.205	11.58	1.151	12
821	P-118	TM3	J-51	125	Steel	100	FALSE	0.205	16.67	2.797	13
822	P-119	J-51	E15	200	DI	100	FALSE	0.005	0.15	0	1,056
823	P-120	E15	RK	150	DI	100	FALSE	0	0	0	1,437
824	P-122	Jan Meda	J-132	350	DI	100	FALSE	0.1	1.04	0.005	1,075
825	P-123	TM	T12	400	DI	100	FALSE	0.189	1.5	0.008	63
826	P-126	T12	SP15	250	DI	100	FALSE	0.002	0.05	0	2,449
827	P-127	T12	T13	400	DI	100	FALSE	0.158	1.26	0.006	130
828	P-130	EN	J-63	400	DI	100	FALSE	0.139	1.11	0.005	25
829	P-131	J-63	B14	200	DI	100	FALSE	0.057	1.82	0.027	1,885
830	P-132	J-63	J-65	200	Steel	100	FALSE	0.082	2.62	0.052	27
831	P-135	B14	SP16	150	DI	100	FALSE	0.002	0.14	0	2,035
832	P-136	J-65	J-67	150	Steel	100	FALSE	0.046	2.61	0.073	22

833	P-137	J-67	J-64	150	Steel	100	FALSE	0	0	0	20
834	P-139	J-68	R1	150	DI	100	FALSE	-0.054	3.05	0.097	1,244
835	P-140	J-67	Entoto1	150	Steel	100	FALSE	0.046	2.61	0.073	18
836	P-141	Entoto1	J-68	125	Steel	100	FALSE	0.046	3.76	0.177	16
837	P-142	J-64	Entoto2	150	Steel	100	FALSE	0	0	0	19
838	P-143	Entoto2	J-68	125	DI	100	FALSE	0	0	0	33
839	P-145	MO	SP17	350	DI	100	FALSE	0.096	1	0.005	556
840	P-146	MO	J-72	400	Steel	100	FALSE	0.2	1.59	0.009	38
841	P-148	J-72	J-73	300	Steel	100	FALSE	0	0	0	28
842	P-150	J-71	J-74	300	Steel	100	FALSE	0.1	1.41	0.01	27
843	P-151	J-72	MO1	300	Steel	100	FALSE	0.2	2.83	0.038	12
844	P-152	MO1	J-71	250	Steel	100	FALSE	0.2	4.07	0.092	12
845	P-153	J-73	MO2	300	Steel	100	FALSE	0	0	0	12
846	P-154	MO2	J-74	250	Steel	100	FALSE	0	0	0	11
847	P-155	J-74	T-14	300	DI	100	FALSE	0	0	0	3,031
848	P-156	MO	J-75	300	DCI	100	FALSE	0.105	1.49	0.012	41
849	P-157	J-75	MO3	300	Steel	100	FALSE	0.105	1.49	0.012	20
850	P-158	MO3	J-76	250	Steel	100	FALSE	0.105	2.15	0.028	18
851	P-160	L35	J-79	600	DI	100	FALSE	0.055	0.2	0	1,142
852	P-162	M23	J-81	250	Steel	100	FALSE	0	0	0	37
853	P-161	J-79	J-82	500	DI	100	FALSE	0.091	0.46	0.001	954
854	P-163	J-82	J-78	500	DI	100	FALSE	0.091	0.46	0.001	45
855	P-164	J-81	ME2	300	Steel	120	FALSE	0	0	0	17
856	P-165	ME2	J-82	400	Steel	120	FALSE	0	0	0	12
857	P-169	J-78	ME1	400	Steel	120	FALSE	0.009	0.08	0	13
858	P-170	ME1	M23	300	Steel	100	FALSE	0.009	0.13	0	16
860	P-174	M19	J-78	600	DI	110	FALSE	-0.003	0.01	0	734
869	P-184	R1	J-90	150	DCI	100	FALSE	0.01	0.59	0.005	32
870	P-185	J-90	R1(1)	125	Steel	100	FALSE	0.01	0.86	0.011	19
871	P-186	R1(1)	E13	100	Steel	100	FALSE	0.01	1.34	0.034	20
872	P-187	E13	R2	125	DI	90	FALSE	0.006	0.45	0.004	410
873	P-188	R2	J-92	100	DCI	100	FALSE	0	0	0	22
874	P-190	E14	R3	100	GI	90	FALSE	0	0	0	472
875	P-189	J-92	R2(1)	100	Steel	100	FALSE	0.002	0.29	0	16
876	P-191	R2(1)	E14	80	Steel	100	FALSE	0.002	0.45	0	19
913	P-250	L112	C45	300	Steel	100	FALSE	0.114	1.61	0.013	63
914	P-251	C45	UR1	250	Steel	100	FALSE	0.114	2.32	0.032	17
915	P-252	UR1	J-55	200	Steel	100	FALSE	0.114	3.63	0.096	19
935	P-287	L112	L116	900	Steel	90	FALSE	0.767	1.2	0.003	457
936	P-289	L116	L46	450	DI	90	FALSE	0.563	3.54	0.043	1,331
937	P-288	L116	L36	250	Steel	90	FALSE	0.201	4.1	0.113	588
938	P-290	L36	L35	900	Steel	100	FALSE	0.096	0.15	0	213
939	P-293	L40	L41	400	DI	110	FALSE	0.025	0.2	0	1,064
940	P-294	L37	L44	300	DI	110	FALSE	0.047	0.66	0.002	2,498
941	P-296	L47	L46	450	DI	90	FALSE	-0.5	3.14	0.035	738
942	P-299	L44	L45	200	DI	90	FALSE	0.047	1.5	0.023	562
944	P-301	L44	L42	200	DI	90	FALSE	-0.008	0.27	0.001	461
946	P-305	L154	J-79	300	DI	100	FALSE	0.009	0.12	0	626
947	P-306	J-79	L113	300	DI	100	FALSE	0.034	0.48	0.001	995
948	P-307	L113	L69	300	DI	100	FALSE	0.078	1.11	0.007	2,859
953	P-316	L81	L83	250	DI	110	FALSE	0.064	1.3	0.009	704
954	P-317	L83	L104	250	DI	90	FALSE	0.022	0.45	0.002	940
955	P-318	L113	J-70	300	DI	100	FALSE	-0.076	1.07	0.006	57
956	P-319	J-70	J-78	300	DI	100	FALSE	-0.076	1.07	0.006	47
957	P-320	L104	J-70	300	DI	100	FALSE	0	0	0	873
959	P-323	L112	L27	250	DI	110	FALSE	0.055	1.12	0.007	2,008
960	P-324	L20	L24	200	DI	110	FALSE	0.014	0.45	0.002	800
961	P-325	L69	L70	300	DI	110	FALSE	0.073	1.03	0.005	76
962	P-326	L70	L81	300	DI	110	FALSE	0.067	0.95	0.004	856

964	P-328	L20	L19	400	DI	100	FALSE	0.111	0.88	0.003	770
965	P-330	L19	L18	200	DI	110	FALSE	0.073	2.33	0.035	607
966	P-332	J-80	L112	900	Steel	90	FALSE	0.958	1.51	0.004	563
967	P-333	J-80	L26	200	DI	100	FALSE	0.029	0.91	0.007	2,077
977	P-344	L35	L155	400	DI	100	FALSE	0.02	0.16	0	455
978	P-345	L155	L154	400	DI	100	FALSE	0.013	0.11	0	127
979	P-346	L37	L38	600	DI	110	FALSE	0.052	0.19	0	616
980	P-347	L38	L40	600	DI	110	FALSE	0.033	0.12	0	345
981	P-348	L155	L38	200	DI	110	FALSE	0.005	0.16	0	407
982	P-350	L154	L108	300	Steel	90	FALSE	0.002	0.03	0	796
1014	P-428	J-27	J-138	150	DI	100	FALSE	0.078	4.39	0.191	100
1027	P-460	L130	J-127	400	DI	100	FALSE	0.442	3.52	0.04	2,732
1028	P-461	J-127	J-125	400	DI	90	FALSE	0.144	1.15	0.006	1,458
1029	P-463	J-125	J-126	400	DI	100	FALSE	0	0	0	20
1030	P-464	J-126	J-124	350	DI	90	FALSE	-0.039	0.4	0.001	562
1031	P-465	J-125	J-123	150	DI	90	FALSE	-0.026	1.45	0.03	1,365
1032	P-466	J-123	J-124	150	DI	100	FALSE	-0.041	2.33	0.059	1,165
1033	P-467	J-124	J-129	350	DI	100	FALSE	-0.118	1.23	0.007	1,369
1034	P-468	J-129	J-131	350	DI	100	FALSE	-0.164	1.7	0.012	689
1035	P-469	J-129	J-122	150	DI	90	FALSE	0.033	1.87	0.048	1,107
1036	P-470	J-122	J-123	150	DI	90	FALSE	0.035	1.98	0.053	473
1037	P-471	J-122	J-120	250	DI	100	FALSE	-0.012	0.24	0	478
1038	P-472	J-120	J-121	150	DI	100	FALSE	0.11	6.22	0.364	654
1039	P-473	J-120	J-115	300	DI	90	FALSE	-0.209	2.95	0.05	860
1040	P-474	J-115	J-116	500	DI	100	FALSE	-0.483	2.46	0.016	629
1041	P-475	J-116	J-130	500	DI	100	FALSE	-0.486	2.48	0.016	783
1042	P-476	J-118	J-117	200	Steel	100	FALSE	0.013	0.42	0.002	393
1043	P-478	J-116	J-117	200	DI	100	FALSE	0	0	0	11
1044	P-479	J-130	J-133	800	DI	100	FALSE	-0.491	0.98	0.002	143
1045	P-480	J-133	J-132	350	DI	100	FALSE	0.259	2.7	0.029	44
1046	P-481	J-132	J-131	350	DI	100	FALSE	0.358	3.72	0.052	63
1047	P-483	J-118	J-134	150	Steel	90	FALSE	0.024	1.38	0.027	526
1048	P-485	J-131	J-119	300	DI	90	FALSE	0.192	2.72	0.043	667
1049	P-487	J-119	T3	200	DI	80	FALSE	0.02	0.65	0.006	1,366
1050	P-488	J-119	J-118	200	DI	100	FALSE	0.04	1.28	0.014	407
1051	P-490	T9	T8	250	DI	90	FALSE	-0.016	0.32	0.001	1,287
1052	P-491	T12	T10	200	DI	100	FALSE	0.023	0.73	0.005	1,222
1053	P-493	T8	T10	150	DI	80	FALSE	0.004	0.2	0.001	960
1054	P-494	T10	T5	150	DI	90	FALSE	0.009	0.53	0.005	260
1055	P-495	T8	T7	250	DI	90	FALSE	-0.031	0.63	0.004	84
1056	P-496	T7	T1	250	DI	90	FALSE	0.02	0.41	0.002	868
1057	P-499	T1	T6	150	DI	90	FALSE	0.01	0.57	0.005	1,131
1058	P-500	T6	T7	250	DI	90	FALSE	-0.053	1.09	0.01	761
1059	P-501	IC5	IC1	200	DI	80	FALSE	-0.006	0.2	0.001	530
1060	P-502	IC1	SP17	350	DI	90	FALSE	-0.067	0.7	0.003	169
1061	P-503	IC1	IC2	350	DI	80	FALSE	0.055	0.57	0.002	359
1062	P-504	IC2	IC3	300	DI	90	FALSE	0.042	0.59	0.003	234
1063	P-505	IC3	IC4	200	DI	90	FALSE	0.012	0.38	0.002	205
1064	P-506	SP17	IC6	200	DI	90	FALSE	0.006	0.2	0.001	213
1065	P-507	T6	SP27	500	DI	100	FALSE	0.205	1.04	0.003	1,642
1066	P-508	SP27	MO	500	DI	100	FALSE	0.205	1.04	0.003	57
1076	P-524	L20	L23	200	DI	100	FALSE	0.047	1.48	0.018	637
1077	P-525	L18	L160	150	DI	90	FALSE	0.024	1.38	0.027	483
1078	P-526	L18	L16	150	DI	100	FALSE	0.024	1.38	0.022	640
1079	P-528	L13	L22	900	Steel	94	FALSE	0.277	0.44	0	2,661
1080	P-529	L13	L8	200	DI	120	FALSE	0.128	4.08	0.085	1,548
1081	P-530	L8	L9	150	PVC	120	FALSE	0.11	6.2	0.258	646
1082	P-531	L8	L7	150	PVC	120	FALSE	0.009	0.53	0.003	376
1083	P-532	J-7	L11	900	Steel	90	FALSE	0.714	1.12	0.002	5,178

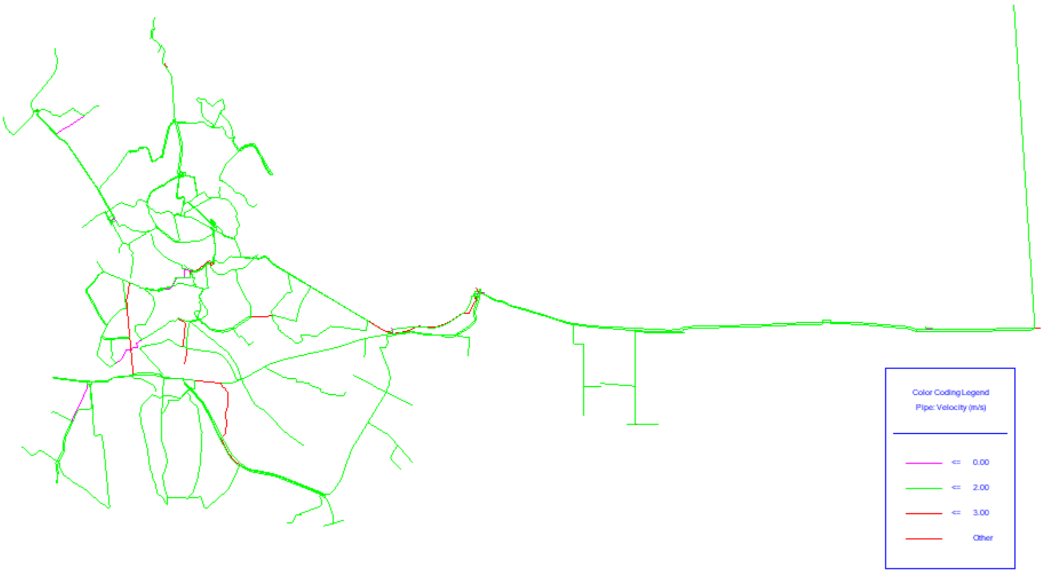
1084	P-534	L11	L5	350	DI	100	FALSE	0.111	1.16	0.006	1,209
1085	P-535	L5	L6	250	PVC	120	FALSE	0.009	0.19	0	754
1086	P-536	L5	L3	250	PVC	120	FALSE	0.092	1.88	0.016	839
1087	P-537	L3	L4	250	PVC	120	FALSE	0.018	0.37	0.001	173
1088	P-538	L11	L10	350	DI	100	FALSE	0.026	0.27	0	1,084
1100	P-554	T11	T19	150	DI	100	FALSE	-0.014	0.81	0.008	1,097
1101	P-555	T19	T4	150	DI	100	FALSE	0.01	0.57	0.004	717
1102	P-556	J-133	T19	150	DI	100	FALSE	0.034	1.94	0.042	30
1108	P-666	J-110	J-109	150	DI	90	FALSE	0.011	0.63	0.006	864
1115	P-852	L31	L30	150	DI	100	FALSE	-0.013	0.72	0.007	226
1116	P-654	RK7	RK10	50	PVC	110	FALSE	-0.002	1.2	0.052	377
1128	P-585	B7	SP26	150	GI	90	FALSE	0.109	6.14	0.436	2,909
1134	P-673	J-107	J-106	150	GI	80	FALSE	-0.028	1.59	0.044	618
1139	P-831	RK15	RK14	100	GI	90	FALSE	-0.024	3	0.192	0
1142	P-583	B10	B9	110	PVC	110	FALSE	0	0	0	699
1144	P-634	J-142	J-143	400	Steel	80	FALSE	-0.129	1.03	0.006	154
1148	P-671	J-143	J-108	200	PVC	110	FALSE	0.087	2.76	0.049	1,195
1149	P-660	RK8	RK7	50	PVC	110	FALSE	-0.001	0.56	0.014	703
1153	P-658	RK9	RK8	50	PVC	110	FALSE	0	0.08	0	812
1164	P-685	G1	J-144	150	Steel	80	FALSE	-0.009	0.52	0.005	97
1165	P-672	J-108	J-107	150	DI	90	FALSE	0.013	0.72	0.008	404
1171	P-830	RK20	RK15	100	GI	90	FALSE	-0.022	2.84	0.168	371
1173	P-576	B8	B1	100	PVC	110	FALSE	0.011	1.43	0.033	1,647
1175	P-854	L30	L29	125	GI	100	FALSE	0.013	1.03	0.016	247
1177	P-678	J-112	J-113	350	DI	90	FALSE	-0.202	2.1	0.022	938
1183	P-849	L33	L32	200	DI	100	FALSE	-0.013	0.4	0.002	420
1184	P-686	J-144	L109	100	GI	90	FALSE	0.002	0.31	0.003	1,042
1195	P-758	L1	L2	125	DI	100	FALSE	-0.025	2	0.055	470
1198	P-677	J-106	J-112	300	DI	90	FALSE	0	0	0	900
1199	P-584	B10	B11	200	DI	90	FALSE	0.005	0.14	0	404
1202	P-703	J-143	J-84	400	Steel	80	FALSE	-0.224	1.78	0.017	384
1203	P-704	J-84	J-137	500	DI	90	FALSE	-0.015	0.07	0	455
1205	P-706	R3	E2	50	PVC	110	FALSE	0	0	0	281
1206	P-708	E3	R2	100	DI	90	FALSE	0	0	0	157
1207	P-710	R1	E4	100	PVC	110	FALSE	0.024	3.1	0.135	90
1208	P-711	E1	R3	75	GI	90	FALSE	0	0	0	262
1209	P-712	EN	E16	100	GI	90	FALSE	0.008	0.99	0.024	293
1210	P-718	RK10	RK9	75	GI	90	FALSE	0.007	1.58	0.082	358
1211	P-713	RK	RK14	100	GI	90	FALSE	0	0	0	769
1212	P-716	RK21	RK13	150	DI	90	FALSE	0.003	0.2	0.002	1,101
1213	P-717	RK13	RK22	150	DI	50	FALSE	0.026	1.47	0.09	1,945
1214	P-719	RK	RK13	250	DI	15	FALSE	0	0	0	307
1215	P-720	RK13	RK21	150	DI	90	FALSE	-0.003	0.2	0.002	1,122
1216	P-721	RK20	RK21	100	GI	90	FALSE	0.02	2.51	0.122	180
1217	P-722	B7	T-14	250	DI	80	FALSE	0	0	0	62
1218	P-723	B7	B9	125	GI	90	FALSE	0.006	0.48	0	659
1237	P-749	J-142	J-86	400	Steel	80	FALSE	0.08	0.64	0.003	482
1238	P-750	J-86	J-110	200	DI	90	FALSE	0.024	0.76	0.007	580
1239	P-751	J-86	J-110	250	DI	90	FALSE	0.042	0.86	0.006	611
1240	P-752	J-110	J-109	250	DI	90	FALSE	0.042	0.85	0.006	903
1241	P-753	J-109	J-105	250	DI	90	FALSE	0.079	1.62	0.02	1,101
1242	P-754	J-105	J-106	300	DI	90	FALSE	0.052	0.73	0.004	165
1243	P-755	J-108	J-79	200	DI	90	FALSE	0.062	1.98	0.038	833
1244	P-756	J-108	J-107	150	DI	90	FALSE	0.008	0.46	0.004	899
1245	P-757	J-142	J-111	300	DI	90	FALSE	0.041	0.58	0.002	361
1246	P-759	J-111	J-109	200	DI	90	FALSE	0.033	1.04	0.012	839
1247	P-760	J-84	J-112	350	DI	90	FALSE	-0.08	0.83	0.004	1,487
1248	P-761	J-84	J-135	150	Steel	90	FALSE	-0.003	0.17	0.001	461
1249	P-764	J-135	J-134	150	Steel	90	FALSE	-0.022	1.25	0.023	195

1250	P-769	J-141	J-137	500	DI	90	FALSE	0	0	0	898
1251	P-770	J-137	J-135	150	DI	90	FALSE	-0.017	0.95	0.014	18
1252	P-771	J-119	J-136	300	DI	90	FALSE	0.129	1.82	0.02	766
1253	P-773	J-136	J-84	300	DI	90	FALSE	0.127	1.79	0.02	468
1254	P-775	J-135	J-136	150	DI	90	FALSE	0	0	0	21
1255	P-778	J-117	J-114	200	Steel	100	FALSE	0.009	0.3	0.001	379
1256	P-781	J-114	PG	200	Steel	100	FALSE	-0.024	0.77	0.005	108
1257	P-783	J-114	J-120	150	DI	100	FALSE	0.026	1.45	0.025	1,063
1258	P-784	J-120	J-122	150	DI	100	FALSE	0.003	0.17	0	490
1259	P-785	J-144	J-113	150	DI	100	FALSE	-0.054	3.07	0.098	716
1260	P-786	J-113	J-115	400	DI	100	FALSE	-0.266	2.12	0.016	521
1261	P-787	G2	G1	150	DI	100	FALSE	-0.053	3.02	0.096	376
1262	P-804	PG	G1	200	DI	100	FALSE	0.094	2.99	0.067	942
1263	P-806	L38	L157	200	DI	110	FALSE	0.018	0.57	0.003	378
1264	P-807	L157	L42	200	DI	110	FALSE	0.016	0.5	0.002	1,878
1265	P-808	L157	L37	150	Steel	80	FALSE	-0.004	0.23	0.001	829
1266	P-805	L36	L153	600	DI	110	FALSE	0.103	0.36	0	290
1267	P-809	L153	L37	600	DI	110	FALSE	0.104	0.37	0	84
1268	P-810	L35	L34	400	DI	100	FALSE	0.019	0.15	0	139
1269	P-811	L153	L34	200	DI	100	FALSE	-0.006	0.18	0	174
1270	P-813	L34	L153	200	DI	100	FALSE	0.006	0.18	0	177
1271	P-814	L153	L37	150	Steel	80	FALSE	0.002	0.1	0	102
1272	P-815	L34	L153	200	Steel	90	FALSE	0.005	0.15	0	207
1273	P-816	L153	L47	200	DI	100	FALSE	0.03	0.96	0.008	2,046
1274	P-817	L47	L45	350	DI	100	FALSE	0.045	0.47	0.001	1,234
1275	P-818	L153	L47	200	DI	100	FALSE	0.03	0.96	0.008	2,070
1276	P-819	L153	L46	250	DI	100	FALSE	-0.049	1.01	0.007	1,291
1277	P-820	L30	L28	250	DI	100	FALSE	-0.038	0.78	0.004	604
1278	P-821	L19	L32	400	DI	100	FALSE	0.025	0.2	0	2,787
1279	P-822	L28	L47	200	DI	100	FALSE	-0.004	0.14	0	2,055
1280	P-823	L42	L43	200	DI	110	FALSE	-0.001	0.02	0	159
1282	P-825	L43	L41	150	DI	100	FALSE	-0.009	0.48	0.003	1,455
1283	P-826	J-79	L156	150	GI	90	FALSE	0.001	0.08	0	691
1284	P-827	L113	L82	200	DI	100	FALSE	0.027	0.87	0.007	2,150
1285	P-828	L82	L79	125	Steel	100	FALSE	0.019	1.52	0.033	385
1286	P-829	L83	L79	150	DI	100	FALSE	-0.01	0.56	0.004	490
1293	P-838	L83	L84	200	DI	90	FALSE	0.009	0.28	0.001	944
1308	P-868	L104	L105	150	DI	100	FALSE	0.018	1.02	0.013	505
1325	P-885	J-78	M18	300	DI	100	FALSE	0.003	0.04	0	778
1327	P-887	SP27	J-76	300	DI	100	FALSE	0	0	0	173
1329	P-889	J-76	SP12	300	DI	120	FALSE	0.105	1.49	0.008	854
1337	P-898	IC7	J-86	400	Steel	90	FALSE	-0.014	0.11	0	257
1338	P-897	L114	L115	900	Steel	90	FALSE	0.996	1.57	0.004	611
1339	P-899	L115	J-80	900	Steel	90	FALSE	0.986	1.55	0.004	2,300
1340	P-900	J-91	L115	150	Steel	90	FALSE	0	0	0	409
1341	P-901	J-87	J-128	150	GI	90	FALSE	0.021	1.18	0.021	2,182
1342	P-902	L14	L114	900	Steel	90	FALSE	1.273	2	0.007	1,423
1343	P-903	L15	L14	150	DI	100	FALSE	-0.015	0.85	0.009	700
1344	P-904	L11	L12	900	Steel	94	FALSE	0.507	0.8	0.001	906
1345	P-905	L12	L13	900	Steel	94	FALSE	0.439	0.69	0.001	781
1405	P-965	J-141	J-130	800	DI	100	FALSE	-0.003	0.01	0	384
1406	P-966	B7	B13	200	DI	60	FALSE	0.047	1.51	0.049	794
1407	P-967	B13	B4	200	DI	90	FALSE	0.041	1.31	0.042	464
1408	P-968	J-127	J-139	150	DI	100	FALSE	0.008	0.48	0.003	984
1409	P-969	J-139	J-140	150	DI	100	FALSE	-0.014	0.76	0.008	996
1410	P-970	J-140	J-123	150	DI	100	FALSE	-0.029	1.66	0.031	868
1411	P-971	J-55	G3	200	DI	100	FALSE	0.014	0.45	0.002	520
1412	P-972	G3	G1	200	DI	100	FALSE	-0.023	0.75	0.005	1,005
1413	P-973	G4	G5	200	DI	90	FALSE	-0.012	0.38	0.002	928

1414	P-974	G5	G6	200	DI	90	FALSE	-0.038	1.2	0.015	768
1415	P-975	G6	PG	200	DI	90	FALSE	-0.049	1.55	0.024	374
1416	P-976	T13	T15	150	DI	100	FALSE	0.018	1	0.012	431
1417	P-977	T15	T1	150	DI	100	FALSE	-0.001	0.06	0	587
1418	P-978	T13	T14	400	DI	100	FALSE	0.135	1.07	0.004	427
1419	P-979	T14	T7	400	DI	100	FALSE	0.116	0.92	0.003	604
1420	P-980	J-29	T16	500	DI	100	FALSE	0.172	0.87	0.002	590
1421	P-981	T16	T6	500	DI	100	FALSE	0.152	0.77	0.002	495
1422	P-982	Jan Meda	T17	800	DI	100	FALSE	0.807	1.6	0.004	539
1423	P-983	T17	J-133	800	DI	100	FALSE	0.787	1.56	0.004	442
1424	P-984	T10	T18	200	DI	100	FALSE	0.008	0.25	0.001	520
1425	P-985	T18	T9	200	DI	100	FALSE	-0.001	0.04	0	586
1431	P-991	L28	L110	400	DI	110	FALSE	-0.027	0.21	0	1,334
1432	P-992	L110	L47	400	DI	110	FALSE	-0.037	0.29	0	638
1433	P-993	L47	L111	400	DI	100	FALSE	0.03	0.24	0	1,492
1434	P-994	L111	L28	400	DI	100	FALSE	0.02	0.16	0	516
1437	P-997	L125	J-87	150	GI	90	FALSE	0.021	1.18	0.021	43
1438	P-998	L2	L3	125	DI	100	FALSE	-0.053	4.31	0.228	36
1441	P-636	J-65	E12	150	DI	100	FALSE	0.036	2.04	0.046	99
1442	P-637	E12	B14	150	DCI	100	FALSE	0.026	1.46	0.025	1,783
1447	P-643	L117	FCV-1	900	Steel	100	FALSE	1.304	2.05	0.006	16
1448	P-644	FCV-1	L14	900	Steel	90	FALSE	1.304	2.05	0.007	1,046
1449	P-646	J-101	RK10	75	GI	90	FALSE	0.011	2.39	0.173	622
1450	P-645	RK	PMP-47	75	GI	90	FALSE	0	0	0	21
1451	P-647	PMP-47	J-101	75	GI	90	FALSE	0.074	16.69	5.935	19
1452	P-648	T-14	PMP-48	100	DI	90	FALSE	0	0	0	23
1453	P-649	PMP-48	B8	100	DI	90	FALSE	0.057	7.32	1.026	24
1454	P-650	RK	PMP-49	150	DCI	100	FALSE	0	0	0	27
1455	P-651	PMP-49	J-101	150	DCI	100	FALSE	0.037	2.09	0	29
1456	P-652	T-14	PMP-50	100	Steel	100	FALSE	0	0	0	29
1457	P-653	PMP-50	B8	100	Steel	100	FALSE	0.057	7.32	0.714	34
1460	P-582a	B7	J-104	90	DI	80	FALSE	0.077	12.07	3.765	16
1461	P-582	J-104	B10	250	DI	90	FALSE	0.077	1.56	0.017	1,161
1478	P-1	R-1	LAGA TANK	600	DI	130	FALSE	0.238	0.84	0.001	9,149
1479	P-2	R-2	LAGA TANK	900	DI	130	FALSE	2.932	4.61	0.016	126

Figure B. 6 Velocity Map of Links for Peak hour + 1-Hr Fire Demand Scenario, EPS Analysis

Scenario: Peak hour + 1- Hr Fire flow



Existing Water System of Legedadi sub system 2.wtg
5/13/2014

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W Watertown, CT 06795 USA +1-203-755-1666

Bentley WaterCAD V8i (SELECTseries 4)
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FUTURE WATER REQUIREMENT IS CHECKED FOR THE EXISTING DEMAND, 2020 AND 2025

Appendix A .11 Nodes EPS Analysis Results at Peak Hour Demand+1-Hr fire flow & Future Demand, 2025

Current Time: 14 hours

ID	Label	Elevation (m)	Demand Pattern	Demand (m^3/s)	Hydraulic Grade (m)	Pressure (m H2O)
129	C1	2,410.00		0.000	2,422.39	12.36
130	C1a	2,410.00		0.000	2,422.39	12.36
131	J-4	2,410.00		0.000	2,423.03	13.00
132	J-5	2,410.00		0.000	2,422.88	12.86
133	J-6	2,400.00		0.000	2,419.14	19.10
134	J-7	2,400.00		0.000	2,419.04	19.00
135	L22	2,406.00	D	0.031	2,404.27	-1.73
136	L117	2,406.00		0.000	-207,374.22	-209,357.67
137	L114	2,375.00	D	0.014	-207,374.20	-209,326.72
138	L20	2,351.00	D	0.137	-207,380.93	-209,309.47
139	L118	2,402.00	D & F	0.142	2,464.98	62.85
140	L119	2,402.00		0.000	2,404.14	2.14
141	L120	2,402.00	D & F	0.142	2,464.98	62.85
142	L121	2,402.00	D & F	0.142	2,464.98	62.85
143	L122	2,402.00		0.000	2,404.14	2.14
144	L123	2,402.00		0.000	2,404.14	2.14
145	L124	2,402.00		0.000	-11,617.97	-13,991.73
146	L125	2,404.00		0.000	-11,558.72	-13,934.59
147	L126	2,402.00		0.000	-11,589.45	-13,963.27
148	L127	2,402.00		0.000	-15,937.90	-18,302.96
149	L128	2,402.00		0.000	-11,610.89	-13,984.67
150	L129	2,402.00		0.000	-15,937.90	-18,302.96
151	L130	2,402.00		0.000	-15,958.79	-18,323.81
152	J-131	2,427.00	D	0.003	-180,507.46	-182,565.98
153	J-124	2,420.00	D	0.054	-179,373.89	-181,427.70
154	J-27	2,400.00		0.000	2,404.17	4.16
155	J-28	2,460.00		0.000	2,434.97	-24.98
156	J-29	2,460.00		0.000	2,488.72	28.66
157	J-30	2,460.00		0.000	2,488.72	28.66
158	J-31	2,460.00		0.000	2,434.97	-24.98
159	J-32	2,460.00		0.000	2,434.97	-24.98
160	J-33	2,460.00		0.000	2,488.72	28.66
161	J-35	2,460.00		0.000	2,434.97	-24.98
162	J-36	2,460.00		0.000	2,508.30	48.20
163	J-37	2,460.00		0.000	2,434.97	-24.98
164	J-38	2,460.00		0.000	2,508.30	48.20
165	J-39	2,460.00		0.000	1,783.94	-674.70
166	J-40	2,460.00	F	0.142	1,858.97	-599.82
167	J-41	2,460.00	F	0.142	1,863.05	-595.75
168	J-42	2,460.00		0.000	1,783.94	-674.70
169	J-43	2,460.00		0.000	1,783.94	-674.70
170	J-44	2,460.00	F	0.142	1,859.94	-598.85
171	J-45	2,507.00		0.000	2,508.02	1.02
172	J-46	2,507.00		0.000	2,566.40	59.28
173	J-47	2,507.00		0.000	2,508.10	1.10
174	J-48	2,507.00		0.000	2,566.40	59.28
175	J-49	2,507.00		0.000	2,463.34	-43.57
176	J-50	2,507.00		0.000	2,484.91	-22.05

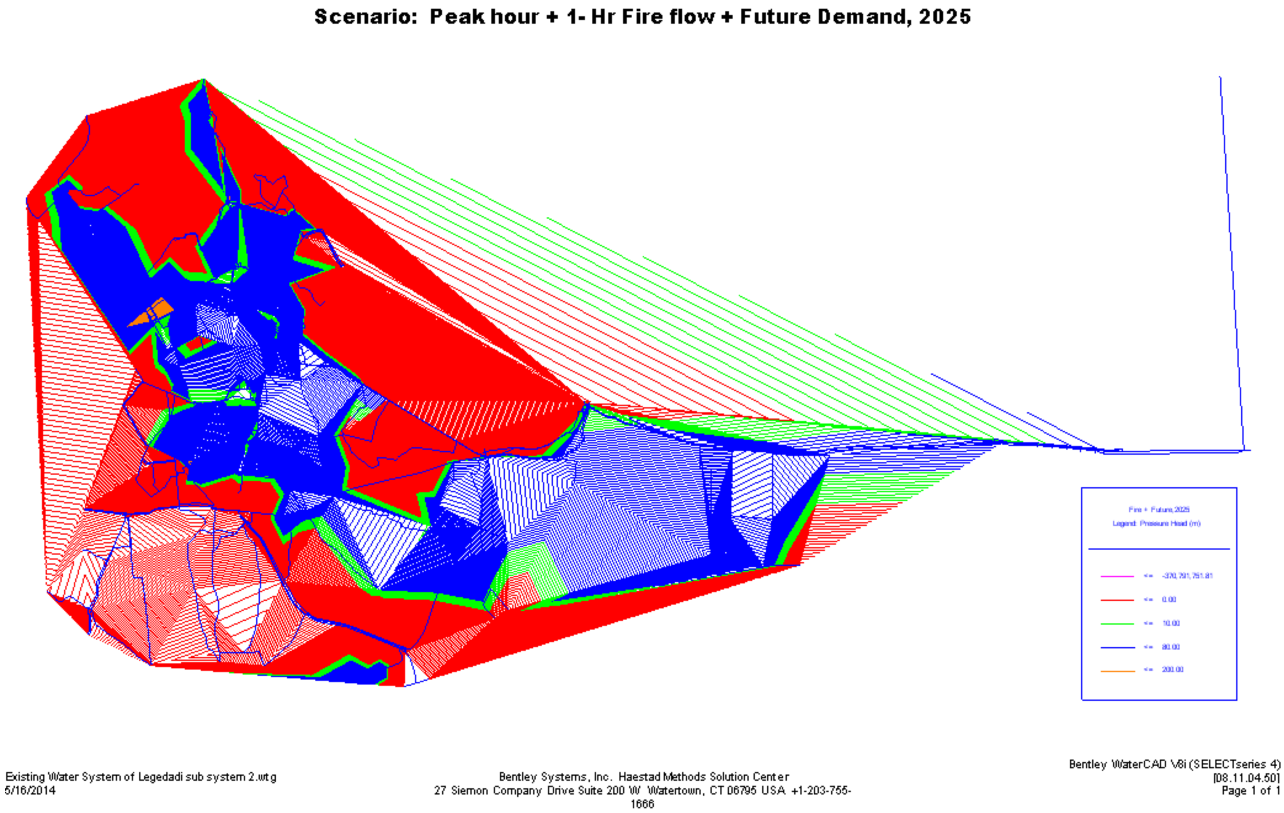
177	J-51	2,507.00	F	0.142	-121.64	-2,623.35
178	J-52	2,507.00	F	0.142	-144.19	-2,645.85
179	E15	2,564.00	D	0.007	-122.15	-2,680.74
180	J-133	2,432.00	D	0.003	-180,518.22	-182,581.71
181	J-132	2,433.00	D	0.003	-180,513.80	-182,578.30
182	T7	2,473.00	D	0.017	2,499.29	26.24
183	T12	2,512.00	D	0.008	2,507.44	-4.55
184	T9	2,459.00	D	0.020	2,496.06	36.99
185	SP15	2,490.00	D	0.003	2,507.32	17.29
186	T13	2,510.00	D	0.008	2,506.04	-3.95
187	T1	2,469.00	D	0.013	2,496.90	27.84
188	B14	2,536.00	D	0.000	2,536.00	0.00
189	J-63	2,560.00		0.000	-147,944,262.91	-147,648,815.75
190	J-64	2,560.00		0.000	-147,944,262.91	-147,648,815.75
191	J-65	2,560.00		0.000	-147,944,262.91	-147,648,815.75
192	SP16	2,490.00	D	0.000	2,490.00	0.00
193	J-67	2,560.00		0.000	-147,944,262.91	-147,648,815.75
194	J-68	2,560.00	F	0.000	2,560.00	0.00
195	L35	2,345.00	D	0.004	-206,981.32	-208,904.67
196	SP17	2,476.00	D	0.032	2,483.68	7.66
197	J-71	2,483.00	F	0.142	1,931.01	-550.88
198	J-72	2,483.00		0.000	2,487.88	4.87
199	J-73	2,483.00		0.000	2,487.88	4.87
200	J-74	2,483.00	F	0.142	1,930.48	-551.40
201	J-75	2,483.00		0.000	2,487.39	4.38
202	J-76	2,483.00		0.000	2,494.76	11.74
204	J-78	2,352.00		0.000	-206,933.84	-208,864.29
205	J-79	2,340.00		0.000	-206,932.42	-208,850.89
206	M23	2,352.00	D	0.014	-206,893.92	-208,824.44
207	J-81	2,352.00		0.000	-206,893.92	-208,824.44
208	J-82	2,352.00		0.000	-206,933.79	-208,864.23
209	M18	2,345.00	D	0.004	-206,933.86	-208,857.33
211	M19	2,345.00	D	0.004	-206,933.84	-208,857.31
215	J-90	2,637.00		0.000	-3,812,123.85	-3,807,076.85
216	E13	2,637.00	D	0.000	2,637.00	0.00
217	J-92	2,682.00		0.000	-3,433,627.47	-3,429,387.87
218	E14	2,682.00	D	0.000	2,682.00	0.00
243	L37	2,349.00	D	0.004	-206,987.22	-208,914.56
244	L112	2,350.00	D	0.032	-207,370.74	-209,298.31
245	C45	2,350.00		0.000	-207,370.74	-209,298.31
246	J-55	2,350.00	F	0.142	-183,949.85	-185,924.58
247	J-118	2,423.00	D	0.004	-181,002.89	-183,056.42
256	L28	2,325.00	D	0.018	-207,377.73	-209,280.33
257	L116	2,332.00	D	0.004	-207,369.98	-209,279.59
258	L46	2,335.00	D	0.019	-207,368.36	-209,280.95
259	L36	2,336.00	D	0.004	-206,982.63	-208,897.01
260	L40	2,347.00	D	0.012	-206,987.37	-208,912.72
261	L41	2,326.00	D	0.023	-206,988.14	-208,892.52
262	L44	2,311.00	D	0.011	-207,066.01	-208,955.27
263	L47	2,317.00	D	0.631	-207,376.83	-209,271.46
265	L45	2,305.00	D	0.132	-207,367.23	-209,249.90
267	L42	2,300.00	D	0.011	-207,043.65	-208,921.97
269	L154	2,340.00	D	0.003	-206,974.88	-208,893.27
270	L113	2,351.00	D	0.006	-206,935.10	-208,864.56
271	L69	2,283.00	D	0.008	-206,971.54	-208,833.05
276	L81	2,292.00	D	0.005	-206,979.20	-208,849.68
277	L104	2,320.00	D	0.006	-206,995.11	-208,893.49
278	L83	2,316.00	D	0.060	-206,991.64	-208,886.04
279	J-70	2,352.00		0.000	-206,934.42	-208,864.86

281	L27	2,339.00	D	0.078	-207,397.67	-209,314.21
282	L24	2,351.00	D	0.020	-207,383.58	-209,312.13
283	L70	2,280.00	D	0.008	-206,972.04	-208,830.54
284	L19	2,327.00	D	0.017	-207,385.54	-209,290.13
285	L18	2,332.00	D	0.035	-207,441.32	-209,350.77
286	J-80	2,345.00		0.000	-207,371.38	-209,293.96
287	L26	2,342.00	D	0.041	-207,400.76	-209,320.28
296	L155	2,340.00	D	0.002	-206,976.92	-208,895.29
297	L38	2,349.00	D	0.009	-206,987.32	-208,914.65
298	L108	2,345.00	D	0.003	-206,974.90	-208,898.28
332	J-138	2,390.00	D	0.110	2,367.55	-22.40
339	J-127	2,387.00	D	0.411	-22,291.32	-24,628.61
340	J-123	2,376.00	D	0.030	-137,512.70	-139,606.92
341	J-125	2,418.00	D	0.242	-23,575.73	-25,941.38
342	J-126	2,418.00	D	0.055	-179,374.99	-181,426.81
343	J-129	2,411.00	D	0.018	-180,049.36	-182,092.84
344	J-122	2,386.00	D	0.018	-178,151.66	-180,174.00
345	J-120	2,371.00	D & F	0.156	-179,569.49	-181,574.02
346	J-121	2,366.00	D & F	0.156	-180,026.21	-182,024.83
347	J-115	2,405.00	D	0.012	-180,535.78	-182,572.29
348	J-130	2,425.00	D	0.003	-180,518.39	-182,574.90
349	J-116	2,405.00	D	0.005	-180,528.14	-182,564.67
350	J-117	2,406.00	D	0.005	-180,906.46	-182,943.22
351	J-84	2,410.00		0.000	-181,856.39	-183,895.22
352	J-134	2,411.00	D	0.003	-181,619.56	-183,659.87
353	J-119	2,431.00	D	0.004	-181,002.89	-183,064.41
354	T3	2,440.00	D	0.029	-181,018.66	-183,089.13
355	T11	2,410.00	D	0.020	-180,538.37	-182,579.87
356	T4	2,435.00	D	0.014	-180,526.62	-182,593.09
357	T8	2,472.00	D	0.017	2,498.69	26.63
358	T10	2,472.00	D	0.013	2,496.62	24.57
359	T5	2,455.00	D	0.013	2,494.34	39.26
360	T6	2,460.00	D	0.014	2,488.76	28.70
361	IC5	2,437.00	D	0.009	2,482.06	44.97
362	IC1	2,472.00	D	0.009	2,482.76	10.74
363	IC2	2,463.00	D	0.019	2,481.07	18.03
364	IC3	2,450.00	D	0.043	2,479.93	29.87
365	IC4	2,432.00	D	0.017	2,479.24	47.15
366	IC6	2,465.00	D	0.009	2,483.46	18.42
367	SP27	2,491.00		0.000	2,488.57	-2.43
378	L23	2,352.00	D	0.066	-207,403.26	-209,332.76
379	L160	2,334.00	D	0.035	-207,466.62	-209,378.02
380	L16	2,327.00	D	0.035	-207,468.92	-209,373.34
381	L13	2,387.00	D	0.048	2,404.52	17.49
382	L8	2,340.00	D	0.013	2,151.22	-188.40
383	L9	2,332.00	F	0.156	1,830.95	-500.04
384	L7	2,363.00	D	0.013	2,149.27	-213.30
385	L11	2,382.00	D	0.100	2,405.85	23.80
386	L5	2,362.00	D	0.013	2,391.92	29.86
387	L6	2,365.00	D	0.013	2,391.59	26.54
388	L3	2,360.00	D	0.031	2,366.65	6.64
389	L4	2,360.00	D	0.026	2,366.40	6.38
390	L10	2,392.00	D	0.037	2,405.02	12.99
397	T19	2,430.00	D	0.014	-180,520.70	-182,582.19
398	RK22	2,431.00	D	0.000	2,431.00	0.00
403	J-144	2,364.00	D	0.061	-183,245.72	-185,235.86
405	RK7	2,511.00	D	0.000	2,511.00	0.00
412	G4	2,351.00	D	0.000	2,351.00	0.00
413	L156	2,347.00	D	0.002	-206,932.59	-208,858.05

421	J-87	2,404.00		0.000	-11,560.42	-13,936.29
422	L31	2,320.00	D	0.018	-207,385.67	-209,283.28
424	SP26	2,493.00	D & F	0.000	2,493.00	0.00
425	RK20	2,500.00	D	0.000	2,500.00	0.00
426	RK15	2,522.00	D	0.000	2,522.00	0.00
427	J-143	2,423.00	D	0.011	-182,243.06	-184,294.09
428	J-112	2,346.00	D & F	0.173	-181,257.51	-183,233.69
431	B9	2,582.00	D	0.000	2,582.00	0.00
435	L2	2,360.00	D	0.040	2,350.89	-9.09
438	J-106	2,355.00	D	0.034	-183,659.68	-185,639.99
440	E1	2,734.00	D	0.000	2,734.00	0.00
441	L30	2,320.00	D	0.018	-207,382.78	-209,280.38
443	E4	2,635.00	D	0.000	2,635.00	0.00
444	L33	2,325.00	D	0.018	-207,387.94	-209,290.53
445	J-128	2,385.00	D	0.030	-11,646.37	-14,003.11
447	B4	2,593.00	D	0.000	2,593.00	0.00
448	J-109	2,385.00	D	0.009	-182,633.95	-184,646.27
452	E3	2,673.00	D	0.000	2,673.00	0.00
453	L105	2,308.00	D	0.026	-207,007.59	-208,893.97
458	J-141	2,432.00	D	0.004	-180,518.39	-182,581.88
459	L29	2,317.00	D	0.018	-207,390.45	-209,285.06
463	RK21	2,490.00	D	0.000	2,490.00	0.00
464	J-108	2,353.00	D	0.006	-191,160.84	-193,124.07
467	J-110	2,417.00	D	0.019	-182,405.41	-184,450.13
469	E2	2,708.00	D	0.000	2,708.00	0.00
470	B7	2,631.00	D	0.000	2,631.00	0.00
478	RK8	2,538.00	D	0.000	2,538.00	0.00
479	L15	2,360.00	D	0.021	-207,386.55	-209,324.06
485	E16	2,547.00	D	0.000	2,547.00	0.00
488	B8	2,636.00	D & F	0.000	2,636.00	0.00
490	RK14	2,523.00	D	0.000	2,523.00	0.00
493	L79	2,292.00	D	0.013	-206,987.68	-208,858.14
495	RK10	2,553.00	D	0.000	2,553.00	0.00
501	L1	2,356.00	D	0.035	2,301.08	-54.81
504	J-142	2,424.00	D	0.012	-182,264.09	-184,316.09
505	L109	2,345.00	D	0.003	-183,251.09	-185,222.26
506	J-107	2,379.00	D	0.070	-190,120.54	-192,111.80
507	B11	2,610.00	D	0.000	2,610.00	0.00
509	G2	2,343.00	D	0.076	-183,681.55	-185,649.84
522	B10	2,600.00	D	0.000	2,600.00	0.00
524	J-86	2,434.00		0.000	-182,292.42	-184,354.34
528	J-91	2,360.00		0.000	-207,373.63	-209,311.18
543	J-113	2,403.00	D	0.014	-180,745.30	-182,779.39
547	G1	2,364.00	D	0.037	-183,612.32	-185,601.72
550	B1	2,706.00	D	0.000	2,706.00	0.00
552	RK9	2,588.00	D	0.000	2,588.00	0.00
554	J-137	2,390.00	D	0.003	-181,855.38	-183,874.26
559	L32	2,325.00	D	0.018	-207,386.62	-209,289.21
562	RK13	2,520.00	D	0.000	2,520.00	0.00
565	J-105	2,358.00	D	0.039	-183,606.64	-185,590.05
566	J-111	2,397.00	D	0.011	-182,286.82	-184,311.82
567	J-135	2,390.00	D	0.003	-181,840.63	-183,859.54
568	J-136	2,390.00	D	0.003	-181,534.08	-183,553.61
569	J-114	2,417.00	D	0.012	-180,808.60	-182,856.53
570	L157	2,339.00	D	0.009	-206,995.83	-208,913.18
571	L153	2,345.00	D	0.004	-206,987.05	-208,910.41
572	L34	2,345.00	D	0.004	-206,982.25	-208,905.62
573	L43	2,303.00	D	0.011	-207,043.10	-208,924.43
574	L82	2,311.00	D	0.012	-206,963.03	-208,852.49

576	L84	2,321.00	D	0.012	-206,993.43	-208,892.81
586	SP12	2,463.00	D & F	0.150	2,481.29	18.25
589	IC7	2,441.00	D	0.020	-182,292.46	-184,361.37
590	L115	2,370.00	D	0.014	-207,373.63	-209,321.16
591	L14	2,377.00	D	0.022	-207,374.22	-209,328.74
592	L12	2,385.00	D	0.097	2,405.00	19.96
611	B13	2,595.00	D	0.000	2,595.00	0.00
612	J-139	2,373.00	D	0.031	-63,542.09	-65,782.32
613	J-140	2,365.00	D	0.022	-103,625.54	-105,777.05
614	G3	2,358.00	D	0.053	-183,874.66	-185,857.53
615	G5	2,367.00	D	0.000	2,367.00	0.00
616	G6	2,402.00	D	0.000	2,402.00	0.00
617	T15	2,497.00	D	0.027	2,496.67	-0.33
618	T14	2,492.00	D	0.027	2,502.75	10.73
619	T16	2,447.00	D	0.028	2,488.72	41.64
620	T17	2,454.00	D	0.028	-180,518.22	-182,603.67
621	T18	2,459.00	D	0.013	2,496.01	36.93
625	L110	2,306.00	D	0.014	-207,377.23	-209,260.87
626	L111	2,324.00	D	0.014	-207,377.60	-209,279.19
629	E12	2,560.00	D	0.000	2,560.00	0.00
632	J-101	2,545.00	D & F	0.000	2,545.00	0.00
634	J-104	2,615.00		0.000	-370,795,822.70	-370,051,551.42

Figure B.7 Pressure Map of Links for Peak hour + 1-Hr Fire Demand Scenario, EPS Analysis & Future Demand, 2025



Appendix A.12

Links EPS Analysis Results at Peak Hour Demand+1-Hr fire flow & Future Demand, 2025

ID	Label	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Flow (m³/s)	Velocity (m/s)	Head loss Gradient (m/m)	Has User Defined Length?	Length (User Defined) (m)
1460	P-582a	B7	J-104	90.0	DI	80.0	False	0.109	17.16	7.529	False	16
1479	P-2	R-2	LAG.TANK	900.0	DI	130.0	False	2.932	4.61	0.016	False	126
1014	P-428	J-27	J-138	150.0	DI	100.0	False	0.110	6.24	0.366	False	100
1438	P-998	L2	L3	125.0	DI	100.0	False	-0.075	6.13	0.438	False	36
937	P-288	L116	L36	250.0	Steel	90.0	False	-0.522	10.64	0.659	False	588
936	P-289	L116	L46	450.0	DI	90.0	False	-0.082	0.52	0.001	False	1,331
1027	P-460	L130	J-127	400.0	DI	100.0	False	3.939	31.35	2.318	False	2,732
941	P-296	L47	L46	450.0	DI	90.0	False	-0.275	1.73	0.011	False	738
1046	P-481	J-132	J-131	350.0	DI	100.0	False	-0.510	5.30	0.101	False	63
1207	P-710	R1	E4	100.0	PVC	110.0	False	0.000	0.00	0.000	False	90
769	P-50	L124	TR4	300.0	Steel	100.0	False	1.972	27.89	2.612	False	21
770	P-51	TR4	L130	300.0	Steel	100.0	False	1.972	27.89	2.612	False	26
767	P-48	L128	TR5	300.0	Steel	100.0	False	1.967	27.83	2.602	False	24
768	P-49	TR5	L129	300.0	Steel	100.0	False	1.967	27.83	2.602	False	24
1261	P-787	G2	G1	150.0	DI	100.0	False	-0.076	4.30	0.184	False	376
1036	P-470	J-122	J-123	150.0	DI	90.0	False	-1.891	106.99	85.964	False	473
1217	P-722	B7	T-14	250.0	DI	80.0	False	0.000	0.00	0.000	False	62
1148	P-671	J-143	J-108	200.0	PVC	110.0	False	1.316	41.89	7.462	False	1,195
1259	P-785	J-144	J-113	150.0	DI	100.0	False	-0.373	21.09	3.494	False	716
1450	P-645	RK	PMP-47	75.0	GI	90.0	False	0.000	0.00	0.000	False	21
1451	P-647	PMP-47	J-101	75.0	GI	90.0	False	0.105	23.73	11.871	False	19
1449	P-646	J-101	RK10	75.0	GI	90.0	False	0.015	3.41	0.329	False	622
1045	P-480	J-133	J-132	350.0	DI	100.0	False	-0.507	5.27	0.100	False	44
965	P-330	L19	L18	200.0	DI	110.0	False	0.104	3.32	0.068	False	607
1048	P-485	J-131	J-119	300.0	DI	90.0	False	0.900	12.73	0.743	False	667
761	P-40	TR1	L125	500.0	Steel	100.0	False	0.000	0.00	0.000	False	24
762	P-39	L125	L126	500.0	Steel	100.0	False	3.939	20.06	0.782	False	39
763	P-41	L126	L128	500.0	Steel	100.0	False	3.939	20.06	0.782	False	27
1032	P-466	J-123	J-124	150.0	DI	100.0	False	1.311	74.21	35.925	False	1,165
1441	P-636	J-65	E12	150.0	DI	100.0	False	0.052	2.92	0.098	False	99
1243	P-755	J-108	J-79	200.0	DI	90.0	False	1.780	56.65	18.926	False	833
1262	P-804	PG	G1	200.0	DI	100.0	False	0.000	0.00	0.000	False	942
1410	P-970	J-140	J-123	150.0	DI	100.0	False	1.372	77.62	39.037	False	868
1195	P-758	L1	L2	125.0	DI	100.0	False	-0.035	2.85	0.106	False	470
1447	P-643	L117	FCV-1	900.0	Steel	100.0	False	0.000	0.00	0.000	False	16
1448	P-644	FCV-1	L14	900.0	Steel	90.0	False	0.000	0.00	0.000	False	1,046
1102	P-556	J-133	T19	150.0	DI	100.0	False	0.049	2.77	0.081	False	30
1342	P-902	L14	L114	900.0	Steel	90.0	False	-0.043	0.07	0.000	False	1,423
1086	P-536	L5	L3	250.0	PVC	120.0	False	0.132	2.68	0.030	False	839
1031	P-465	J-125	J-123	150.0	DI	90.0	False	1.861	105.29	83.458	False	1,365
829	P-131	J-63	B14	200.0	DI	100.0	False	0.081	2.58	0.047	False	1,885
1202	P-703	J-143	J-84	400.0	Steel	80.0	False	-2.010	15.99	1.008	False	384
742	P-14	L22	TR2	900.0	Steel	100.0	False	0.735	1.15	0.002	True	35
821	P-118	TM3	J-51	125.0	Steel	100.0	False	0.291	23.71	5.372	False	13
915	P-252	UR1	J-55	200.0	Steel	100.0	False	0.000	0.00	0.000	False	19
1411	P-971	J-55	G3	200.0	DI	100.0	False	-0.142	4.53	0.145	False	520
772	P-53	L129	L130	400.0	DI	100.0	False	1.967	15.66	0.641	False	33
830	P-132	J-63	J-65	200.0	Steel	100.0	False	0.056	1.79	0.000	False	27
805	P-100	JM7	J-41	150.0	Steel	100.0	False	0.000	0.00	0.000	False	13

736	P-8	J-5	J-4	1,000.0	Steel	100.0	False	-1.560	1.99	0.005	True	30
1241	P-753	J-109	J-105	250.0	DI	90.0	False	0.612	12.46	0.883	False	1,101
803	P-98	JM8	J-44	150.0	Steel	100.0	False	0.000	0.00	0.000	False	14
785	P-72	JM5	J-29	250.0	Steel	100.0	False	0.000	0.00	0.000	False	14
1134	P-673	J-107	J-106	150.0	GI	80.0	False	-0.539	30.49	10.457	False	618
783	P-70	JM4	J-33	250.0	Steel	100.0	False	0.000	0.00	0.000	False	15
746	P-19	TR1	L117	1,000.0	Steel	100.0	False	0.000	0.00	0.000	True	40
1260	P-786	J-113	J-115	400.0	DI	100.0	False	-1.530	12.18	0.402	False	521
1210	P-718	RK10	RK9	75.0	GI	90.0	False	0.010	2.24	0.136	False	358
1461	P-582	J-104	B10	250.0	DI	90.0	False	0.109	2.22	0.034	False	1,161
1415	P-975	G6	PG	200.0	DI	90.0	False	0.000	0.00	0.000	False	374
1285	P-828	L82	L79	125.0	Steel	100.0	False	0.027	2.17	0.064	False	385
1041	P-475	J-116	J-130	500.0	DI	100.0	False	-0.421	2.15	0.012	False	783
757	P-36	TR2	L120	500.0	Steel	100.0	False	0.394	2.01	0.011	False	19
758	P-35	L123	TP1	500.0	Steel	100.0	False	0.394	2.01	0.011	False	19
759	P-37	TP1	L121	500.0	Steel	100.0	False	0.394	2.01	0.011	False	20
942	P-299	L44	L45	200.0	DI	90.0	False	0.260	8.27	0.536	False	562
1406	P-966	B7	B13	200.0	DI	60.0	False	0.067	2.14	0.098	False	794
1040	P-474	J-115	J-116	500.0	DI	100.0	False	-0.416	2.12	0.012	False	629
1177	P-678	J-112	J-113	350.0	DI	90.0	False	-1.143	11.88	0.546	False	938
825	P-123	TM	T12	400.0	DI	100.0	False	0.255	2.03	0.015	False	63
1076	P-524	L20	L23	200.0	DI	100.0	False	0.066	2.11	0.035	False	637
1442	P-637	E12	B14	150.0	DCI	100.0	False	0.037	2.10	0.044	False	1,783
1338	P-897	L114	L115	900.0	Steel	90.0	False	-0.437	0.69	0.001	False	611
1213	P-717	RK13	RK22	150.0	DI	50.0	False	0.037	2.08	0.173	False	1,945
1034	P-468	J-129	J-131	350.0	DI	100.0	False	1.412	14.68	0.665	False	689
1339	P-899	L115	J-80	900.0	Steel	90.0	False	-0.451	0.71	0.001	False	2,300
1173	P-576	B8	B1	100.0	PVC	110.0	False	0.016	2.03	0.059	False	1,647
966	P-332	J-80	L112	900.0	Steel	90.0	False	-0.492	0.77	0.001	False	563
1078	P-526	L18	L16	150.0	DI	100.0	False	0.035	1.97	0.043	False	640
1077	P-525	L18	L160	150.0	DI	90.0	False	0.035	1.96	0.052	False	483
1252	P-771	J-119	J-136	300.0	DI	90.0	False	0.867	12.26	0.693	False	766
1253	P-773	J-136	J-84	300.0	DI	90.0	False	0.864	12.22	0.688	False	468
1211	P-713	RK	RK14	100.0	GI	90.0	False	0.000	0.00	0.000	False	769
1407	P-967	B13	B4	200.0	DI	90.0	False	0.058	1.86	0.084	False	464
953	P-316	L81	L83	250.0	DI	110.0	False	0.090	1.84	0.018	False	704
793	P-83	JM2	J-36	250.0	Steel	100.0	False	0.000	0.00	0.000	False	14
836	P-141	Entoto1	J-68	125.0	Steel	100.0	False	0.005	0.39	0.000	False	16
789	P-80	J-38	J-36	250.0	Steel	100.0	False	0.000	0.00	0.000	False	14
791	P-81	JM1	J-38	250.0	Steel	100.0	False	0.000	0.00	0.000	False	16
1247	P-760	J-84	J-112	350.0	DI	90.0	False	-0.970	10.08	0.403	False	1,487
1039	P-473	J-120	J-115	300.0	DI	90.0	False	1.126	15.92	1.124	False	860
1050	P-488	J-119	J-118	200.0	DI	100.0	False	0.000	0.01	0.000	False	407
827	P-127	T12	T13	400.0	DI	100.0	False	0.213	1.69	0.010	False	130
844	P-152	MO1	J-71	250.0	Steel	100.0	False	0.284	5.80	0.176	False	12
935	P-287	L112	L116	900.0	Steel	90.0	False	-0.601	0.94	0.002	False	457
1414	P-974	G5	G6	200.0	DI	90.0	False	-0.053	1.70	0.032	False	768
1116	P-654	RK7	RK10	50.0	PVC	110.0	False	-0.003	1.70	0.105	False	377
820	P-117	J-49	TM3	150.0	Steel	100.0	False	0.291	16.47	2.210	False	12
1341	P-901	J-87	J-128	150.0	GI	90.0	False	0.030	1.68	0.039	False	2,182
1437	P-997	L125	J-87	150.0	GI	90.0	False	0.030	1.68	0.039	False	43
1033	P-467	J-124	J-129	350.0	DI	100.0	False	1.202	12.50	0.493	False	1,369
806	P-101	J-41	TM	250.0	DI	100.0	False	-0.427	8.69	0.373	False	1,730
1422	P-982	Jan Meda	T17	800.0	DI	100.0	False	0.000	0.00	0.000	False	539
812	P-107	TM1	J-48	300.0	Steel	100.0	False	0.095	1.34	0.009	False	15
1139	P-831	RK15	RK14	100.0	GI	90.0	False	-0.034	4.27	0.357	False	0
1084	P-534	L11	L5	350.0	DI	100.0	False	0.158	1.64	0.012	False	1,209
871	P-186	R1(1)	E13	100.0	Steel	100.0	False	0.004	0.45	0.018	False	20
1423	P-983	T17	J-133	800.0	DI	100.0	False	-0.028	0.06	0.000	False	442

784	P-71	J-28	JM5	300.0	Steel	100.0	False	0.000	0.00	0.000	False	13
1409	P-969	J-139	J-140	150.0	DI	100.0	False	1.394	78.89	40.229	False	996
782	P-69	J-32	JM4	300.0	Steel	100.0	False	0.000	0.00	0.000	False	12
780	P-67	J-29	J-33	300.0	Steel	100.0	False	0.000	0.00	0.000	False	16
959	P-323	L112	L27	250.0	DI	110.0	False	0.078	1.59	0.013	False	2,008
948	P-307	L113	L69	300.0	DI	100.0	False	0.111	1.57	0.013	False	2,859
1028	P-461	J-127	J-125	400.0	DI	90.0	False	2.103	16.73	0.881	False	1,458
914	P-251	C45	UR1	250.0	Steel	100.0	False	0.000	0.00	0.000	False	17
764	P-43	L128	L124	500.0	Steel	100.0	False	1.972	10.04	0.217	False	33
1205	P-706	R3	E2	50.0	PVC	110.0	False	0.000	0.00	0.000	False	281
956	P-319	J-70	J-78	300.0	DI	100.0	False	-0.108	1.53	0.012	False	47
955	P-318	L113	J-70	300.0	DI	100.0	False	-0.108	1.53	0.012	False	57
1418	P-978	T13	T14	400.0	DI	100.0	False	0.181	1.44	0.008	False	427
756	P-34	L122	TR2	600.0	Steel	100.0	False	0.394	1.39	0.005	False	19
744	P-16	J-7	J-6	1,000.0	Steel	100.0	False	-1.087	1.38	0.002	True	40
1246	P-759	J-111	J-109	200.0	DI	90.0	False	0.226	7.19	0.414	False	839
1058	P-500	T6	T7	250.0	DI	90.0	False	-0.065	1.32	0.014	False	761
1175	P-854	L30	L29	125.0	GI	100.0	False	0.018	1.47	0.031	False	247
1144	P-634	J-142	J-143	400.0	Steel	80.0	False	-0.682	5.43	0.136	False	154
961	P-325	L69	L70	300.0	DI	110.0	False	0.104	1.47	0.009	False	76
738	P-10	J-6	C1	1,200.0	Steel	100.0	False	-1.417	1.25	0.002	True	1,964
1308	P-868	L104	L105	150.0	DI	100.0	False	0.026	1.45	0.025	False	505
1208	P-711	E1	R3	75.0	GI	90.0	False	0.000	0.00	0.000	False	262
1257	P-783	J-114	J-120	150.0	DI	100.0	False	-0.206	11.66	1.166	False	1,063
787	P-77	Jan Meda	J-37	600.0	Steel	100.0	False	0.000	0.00	0.000	False	20
876	P-191	R2(1)	E14	80.0	Steel	100.0	False	0.003	0.64	0.019	False	19
839	P-145	MO	SP17	350.0	DI	100.0	False	0.137	1.42	0.009	False	556
1276	P-819	L153	L46	250.0	DI	100.0	False	0.376	7.67	0.295	False	1,291
1209	P-712	EN	E16	100.0	GI	90.0	False	0.000	0.00	0.000	False	293
794	P-84	J-36	TM	400.0	DI	100.0	False	0.000	0.00	0.000	False	1,782
1416	P-976	T13	T15	150.0	DI	100.0	False	0.024	1.36	0.022	False	431
1171	P-830	RK20	RK15	100.0	GI	90.0	False	-0.032	4.03	0.317	False	371
1066	P-508	SP27	MO	500.0	DI	100.0	False	0.034	0.17	0.000	False	57
1065	P-507	T6	SP27	500.0	DI	100.0	False	0.034	0.17	0.000	False	1,642
1273	P-816	L153	L47	200.0	DI	100.0	False	0.165	5.25	0.190	False	2,046
1275	P-818	L153	L47	200.0	DI	100.0	False	0.164	5.22	0.188	False	2,070
962	P-326	L70	L81	300.0	DI	110.0	False	0.096	1.36	0.008	False	856
1452	P-648	T-14	PMP-48	100.0	DI	90.0	False	0.000	0.00	0.000	False	23
1453	P-649	PMP-48	B8	100.0	DI	90.0	False	0.082	10.41	2.051	False	24
1456	P-652	T-14	PMP-50	100.0	Steel	100.0	False	0.000	0.00	0.000	False	29
1457	P-653	PMP-50	B8	100.0	Steel	100.0	False	0.082	10.41	1.714	False	34
748	P-22	L114	L20	600.0	DI	100.0	False	0.381	1.35	0.004	False	1,585
753	P-30	L121	Jan Meda	900.0	DI	120.0	False	0.361	0.57	0.000	False	7,550
1047	P-483	J-118	J-134	150.0	Steel	90.0	False	0.186	10.53	1.173	False	526
823	P-120	E15	RK	150.0	DI	100.0	False	0.000	0.00	0.000	False	1,437
804	P-99	J-42	JM7	200.0	Steel	100.0	False	0.000	0.00	0.000	False	13
741	P-13	J-7	L22	1,200.0	Steel	100.0	False	1.368	1.21	0.002	True	9,526
802	P-97	J-43	JM8	200.0	Steel	100.0	False	0.000	0.00	0.000	False	13
1419	P-979	T14	T7	400.0	DI	100.0	False	0.154	1.23	0.006	False	604
967	P-333	J-80	L26	200.0	DI	100.0	False	0.041	1.29	0.014	False	2,077
1080	P-529	L13	L8	200.0	DI	120.0	False	0.182	5.80	0.163	False	1,548
792	P-82	J-35	JM2	300.0	Steel	100.0	False	0.000	0.00	0.000	False	13
835	P-140	J-67	Entoto1	150.0	Steel	100.0	False	0.005	0.27	0.000	False	18
832	P-136	J-65	J-67	150.0	Steel	100.0	False	0.005	0.27	0.000	False	22
834	P-139	J-68	R1	150.0	DI	100.0	False	0.000	0.00	0.000	False	1,244
964	P-328	L20	L19	400.0	DI	100.0	False	0.157	1.25	0.006	False	770
790	P-79	J-37	JM1	300.0	Steel	100.0	False	0.000	0.00	0.000	False	13
1083	P-532	J-7	L11	900.0	Steel	90.0	False	0.755	1.19	0.003	True	5,178
828	P-130	EN	J-63	400.0	DI	100.0	False	0.000	0.00	0.000	False	25

1284	P-827	L113	L82	200.0	DI	100.0	False	0.039	1.23	0.013	False	2,150
842	P-150	J-71	J-74	300.0	Steel	100.0	False	0.142	2.01	0.020	False	27
843	P-151	J-72	MO1	300.0	Steel	100.0	False	0.284	4.02	0.072	False	12
847	P-155	J-74	T-14	300.0	DI	100.0	False	0.000	0.00	0.000	False	3,031
1239	P-751	J-86	J-110	250.0	DI	90.0	False	0.263	5.36	0.185	False	611
774	P-57	J-27	TR2	1,000.0	Steel	100.0	False	-0.898	1.14	0.002	True	16
739	P-11	C1a	J-6	900.0	Steel	100.0	False	0.665	1.04	0.002	True	1,964
1240	P-752	J-110	J-109	250.0	DI	90.0	False	0.311	6.34	0.253	False	903
811	P-105	J-45	TM1	350.0	Steel	100.0	False	0.095	0.98	0.004	False	14
1343	P-903	L15	L14	150.0	DI	100.0	False	-0.021	1.21	0.018	False	700
1256	P-781	J-114	PG	200.0	Steel	100.0	False	0.000	0.00	0.000	False	108
1037	P-471	J-122	J-120	250.0	DI	100.0	False	1.307	26.63	2.967	False	478
732	P-4	LAGA TANK	J-4	1,400.0	Steel	110.0	False	1.560	1.01	0.001	True	6,360
735	P-7	J-5	C1	1,400.0	Steel	100.0	False	1.560	1.01	0.001	True	528
1206	P-708	E3	R2	100.0	DI	90.0	False	0.000	0.00	0.000	False	157
1100	P-554	T11	T19	150.0	DI	100.0	False	-0.020	1.16	0.016	False	1,097
1420	P-980	J-29	T16	500.0	DI	100.0	False	0.000	0.00	0.000	False	590
1249	P-764	J-135	J-134	150.0	Steel	90.0	False	-0.183	10.34	1.135	False	195
1214	P-719	RK	RK13	250.0	DI	15.0	False	0.000	0.00	0.000	False	307
824	P-122	Jan Meda	J-132	350.0	DI	100.0	False	0.000	0.00	0.000	False	1,075
1035	P-469	J-129	J-122	150.0	DI	90.0	False	-0.228	12.92	1.715	False	1,107
788	P-78	J-37	J-35	600.0	Steel	100.0	False	0.000	0.00	0.000	False	16
737	P-9	ST3	J-6	1,200.0	Steel	100.0	False	-0.994	0.88	0.001	True	20
1277	P-820	L30	L28	250.0	DI	100.0	False	-0.054	1.10	0.008	False	604
1238	P-750	J-86	J-110	200.0	DI	90.0	False	0.150	4.79	0.195	False	580
1478	P-1	R-1	LAG TANK	600.0	DI	130.0	False	0.238	0.84	0.001	False	0
913	P-250	L112	C45	300.0	Steel	100.0	False	0.000	0.00	0.000	False	63
773	P-56	L123	J-27	1,000.0	Steel	100.0	False	-0.788	1.00	0.001	True	22
1242	P-754	J-105	J-106	300.0	DI	90.0	False	0.573	8.10	0.322	False	165
870	P-185	J-90	R1(1)	125.0	Steel	100.0	False	0.004	0.29	0.000	False	19
1052	P-491	T12	T10	200.0	DI	100.0	False	0.031	1.00	0.009	False	1,222
1115	P-852	L31	L30	150.0	DI	100.0	False	-0.018	1.02	0.013	False	226
1421	P-981	T16	T6	500.0	DI	100.0	False	-0.028	0.14	0.000	False	495
1060	P-502	IC1	SP17	350.0	DI	90.0	False	-0.096	1.00	0.006	False	169
1165	P-672	J-108	J-107	150.0	DI	90.0	False	-0.285	16.10	2.578	False	404
730	P-2	LAG TANK	C1a	900.0	Steel	115.0	False	0.522	0.82	0.001	True	6,890
816	P-111	J-50	J-49	200.0	Steel	100.0	False	0.291	9.26	0.544	False	40
815	P-110	TM	J-50	200.0	Steel	100.0	False	0.291	9.26	0.544	False	43
822	P-119	J-51	E15	200.0	DI	100.0	False	0.007	0.21	0.000	False	1,056
740	P-12	ST3	J-7	1,200.0	DCI	100.0	False	1.036	0.92	0.001	False	88
940	P-294	L37	L44	300.0	DI	110.0	False	0.200	2.83	0.032	False	2,498
1216	P-721	RK20	RK21	100.0	GI	90.0	False	0.028	3.57	0.257	False	180
814	P-109	J-48	EN	400.0	DI	100.0	False	0.095	0.75	0.002	False	1,246
807	P-102	TM	J-47	400.0	Steel	100.0	False	0.095	0.75	0.002	False	85
808	P-103	J-47	J-45	400.0	Steel	100.0	False	0.095	0.75	0.002	False	34
1049	P-487	J-119	T3	200.0	DI	80.0	False	0.029	0.93	0.012	False	1,366
1042	P-476	J-118	J-117	200.0	Steel	100.0	False	-0.189	6.03	0.245	False	393
1237	P-749	J-142	J-86	400.0	Steel	80.0	False	0.434	3.45	0.059	False	482
873	P-188	R2	J-92	100.0	DCI	100.0	False	0.000	0.00	0.000	False	22
875	P-189	J-92	R2(1)	100.0	Steel	100.0	False	0.003	0.41	0.000	False	16
1055	P-495	T8	T7	250.0	DI	90.0	False	-0.045	0.92	0.007	False	84
1108	P-666	J-110	J-109	150.0	DI	90.0	False	0.083	4.71	0.265	False	864
1044	P-479	J-130	J-133	800.0	DI	100.0	False	-0.428	0.85	0.001	False	143
795	P-88	Jan Meda	J-42	350.0	Steel	100.0	False	0.000	0.00	0.000	False	23
1258	P-784	J-120	J-122	150.0	DI	100.0	False	-0.337	19.05	2.895	False	490
1062	P-504	IC2	IC3	300.0	DI	90.0	False	0.059	0.84	0.005	False	234
799	P-93	J-44	J-41	250.0	Steel	100.0	False	-0.284	5.80	0.176	False	18
1245	P-757	J-142	J-111	300.0	DI	90.0	False	0.237	3.36	0.063	False	361

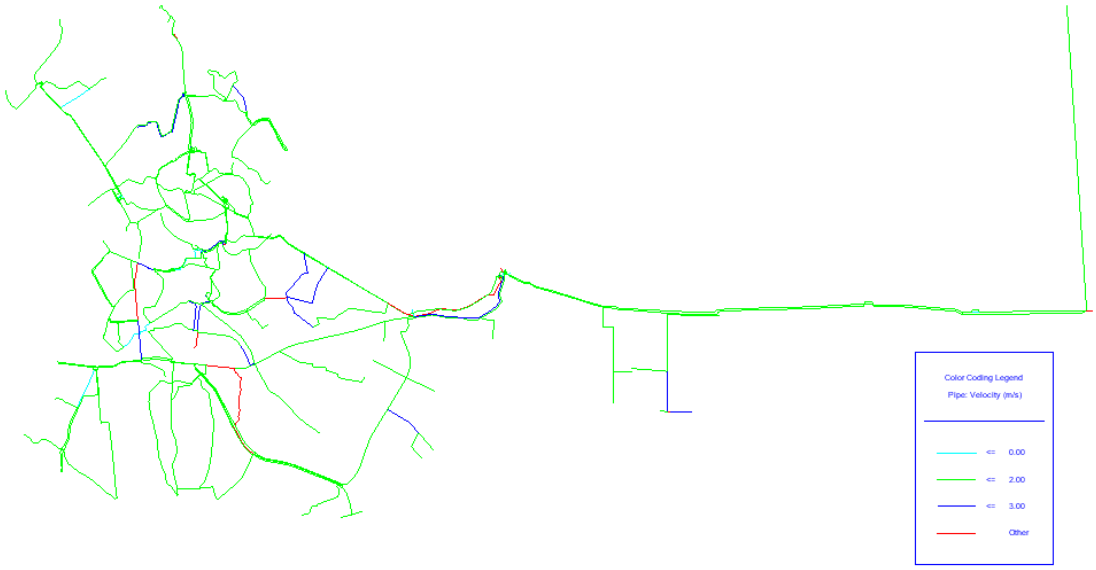
1251	P-770	J-137	J-135	150.0	DI	90.0	False	-0.152	8.60	0.806	False	18
1061	P-503	IC1	IC2	350.0	DI	80.0	False	0.078	0.81	0.005	False	359
1263	P-806	L38	L157	200.0	DI	110.0	False	0.057	1.82	0.023	False	378
1101	P-555	T19	T4	150.0	DI	100.0	False	0.014	0.81	0.008	False	717
786	P-75	J-35	J-31	600.0	Steel	100.0	False	0.000	0.00	0.000	False	16
778	P-65	J-31	J-32	600.0	Steel	100.0	False	0.000	0.00	0.000	False	19
1149	P-660	RK8	RK7	50.0	PVC	110.0	False	-0.002	0.80	0.014	False	703
1286	P-829	L83	L79	150.0	DI	100.0	False	-0.014	0.80	0.008	False	490
1038	P-472	J-120	J-121	150.0	DI	100.0	False	0.156	8.84	0.699	False	654
1057	P-499	T1	T6	150.0	DI	90.0	False	0.012	0.67	0.007	False	1,131
1344	P-904	L11	L12	900.0	Steel	94.0	False	0.461	0.72	0.001	True	906
1081	P-530	L8	L9	150.0	PVC	120.0	False	0.156	8.82	0.496	False	646
1082	P-531	L8	L7	150.0	PVC	120.0	False	0.013	0.75	0.005	False	376
1255	P-778	J-117	J-114	200.0	Steel	100.0	False	-0.195	6.20	0.259	False	379
1054	P-494	T10	T5	150.0	DI	90.0	False	0.013	0.75	0.009	False	260
1412	P-972	G3	G1	200.0	DI	100.0	False	-0.196	6.23	0.261	False	1,005
760	P-38	TR2	L125	150.0	Steel	100.0	False	3.969	224.59	279.258	True	50
869	P-184	R1	J-90	150.0	DCI	100.0	False	0.000	0.00	0.000	False	32
1264	P-807	L157	L42	200.0	DI	110.0	False	0.061	1.95	0.025	False	1,878
840	P-146	MO	J-72	400.0	Steel	100.0	False	0.284	2.26	0.018	False	38
1282	P-825	L43	L41	150.0	DI	100.0	False	-0.032	1.83	0.038	False	1,455
1128	P-585	B7	SP26	150.0	GI	90.0	False	0.154	8.73	0.831	False	2,909
1218	P-723	B7	B9	125.0	GI	90.0	False	0.008	0.68	0.059	False	659
947	P-306	J-79	L113	300.0	DI	100.0	False	0.048	0.68	0.003	False	995
1274	P-817	L47	L45	350.0	DI	100.0	False	-0.128	1.33	0.008	False	1,234
752	P-29	L120	L121	900.0	DI	100.0	False	0.110	0.17	0.000	False	18
853	P-161	J-79	J-82	500.0	DI	100.0	False	0.129	0.66	0.001	False	954
854	P-163	J-82	J-78	500.0	DI	100.0	False	0.129	0.66	0.001	False	45
954	P-317	L83	L104	250.0	DI	90.0	False	0.032	0.65	0.004	False	940
960	P-324	L20	L24	200.0	DI	110.0	False	0.020	0.65	0.003	False	800
1244	P-756	J-108	J-107	150.0	DI	90.0	False	-0.185	10.45	1.157	False	899
1345	P-905	L12	L13	900.0	Steel	94.0	False	0.364	0.57	0.001	True	781
1030	P-464	J-126	J-124	350.0	DI	90.0	False	-0.055	0.57	0.002	False	562
1183	P-849	L33	L32	200.0	DI	100.0	False	-0.018	0.57	0.003	False	420
1056	P-496	T7	T1	250.0	DI	90.0	False	0.027	0.55	0.003	False	868
755	P-32	L122	L123	1,000.0	Steel	100.0	False	-0.394	0.50	0.000	True	5
1413	P-973	G4	G5	200.0	DI	90.0	False	-0.017	0.54	0.005	False	928
1063	P-505	IC3	IC4	200.0	DI	90.0	False	0.017	0.54	0.003	False	205
1087	P-537	L3	L4	250.0	PVC	120.0	False	0.026	0.52	0.001	False	173
1267	P-809	L153	L37	600.0	DI	110.0	False	0.284	1.00	0.002	False	84
1266	P-805	L36	L153	600.0	DI	110.0	False	0.834	2.95	0.015	False	290
1079	P-528	L13	L22	900.0	Steel	94.0	False	0.134	0.21	0.000	True	2,661
1051	P-490	T9	T8	250.0	DI	90.0	False	-0.023	0.47	0.002	False	1,287
872	P-187	E13	R2	125.0	DI	90.0	False	0.000	0.00	0.000	False	410
1184	P-686	J-144	L109	100.0	GI	90.0	False	0.003	0.44	0.005	False	1,042
731	P-3	C1a	C1	700.0	Steel	100.0	False	-0.143	0.37	0.000	True	10
796	P-89	J-42	J-43	350.0	Steel	100.0	False	0.000	0.00	0.000	False	17
1432	P-992	L110	L47	400.0	DI	110.0	False	-0.052	0.42	0.001	False	638
779	P-66	J-32	J-28	600.0	Steel	100.0	False	0.000	0.00	0.000	False	19
1293	P-838	L83	L84	200.0	DI	90.0	False	0.012	0.39	0.002	False	944
944	P-301	L44	L42	200.0	DI	90.0	False	-0.071	2.26	0.049	False	461
1088	P-538	L11	L10	350.0	DI	100.0	False	0.037	0.38	0.001	False	1,084
1424	P-984	T10	T18	200.0	DI	100.0	False	0.011	0.34	0.001	False	520
1433	P-993	L47	L111	400.0	DI	100.0	False	0.042	0.34	0.001	False	1,492
1265	P-808	L157	L37	150.0	Steel	80.0	False	-0.013	0.73	0.010	False	829
1212	P-716	RK21	RK13	150.0	DI	90.0	False	0.005	0.28	0.002	False	1,101
1431	P-991	L28	L110	400.0	DI	110.0	False	-0.038	0.30	0.000	False	1,334
1215	P-720	RK13	RK21	150.0	DI	90.0	False	-0.005	0.28	0.002	False	1,122
1053	P-493	T8	T10	150.0	DI	80.0	False	0.006	0.31	0.002	False	960

1278	P-821	L19	L32	400.0	DI	100.0	False	0.036	0.29	0.000	False	2,787
1059	P-501	IC5	IC1	200.0	DI	80.0	False	-0.009	0.29	0.001	False	530
1064	P-506	SP17	IC6	200.0	DI	90.0	False	0.009	0.29	0.001	False	213
939	P-293	L40	L41	400.0	DI	110.0	False	0.055	0.44	0.001	False	1,064
851	P-160	L35	J-79	600.0	DI	100.0	False	-1.326	4.69	0.043	False	1,142
1085	P-535	L5	L6	250.0	PVC	120.0	False	0.013	0.27	0.000	False	754
979	P-346	L37	L38	600.0	DI	110.0	False	0.072	0.26	0.000	False	616
1269	P-811	L153	L34	200.0	DI	100.0	False	-0.058	1.85	0.028	False	174
1270	P-813	L34	L153	200.0	DI	100.0	False	0.058	1.83	0.027	False	177
745	P-17	L22	TR1	900.0	Steel	100.0	False	0.737	1.16	0.002	True	35
981	P-348	L155	L38	200.0	DI	110.0	False	0.061	1.96	0.026	False	407
977	P-344	L35	L155	400.0	DI	100.0	False	-0.204	1.63	0.010	False	455
1434	P-994	L111	L28	400.0	DI	100.0	False	0.028	0.22	0.000	False	516
1272	P-815	L34	L153	200.0	Steel	90.0	False	0.048	1.52	0.023	False	207
1268	P-810	L35	L34	400.0	DI	100.0	False	0.167	1.33	0.007	False	139
938	P-290	L36	L35	900.0	Steel	100.0	False	-1.360	2.14	0.006	False	213
1199	P-584	B10	B11	200.0	DI	90.0	False	0.006	0.20	0.000	False	404
1279	P-822	L28	L47	200.0	DI	100.0	False	-0.006	0.20	0.000	False	2,055
831	P-135	B14	SP16	150.0	DI	100.0	False	0.003	0.19	0.005	False	2,035
858	P-170	ME1	M23	300.0	Steel	100.0	False	0.014	0.19	0.001	False	16
1408	P-968	J-127	J-139	150.0	DI	100.0	False	1.425	80.66	41.913	False	984
980	P-347	L38	L40	600.0	DI	110.0	False	0.068	0.24	0.000	False	345
946	P-305	L154	J-79	300.0	DI	100.0	False	-0.275	3.88	0.068	False	626
1337	P-898	IC7	J-86	400.0	Steel	90.0	False	-0.020	0.16	0.000	False	257
850	P-158	MO3	J-76	250.0	Steel	100.0	False	0.150	3.05	0.054	False	18
978	P-345	L155	L154	400.0	DI	100.0	False	-0.268	2.13	0.016	False	127
1248	P-761	J-84	J-135	150.0	Steel	90.0	False	-0.028	1.56	0.034	False	461
1271	P-814	L153	L37	150.0	Steel	80.0	False	0.005	0.27	0.002	False	102
1153	P-658	RK9	RK8	50.0	PVC	110.0	False	0.000	0.12	0.000	False	812
1283	P-826	J-79	L156	150.0	GI	90.0	False	0.002	0.11	0.000	False	691
848	P-156	MO	J-75	300.0	DCI	100.0	False	0.150	2.12	0.022	False	41
849	P-157	J-75	MO3	300.0	Steel	100.0	False	0.150	2.12	0.022	False	20
1329	P-889	J-76	SP12	300.0	DI	120.0	False	0.150	2.12	0.016	False	854
857	P-169	J-78	ME1	400.0	Steel	120.0	False	0.014	0.11	0.000	False	13
1417	P-977	T15	T1	150.0	DI	100.0	False	-0.003	0.15	0.000	False	587
874	P-190	E14	R3	100.0	GI	90.0	False	0.000	0.00	0.000	False	472
826	P-126	T12	SP15	250.0	DI	100.0	False	0.003	0.07	0.000	False	2,449
1425	P-985	T18	T9	200.0	DI	100.0	False	-0.003	0.08	0.000	False	586
1203	P-704	J-84	J-137	500.0	DI	90.0	False	-0.149	0.76	0.002	False	455
1325	P-885	J-78	M18	300.0	DI	100.0	False	0.004	0.05	0.000	False	778
982	P-350	L154	L108	300.0	Steel	90.0	False	0.003	0.05	0.000	False	796
1164	P-685	G1	J-144	150.0	Steel	80.0	False	-0.309	17.46	3.724	False	97
1280	P-823	L42	L43	200.0	DI	110.0	False	-0.021	0.67	0.003	False	159
860	P-174	M19	J-78	600.0	DI	110.0	False	-0.004	0.01	0.000	False	734
1405	P-965	J-141	J-130	800.0	DI	100.0	False	-0.004	0.01	0.000	False	384
1340	P-900	J-91	L115	150.0	Steel	90.0	False	0.000	0.00	0.000	False	409
852	P-162	M23	J-81	250.0	Steel	100.0	False	0.000	0.00	0.000	False	37
838	P-143	Entoto2	J-68	125.0	DI	100.0	False	0.000	0.00	0.000	False	33
809	P-104	J-46	TM2	300.0	Steel	100.0	False	0.000	0.00	0.000	False	15
819	P-116	TM4	J-52	125.0	Steel	100.0	False	0.000	0.00	0.000	False	12
837	P-142	J-64	Entoto2	150.0	Steel	100.0	False	0.000	0.00	0.000	False	19
833	P-137	J-67	J-64	150.0	Steel	100.0	False	0.000	0.00	0.000	False	20
801	P-96	JM9	J-40	150.0	Steel	100.0	False	0.000	0.00	0.000	False	15
818	P-115	J-50	TM4	150.0	Steel	100.0	False	0.000	0.00	0.000	False	12
817	P-113	J-52	J-51	150.0	Steel	100.0	False	-0.142	8.05	0.587	False	38
855	P-164	J-81	ME2	300.0	Steel	120.0	False	0.000	0.00	0.000	False	17
846	P-154	MO2	J-74	250.0	Steel	100.0	False	0.000	0.00	0.000	False	11
1455	P-651	PMP-49	J-101	150.0	DCI	100.0	False	0.052	2.97	0.000	False	29
1454	P-650	RK	PMP-49	150.0	DCI	100.0	False	0.000	0.00	0.000	False	27

841	P-148	J-72	J-73	300.0	Steel	100.0	False	0.000	0.00	0.000	False	28
845	P-153	J-73	MO2	300.0	Steel	100.0	False	0.000	0.00	0.000	False	12
800	P-95	J-39	JM9	200.0	Steel	100.0	False	0.000	0.00	0.000	False	12
749	P-26	L119	TR3	600.0	Steel	100.0	False	0.000	0.00	0.000	False	19
798	P-92	J-40	J-44	250.0	Steel	100.0	False	-0.142	2.90	0.049	False	20
856	P-165	ME2	J-82	400.0	Steel	120.0	False	0.000	0.00	0.000	False	12
765	P-46	L126	TR6	150.0	Steel	100.0	False	0.000	0.00	0.000	False	25
766	P-47	TR6	L127	150.0	Steel	100.0	False	0.000	0.00	0.000	False	23
754	P-31	L119	L122	1,000.0	Steel	100.0	False	0.000	0.00	0.000	True	7
751	P-28	L118	L120	900.0	DI	100.0	False	-0.142	0.22	0.000	False	24
777	P-63	JM3	J-30	250.0	Steel	100.0	False	0.000	0.00	0.000	False	10
797	P-91	J-43	J-39	350.0	Steel	100.0	False	0.000	0.00	0.000	False	20
813	P-108	J-46	J-48	400.0	DI	100.0	False	0.000	0.00	0.000	False	34
781	P-68	J-33	J-30	300.0	Steel	100.0	False	0.000	0.00	0.000	False	19
750	P-27	TR3	L118	500.0	Steel	100.0	False	0.000	0.00	0.000	False	18
771	P-52	L127	L129	400.0	DI	100.0	False	0.000	0.00	0.000	False	30
810	P-106	TM2	J-47	350.0	Steel	100.0	False	0.000	0.00	0.000	False	16
776	P-62	J-31	JM3	300.0	Steel	100.0	False	0.000	0.00	0.000	False	9
733	P-5	J-4	ST2	1,200.0	Steel	100.0	False	0.000	0.00	0.000	True	20
734	P-6	ST2	J-5	1,200.0	Steel	100.0	False	0.000	0.00	0.000	True	20
743	P-15	L22	ST4	1,200.0	Steel	100.0	False	0.000	0.00	0.000	True	10
747	P-21	L114	AN	600.0	Steel	100.0	False	0.000	0.00	0.000	False	148
775	P-58	J-27	L117	1,000.0	Steel	100.0	False	0.000	0.00	0.000	True	20
957	P-320	L104	J-70	300.0	DI	100.0	False	0.000	0.00	0.000	False	873
1029	P-463	J-125	J-126	400.0	DI	100.0	False	0.000	0.00	0.000	False	20
1043	P-478	J-116	J-117	200.0	DI	100.0	False	0.000	0.00	0.000	False	11
1142	P-583	B10	B9	110.0	PVC	110.0	False	0.000	0.00	0.000	False	699
1198	P-677	J-106	J-112	300.0	DI	90.0	False	0.000	0.00	0.000	False	900
1250	P-769	J-141	J-137	500.0	DI	90.0	False	0.000	0.00	0.000	False	898
1254	P-775	J-135	J-136	150.0	DI	90.0	False	0.000	0.00	0.000	False	21
1327	P-887	SP27	J-76	300.0	DI	100.0	False	0.000	0.00	0.000	False	173

Figure B.8 Velocity Map of Links for Link Results at Peak Hour for Future Demand 2025, EPS Analysis

Scenario: Peak hour + 1- Hr Fire flow + Future Demand, 2025



Existing Water System of Legedadi sub system 2.wtg
5/17/2014

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W Watertown, CT 06795 USA +1-203-755-1666

Bentley WaterCAD V8i (SELECTseries 4)
[08.11.04.50]
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LOW FLOW DEMAND SCENARIO

Appendix-A.13 Nodes EPS Analysis Results at Low Hour Demand

Flex Table: Junction Table (Existing Water System of Legedadi sub system.wtg) Current Time: 20 hours

ID	Label	Elevation (m)	Demand Pattern	Demand (m^3/s)	Hydraulic Grade (m)	Pressure (m H2O)
129	C1	2,410.00		0.000	2,421.96	11.94
130	C1a	2,410.00		0.000	2,421.96	11.93
131	J-4	2,410.00		0.000	2,422.65	12.62
132	J-5	2,410.00		0.000	2,422.49	12.46
133	J-6	2,400.00		0.000	2,418.46	18.42
134	J-7	2,400.00		0.000	2,418.38	18.34
135	L22	2,406.00	Domestic	0.006	2,405.17	-0.83
136	L117	2,406.00		0.000	2,405.08	-0.92
137	L114	2,375.00	Domestic	0.003	2,403.86	28.80
138	L20	2,351.00	Domestic	0.025	2,403.56	52.46
139	L118	2,402.00		0.000	2,472.80	70.66
140	L119	2,402.00		0.000	2,405.01	3.00
141	L120	2,402.00		0.000	2,472.80	70.66
142	L121	2,402.00		0.000	2,472.79	70.65
143	L122	2,402.00		0.000	2,405.01	3.00
144	L123	2,402.00		0.000	2,405.01	3.00
145	L124	2,402.00		0.000	2,404.89	2.89
146	L125	2,404.00		0.000	2,405.04	1.04
147	L126	2,402.00		0.000	2,404.96	2.96
148	L127	2,402.00		0.000	2,497.96	95.76
149	L128	2,402.00		0.000	2,404.91	2.90
150	L129	2,402.00		0.000	2,497.96	95.76
151	L130	2,402.00		0.000	2,497.91	95.71
152	J-131	2,427.00	Domestic	0.000	2,461.52	34.45
153	J-124	2,420.00	Domestic	0.010	2,461.11	41.03
154	J-27	2,400.00		0.000	2,405.03	5.02
155	J-28	2,460.00		0.000	2,462.44	2.43
156	J-29	2,460.00		0.000	2,498.51	38.44
157	J-30	2,460.00		0.000	2,498.59	38.51
158	J-31	2,460.00		0.000	2,462.45	2.45
159	J-32	2,460.00		0.000	2,462.44	2.44
160	J-33	2,460.00		0.000	2,498.59	38.51
161	J-35	2,460.00		0.000	2,462.47	2.46
162	J-36	2,460.00		0.000	2,517.72	57.60
163	J-37	2,460.00		0.000	2,462.49	2.49
164	J-38	2,460.00		0.000	2,517.92	57.80
165	J-39	2,460.00		0.000	2,462.48	2.47
166	J-40	2,460.00		0.000	2,529.79	69.65
167	J-41	2,460.00		0.000	2,529.73	69.59
168	J-42	2,460.00		0.000	2,462.49	2.48
169	J-43	2,460.00		0.000	2,462.48	2.47
170	J-44	2,460.00		0.000	2,529.79	69.65
171	J-45	2,507.00		0.000	2,508.05	1.05
172	J-46	2,507.00		0.000	2,568.28	61.16
173	J-47	2,507.00		0.000	2,508.12	1.12
174	J-48	2,507.00		0.000	2,568.28	61.16
175	J-49	2,507.00		0.000	2,507.93	0.93
176	J-50	2,507.00		0.000	2,508.11	1.11
177	J-51	2,507.00		0.000	2,576.96	69.82
178	J-52	2,507.00		0.000	2,576.96	69.82

179	E15	2,564.00	Domestic	0.001	2,572.12	8.10
180	J-133	2,432.00	Domestic	0.000	2,462.12	30.06
181	J-132	2,433.00	Domestic	0.000	2,461.95	28.89
182	T7	2,473.00	Domestic	0.003	2,506.08	33.02
183	T12	2,512.00	Domestic	0.001	2,508.13	-3.86
184	T9	2,459.00	Domestic	0.004	2,506.08	46.98
185	SP15	2,490.00	Domestic	0.001	2,508.13	18.09
186	T13	2,510.00	Domestic	0.001	2,507.83	-2.17
187	T1	2,469.00	Domestic	0.002	2,505.66	36.59
188	B14	2,536.00	Domestic	0.021	2,561.23	25.18
189	J-63	2,560.00	Domestic	0.000	2,565.56	5.55
190	J-64	2,560.00		0.000	2,565.08	5.07
191	J-65	2,560.00		0.000	2,565.37	5.36
192	SP16	2,490.00	Domestic	0.001	2,561.17	71.03
193	J-67	2,560.00		0.000	2,565.08	5.07
194	J-68	2,560.00	Domestic	0.000	2,656.56	96.37
195	L35	2,345.00	Domestic	0.001	2,399.65	54.54
196	SP17	2,476.00	Domestic	0.006	2,489.95	13.93
197	J-71	2,483.00		0.000	2,653.55	170.21
198	J-72	2,483.00		0.000	2,490.12	7.10
199	J-73	2,483.00		0.000	2,490.12	7.10
200	J-74	2,483.00		0.000	2,653.40	170.06
201	J-75	2,483.00		0.000	2,490.17	7.16
202	J-76	2,483.00		0.000	2,534.17	51.06
204	J-78	2,352.00		0.000	2,399.61	47.51
205	J-79	2,340.00		0.000	2,399.67	59.55
206	M23	2,352.00	Domestic	0.003	2,439.61	87.43
207	J-81	2,352.00		0.000	2,439.61	87.43
208	J-82	2,352.00		0.000	2,399.61	47.51
209	M18	2,345.00	Domestic	0.001	2,399.61	54.50
211	M19	2,345.00	Domestic	0.001	2,399.61	54.50
215	J-90	2,637.00		0.000	2,639.37	2.36
216	E13	2,637.00	Domestic	0.001	2,687.50	50.40
217	J-92	2,682.00		0.000	2,683.31	1.31
218	E14	2,682.00		0.001	2,750.65	68.52
243	L37	2,349.00	Domestic	0.001	2,399.63	50.52
244	L112	2,350.00	Domestic	0.006	2,402.89	52.78
245	C45	2,350.00		0.000	2,402.85	52.75
246	J-55	2,350.00		0.000	2,445.60	95.41
247	J-118	2,423.00	Domestic	0.001	2,446.51	23.46
256	L28	2,325.00	Domestic	0.003	2,397.41	72.26
257	L116	2,332.00	Domestic	0.001	2,402.82	70.68
258	L46	2,335.00	Domestic	0.004	2,399.42	64.29
259	L36	2,336.00	Domestic	0.001	2,399.65	63.52
260	L40	2,347.00	Domestic	0.002	2,399.62	52.51
261	L41	2,326.00	Domestic	0.004	2,399.60	73.46
262	L44	2,311.00	Domestic	0.002	2,399.02	87.84
263	L47	2,317.00	Domestic	0.117	2,397.45	80.28
265	L45	2,305.00	Domestic	0.025	2,397.38	92.19
267	L42	2,300.00	Domestic	0.002	2,399.09	98.89
269	L154	2,340.00	Domestic	0.001	2,399.65	59.53
270	L113	2,351.00	Domestic	0.001	2,399.55	48.45
271	L69	2,283.00	Domestic	0.001	2,397.93	114.70
276	L81	2,292.00	Domestic	0.001	2,397.59	105.38
277	L104	2,320.00	Domestic	0.001	2,396.89	76.73
278	L83	2,316.00	Domestic	0.011	2,397.04	80.88
279	J-70	2,352.00		0.000	2,399.58	47.49
281	L27	2,339.00	Domestic	0.015	2,401.69	62.56
282	L24	2,351.00	Domestic	0.004	2,403.45	52.34

283	L70	2,280.00	Domestic	0.001	2,397.91	117.67
284	L19	2,327.00	Domestic	0.003	2,403.36	76.21
285	L18	2,332.00	Domestic	0.006	2,400.88	68.74
286	J-80	2,345.00	Domestic	0.000	2,403.04	57.92
287	L26	2,342.00	Domestic	0.008	2,401.73	59.61
296	L155	2,340.00	Domestic	0.000	2,399.65	59.53
297	L38	2,349.00	Domestic	0.002	2,399.62	50.52
298	L108	2,345.00	Domestic	0.001	2,399.65	54.54
332	J-138	2,390.00	Domestic	0.021	2,403.41	13.38
339	J-127	2,387.00	Domestic	0.076	2,482.11	94.92
340	J-123	2,376.00	Domestic	0.006	2,463.01	86.83
341	J-125	2,418.00	Domestic	0.045	2,480.28	62.15
342	J-126	2,418.00	Domestic	0.010	2,461.06	42.98
343	J-129	2,411.00	Domestic	0.003	2,461.30	50.20
344	J-122	2,386.00	Domestic	0.003	2,459.64	73.49
345	J-120	2,371.00	Domestic	0.003	2,459.45	88.27
346	J-121	2,366.00	Domestic	0.003	2,459.21	93.03
347	J-115	2,405.00	Domestic	0.002	2,460.02	54.91
348	J-130	2,425.00	Domestic	0.000	2,462.10	37.03
349	J-116	2,405.00	Domestic	0.001	2,460.94	55.83
350	J-117	2,406.00	Domestic	0.001	2,436.61	30.55
351	J-84	2,410.00		0.000	2,450.51	40.43
352	J-134	2,411.00	Domestic	0.001	2,449.28	38.20
353	J-119	2,431.00	Domestic	0.001	2,453.79	22.74
354	T3	2,440.00	Domestic	0.005	2,453.08	13.06
355	T11	2,410.00	Domestic	0.004	2,461.23	51.12
356	T4	2,435.00	Domestic	0.003	2,461.75	26.70
357	T8	2,472.00	Domestic	0.003	2,506.08	34.01
358	T10	2,472.00	Domestic	0.002	2,506.32	34.25
359	T5	2,455.00	Domestic	0.002	2,506.21	51.11
360	T6	2,460.00	Domestic	0.003	2,496.50	36.42
361	IC5	2,437.00	Domestic	0.002	2,489.88	52.78
362	IC1	2,472.00	Domestic	0.002	2,489.91	17.88
363	IC2	2,463.00	Domestic	0.003	2,489.84	26.78
364	IC3	2,450.00	Domestic	0.008	2,489.79	39.71
365	IC4	2,432.00	Domestic	0.003	2,489.76	57.64
366	IC6	2,465.00	Domestic	0.002	2,489.94	24.89
367	SP27	2,491.00	Domestic	0.000	2,490.38	-0.61
378	L23	2,352.00	Domestic	0.012	2,402.57	50.47
379	L160	2,334.00	Domestic	0.006	2,399.76	65.63
380	L16	2,327.00	Domestic	0.006	2,399.66	72.51
381	L13	2,387.00	Domestic	0.009	2,408.07	21.03
382	L8	2,340.00	Domestic	0.002	2,407.39	67.25
383	L9	2,332.00	Domestic	0.003	2,407.23	75.08
384	L7	2,363.00	Domestic	0.002	2,407.30	44.21
385	L11	2,382.00	Domestic	0.019	2,410.09	28.03
386	L5	2,362.00	Domestic	0.002	2,409.47	47.37
387	L6	2,365.00	Domestic	0.002	2,409.45	44.36
388	L3	2,360.00	Domestic	0.006	2,408.35	48.25
389	L4	2,360.00	Domestic	0.005	2,408.34	48.24
390	L10	2,392.00	Domestic	0.007	2,410.05	18.01
397	T19	2,430.00	Domestic	0.003	2,462.01	31.95
398	RK22	2,431.00		0.007	2,529.06	97.87
403	J-144	2,364.00	Domestic	0.011	2,431.86	67.72
405	RK7	2,511.00		0.000	2,704.83	193.44
412	G4	2,351.00		0.003	2,420.00	68.87
413	L156	2,347.00	Domestic	0.000	2,399.66	52.56
421	J-87	2,404.00		0.000	2,404.96	0.96
422	L31	2,320.00	Domestic	0.003	2,397.05	76.90

424	SP26	2,493.00		0.002	2,634.65	141.36
425	RK20	2,500.00		0.001	2,544.14	44.05
426	RK15	2,522.00		0.000	2,544.90	22.85
427	J-143	2,423.00	Domestic	0.002	2,449.01	25.96
428	J-112	2,346.00	Domestic	0.006	2,455.08	108.86
431	B9	2,582.00		0.002	2,635.34	53.24
435	L2	2,360.00	Domestic	0.007	2,407.65	47.55
438	J-106	2,355.00	Domestic	0.006	2,442.20	87.02
440	E1	2,734.00		0.001	2,746.26	12.24
441	L30	2,320.00	Domestic	0.003	2,397.18	77.03
443	E4	2,635.00	Domestic	0.006	2,638.48	3.47
444	L33	2,325.00	Domestic	0.003	2,403.25	78.09
445	J-128	2,385.00	Domestic	0.006	2,401.15	16.11
447	B4	2,593.00		0.011	2,631.62	38.55
448	J-109	2,385.00	Domestic	0.002	2,446.91	61.79
452	E3	2,673.00		0.002	2,683.30	10.28
453	L105	2,308.00	Domestic	0.005	2,396.33	88.15
458	J-141	2,432.00	Domestic	0.001	2,462.10	30.04
459	L29	2,317.00	Domestic	0.003	2,396.84	79.68
463	RK21	2,490.00		0.003	2,543.97	53.86
464	J-108	2,353.00	Domestic	0.001	2,427.06	73.91
467	J-110	2,417.00	Domestic	0.003	2,448.01	30.95
469	E2	2,708.00		0.001	2,746.00	37.92
470	B7	2,631.00		0.001	2,635.61	4.60
478	RK8	2,538.00		0.000	2,704.07	165.73
479	L15	2,360.00	Domestic	0.004	2,404.00	43.91
485	E16	2,547.00	Domestic	0.002	2,564.98	17.95
488	B8	2,636.00		0.001	2,763.83	127.57
490	RK14	2,523.00		0.000	2,545.38	22.33
493	L79	2,292.00	Domestic	0.002	2,397.22	105.00
495	RK10	2,553.00	Domestic	0.000	2,706.48	153.17
501	L1	2,356.00	Domestic	0.007	2,405.43	49.33
504	J-142	2,424.00	Domestic	0.002	2,448.86	24.81
505	L109	2,345.00	Domestic	0.001	2,431.62	86.44
506	J-107	2,379.00	Domestic	0.013	2,427.51	48.41
507	B11	2,610.00	Domestic	0.001	2,629.20	19.16
509	G2	2,343.00	Domestic	0.014	2,426.45	83.28
522	B10	2,600.00	Domestic	0.019	2,629.21	29.15
524	J-86	2,434.00		0.000	2,448.67	14.64
528	J-91	2,360.00		0.000	2,403.69	43.60
543	J-113	2,403.00	Domestic	0.003	2,458.42	55.30
547	G1	2,364.00	Domestic	0.007	2,429.52	65.39
550	B1	2,706.00		0.003	2,759.32	53.22
552	RK9	2,588.00		0.002	2,704.09	115.86
554	J-137	2,390.00	Domestic	0.001	2,450.51	60.39
559	L32	2,325.00	Domestic	0.003	2,403.31	78.15
562	RK13	2,520.00		0.002	2,544.05	24.01
565	J-105	2,358.00	Domestic	0.007	2,442.38	84.21
566	J-111	2,397.00	Domestic	0.002	2,448.72	51.62
567	J-135	2,390.00	Domestic	0.001	2,450.42	60.30
568	J-136	2,390.00	Domestic	0.001	2,451.73	61.61
569	J-114	2,417.00	Domestic	0.002	2,427.39	10.37
570	L157	2,339.00	Domestic	0.002	2,399.52	60.40
571	L153	2,345.00	Domestic	0.001	2,399.63	54.52
572	L34	2,345.00	Domestic	0.001	2,399.65	54.54
573	L43	2,303.00	Domestic	0.002	2,399.09	95.90
574	L82	2,311.00	Domestic	0.002	2,398.31	87.14
576	L84	2,321.00	Domestic	0.002	2,396.96	75.81
586	SP12	2,463.00	Domestic	0.001	2,534.17	71.02

589	IC7	2,441.00	Domestic	0.004	2,448.67	7.65
590	L115	2,370.00	Domestic	0.003	2,403.69	33.62
591	L14	2,377.00	Domestic	0.004	2,404.55	27.49
592	L12	2,385.00	Domestic	0.018	2,408.97	23.92
611	B13	2,595.00		0.002	2,632.32	37.24
612	J-139	2,373.00	Domestic	0.006	2,470.53	97.33
613	J-140	2,365.00	Domestic	0.004	2,465.06	99.85
614	G3	2,358.00	Domestic	0.010	2,438.13	79.97
615	G5	2,367.00		0.007	2,420.14	53.04
616	G6	2,402.00		0.003	2,421.12	19.09
617	T15	2,497.00	Domestic	0.005	2,506.20	9.18
618	T14	2,492.00	Domestic	0.005	2,507.06	15.03
619	T16	2,447.00	Domestic	0.005	2,497.39	50.29
620	T17	2,454.00	Domestic	0.005	2,462.31	8.29
621	T18	2,459.00	Domestic	0.002	2,506.14	47.04
625	L110	2,306.00	Domestic	0.003	2,397.43	91.24
626	L111	2,324.00	Domestic	0.003	2,397.41	73.26
629	E12	2,560.00	Domestic	0.003	2,564.98	4.97
632	J-101	2,545.00		0.000	2,715.48	170.13
634	J-104	2,615.00		0.000	2,631.09	16.05

Appendix A.14 Link EPS Analysis Results at Low Hour Demand

FlexTable: Pipe Table (Existing Water System of Legedadi sub system.wtg) **Current Time: 20 hours**

ID	Label	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Has Check Valve?	Flow (m^3/s)	Velocity (m/s)	Head loss Gradient (m/m)	Has User Defined Length?	Length (m)
730	P-2	LAGA TANK	C1a	900.0	Steel	115.0	False	0.543	0.85	0.001	True	6,890
731	P-3	C1a	C1	700.0	Steel	100.0	False	-0.149	0.39	0.000	True	10
732	P-4	LAGA TANK	J-4	1,400.0	Steel	110.0	False	1.623	1.05	0.001	True	6,360
733	P-5	J-4	ST2	1,200.0	Steel	100.0	False	0.000	0.00	0.000	True	20
734	P-6	ST2	J-5	1,200.0	Steel	100.0	False	0.000	0.00	0.000	True	20
735	P-7	J-5	C1	1,400.0	Steel	100.0	False	1.623	1.05	0.001	True	528
736	P-8	J-5	J-4	1,000.0	Steel	100.0	False	-1.623	2.07	0.005	True	30
737	P-9	ST3	J-6	1,200.0	Steel	100.0	False	-1.172	1.04	0.001	True	20
738	P-10	J-6	C1	1,200.0	Steel	100.0	False	-1.475	1.30	0.002	True	1,964
739	P-11	C1a	J-6	900.0	Steel	100.0	False	0.692	1.09	0.002	True	1,964
740	P-12	ST3	J-7	1,200.0	DCI	100.0	False	0.881	0.78	0.001	False	88
741	P-13	J-7	L22	1,200.0	Steel	100.0	False	1.288	1.14	0.001	True	9,526
742	P-14	L22	TR2	900.0	Steel	100.0	False	0.980	1.54	0.003	True	35
743	P-15	L22	ST4	1,200.0	Steel	100.0	False	0.000	0.00	0.000	True	10
744	P-16	J-7	J-6	1,000.0	Steel	100.0	False	-0.995	1.27	0.002	True	40
745	P-17	L22	TR1	900.0	Steel	100.0	False	0.801	1.26	0.002	True	35
746	P-19	TR1	L117	1,000.0	Steel	100.0	False	0.315	0.40	0.000	True	40
747	P-21	L114	AN	600.0	Steel	100.0	False	0.000	0.00	0.000	False	148
748	P-22	L114	L20	600.0	DI	100.0	False	0.071	0.25	0.000	False	1,585
749	P-26	L119	TR3	600.0	Steel	100.0	False	0.000	0.00	0.000	False	19
750	P-27	TR3	L118	500.0	Steel	100.0	False	0.000	0.00	0.000	False	18
751	P-28	L118	L120	900.0	DI	100.0	False	0.000	0.00	0.000	False	24
752	P-29	L120	L121	900.0	DI	100.0	False	0.359	0.56	0.001	False	18
753	P-30	L121	Jan Meda	900.0	DI	120.0	False	0.717	1.13	0.001	False	7,550
754	P-31	L119	L122	1,000.0	Steel	100.0	False	0.000	0.00	0.000	True	7
755	P-32	L122	L123	1,000.0	Steel	100.0	False	-0.359	0.46	0.000	True	5
756	P-34	L122	TR2	600.0	Steel	100.0	False	0.359	1.27	0.004	False	19
757	P-36	TR2	L120	500.0	Steel	100.0	False	0.359	1.83	0.009	False	19
758	P-35	L123	TP1	500.0	Steel	100.0	False	0.358	1.82	0.009	False	19
759	P-37	TP1	L121	500.0	Steel	100.0	False	0.358	1.82	0.009	False	20
760	P-38	TR2	L125	150.0	Steel	100.0	False	0.002	0.12	0.000	True	50
761	P-40	TR1	L125	500.0	Steel	100.0	False	0.158	0.81	0.002	False	24
762	P-39	L125	L126	500.0	Steel	100.0	False	0.155	0.79	0.002	False	39
763	P-41	L126	L128	500.0	Steel	100.0	False	0.155	0.79	0.002	False	27
764	P-43	L128	L124	500.0	Steel	100.0	False	0.078	0.39	0.001	False	33
765	P-46	L126	TR6	150.0	Steel	100.0	False	0.000	0.00	0.000	False	25
766	P-47	TR6	L127	150.0	Steel	100.0	False	0.000	0.00	0.000	False	23
767	P-48	L128	TR5	300.0	Steel	100.0	False	0.077	1.09	0.006	False	24
768	P-49	TR5	L129	300.0	Steel	100.0	False	0.077	1.09	0.006	False	24
769	P-50	L124	TR4	300.0	Steel	100.0	False	0.078	1.10	0.007	False	21
770	P-51	TR4	L130	300.0	Steel	100.0	False	0.078	1.10	0.007	False	26
771	P-52	L127	L129	400.0	DI	100.0	False	0.000	0.00	0.000	False	30
772	P-53	L129	L130	400.0	DI	100.0	False	0.077	0.62	0.002	False	33
773	P-56	L123	J-27	1,000.0	Steel	100.0	False	-0.717	0.91	0.001	True	22
774	P-57	J-27	TR2	1,000.0	Steel	100.0	False	-0.738	0.94	0.001	True	16
775	P-58	J-27	L117	1,000.0	Steel	100.0	False	0.000	0.00	0.000	True	20
776	P-62	J-31	JM3	300.0	Steel	100.0	False	0.000	0.00	0.000	False	9

777	P-63	JM3	J-30	250.0	Steel	100.0	False	0.000	0.00	0.000	False	10
778	P-65	J-31	J-32	600.0	Steel	100.0	False	0.153	0.54	0.001	False	19
779	P-66	J-32	J-28	600.0	Steel	100.0	False	0.077	0.27	0.000	False	19
780	P-67	J-29	J-33	300.0	Steel	100.0	False	-0.076	1.08	0.006	False	16
781	P-68	J-33	J-30	300.0	Steel	100.0	False	0.000	0.00	0.000	False	19
782	P-69	J-32	JM4	300.0	Steel	100.0	False	0.076	1.08	0.006	False	12
783	P-70	JM4	J-33	250.0	Steel	100.0	False	0.076	1.56	0.015	False	15
784	P-71	J-28	JM5	300.0	Steel	100.0	False	0.077	1.09	0.006	False	13
785	P-72	JM5	J-29	250.0	Steel	100.0	False	0.077	1.56	0.016	False	14
786	P-75	J-35	J-31	600.0	Steel	100.0	False	0.153	0.54	0.001	False	16
787	P-77	Jan Meda	J-37	600.0	Steel	100.0	False	0.301	1.06	0.003	False	20
788	P-78	J-37	J-35	600.0	Steel	100.0	False	0.227	0.80	0.002	False	16
789	P-80	J-38	J-36	250.0	Steel	100.0	False	0.073	1.50	0.014	False	14
790	P-79	J-37	JM1	300.0	Steel	100.0	False	0.073	1.04	0.006	False	13
791	P-81	JM1	J-38	250.0	Steel	100.0	False	0.073	1.50	0.014	False	16
792	P-82	J-35	JM2	300.0	Steel	100.0	False	0.074	1.05	0.006	False	13
793	P-83	JM2	J-36	250.0	Steel	100.0	False	0.074	1.51	0.014	False	14
794	P-84	J-36	TM	400.0	DI	100.0	False	0.147	1.17	0.005	False	1,782
795	P-88	Jan Meda	J-42	350.0	Steel	100.0	False	0.068	0.71	0.002	False	23
796	P-89	J-42	J-43	350.0	Steel	100.0	False	0.034	0.35	0.001	False	17
797	P-91	J-43	J-39	350.0	Steel	100.0	False	0.000	0.00	0.000	False	20
798	P-92	J-40	J-44	250.0	Steel	100.0	False	0.000	0.00	0.000	False	20
799	P-93	J-44	J-41	250.0	Steel	100.0	False	0.034	0.69	0.003	False	18
800	P-95	J-39	JM9	200.0	Steel	100.0	False	0.000	0.00	0.000	False	12
801	P-96	JM9	J-40	150.0	Steel	100.0	False	0.000	0.00	0.000	False	15
802	P-97	J-43	JM8	200.0	Steel	100.0	False	0.034	1.08	0.010	False	13
803	P-98	JM8	J-44	150.0	Steel	100.0	False	0.034	1.91	0.041	False	14
804	P-99	J-42	JM7	200.0	Steel	100.0	False	0.034	1.08	0.010	False	13
805	P-100	JM7	J-41	150.0	Steel	100.0	False	0.034	1.92	0.041	False	13
806	P-101	J-41	TM	250.0	DI	100.0	False	0.068	1.38	0.012	False	1,730
807	P-102	TM	J-47	400.0	Steel	100.0	False	0.091	0.73	0.002	False	85
808	P-103	J-47	J-45	400.0	Steel	100.0	False	0.091	0.73	0.002	False	34
809	P-104	J-46	TM2	300.0	Steel	100.0	False	0.000	0.00	0.000	False	15
810	P-106	TM2	J-47	350.0	Steel	100.0	False	0.000	0.00	0.000	False	16
811	P-105	J-45	TM1	350.0	Steel	100.0	False	0.091	0.95	0.004	False	14
812	P-107	TM1	J-48	300.0	Steel	100.0	False	0.091	1.29	0.009	False	15
813	P-108	J-46	J-48	400.0	DI	100.0	False	0.000	0.00	0.000	False	34
814	P-109	J-48	EN	400.0	DI	100.0	False	0.091	0.73	0.002	False	1,246
815	P-110	TM	J-50	200.0	Steel	100.0	False	0.022	0.70	0.005	False	43
816	P-111	J-50	J-49	200.0	Steel	100.0	False	0.022	0.70	0.005	False	40
817	P-113	J-52	J-51	150.0	Steel	100.0	False	0.000	0.00	0.000	False	38
818	P-115	J-50	TM4	150.0	Steel	100.0	False	0.000	0.00	0.000	False	12
819	P-116	TM4	J-52	125.0	Steel	100.0	False	0.000	0.00	0.000	False	12
820	P-117	J-49	TM3	150.0	Steel	100.0	False	0.022	1.25	0.019	False	12
821	P-118	TM3	J-51	125.0	Steel	100.0	False	0.022	1.80	0.045	False	13
822	P-119	J-51	E15	200.0	DI	100.0	False	0.022	0.70	0.005	False	1,056
823	P-120	E15	RK	150.0	DI	100.0	False	0.021	1.18	0.017	False	1,437
824	P-122	Jan Meda	J-132	350.0	DI	100.0	False	0.031	0.32	0.001	False	1,075
825	P-123	TM	T12	400.0	DI	100.0	False	0.108	0.86	0.003	False	63
826	P-126	T12	SP15	250.0	DI	100.0	False	0.001	0.01	0.000	False	2,449
827	P-127	T12	T13	400.0	DI	100.0	False	0.093	0.74	0.002	False	130
828	P-130	EN	J-63	400.0	DI	100.0	False	0.043	0.34	0.001	False	25
829	P-131	J-63	B14	200.0	DI	100.0	False	0.015	0.48	0.002	False	1,885
830	P-132	J-63	J-65	200.0	Steel	100.0	False	0.028	0.89	0.007	False	27
831	P-135	B14	SP16	150.0	DI	100.0	False	0.001	0.04	0.000	False	2,035
832	P-136	J-65	J-67	150.0	Steel	100.0	False	0.019	1.05	0.014	False	22
833	P-137	J-67	J-64	150.0	Steel	100.0	False	0.000	0.00	0.000	False	20
834	P-139	J-68	R1	150.0	DI	100.0	False	0.019	1.05	0.014	False	1,244
835	P-140	J-67	Entoto1	150.0	Steel	100.0	False	0.019	1.05	0.014	False	18

836	P-141	Entoto1	J-68	125.0	Steel	100.0	False	0.019	1.51	0.033	False	16
837	P-142	J-64	Entoto2	150.0	Steel	100.0	False	0.000	0.00	0.000	False	19
838	P-143	Entoto2	J-68	125.0	DI	100.0	False	0.000	0.00	0.000	False	33
839	P-145	MO	SP17	350.0	DI	100.0	False	0.025	0.26	0.000	False	556
840	P-146	MO	J-72	400.0	Steel	100.0	False	0.072	0.58	0.001	False	38
841	P-148	J-72	J-73	300.0	Steel	100.0	False	0.000	0.00	0.000	False	28
842	P-150	J-71	J-74	300.0	Steel	100.0	False	0.072	1.02	0.006	False	27
843	P-151	J-72	MO1	300.0	Steel	100.0	False	0.072	1.02	0.006	False	12
844	P-152	MO1	J-71	250.0	Steel	100.0	False	0.072	1.47	0.014	False	12
845	P-153	J-73	MO2	300.0	Steel	100.0	False	0.000	0.00	0.000	False	12
846	P-154	MO2	J-74	250.0	Steel	100.0	False	0.000	0.00	0.000	False	11
847	P-155	J-74	T-14	300.0	DI	100.0	False	0.072	1.02	0.006	False	3,031
848	P-156	MO	J-75	300.0	DCI	100.0	False	0.001	0.02	0.000	False	41
849	P-157	J-75	MO3	300.0	Steel	100.0	False	0.001	0.02	0.000	False	20
850	P-158	MO3	J-76	250.0	Steel	100.0	False	0.001	0.03	0.000	False	18
851	P-160	L35	J-79	600.0	DI	100.0	False	-0.020	0.07	0.000	False	1,142
852	P-162	M23	J-81	250.0	Steel	100.0	False	0.000	0.00	0.000	False	37
853	P-161	J-79	J-82	500.0	DI	100.0	False	0.024	0.12	0.000	False	954
854	P-163	J-82	J-78	500.0	DI	100.0	False	0.024	0.12	0.000	False	45
855	P-164	J-81	ME2	300.0	Steel	120.0	False	0.000	0.00	0.000	False	17
856	P-165	ME2	J-82	400.0	Steel	120.0	False	0.000	0.00	0.000	False	12
857	P-169	J-78	ME1	400.0	Steel	120.0	False	0.003	0.02	0.000	False	13
858	P-170	ME1	M23	300.0	Steel	100.0	False	0.003	0.04	0.000	False	16
860	P-174	M19	J-78	600.0	DI	110.0	False	-0.001	0.00	0.000	False	734
869	P-184	R1	J-90	150.0	DCI	100.0	False	0.010	0.56	0.004	False	32
870	P-185	J-90	R1(1)	125.0	Steel	100.0	False	0.010	0.81	0.010	False	19
871	P-186	R1(1)	E13	100.0	Steel	100.0	False	0.010	1.27	0.031	False	20
872	P-187	E13	R2	125.0	DI	90.0	False	0.009	0.70	0.010	False	410
873	P-188	R2	J-92	100.0	DCI	100.0	False	0.005	0.69	0.010	False	22
874	P-190	E14	R3	100.0	GI	90.0	False	0.004	0.54	0.008	False	472
875	P-189	J-92	R2(1)	100.0	Steel	100.0	False	0.005	0.69	0.010	False	16
876	P-191	R2(1)	E14	80.0	Steel	100.0	False	0.005	1.08	0.029	False	19
913	P-250	L112	C45	300.0	Steel	100.0	False	0.041	0.58	0.002	False	63
914	P-251	C45	UR1	250.0	Steel	100.0	False	0.041	0.83	0.005	False	17
915	P-252	UR1	J-55	200.0	Steel	100.0	False	0.041	1.30	0.014	False	19
935	P-287	L112	L116	900.0	Steel	90.0	False	0.162	0.25	0.000	False	457
936	P-289	L116	L46	450.0	DI	90.0	False	0.122	0.77	0.003	False	1,331
937	P-288	L116	L36	250.0	Steel	90.0	False	0.039	0.79	0.005	False	588
938	P-290	L36	L35	900.0	Steel	100.0	False	-0.010	0.02	0.000	False	213
939	P-293	L40	L41	400.0	DI	110.0	False	0.007	0.05	0.000	False	1,064
940	P-294	L37	L44	300.0	DI	110.0	False	0.014	0.20	0.000	False	2,498
941	P-296	L47	L46	450.0	DI	90.0	False	-0.125	0.79	0.003	False	738
942	P-299	L44	L45	200.0	DI	90.0	False	0.016	0.50	0.003	False	562
944	P-301	L44	L42	200.0	DI	90.0	False	-0.003	0.10	0.000	False	461
946	P-305	L154	J-79	300.0	DI	100.0	False	-0.004	0.06	0.000	False	626
947	P-306	J-79	L113	300.0	DI	100.0	False	0.009	0.13	0.000	False	995
948	P-307	L113	L69	300.0	DI	100.0	False	0.021	0.29	0.001	False	2,859
953	P-316	L81	L83	250.0	DI	110.0	False	0.017	0.34	0.001	False	704
954	P-317	L83	L104	250.0	DI	90.0	False	0.006	0.12	0.000	False	940
955	P-318	L113	J-70	300.0	DI	100.0	False	-0.020	0.28	0.001	False	57
956	P-319	J-70	J-78	300.0	DI	100.0	False	-0.020	0.28	0.001	False	47
957	P-320	L104	J-70	300.0	DI	100.0	False	0.000	0.00	0.000	False	873
959	P-323	L112	L27	250.0	DI	110.0	False	0.015	0.30	0.001	False	2,008
960	P-324	L20	L24	200.0	DI	110.0	False	0.004	0.12	0.000	False	800
961	P-325	L69	L70	300.0	DI	110.0	False	0.019	0.27	0.000	False	76
962	P-326	L70	L81	300.0	DI	110.0	False	0.018	0.25	0.000	False	856
964	P-328	L20	L19	400.0	DI	100.0	False	0.029	0.23	0.000	False	770
965	P-330	L19	L18	200.0	DI	110.0	False	0.019	0.62	0.003	False	607
966	P-332	J-80	L112	900.0	Steel	90.0	False	0.223	0.35	0.000	False	563

967	P-333	J-80	L26	200.0	DI	100.0	False	0.008	0.24	0.001	False	2,077
977	P-344	L35	L155	400.0	DI	100.0	False	0.000	0.00	0.000	False	455
978	P-345	L155	L154	400.0	DI	100.0	False	-0.003	0.02	0.000	False	127
979	P-346	L37	L38	600.0	DI	110.0	False	0.013	0.05	0.000	False	616
980	P-347	L38	L40	600.0	DI	110.0	False	0.009	0.03	0.000	False	345
981	P-348	L155	L38	200.0	DI	110.0	False	0.003	0.08	0.000	False	407
982	P-350	L154	L108	300.0	Steel	90.0	False	0.001	0.01	0.000	False	796
1014	P-428	J-27	J-138	150.0	DI	100.0	False	0.021	1.16	0.016	False	100
1027	P-460	L130	J-127	400.0	DI	100.0	False	0.155	1.23	0.006	False	2,732
1028	P-461	J-127	J-125	400.0	DI	90.0	False	0.061	0.49	0.001	False	1,458
1029	P-463	J-125	J-126	400.0	DI	100.0	False	0.000	0.00	0.000	False	20
1030	P-464	J-126	J-124	350.0	DI	90.0	False	-0.010	0.11	0.000	False	562
1031	P-465	J-125	J-123	150.0	DI	90.0	False	0.016	0.91	0.013	False	1,365
1032	P-466	J-123	J-124	150.0	DI	100.0	False	0.006	0.33	0.002	False	1,165
1033	P-467	J-124	J-129	350.0	DI	100.0	False	-0.014	0.15	0.000	False	1,369
1034	P-468	J-129	J-131	350.0	DI	100.0	False	-0.023	0.24	0.000	False	689
1035	P-469	J-129	J-122	150.0	DI	90.0	False	0.005	0.29	0.001	False	1,107
1036	P-470	J-122	J-123	150.0	DI	90.0	False	-0.012	0.67	0.007	False	473
1037	P-471	J-122	J-120	250.0	DI	100.0	False	0.011	0.22	0.000	False	478
1038	P-472	J-120	J-121	150.0	DI	100.0	False	0.003	0.15	0.000	False	654
1039	P-473	J-120	J-115	300.0	DI	90.0	False	-0.020	0.29	0.001	False	860
1040	P-474	J-115	J-116	500.0	DI	100.0	False	-0.133	0.68	0.001	False	629
1041	P-475	J-116	J-130	500.0	DI	100.0	False	-0.134	0.68	0.001	False	783
1042	P-476	J-118	J-117	200.0	Steel	100.0	False	0.055	1.76	0.025	False	393
1043	P-478	J-116	J-117	200.0	DI	100.0	False	0.000	0.00	0.000	False	11
1044	P-479	J-130	J-133	800.0	DI	100.0	False	-0.135	0.27	0.000	False	143
1045	P-480	J-133	J-132	350.0	DI	100.0	False	0.088	0.92	0.004	False	44
1046	P-481	J-132	J-131	350.0	DI	100.0	False	0.119	1.23	0.007	False	63
1047	P-483	J-118	J-134	150.0	Steel	90.0	False	-0.010	0.57	0.005	False	526
1048	P-485	J-131	J-119	300.0	DI	90.0	False	0.095	1.35	0.012	False	667
1049	P-487	J-119	T3	200.0	DI	80.0	False	0.005	0.17	0.001	False	1,366
1050	P-488	J-119	J-118	200.0	DI	100.0	False	0.046	1.46	0.018	False	407
1051	P-490	T9	T8	250.0	DI	90.0	False	-0.001	0.02	0.000	False	1,287
1052	P-491	T12	T10	200.0	DI	100.0	False	0.012	0.38	0.001	False	1,222
1053	P-493	T8	T10	150.0	DI	80.0	False	-0.002	0.10	0.000	False	960
1054	P-494	T10	T5	150.0	DI	90.0	False	0.002	0.14	0.000	False	260
1055	P-495	T8	T7	250.0	DI	90.0	False	-0.002	0.05	0.000	False	84
1056	P-496	T7	T1	250.0	DI	90.0	False	0.011	0.22	0.000	False	868
1057	P-499	T1	T6	150.0	DI	90.0	False	0.013	0.72	0.008	False	1,131
1058	P-500	T6	T7	250.0	DI	90.0	False	-0.062	1.26	0.013	False	761
1059	P-501	IC5	IC1	200.0	DI	80.0	False	-0.002	0.05	0.000	False	530
1060	P-502	IC1	SP17	350.0	DI	90.0	False	-0.018	0.19	0.000	False	169
1061	P-503	IC1	IC2	350.0	DI	80.0	False	0.015	0.15	0.000	False	359
1062	P-504	IC2	IC3	300.0	DI	90.0	False	0.011	0.16	0.000	False	234
1063	P-505	IC3	IC4	200.0	DI	90.0	False	0.003	0.10	0.000	False	205
1064	P-506	SP17	IC6	200.0	DI	90.0	False	0.002	0.05	0.000	False	213
1065	P-507	T6	SP27	500.0	DI	100.0	False	0.220	1.12	0.004	False	1,642
1066	P-508	SP27	MO	500.0	DI	100.0	False	0.220	1.12	0.004	False	57
1076	P-524	L20	L23	200.0	DI	100.0	False	0.012	0.39	0.002	False	637
1077	P-525	L18	L160	150.0	DI	90.0	False	0.006	0.37	0.002	False	483
1078	P-526	L18	L16	150.0	DI	100.0	False	0.006	0.37	0.002	False	640
1079	P-528	L13	L22	900.0	Steel	94.0	False	0.499	0.78	0.001	True	2,661
1080	P-529	L13	L8	200.0	DI	120.0	False	0.007	0.24	0.000	False	1,548
1081	P-530	L8	L9	150.0	PVC	120.0	False	0.003	0.14	0.000	False	646
1082	P-531	L8	L7	150.0	PVC	120.0	False	0.002	0.14	0.000	False	376
1083	P-532	J-7	L11	900.0	Steel	90.0	False	0.588	0.92	0.002	True	5,178
1084	P-534	L11	L5	350.0	DI	100.0	False	0.029	0.31	0.001	False	1,209
1085	P-535	L5	L6	250.0	PVC	120.0	False	0.002	0.05	0.000	False	754
1086	P-536	L5	L3	250.0	PVC	120.0	False	0.024	0.50	0.001	False	839

1087	P-537	L3	L4	250.0	PVC	120.0	False	0.005	0.10	0.000	False	173
1088	P-538	L11	L10	350.0	DI	100.0	False	0.007	0.07	0.000	False	1,084
1100	P-554	T11	T19	150.0	DI	100.0	False	-0.004	0.22	0.001	False	1,097
1101	P-555	T19	T4	150.0	DI	100.0	False	0.003	0.15	0.000	False	717
1102	P-556	J-133	T19	150.0	DI	100.0	False	0.009	0.51	0.004	False	30
1108	P-666	J-110	J-109	150.0	DI	90.0	False	0.005	0.26	0.001	False	864
1115	P-852	L31	L30	150.0	DI	100.0	False	-0.003	0.19	0.001	False	226
1116	P-654	RK7	RK10	50.0	PVC	110.0	False	-0.001	0.32	0.004	False	377
1128	P-585	B7	SP26	150.0	GI	90.0	False	0.002	0.13	0.000	False	2,909
1134	P-673	J-107	J-106	150.0	GI	80.0	False	-0.020	1.14	0.024	False	618
1139	P-831	RK15	RK14	100.0	GI	90.0	False	-0.002	0.31	0.003	False	0
1142	P-583	B10	B9	110.0	PVC	110.0	False	0.000	0.00	0.000	False	699
1144	P-634	J-142	J-143	400.0	Steel	80.0	False	-0.047	0.37	0.001	False	154
1148	P-671	J-143	J-108	200.0	PVC	110.0	False	0.051	1.63	0.018	False	1,195
1149	P-660	RK8	RK7	50.0	PVC	110.0	False	0.000	0.15	0.001	False	703
1153	P-658	RK9	RK8	50.0	PVC	110.0	False	0.000	0.02	0.000	False	812
1164	P-685	G1	J-144	150.0	Steel	80.0	False	-0.020	1.14	0.024	False	97
1165	P-672	J-108	J-107	150.0	DI	90.0	False	-0.004	0.25	0.001	False	404
1171	P-830	RK20	RK15	100.0	GI	90.0	False	-0.002	0.26	0.002	False	371
1173	P-576	B8	B1	100.0	PVC	110.0	False	0.003	0.38	0.003	False	1,647
1175	P-854	L30	L29	125.0	GI	100.0	False	0.003	0.27	0.001	False	247
1177	P-678	J-112	J-113	350.0	DI	90.0	False	-0.075	0.78	0.004	False	938
1183	P-849	L33	L32	200.0	DI	100.0	False	-0.003	0.11	0.000	False	420
1184	P-686	J-144	L109	100.0	GI	90.0	False	0.001	0.08	0.000	False	1,042
1195	P-758	L1	L2	125.0	DI	100.0	False	-0.007	0.53	0.005	False	470
1198	P-677	J-106	J-112	300.0	DI	90.0	False	0.000	0.00	0.000	False	900
1199	P-584	B10	B11	200.0	DI	90.0	False	0.001	0.04	0.000	False	404
1202	P-703	J-143	J-84	400.0	Steel	80.0	False	-0.100	0.80	0.004	False	384
1203	P-704	J-84	J-137	500.0	DI	90.0	False	0.010	0.05	0.000	False	455
1205	P-706	R3	E2	50.0	PVC	110.0	False	0.001	0.29	0.004	False	281
1206	P-708	E3	R2	100.0	DI	90.0	False	-0.002	0.22	0.001	False	157
1207	P-710	R1	E4	100.0	PVC	110.0	False	0.006	0.82	0.011	False	90
1208	P-711	E1	R3	75.0	GI	90.0	False	-0.001	0.27	0.003	False	262
1209	P-712	EN	E16	100.0	GI	90.0	False	0.002	0.26	0.002	False	293
1210	P-718	RK10	RK9	75.0	GI	90.0	False	0.002	0.42	0.007	False	358
1211	P-713	RK	RK14	100.0	GI	90.0	False	0.003	0.35	0.003	False	769
1212	P-716	RK21	RK13	150.0	DI	90.0	False	-0.001	0.06	0.000	False	1,101
1213	P-717	RK13	RK22	150.0	DI	50.0	False	0.007	0.39	0.008	False	1,945
1214	P-719	RK	RK13	250.0	DI	15.0	False	0.010	0.21	0.013	False	307
1215	P-720	RK13	RK21	150.0	DI	90.0	False	0.001	0.06	0.000	False	1,122
1216	P-721	RK20	RK21	100.0	GI	90.0	False	0.001	0.17	0.001	False	180
1217	P-722	B7	T-14	250.0	DI	80.0	False	-0.038	0.77	0.006	False	62
1218	P-723	B7	B9	125.0	GI	90.0	False	0.002	0.13	0.000	False	659
1237	P-749	J-142	J-86	400.0	Steel	80.0	False	0.029	0.23	0.000	False	482
1238	P-750	J-86	J-110	200.0	DI	90.0	False	0.009	0.30	0.001	False	580
1239	P-751	J-86	J-110	250.0	DI	90.0	False	0.016	0.33	0.001	False	611
1240	P-752	J-110	J-109	250.0	DI	90.0	False	0.017	0.36	0.001	False	903
1241	P-753	J-109	J-105	250.0	DI	90.0	False	0.034	0.69	0.004	False	1,101
1242	P-754	J-105	J-106	300.0	DI	90.0	False	0.026	0.37	0.001	False	165
1243	P-755	J-108	J-79	200.0	DI	90.0	False	0.058	1.83	0.033	False	833
1244	P-756	J-108	J-107	150.0	DI	90.0	False	-0.003	0.16	0.001	False	899
1245	P-757	J-142	J-111	300.0	DI	90.0	False	0.015	0.22	0.000	False	361
1246	P-759	J-111	J-109	200.0	DI	90.0	False	0.013	0.42	0.002	False	839
1247	P-760	J-84	J-112	350.0	DI	90.0	False	-0.070	0.72	0.003	False	1,487
1248	P-761	J-84	J-135	150.0	Steel	90.0	False	0.002	0.10	0.000	False	461
1249	P-764	J-135	J-134	150.0	Steel	90.0	False	0.011	0.60	0.006	False	195
1250	P-769	J-141	J-137	500.0	DI	90.0	False	0.000	0.00	0.000	False	898
1251	P-770	J-137	J-135	150.0	DI	90.0	False	0.010	0.54	0.005	False	18
1252	P-771	J-119	J-136	300.0	DI	90.0	False	0.043	0.61	0.003	False	766

1253	P-773	J-136	J-84	300.0	DI	90.0	False	0.043	0.60	0.003	False	468
1254	P-775	J-135	J-136	150.0	DI	90.0	False	0.000	0.00	0.000	False	21
1255	P-778	J-117	J-114	200.0	Steel	100.0	False	0.054	1.73	0.024	False	379
1256	P-781	J-114	PG	200.0	Steel	100.0	False	0.081	2.57	0.051	False	108
1257	P-783	J-114	J-120	150.0	DI	100.0	False	-0.029	1.62	0.030	False	1,063
1258	P-784	J-120	J-122	150.0	DI	100.0	False	-0.003	0.16	0.000	False	490
1259	P-785	J-144	J-113	150.0	DI	100.0	False	-0.032	1.81	0.037	False	716
1260	P-786	J-113	J-115	400.0	DI	100.0	False	-0.110	0.88	0.003	False	521
1261	P-787	G2	G1	150.0	DI	100.0	False	-0.014	0.80	0.008	False	376
1262	P-804	PG	G1	200.0	DI	100.0	False	-0.030	0.95	0.008	False	942
1263	P-806	L38	L157	200.0	DI	110.0	False	0.005	0.17	0.000	False	378
1264	P-807	L157	L42	200.0	DI	110.0	False	0.005	0.15	0.000	False	1,878
1265	P-808	L157	L37	150.0	Steel	80.0	False	-0.001	0.07	0.000	False	829
1266	P-805	L36	L153	600.0	DI	110.0	False	0.049	0.17	0.000	False	290
1267	P-809	L153	L37	600.0	DI	110.0	False	0.029	0.10	0.000	False	84
1268	P-810	L35	L34	400.0	DI	100.0	False	0.009	0.07	0.000	False	139
1269	P-811	L153	L34	200.0	DI	100.0	False	-0.003	0.09	0.000	False	174
1270	P-813	L34	L153	200.0	DI	100.0	False	0.003	0.09	0.000	False	177
1271	P-814	L153	L37	150.0	Steel	80.0	False	0.001	0.03	0.000	False	102
1272	P-815	L34	L153	200.0	Steel	90.0	False	0.002	0.08	0.000	False	207
1273	P-816	L153	L47	200.0	DI	100.0	False	0.010	0.32	0.001	False	2,046
1274	P-817	L47	L45	350.0	DI	100.0	False	0.009	0.09	0.000	False	1,234
1275	P-818	L153	L47	200.0	DI	100.0	False	0.010	0.32	0.001	False	2,070
1276	P-819	L153	L46	250.0	DI	100.0	False	0.007	0.13	0.000	False	1,291
1277	P-820	L30	L28	250.0	DI	100.0	False	-0.010	0.21	0.000	False	604
1278	P-821	L19	L32	400.0	DI	100.0	False	0.007	0.05	0.000	False	2,787
1279	P-822	L28	L47	200.0	DI	100.0	False	-0.001	0.04	0.000	False	2,055
1280	P-823	L42	L43	200.0	DI	110.0	False	0.000	0.02	0.000	False	159
1282	P-825	L43	L41	150.0	DI	100.0	False	-0.003	0.15	0.000	False	1,455
1283	P-826	J-79	L156	150.0	GI	90.0	False	0.000	0.02	0.000	False	691
1284	P-827	L113	L82	200.0	DI	100.0	False	0.007	0.23	0.001	False	2,150
1285	P-828	L82	L79	125.0	Steel	100.0	False	0.005	0.40	0.003	False	385
1286	P-829	L83	L79	150.0	DI	100.0	False	-0.003	0.15	0.000	False	490
1293	P-838	L83	L84	200.0	DI	90.0	False	0.002	0.07	0.000	False	944
1308	P-868	L104	L105	150.0	DI	100.0	False	0.005	0.27	0.001	False	505
1325	P-885	J-78	M18	300.0	DI	100.0	False	0.001	0.01	0.000	False	778
1327	P-887	SP27	J-76	300.0	DI	100.0	False	0.000	0.00	0.000	False	173
1329	P-889	J-76	SP12	300.0	DI	120.0	False	0.001	0.02	0.000	False	854
1337	P-898	IC7	J-86	400.0	Steel	90.0	False	-0.004	0.03	0.000	False	257
1338	P-897	L114	L115	900.0	Steel	90.0	False	0.233	0.37	0.000	False	611
1339	P-899	L115	J-80	900.0	Steel	90.0	False	0.231	0.36	0.000	False	2,300
1340	P-900	J-91	L115	150.0	Steel	90.0	False	0.000	0.00	0.000	False	409
1341	P-901	J-87	J-128	150.0	GI	90.0	False	0.006	0.31	0.002	False	2,182
1342	P-902	L14	L114	900.0	Steel	90.0	False	0.307	0.48	0.000	False	1,423
1343	P-903	L15	L14	150.0	DI	100.0	False	-0.004	0.23	0.001	False	700
1344	P-904	L11	L12	900.0	Steel	94.0	False	0.533	0.84	0.001	True	906
1345	P-905	L12	L13	900.0	Steel	94.0	False	0.515	0.81	0.001	True	781
1405	P-965	J-141	J-130	800.0	DI	100.0	False	-0.001	0.00	0.000	False	384
1406	P-966	B7	B13	200.0	DI	60.0	False	0.013	0.40	0.004	False	794
1407	P-967	B13	B4	200.0	DI	90.0	False	0.011	0.35	0.001	False	464
1408	P-968	J-127	J-139	150.0	DI	100.0	False	0.017	0.97	0.012	False	984
1409	P-969	J-139	J-140	150.0	DI	100.0	False	0.011	0.65	0.005	False	996
1410	P-970	J-140	J-123	150.0	DI	100.0	False	0.007	0.41	0.002	False	868
1411	P-971	J-55	G3	200.0	DI	100.0	False	0.041	1.30	0.014	False	520
1412	P-972	G3	G1	200.0	DI	100.0	False	0.031	0.98	0.009	False	1,005
1413	P-973	G4	G5	200.0	DI	90.0	False	-0.003	0.10	0.000	False	928
1414	P-974	G5	G6	200.0	DI	90.0	False	-0.010	0.32	0.001	False	768
1415	P-975	G6	PG	200.0	DI	90.0	False	-0.013	0.41	0.002	False	374
1416	P-976	T13	T15	150.0	DI	100.0	False	0.009	0.53	0.004	False	431

1417	P-977	T15	T1	150.0	DI	100.0	False	0.004	0.25	0.001	False	587
1418	P-978	T13	T14	400.0	DI	100.0	False	0.083	0.66	0.002	False	427
1419	P-979	T14	T7	400.0	DI	100.0	False	0.078	0.62	0.002	False	604
1420	P-980	J-29	T16	500.0	DI	100.0	False	0.153	0.78	0.002	False	590
1421	P-981	T16	T6	500.0	DI	100.0	False	0.148	0.75	0.002	False	495
1422	P-982	Jan Meda	T17	800.0	DI	100.0	False	0.238	0.47	0.000	False	539
1423	P-983	T17	J-133	800.0	DI	100.0	False	0.233	0.46	0.000	False	442
1424	P-984	T10	T18	200.0	DI	100.0	False	0.005	0.17	0.000	False	520
1425	P-985	T18	T9	200.0	DI	100.0	False	0.003	0.09	0.000	False	586
1431	P-991	L28	L110	400.0	DI	110.0	False	-0.007	0.06	0.000	False	1,334
1432	P-992	L110	L47	400.0	DI	110.0	False	-0.010	0.08	0.000	False	638
1433	P-993	L47	L111	400.0	DI	100.0	False	0.008	0.06	0.000	False	1,492
1434	P-994	L111	L28	400.0	DI	100.0	False	0.005	0.04	0.000	False	516
1437	P-997	L125	J-87	150.0	GI	90.0	False	0.006	0.31	0.002	False	43
1438	P-998	L2	L3	125.0	DI	100.0	False	-0.014	1.14	0.019	False	36
1441	P-636	J-65	E12	150.0	DI	100.0	False	0.009	0.54	0.004	False	99
1442	P-637	E12	B14	150.0	DCI	100.0	False	0.007	0.38	0.002	False	1,783
1447	P-643	L117	FCV-1	900.0	Steel	100.0	False	0.315	0.49	0.000	False	16
1448	P-644	FCV-1	L14	900.0	Steel	90.0	False	0.315	0.49	0.001	False	1,046
1449	P-646	J-101	RK10	75.0	GI	90.0	False	0.003	0.63	0.014	False	622
1450	P-645	RK	PMP-47	75.0	GI	90.0	False	0.003	0.63	0.014	False	21
1451	P-647	PMP-47	J-101	75.0	GI	90.0	False	0.003	0.63	0.014	False	19
1452	P-648	T-14	PMP-48	100.0	DI	90.0	False	0.002	0.25	0.002	False	23
1453	P-649	PMP-48	B8	100.0	DI	90.0	False	0.002	0.25	0.002	False	24
1454	P-650	RK	PMP-49	150.0	DCI	100.0	False	0.000	0.00	0.000	False	27
1455	P-651	PMP-49	J-101	150.0	DCI	100.0	False	0.000	0.00	0.000	False	29
1456	P-652	T-14	PMP-50	100.0	Steel	100.0	False	0.002	0.25	0.002	False	29
1457	P-653	PMP-50	B8	100.0	Steel	100.0	False	0.002	0.25	0.002	False	34
1460	P-582a	B7	J-104	90.0	DI	80.0	False	0.020	3.19	0.291	False	16
1461	P-582	J-104	B10	250.0	DI	90.0	False	0.020	0.41	0.002	False	1,161
1478	P-1	R-1	LAGA TANK	600.0	DI	130.0	False	0.238	0.84	0.001	False	9,149
1479	P-2	R-2	LAGA TANK	900.0	DI	130.0	False	2.932	4.61	0.016	False	126

Figure B.9 Pressure and Hydraulic Grade line Fluctuation in sample nodes of the Existing Legedadi Sub-system.

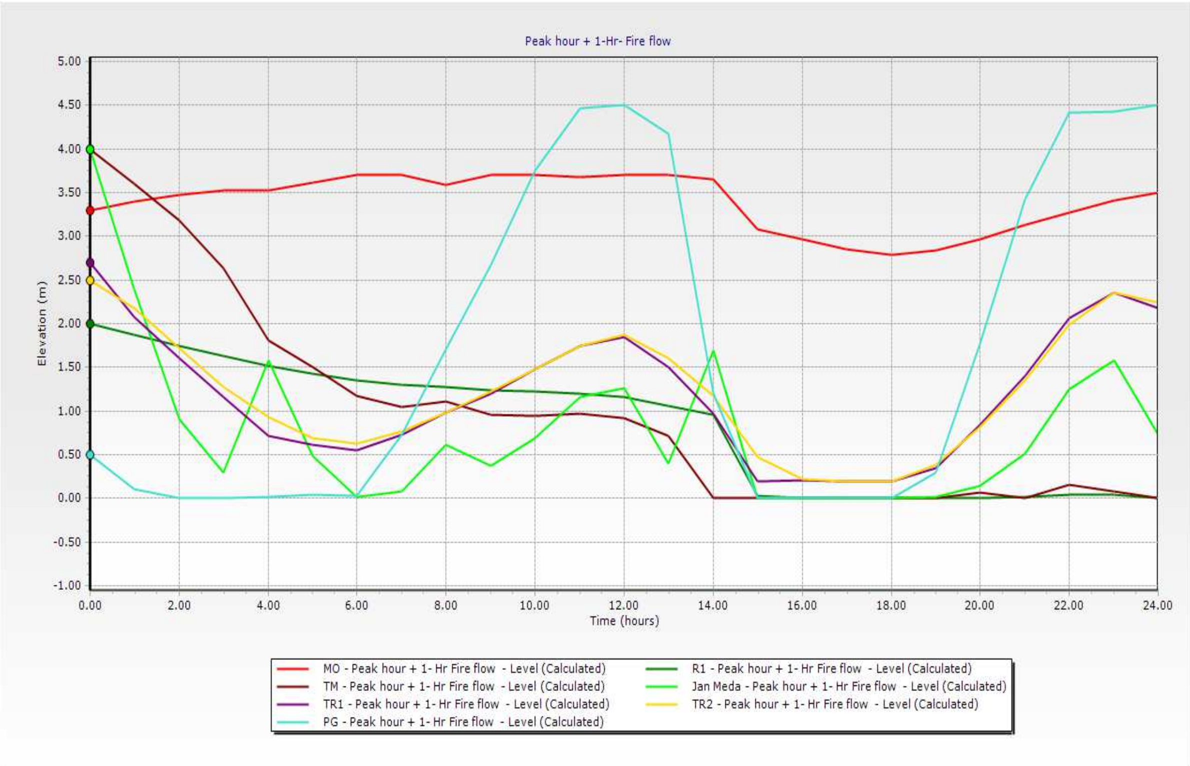
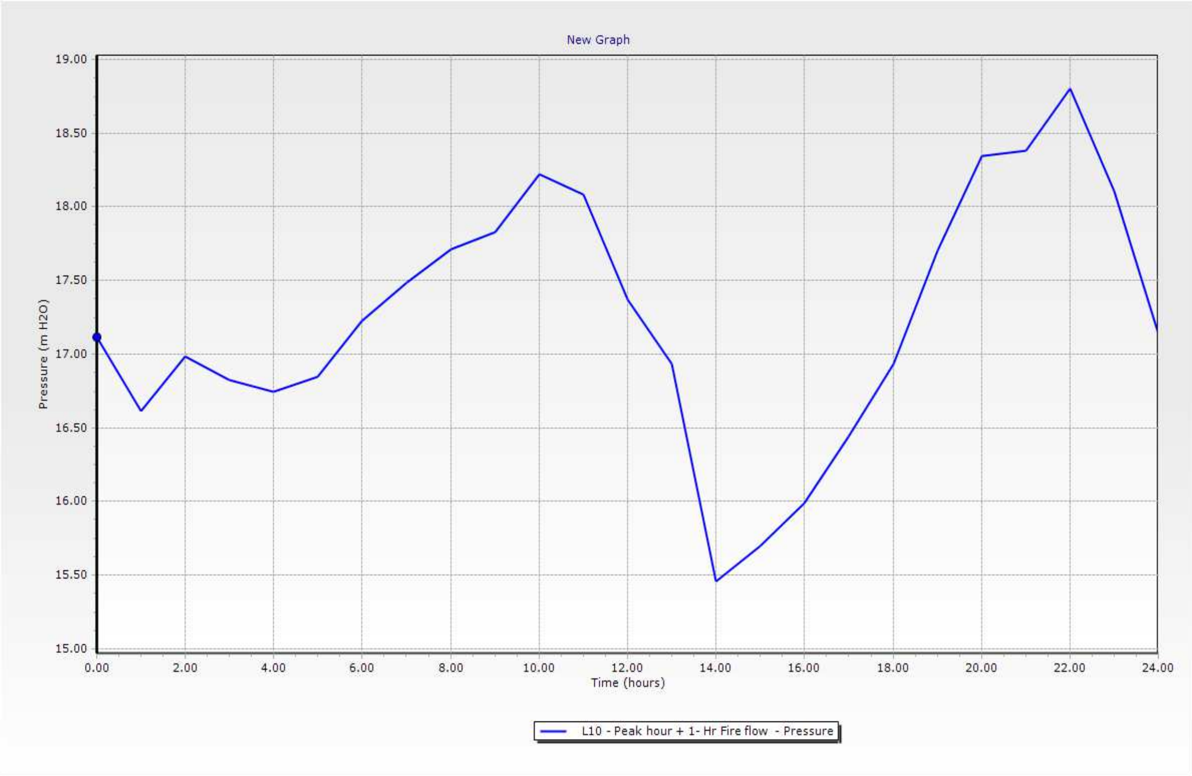
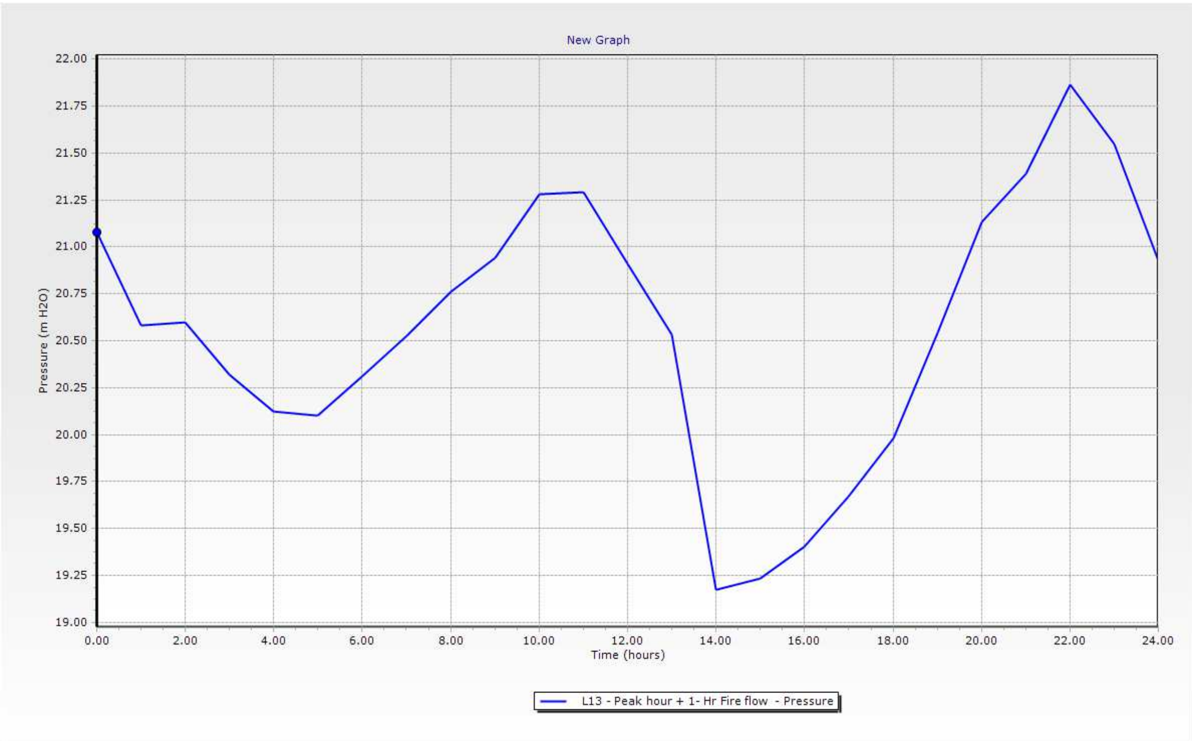
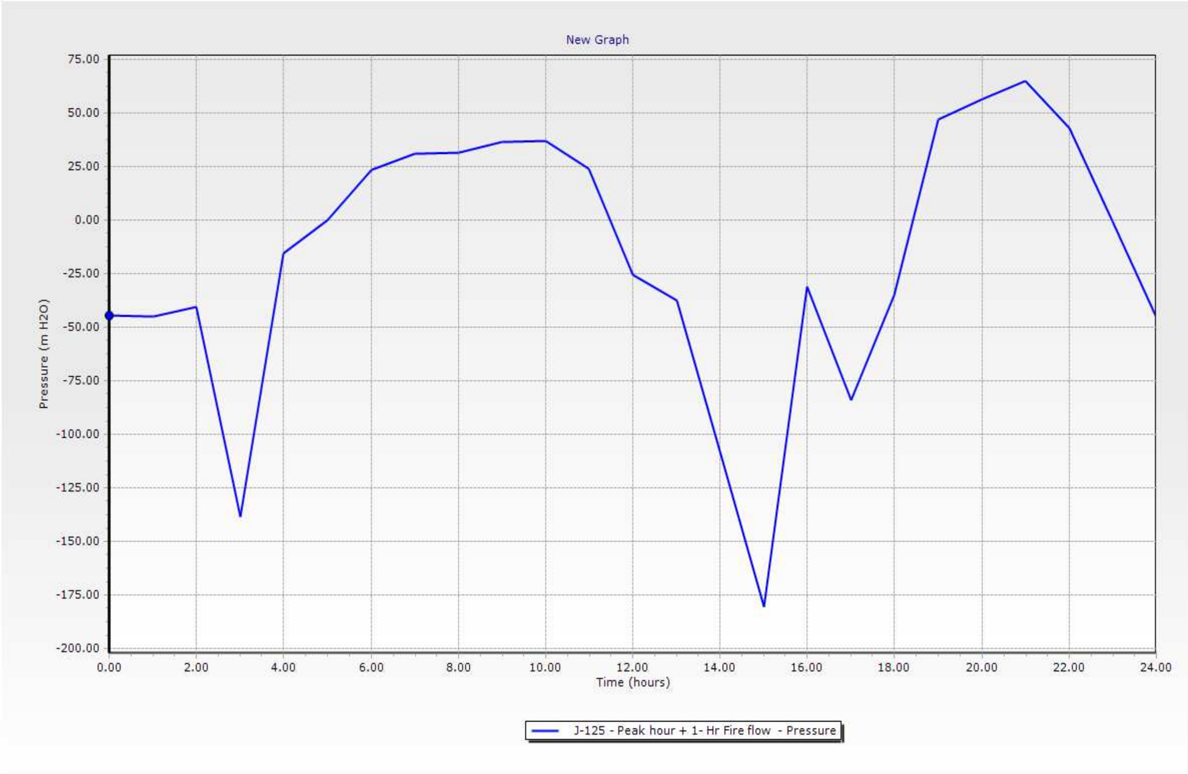


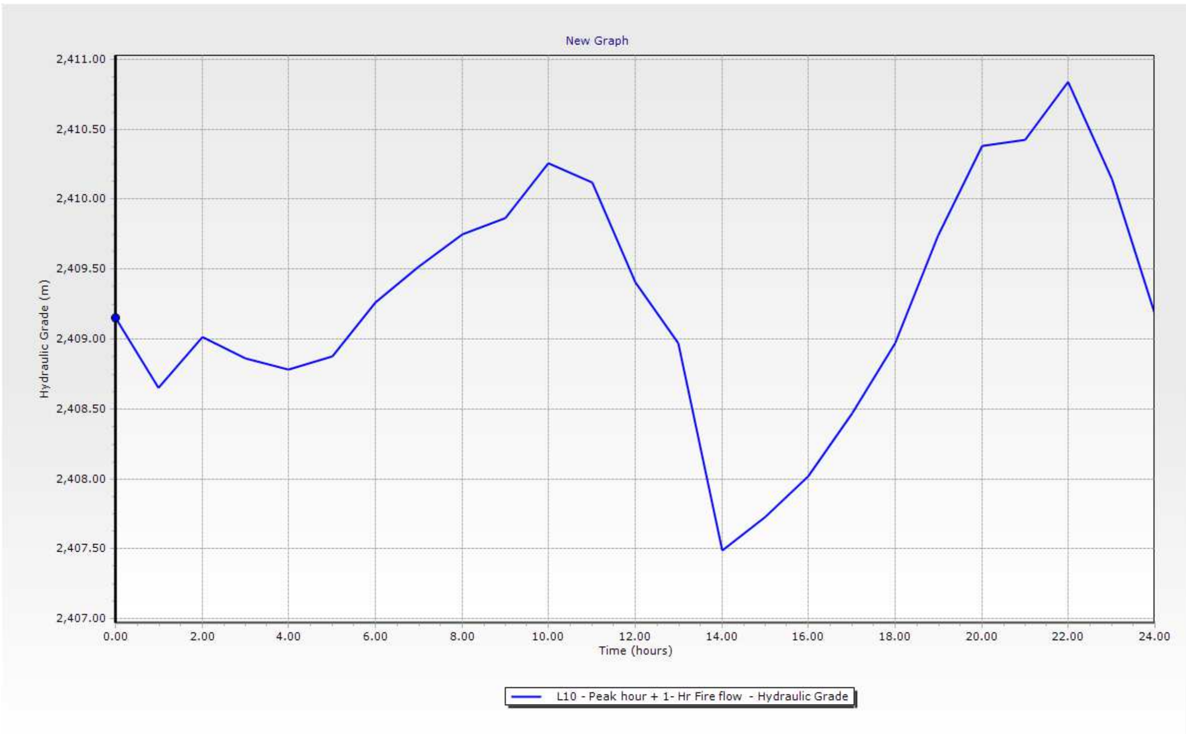
Figure B.10 Sample tank levels and pump flow operation in the system

Figure B.11 Sample nodes Pressure & HGL fluctuation in the system

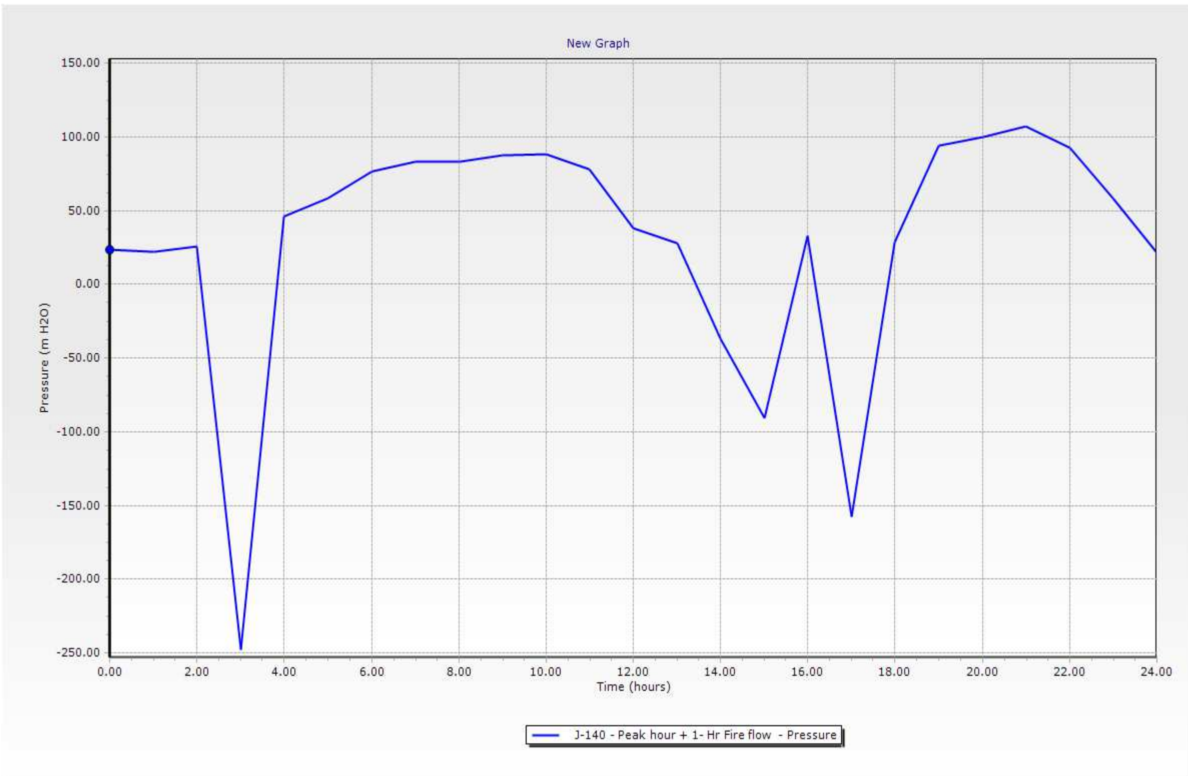


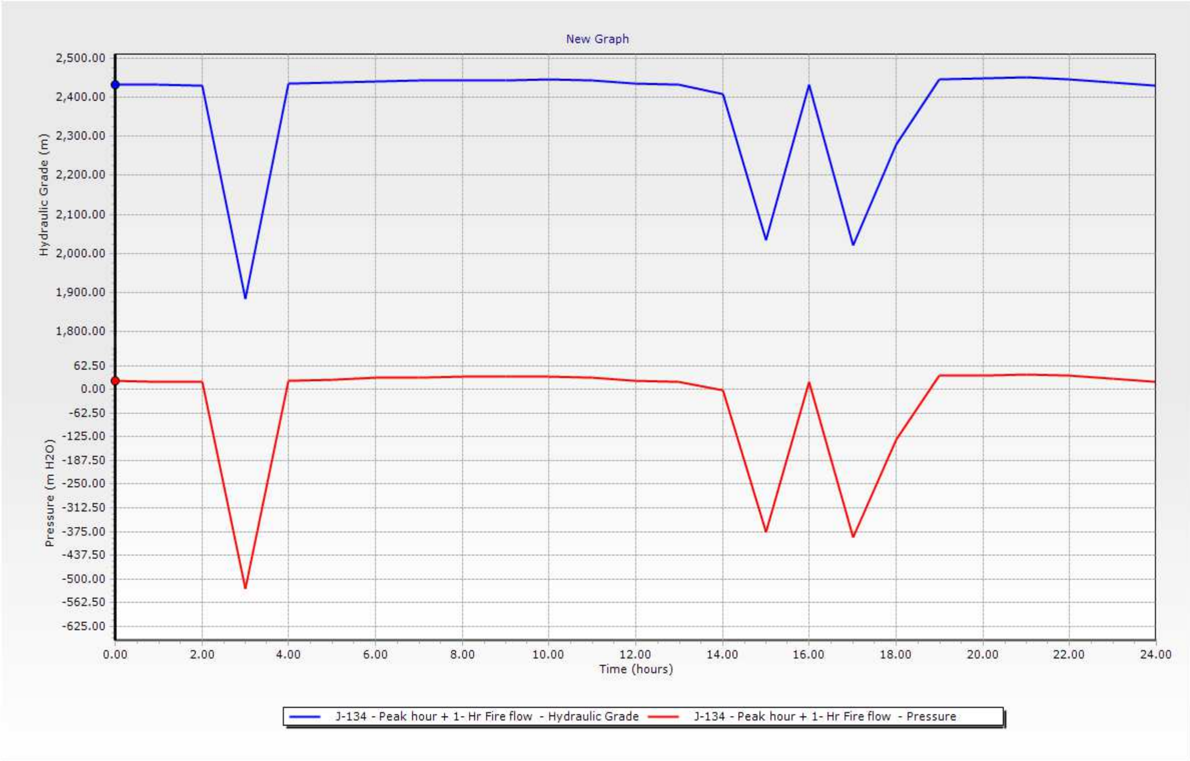


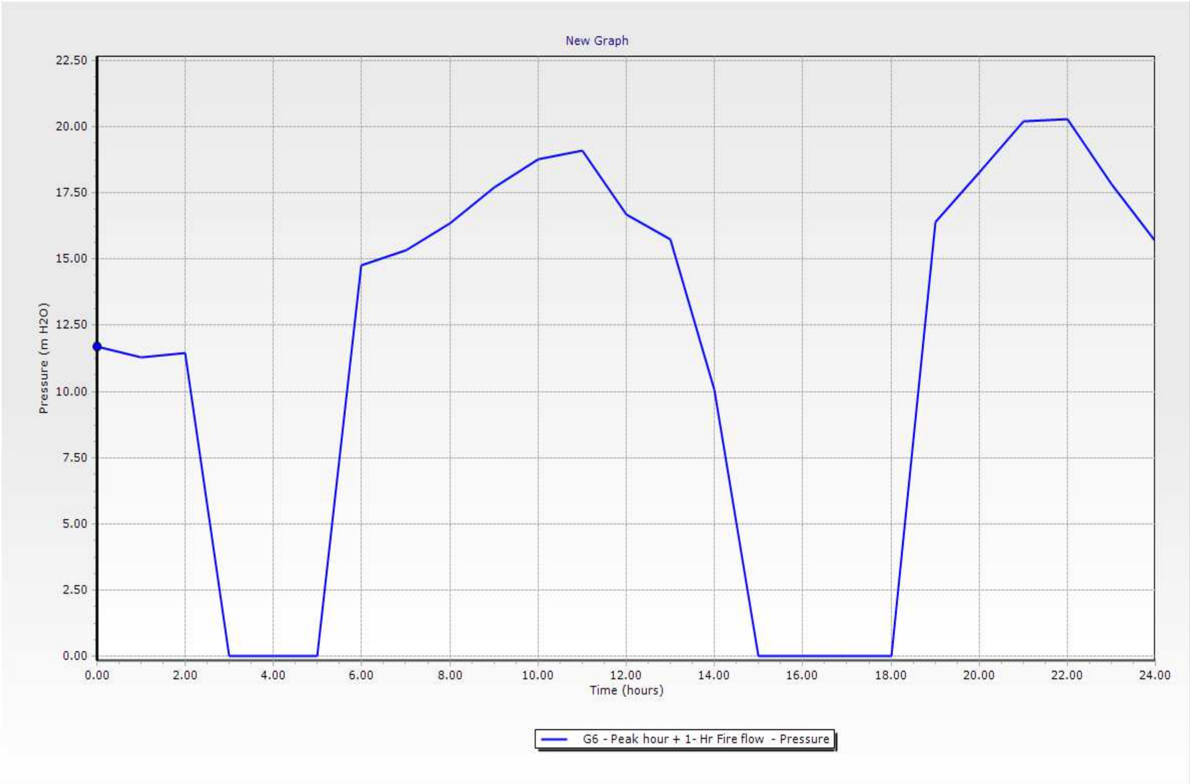

New Graph
Pressure (m H2O)
75.00
50.00
25.00
0.00
-25.00
-50.00
-75.00
-100.00
-125.00
-150.00
-175.00
-200.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
Time (hours)
J-125 - Peak hour + 1- Hr Fire flow - Pressure

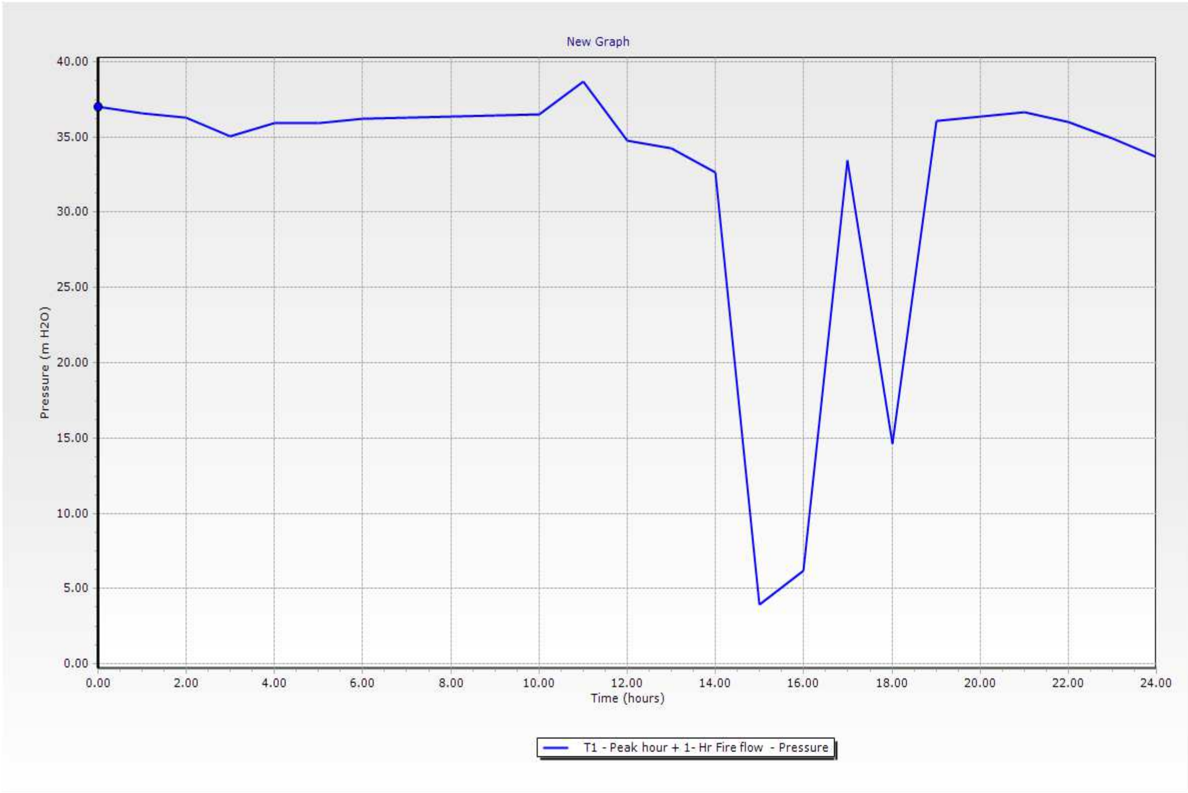

New Graph
Hydraulic Grade (m)
2,411.00
2,410.50
2,410.00
2,409.50
2,409.00
2,408.50
2,408.00
2,407.50
2,407.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
Time (hours)
L10 - Peak hour + 1- Hr Fire flow - Hydraulic Grade

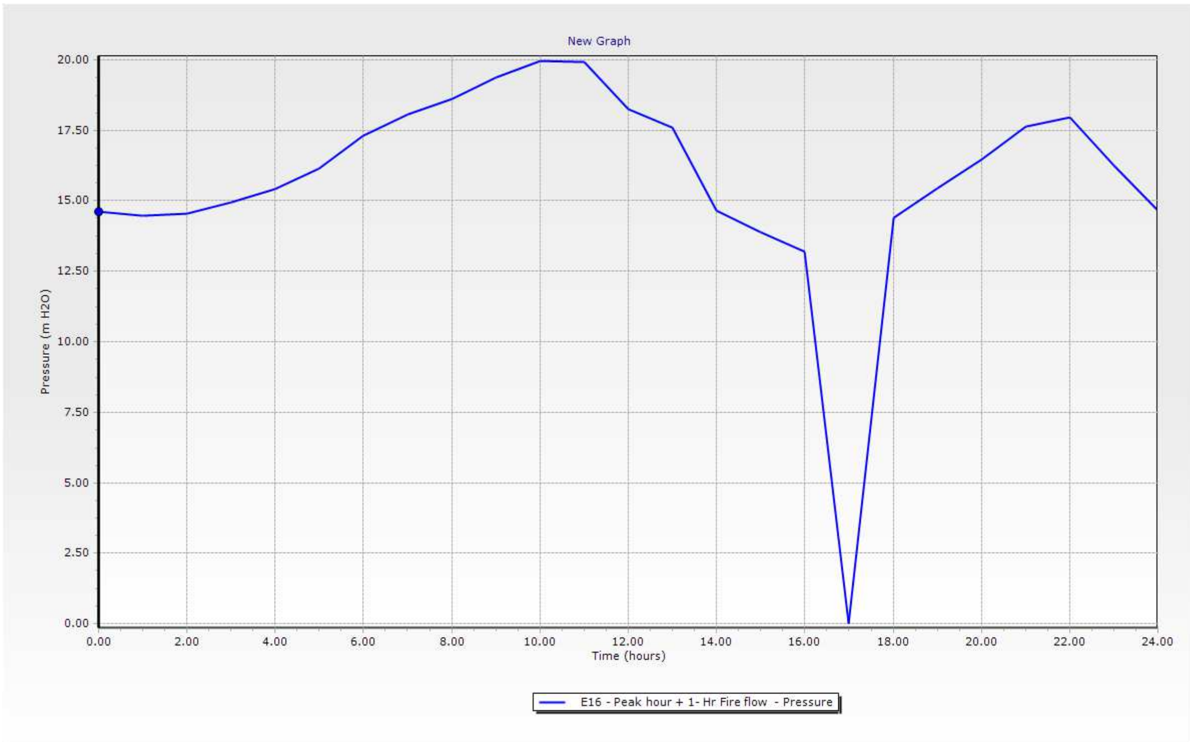

New Graph
Hydraulic Grade (m)
2,500.00
2,475.00
2,450.00
2,425.00
2,400.00
2,375.00
2,350.00
2,325.00
2,300.00
2,275.00
2,250.00
2,225.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
Time (hours)
J-127 - Peak hour + 1- Hr Fire flow - Hydraulic Grade


New Graph
Pressure (m H2O)
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
Time (hours)
J-140 - Peak hour + 1- Hr Fire flow - Pressure

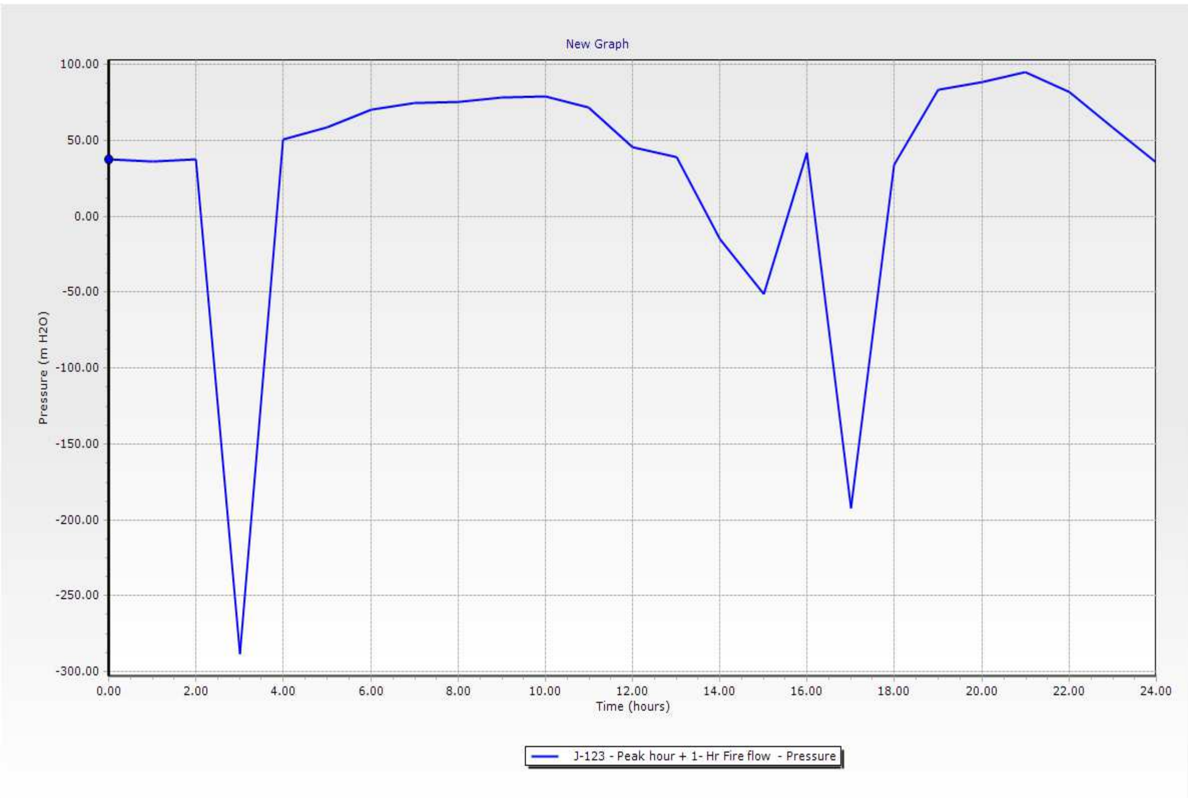

New Graph
Hydraulic Grade (m)
Pressure (m H2O)
Time (hours)
J-134 - Peak hour + 1- Hr Fire flow - Hydraulic Grade
J-134 - Peak hour + 1- Hr Fire flow - Pressure

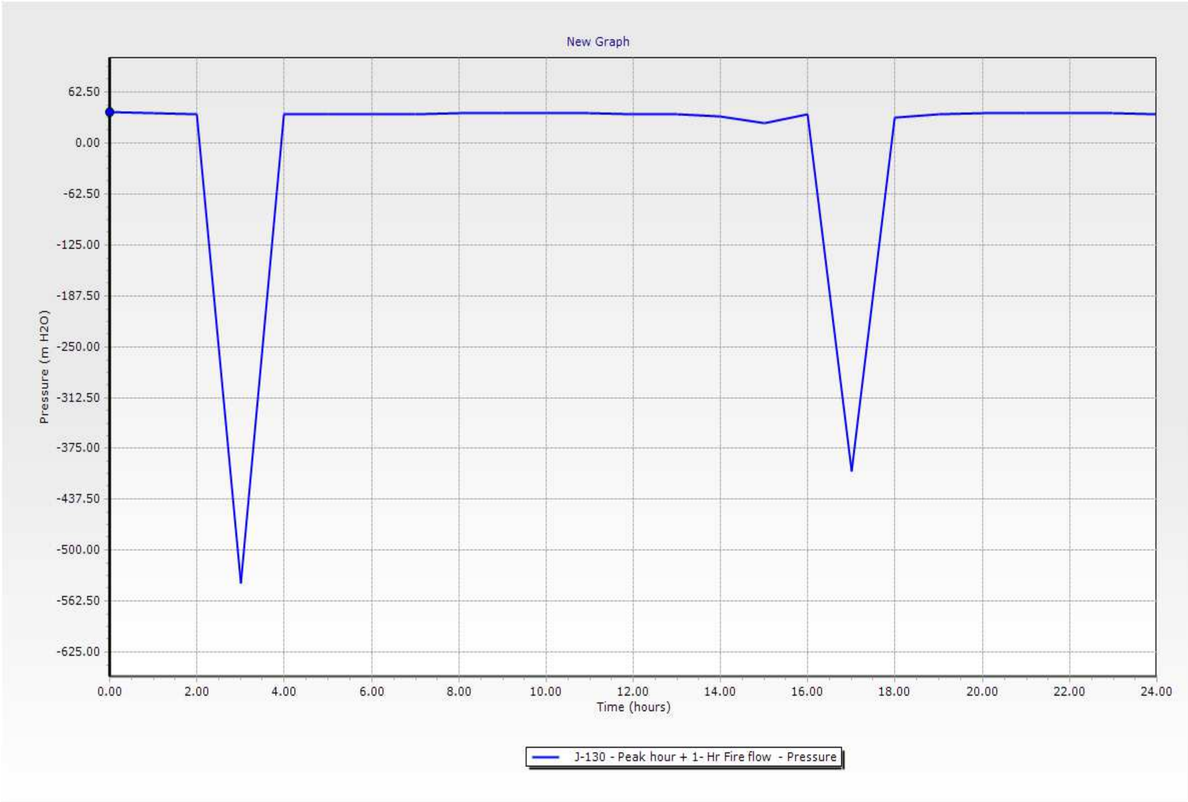

New Graph
Pressure (m H2O)
Time (hours)
G6 - Peak hour + 1- Hr Fire flow - Pressure

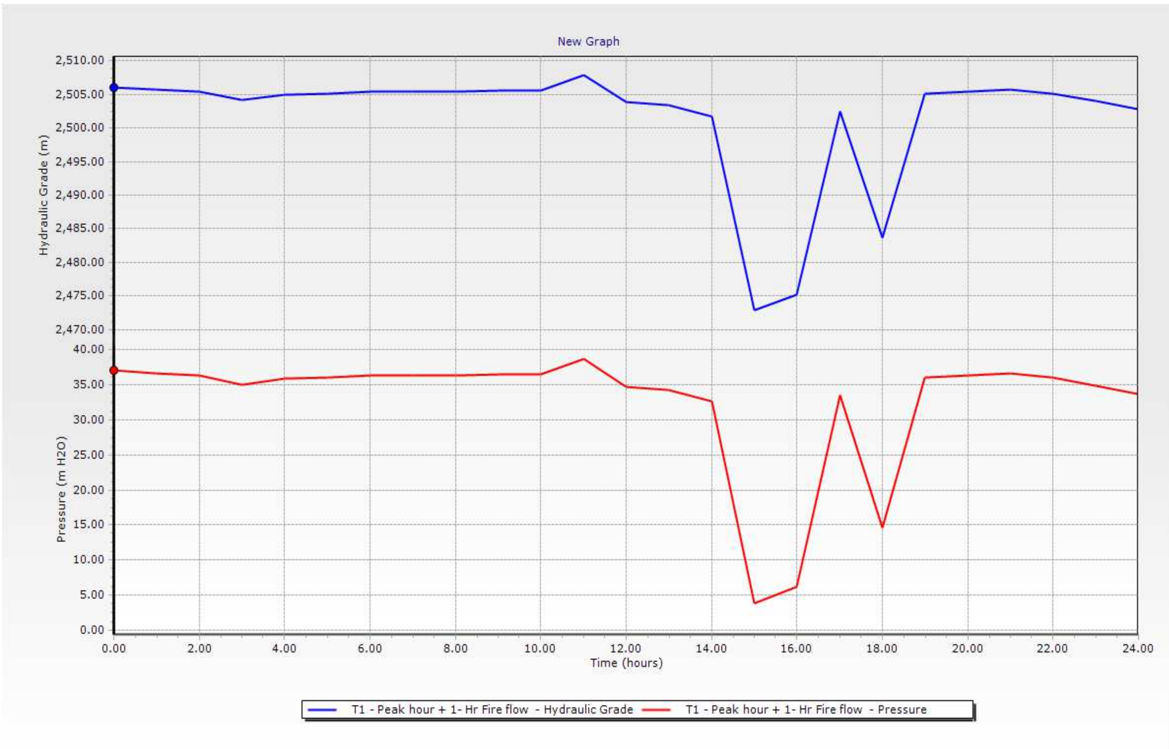

New Graph
Pressure (m H2O)
Time (hours)
T1 - Peak hour + 1- Hr Fire flow - Pressure


New Graph
Pressure (m H2O)
Time (hours)
E16 - Peak hour + 1- Hr Fire flow - Pressure


New Graph
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Pressure (m H2O)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
Time (hours)
E2 - Peak hour + 1- Hr Fire flow - Pressure


New Graph
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
-250.00
-300.00
Pressure (m H2O)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
Time (hours)
J-123 - Peak hour + 1- Hr Fire flow - Pressure


New Graph
Pressure (m H2O)
62.50
0.00
-62.50
-125.00
-187.50
-250.00
-312.50
-375.00
-437.50
-500.00
-562.50
-625.00
0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00 24.00
Time (hours)
J-130 - Peak hour + 1- Hr Fire flow - Pressure


New Graph
Hydraulic Grade (m)
2,510.00
2,505.00
2,500.00
2,495.00
2,490.00
2,485.00
2,480.00
2,475.00
2,470.00
Pressure (m H2O)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00 2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 18.00 20.00 22.00 24.00
Time (hours)
T1 - Peak hour + 1- Hr Fire flow - Hydraulic Grade
T1 - Peak hour + 1- Hr Fire flow - Pressure

Appendix A.15 Results of Nods for New Optimized Design Run of the Proposed System, (EPS) Analysis Continuous Model

Current Time: 14 hours

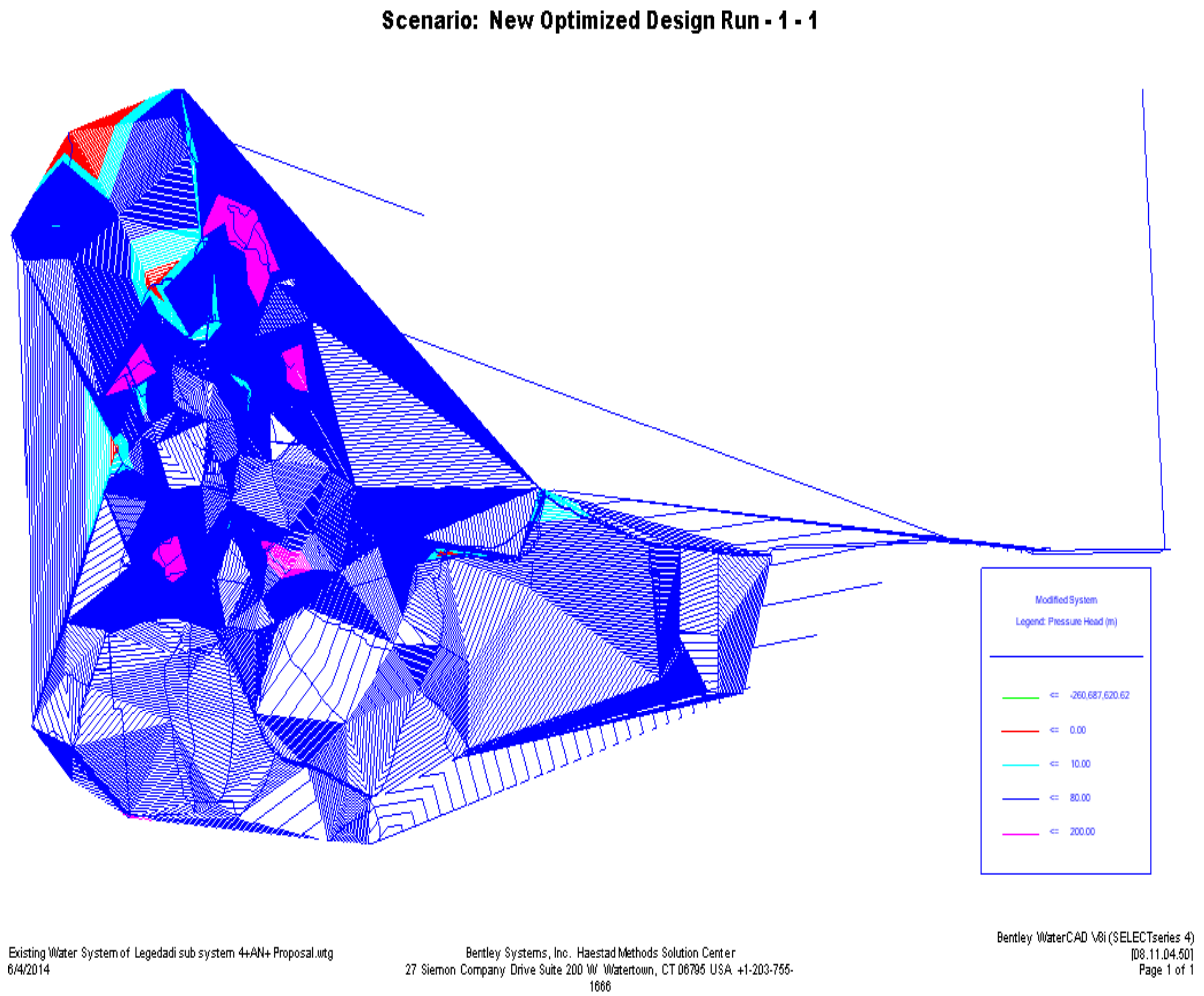
ID	Label	Elevation (m)	Demand Pattern	Demand (m^3/s)	Hydraulic Grade (m)	Pressure (m H2O)	Demand Shortage (m^3/s)
129	C1	2,410.00		0.000	2,421.86	11.83	0.000
130	C1a	2,410.00		0.000	2,421.85	11.83	0.000
131	J-4	2,410.00		0.000	2,422.55	12.53	0.000
132	J-5	2,410.00		0.000	2,422.40	12.37	0.000
133	J-6	2,400.00		0.000	2,418.30	18.26	0.000
134	J-7	2,400.00		0.000	2,418.19	18.15	0.000
135	L22	2,406.00	Domestic	0.022	2,405.53	-0.47	0.000
136	L117	2,406.00		0.000	2,405.17	-0.83	0.000
137	L114	2,375.00	Domestic	0.010	2,395.25	20.21	0.000
138	L20	2,351.00	Domestic	0.096	2,391.74	40.66	0.000
139	L118	2,402.00		0.100	2,467.01	64.88	0.000
140	L119	2,402.00		0.000	2,405.43	3.42	0.000
141	L120	2,402.00		0.100	2,467.02	64.88	0.000
142	L121	2,402.00		0.100	2,467.01	64.88	0.000
143	L122	2,402.00		0.000	2,405.43	3.42	0.000
144	L123	2,402.00		0.000	2,405.43	3.42	0.000
145	L124	2,402.00		0.000	2,403.96	1.95	0.000
146	L125	2,404.00		0.000	2,405.02	1.02	0.000
147	L126	2,402.00		0.000	2,404.47	2.46	0.000
148	L127	2,402.00		0.000	2,447.00	44.91	0.000
149	L128	2,402.00		0.000	2,404.08	2.08	0.000
150	L129	2,402.00		0.000	2,447.00	44.91	0.000
151	L130	2,402.00		0.000	2,446.62	44.53	0.000
152	J-131	2,427.00	Domestic	0.002	2,454.33	27.27	0.000
153	J-124	2,420.00	Domestic	0.038	2,437.20	17.16	0.000
154	J-27	2,400.00		0.000	2,405.46	5.45	0.000
155	J-28	2,460.00		0.000	2,462.02	2.01	0.000
156	J-29	2,460.00		0.000	2,497.80	37.72	0.000
157	J-30	2,460.00		0.000	2,497.88	37.80	0.000
158	J-31	2,460.00		0.000	2,462.03	2.03	0.000
159	J-32	2,460.00		0.000	2,462.02	2.02	0.000
160	J-33	2,460.00		0.000	2,497.88	37.80	0.000
161	J-35	2,460.00		0.000	2,462.05	2.04	0.000
162	J-36	2,460.00		0.000	2,517.59	57.48	0.000
163	J-37	2,460.00		0.000	2,462.07	2.07	0.000
164	J-38	2,460.00		0.000	2,517.79	57.67	0.000
165	J-39	2,460.00		0.000	2,461.63	1.63	0.000
166	J-40	2,460.00		0.100	2,463.92	3.91	0.000
167	J-41	2,460.00		0.100	2,464.86	4.85	0.000
168	J-42	2,460.00		0.000	2,461.72	1.71	0.000
169	J-43	2,460.00		0.000	2,461.63	1.63	0.000
170	J-44	2,460.00		0.100	2,464.43	4.42	0.000
171	J-45	2,507.00		0.000	2,508.08	1.07	0.000
172	J-46	2,507.00		0.000	2,569.17	62.04	0.000
173	J-47	2,507.00		0.000	2,508.15	1.14	0.000
174	J-48	2,507.00		0.000	2,569.17	62.04	0.000
175	J-49	2,507.00		0.000	2,500.43	-6.56	0.000
176	J-50	2,507.00		0.000	2,504.22	-2.78	0.000
177	J-51	2,507.00		0.100	1,306.70	-1,197.89	0.000
178	J-52	2,507.00		0.100	1,303.80	-1,200.77	0.000
179	E15	2,564.00	Domestic	0.005	1,306.43	-1,255.04	0.000
180	J-133	2,432.00	Domestic	0.002	2,457.42	25.37	0.000
181	J-132	2,433.00	Domestic	0.002	2,456.51	23.47	0.000
182	T7	2,473.00	Domestic	0.012	2,501.75	28.69	0.000
183	T12	2,512.00	Domestic	0.005	2,507.74	-4.25	0.000

184	T9	2,459.00	Domestic	0.014	2,500.97	41.88	0.000
185	SP15	2,490.00	Domestic	0.002	2,507.68	17.64	0.000
186	T13	2,510.00	Domestic	0.005	2,506.76	-3.24	0.000
187	T1	2,469.00	Domestic	0.009	2,500.91	31.85	0.000
188	B14	2,536.00	Domestic	0.081	2,516.01	-19.95	0.000
189	J-63	2,560.00	Domestic	0.000	2,566.45	6.44	0.000
190	J-64	2,560.00		0.000	2,564.53	4.52	0.000
191	J-65	2,560.00		0.000	2,565.41	5.40	0.000
192	SP16	2,490.00	Domestic	0.002	2,515.39	25.34	0.000
193	J-67	2,560.00		0.000	2,564.53	4.52	0.000
194	J-68	2,560.00	Domestic	0.100	2,596.02	35.95	0.000
195	L35	2,345.00	Domestic	0.002	2,372.65	27.59	0.000
196	SP17	2,476.00	Domestic	0.022	2,487.57	11.55	0.000
197	J-71	2,483.00		0.100	2,322.95	-159.73	0.000
198	J-72	2,483.00		0.000	2,489.76	6.74	0.000
199	J-73	2,483.00		0.000	2,489.76	6.74	0.000
200	J-74	2,483.00		0.100	2,322.67	-160.00	0.000
201	J-75	2,483.00		0.000	2,489.50	6.49	0.000
202	J-76	2,483.00		0.000	2,515.37	32.30	0.000
204	J-78	2,352.00		0.000	2,371.79	19.75	0.000
205	J-79	2,340.00		0.000	2,372.54	32.47	0.000
206	M23	2,352.00	Domestic	0.009	2,411.76	59.64	0.000
207	J-81	2,352.00		0.000	2,411.76	59.64	0.000
208	J-82	2,352.00		0.000	2,371.82	19.78	0.000
209	M18	2,345.00	Domestic	0.003	2,371.78	26.72	0.000
211	M19	2,345.00	Domestic	0.003	2,371.79	26.73	0.000
215	J-90	2,637.00		0.000	2,640.26	3.25	0.000
216	E13	2,637.00	Domestic	0.005	2,684.34	47.25	0.000
217	J-92	2,682.00		0.000	-2,413,243.03	-2,411,058.64	0.000
218	E14	2,682.00		0.000	2,682.00	0.00	0.004
243	L37	2,349.00	Domestic	0.002	2,372.51	23.47	0.000
244	L112	2,350.00	Domestic	0.022	2,389.16	39.08	0.000
245	C45	2,350.00		0.000	2,389.00	38.92	0.000
246	J-55	2,350.00		0.100	2,389.06	38.98	0.000
247	J-118	2,423.00	Domestic	0.003	2,430.53	7.51	0.000
256	L28	2,325.00	Domestic	0.013	2,364.62	39.54	0.000
257	L116	2,332.00	Domestic	0.002	2,388.64	56.52	0.000
258	L46	2,335.00	Domestic	0.013	2,372.54	37.46	0.000
259	L36	2,336.00	Domestic	0.002	2,372.66	36.59	0.000
260	L40	2,347.00	Domestic	0.009	2,372.45	25.40	0.000
261	L41	2,326.00	Domestic	0.016	2,372.29	46.19	0.000
262	L44	2,311.00	Domestic	0.008	2,367.98	56.87	0.000
263	L47	2,317.00	Domestic	0.444	2,365.09	47.99	0.000
265	L45	2,305.00	Domestic	0.093	2,363.37	58.25	0.000
267	L42	2,300.00	Domestic	0.008	2,368.13	67.99	0.000
269	L154	2,340.00	Domestic	0.002	2,372.59	32.52	0.000
270	L113	2,351.00	Domestic	0.004	2,371.13	20.09	0.000
271	L69	2,283.00	Domestic	0.005	2,352.26	69.12	0.000
276	L81	2,292.00	Domestic	0.004	2,347.57	55.46	0.000
277	L104	2,320.00	Domestic	0.004	2,340.33	20.29	0.000
278	L83	2,316.00	Domestic	0.043	2,341.13	25.08	0.000
279	J-70	2,352.00		0.000	2,371.49	19.45	0.000
281	L27	2,339.00	Domestic	0.055	2,372.42	33.35	0.000
282	L24	2,351.00	Domestic	0.014	2,390.37	39.29	0.000
283	L70	2,280.00	Domestic	0.005	2,351.99	71.85	0.000
284	L19	2,327.00	Domestic	0.012	2,390.46	63.33	0.000
285	L18	2,332.00	Domestic	0.024	2,380.66	48.56	0.000
286	J-80	2,345.00	Domestic	0.000	2,390.10	45.00	0.000
287	L26	2,342.00	Domestic	0.029	2,374.80	32.73	0.000
296	L155	2,340.00	Domestic	0.001	2,372.60	32.53	0.000
297	L38	2,349.00	Domestic	0.006	2,372.47	23.42	0.000
298	L108	2,345.00	Domestic	0.002	2,372.58	27.53	0.000
332	J-138	2,390.00	Domestic	0.078	2,400.76	10.74	0.000
339	J-127	2,387.00	Domestic	0.289	2,407.19	20.15	0.000

340	J-123	2,376.00	Domestic	0.021	2,420.11	44.02	0.000
341	J-125	2,418.00	Domestic	0.170	2,402.51	-15.45	0.000
342	J-126	2,418.00	Domestic	0.039	2,436.90	18.86	0.000
343	J-129	2,411.00	Domestic	0.013	2,446.40	35.33	0.000
344	J-122	2,386.00	Domestic	0.013	2,427.98	41.89	0.000
345	J-120	2,371.00	Domestic	0.110	2,428.16	57.04	0.000
346	J-121	2,366.00	Domestic	0.110	2,190.32	-175.33	0.000
347	J-115	2,405.00	Domestic	0.008	2,441.56	36.49	0.000
348	J-130	2,425.00	Domestic	0.002	2,457.16	32.09	0.000
349	J-116	2,405.00	Domestic	0.004	2,448.46	43.37	0.000
350	J-117	2,406.00	Domestic	0.004	2,426.79	20.75	0.000
351	J-84	2,410.00		0.000	2,419.96	9.94	0.000
352	J-134	2,411.00	Domestic	0.002	2,422.62	11.60	0.000
353	J-119	2,431.00	Domestic	0.003	2,443.50	12.48	0.000
354	T3	2,440.00	Domestic	0.020	2,440.16	0.16	0.000
355	T11	2,410.00	Domestic	0.014	2,446.92	36.84	0.000
356	T4	2,435.00	Domestic	0.010	2,453.04	18.01	0.000
357	T8	2,472.00	Domestic	0.012	2,501.61	29.55	0.000
358	T10	2,472.00	Domestic	0.009	2,501.33	29.27	0.000
359	T5	2,455.00	Domestic	0.009	2,500.73	45.64	0.000
360	T6	2,460.00	Domestic	0.010	2,495.85	35.78	0.000
361	IC5	2,437.00	Domestic	0.006	2,487.18	50.08	0.000
362	IC1	2,472.00	Domestic	0.006	2,487.33	15.29	0.000
363	IC2	2,463.00	Domestic	0.013	2,486.97	23.92	0.000
364	IC3	2,450.00	Domestic	0.030	2,486.67	36.59	0.000
365	IC4	2,432.00	Domestic	0.012	2,486.49	54.38	0.000
366	IC6	2,465.00	Domestic	0.006	2,487.51	22.46	0.000
367	SP27	2,491.00	Domestic	0.000	2,490.30	-0.69	0.000
378	L23	2,352.00	Domestic	0.047	2,380.12	28.06	0.000
379	L160	2,334.00	Domestic	0.024	2,373.99	39.91	0.000
380	L16	2,327.00	Domestic	0.024	2,366.28	39.20	0.000
381	L13	2,387.00	Domestic	0.033	2,407.11	20.07	0.000
382	L8	2,340.00	Domestic	0.009	2,362.62	22.57	0.000
383	L9	2,332.00	Domestic	0.110	2,321.55	-10.43	0.000
384	L7	2,363.00	Domestic	0.009	2,361.61	-1.39	0.000
385	L11	2,382.00	Domestic	0.070	2,408.91	26.85	0.000
386	L5	2,362.00	Domestic	0.009	2,401.65	39.57	0.000
387	L6	2,365.00	Domestic	0.009	2,401.48	36.41	0.000
388	L3	2,360.00	Domestic	0.022	2,388.49	28.43	0.000
389	L4	2,360.00	Domestic	0.018	2,388.36	28.30	0.000
390	L10	2,392.00	Domestic	0.026	2,408.47	16.44	0.000
397	T19	2,430.00	Domestic	0.010	2,456.13	26.07	0.000
398	RK22	2,431.00		0.000	2,431.00	0.00	0.026
403	J-144	2,364.00	Domestic	0.043	2,404.19	40.11	0.000
405	RK7	2,511.00		0.000	2,511.00	0.00	0.001
412	G4	2,351.00		0.012	2,411.82	60.69	0.000
413	L156	2,347.00	Domestic	0.001	2,372.48	25.43	0.000
421	J-87	2,404.00		0.000	2,404.97	0.97	0.000
422	L31	2,320.00	Domestic	0.013	2,360.48	40.40	0.000
424	SP26	2,493.00		0.000	2,493.00	0.00	0.109
425	RK20	2,500.00		0.000	2,500.00	0.00	0.003
426	RK15	2,522.00		0.000	2,522.00	0.00	0.001
427	J-143	2,423.00	Domestic	0.008	2,417.47	-5.52	0.000
428	J-112	2,346.00	Domestic	0.122	2,421.25	75.10	0.000
431	B9	2,582.00		0.000	2,582.00	0.00	0.006
435	L2	2,360.00	Domestic	0.028	2,387.66	27.60	0.000
438	J-106	2,355.00	Domestic	0.024	2,396.91	41.82	0.000
440	E1	2,734.00		0.000	2,734.00	0.00	0.004
441	L30	2,320.00	Domestic	0.013	2,361.99	41.91	0.000
443	E4	2,635.00	Domestic	0.024	2,640.00	4.99	0.000
444	L33	2,325.00	Domestic	0.013	2,389.20	64.07	0.000
445	J-128	2,395.00	Domestic	0.021	2,394.70	-0.30	0.000
447	B4	2,593.00		0.000	2,593.00	0.00	0.041
448	J-109	2,385.00	Domestic	0.006	2,412.62	27.56	0.000

452	E3	2,673.00		0.000	2,673.00	0.00	0.007
453	L105	2,308.00	Domestic	0.018	2,333.84	25.79	0.000
458	J-141	2,432.00	Domestic	0.003	2,457.16	25.11	0.000
459	L29	2,317.00	Domestic	0.013	2,357.99	40.90	0.000
463	RK21	2,490.00		0.000	2,490.00	0.00	0.013
464	J-108	2,353.00	Domestic	0.004	2,391.90	38.82	0.000
467	J-110	2,417.00	Domestic	0.013	2,415.05	-1.95	0.000
469	E2	2,708.00		0.000	2,708.00	0.00	0.002
470	B7	2,631.00		0.000	2,631.00	0.00	0.004
478	RK8	2,538.00		0.000	2,538.00	0.00	0.001
479	L15	2,360.00	Domestic	0.015	2,394.39	34.32	0.000
485	E16	2,547.00	Domestic	0.008	2,562.46	15.43	0.000
488	B8	2,636.00		0.000	2,636.00	0.00	0.104
490	RK14	2,523.00		0.000	2,523.00	0.00	0.001
493	L79	2,292.00	Domestic	0.009	2,343.28	51.17	0.000
495	RK10	2,553.00	Domestic	0.000	2,553.00	0.00	0.001
501	L1	2,356.00	Domestic	0.025	2,361.72	5.71	0.000
504	J-142	2,424.00	Domestic	0.008	2,417.16	-6.83	0.000
505	L109	2,345.00	Domestic	0.002	2,402.54	57.43	0.000
506	J-107	2,379.00	Domestic	0.049	2,389.15	10.13	0.000
507	B11	2,610.00	Domestic	0.000	2,610.00	0.00	0.005
509	G2	2,343.00	Domestic	0.053	2,393.83	50.73	0.000
522	B10	2,600.00	Domestic	0.000	2,600.00	0.00	0.072
524	J-86	2,434.00		0.000	2,416.76	-17.21	0.000
528	J-91	2,360.00		0.000	2,394.15	34.08	0.000
543	J-113	2,403.00	Domestic	0.010	2,433.96	30.90	0.000
547	G1	2,364.00	Domestic	0.026	2,402.71	38.63	0.000
550	B1	2,706.00		0.000	2,706.00	0.00	0.011
552	RK9	2,588.00		0.000	2,588.00	0.00	0.007
554	J-137	2,390.00	Domestic	0.002	2,419.97	29.91	0.000
559	L32	2,325.00	Domestic	0.013	2,389.89	64.76	0.000
562	RK13	2,520.00		0.000	2,520.00	0.00	0.006
565	J-105	2,358.00	Domestic	0.027	2,397.15	39.07	0.000
566	J-111	2,397.00	Domestic	0.008	2,416.77	19.73	0.000
567	J-135	2,390.00	Domestic	0.002	2,420.13	30.07	0.000
568	J-136	2,390.00	Domestic	0.002	2,431.54	41.45	0.000
569	J-114	2,417.00	Domestic	0.008	2,423.92	6.90	0.000
570	L157	2,339.00	Domestic	0.006	2,371.73	32.67	0.000
571	L153	2,345.00	Domestic	0.002	2,372.54	27.48	0.000
572	L34	2,345.00	Domestic	0.002	2,372.62	27.57	0.000
573	L43	2,303.00	Domestic	0.008	2,368.13	65.00	0.000
574	L82	2,311.00	Domestic	0.009	2,356.38	45.29	0.000
576	L84	2,321.00	Domestic	0.009	2,340.66	19.62	0.000
586	SP12	2,463.00	Domestic	0.105	2,508.35	45.26	0.000
589	IC7	2,441.00	Domestic	0.014	2,416.75	-24.20	0.000
590	L115	2,370.00	Domestic	0.010	2,394.15	24.10	0.000
591	L14	2,377.00	Domestic	0.015	2,400.80	23.75	0.000
592	L12	2,385.00	Domestic	0.068	2,407.86	22.82	0.000
611	B13	2,595.00		0.000	2,595.00	0.00	0.006
612	J-139	2,373.00	Domestic	0.022	2,399.14	26.09	0.000
613	J-140	2,365.00	Domestic	0.016	2,401.84	36.77	0.000
614	G3	2,358.00	Domestic	0.038	2,389.09	31.03	0.000
615	G5	2,367.00		0.026	2,412.65	45.56	0.000
616	G6	2,402.00		0.011	2,418.46	16.43	0.000
617	T15	2,497.00	Domestic	0.019	2,500.91	3.90	0.000
618	T14	2,492.00	Domestic	0.019	2,504.38	12.36	0.000
619	T16	2,447.00	Domestic	0.020	2,496.62	49.52	0.000
620	T17	2,454.00	Domestic	0.020	2,459.49	5.48	0.000
621	T18	2,459.00	Domestic	0.009	2,500.96	41.87	0.000
625	L110	2,306.00	Domestic	0.010	2,364.87	58.75	0.000
626	L111	2,324.00	Domestic	0.010	2,364.68	40.60	0.000
629	E12	2,560.00	Domestic	0.010	2,560.80	0.80	0.000
632	J-101	2,545.00		0.000	2,545.00	0.00	0.100
634	J-104	2,615.00		0.000	-260,689,695.13	-260,167,217.78	0.000

Figure B:**12** Nodes Pressure Map for New Optimized Design Run of the Proposed System (EPS) Analysis



Appendix A-16: Results of Links for New Optimized Design Run of the Proposed System, (EPS) Analysis Continuous Model, **Current Time: 14 hours**

ID	Label	Start Node	Stop Node	Diameter (mm)	Material	Hazen - Williams C	Has Check Valve ?	Flow (m^3/s)	Velocity (m/s)	Headloss Gradient (m/m)	Length (User Defined) (m)
730	P-2	LAG TANK	C1a	900.0	Steel	115.0	False	0.548	0.86	0.001	6,890
731	P-3	C1a	C1	700.0	Steel	100.0	False	-0.150	0.39	0.000	10
732	P-4	LAGA TANK	J-4	1,400.0	Steel	110.0	False	1.638	1.06	0.001	6,360
733	P-5	J-4	ST2	1,200.0	Steel	100.0	False	0.000	0.00	0.000	20
734	P-6	ST2	J-5	1,200.0	Steel	100.0	False	0.000	0.00	0.000	20
735	P-7	J-5	C1	1,400.0	Steel	100.0	False	1.638	1.06	0.001	528
736	P-8	J-5	J-4	1,000.0	Steel	100.0	False	-1.638	2.09	0.005	30
737	P-9	ST3	J-6	1,200.0	Steel	100.0	False	-1.044	0.92	0.001	20
738	P-10	J-6	C1	1,200.0	Steel	100.0	False	-1.488	1.32	0.002	1,964
739	P-11	C1a	J-6	900.0	Steel	100.0	False	0.698	1.10	0.002	1,964
740	P-12	ST3	J-7	1,200.0	Ductile Iron	100.0	False	1.089	0.96	0.001	88
741	P-13	J-7	L22	1,200.0	Steel	100.0	False	1.259	1.11	0.001	9,526
742	P-14	L22	TR2	900.0	Steel	100.0	False	0.556	0.87	0.001	35
743	P-15	L22	ST4	1,200.0	Steel	100.0	False	0.000	0.00	0.000	10
744	P-16	J-7	J-6	1,000.0	Steel	100.0	False	-1.143	1.45	0.003	40
745	P-17	L22	TR1	900.0	Steel	100.0	False	1.217	1.91	0.005	35
746	P-19	TR1	L117	1,000.0	Steel	100.0	False	1.510	1.92	0.005	40
747	P-21	L114	AN	600.0	Steel	100.0	False	0.230	0.81	0.002	148
748	P-22	L114	L20	600.0	Ductile Iron	100.0	False	0.268	0.95	0.002	1,585
749	P-26	L119	TR3	600.0	Steel	100.0	False	0.000	0.00	0.000	19
750	P-27	TR3	L118	500.0	Steel	100.0	False	0.000	0.00	0.000	18
751	P-28	L118	L120	900.0	Ductile Iron	100.0	False	-0.100	0.16	0.000	24
752	P-29	L120	L121	900.0	Ductile Iron	100.0	False	0.191	0.30	0.000	18
753	P-30	L121	Jan Meda	900.0	Ductile Iron	120.0	False	0.481	0.76	0.001	7,550
754	P-31	L119	L122	1,000.0	Steel	100.0	False	0.000	0.00	0.000	7
755	P-32	L122	L123	1,000.0	Steel	100.0	False	-0.391	0.50	0.000	5
756	P-34	L122	TR2	600.0	Steel	100.0	False	0.391	1.38	0.004	19
757	P-36	TR2	L120	500.0	Steel	100.0	False	0.391	1.99	0.011	19
758	P-35	L123	TP1	500.0	Steel	100.0	False	0.390	1.99	0.011	19
759	P-37	TP1	L121	500.0	Steel	100.0	False	0.390	1.99	0.011	20
760	P-38	TR2	L125	150.0	Steel	100.0	False	0.015	0.86	0.009	50
761	P-40	TR1	L125	500.0	Steel	100.0	False	0.444	2.26	0.014	24
762	P-39	L125	L126	500.0	Steel	100.0	False	0.450	2.29	0.014	39
763	P-41	L126	L128	500.0	Steel	100.0	False	0.450	2.29	0.014	27
764	P-43	L128	L124	500.0	Steel	100.0	False	0.225	1.15	0.004	33
765	P-46	L126	TR6	150.0	Steel	100.0	False	0.000	0.00	0.000	25
766	P-47	TR6	L127	150.0	Steel	100.0	False	0.000	0.00	0.000	23
767	P-48	L128	TR5	350.0	Steel	100.0	False	0.225	2.33	0.022	24
768	P-49	TR5	L129	350.0	Steel	100.0	False	0.225	2.33	0.022	24
769	P-50	L124	TR4	350.0	Steel	100.0	False	0.225	2.34	0.022	21
770	P-51	TR4	L130	350.0	Steel	100.0	False	0.225	2.34	0.022	26
771	P-52	L127	L129	400.0	Ductile Iron	100.0	False	0.000	0.00	0.000	30
772	P-53	L129	L130	400.0	Ductile Iron	100.0	False	0.225	1.79	0.012	33
773	P-56	L123	J-27	1,000.0	Steel	100.0	False	-0.781	0.99	0.001	22
774	P-57	J-27	TR2	1,000.0	Steel	100.0	False	-0.858	1.09	0.002	16
775	P-58	J-27	L117	1,000.0	Steel	100.0	False	0.000	0.00	0.000	20
776	P-62	J-31	JM3	300.0	Steel	100.0	False	0.000	0.00	0.000	9
777	P-63	JM3	J-30	250.0	Steel	100.0	False	0.000	0.00	0.000	10
778	P-65	J-31	J-32	600.0	Steel	100.0	False	0.157	0.55	0.001	19
779	P-66	J-32	J-28	600.0	Steel	100.0	False	0.079	0.28	0.000	19
780	P-67	J-29	J-33	300.0	Steel	100.0	False	-0.078	1.10	0.007	16
781	P-68	J-33	J-30	300.0	Steel	100.0	False	0.000	0.00	0.000	19
782	P-69	J-32	JM4	300.0	Steel	100.0	False	0.078	1.10	0.007	12
783	P-70	JM4	J-33	250.0	Steel	100.0	False	0.078	1.59	0.016	15
784	P-71	J-28	JM5	300.0	Steel	100.0	False	0.079	1.11	0.007	13
785	P-72	JM5	J-29	250.0	Steel	100.0	False	0.079	1.60	0.016	14

786	P-75	J-35	J-31	600.0	Steel	100.0	False	0.157	0.55	0.001	16
787	P-77	Jan Meda	J-37	600.0	Steel	100.0	False	0.303	1.07	0.003	20
788	P-78	J-37	J-35	600.0	Steel	100.0	False	0.230	0.81	0.002	16
789	P-80	J-38	J-36	250.0	Steel	100.0	False	0.073	1.49	0.014	14
790	P-79	J-37	JM1	300.0	Steel	100.0	False	0.073	1.03	0.006	13
791	P-81	JM1	J-38	250.0	Steel	100.0	False	0.073	1.49	0.014	16
792	P-82	J-35	JM2	300.0	Steel	100.0	False	0.073	1.04	0.006	13
793	P-83	JM2	J-36	250.0	Steel	100.0	False	0.073	1.49	0.014	14
794	P-84	J-36	TM	400.0	Ductile Iron	100.0	False	0.146	1.16	0.005	1,782
795	P-88	Jan Meda	J-42	350.0	Steel	100.0	False	0.201	2.08	0.018	23
796	P-89	J-42	J-43	350.0	Steel	100.0	False	0.101	1.05	0.005	17
797	P-91	J-43	J-39	350.0	Steel	100.0	False	0.000	0.00	0.000	20
798	P-92	J-40	J-44	250.0	Steel	100.0	False	-0.100	2.04	0.025	20
799	P-93	J-44	J-41	250.0	Steel	100.0	False	-0.099	2.01	0.025	18
800	P-95	J-39	JM9	200.0	Steel	100.0	False	0.000	0.00	0.000	12
801	P-96	JM9	J-40	150.0	Steel	100.0	False	0.000	0.00	0.000	15
802	P-97	J-43	JM8	250.0	Steel	100.0	False	0.101	2.07	0.026	13
803	P-98	JM8	J-44	200.0	Steel	100.0	False	0.101	3.23	0.077	14
804	P-99	J-42	JM7	250.0	Steel	100.0	False	0.099	2.02	0.025	13
805	P-100	JM7	J-41	150.0	Steel	100.0	False	0.099	5.61	0.301	13
806	P-101	J-41	TM	250.0	Ductile Iron	100.0	False	-0.099	2.03	0.025	1,730
807	P-102	TM	J-47	400.0	Steel	100.0	False	0.090	0.71	0.002	85
808	P-103	J-47	J-45	400.0	Steel	100.0	False	0.090	0.71	0.002	34
809	P-104	J-46	TM2	300.0	Steel	100.0	False	0.000	0.00	0.000	15
810	P-106	TM2	J-47	350.0	Steel	100.0	False	0.000	0.00	0.000	16
811	P-105	J-45	TM1	350.0	Steel	100.0	False	0.090	0.93	0.004	14
812	P-107	TM1	J-48	300.0	Steel	100.0	False	0.090	1.27	0.009	15
813	P-108	J-46	J-48	400.0	Ductile Iron	100.0	False	0.000	0.00	0.000	34
814	P-109	J-48	EN	400.0	Ductile Iron	100.0	False	0.090	0.71	0.002	1,246
815	P-110	TM	J-50	250.0	Steel	100.0	False	0.205	4.17	0.096	43
816	P-111	J-50	J-49	250.0	Steel	100.0	False	0.205	4.17	0.096	40
817	P-113	J-52	J-51	200.0	Steel	100.0	False	-0.100	3.18	0.075	38
818	P-115	J-50	TM4	150.0	Steel	100.0	False	0.000	0.00	0.000	12
819	P-116	TM4	J-52	125.0	Steel	100.0	False	0.000	0.00	0.000	12
820	P-117	J-49	TM3	200.0	Steel	100.0	False	0.205	6.51	0.283	12
821	P-118	TM3	J-51	200.0	Steel	100.0	False	0.205	6.51	0.283	13
822	P-119	J-51	E15	200.0	Ductile Iron	100.0	False	0.005	0.15	0.000	1,056
823	P-120	E15	RK	150.0	Ductile Iron	100.0	False	0.000	0.00	0.000	1,437
824	P-122	Jan Meda	J-132	350.0	Ductile Iron	100.0	False	0.103	1.07	0.005	1,075
825	P-123	TM	T12	400.0	Ductile Iron	100.0	False	0.207	1.65	0.010	63
826	P-126	T12	SP15	250.0	Ductile Iron	100.0	False	0.002	0.05	0.000	2,449
827	P-127	T12	T13	400.0	Ductile Iron	100.0	False	0.176	1.40	0.007	130
828	P-130	EN	J-63	400.0	Ductile Iron	100.0	False	0.127	1.01	0.004	25
829	P-131	J-63	B14	200.0	Ductile Iron	100.0	False	0.057	1.82	0.027	1,885
830	P-132	J-63	J-65	200.0	Steel	100.0	False	0.070	2.22	0.039	27
831	P-135	B14	SP16	150.0	Ductile Iron	100.0	False	0.002	0.14	0.000	2,035
832	P-136	J-65	J-67	150.0	Steel	100.0	False	0.034	1.90	0.041	22
833	P-137	J-67	J-64	150.0	Steel	100.0	False	0.000	0.00	0.000	20
834	P-139	J-68	R1	200.0	Ductile Iron	100.0	False	-0.066	2.11	0.035	1,244
835	P-140	J-67	Entoto1	150.0	Steel	100.0	False	0.034	1.90	0.041	18
836	P-141	Entoto1	J-68	200.0	Steel	100.0	False	0.034	1.07	0.010	16
837	P-142	J-64	Entoto2	150.0	Steel	100.0	False	0.000	0.00	0.000	19
838	P-143	Entoto2	J-68	125.0	Ductile Iron	100.0	False	0.000	0.00	0.000	33
839	P-145	MO	SP17	350.0	Ductile Iron	100.0	False	0.096	1.00	0.005	556
840	P-146	MO	J-72	400.0	Steel	100.0	False	0.200	1.59	0.009	38
841	P-148	J-72	J-73	300.0	Steel	100.0	False	0.000	0.00	0.000	28
842	P-150	J-71	J-74	300.0	Steel	100.0	False	0.100	1.41	0.010	27
843	P-151	J-72	MO1	300.0	Steel	100.0	False	0.200	2.83	0.038	12
844	P-152	MO1	J-71	300.0	Steel	100.0	False	0.200	2.83	0.038	12
845	P-153	J-73	MO2	300.0	Steel	100.0	False	0.000	0.00	0.000	12
846	P-154	MO2	J-74	250.0	Steel	100.0	False	0.000	0.00	0.000	11
847	P-155	J-74	T-14	300.0	Ductile Iron	100.0	False	0.000	0.00	0.000	3,031
848	P-156	MO	J-75	300.0	Ductile Iron	100.0	False	0.105	1.49	0.012	41
849	P-157	J-75	MO3	300.0	Steel	100.0	False	0.105	1.49	0.012	20

850	P-158	MO3	J-76	250.0	Steel	100.0	False	0.105	2.15	0.028	18
851	P-160	L35	J-79	600.0	Ductile Iron	100.0	False	0.050	0.18	0.000	1,142
852	P-162	M23	J-81	250.0	Steel	100.0	False	0.000	0.00	0.000	37
853	P-161	J-79	J-82	500.0	Ductile Iron	100.0	False	0.091	0.46	0.001	954
854	P-163	J-82	J-78	500.0	Ductile Iron	100.0	False	0.091	0.46	0.001	45
855	P-164	J-81	ME2	300.0	Steel	120.0	False	0.000	0.00	0.000	17
856	P-165	ME2	J-82	400.0	Steel	120.0	False	0.000	0.00	0.000	12
857	P-169	J-78	ME1	400.0	Steel	120.0	False	0.009	0.08	0.000	13
858	P-170	ME1	M23	300.0	Steel	100.0	False	0.009	0.13	0.000	16
860	P-174	M19	J-78	600.0	Ductile Iron	110.0	False	-0.003	0.01	0.000	734
869	P-184	R1	J-90	150.0	Ductile Iron	100.0	False	0.011	0.61	0.005	32
870	P-185	J-90	R1(1)	125.0	Steel	100.0	False	0.011	0.87	0.012	19
871	P-186	R1(1)	E13	100.0	Steel	100.0	False	0.011	1.37	0.035	20
872	P-187	E13	R2	125.0	Ductile Iron	130.0	False	0.006	0.47	0.002	410
873	P-188	R2	J-92	100.0	Ductile Iron	100.0	False	0.000	0.00	0.000	22
874	P-190	E14	R3	100.0	Ductile Iron	130.0	False	0.000	0.00	0.000	472
875	P-189	J-92	R2(1)	100.0	Steel	100.0	False	0.002	0.29	0.000	16
876	P-191	R2(1)	E14	80.0	Steel	100.0	False	0.002	0.45	0.009	19
913	P-250	L112	C45	300.0	Steel	100.0	False	0.098	1.39	0.010	63
914	P-251	C45	UR1	250.0	Steel	100.0	False	0.098	2.00	0.024	17
915	P-252	UR1	J-55	250.0	Steel	100.0	False	0.098	2.00	0.024	19
935	P-287	L112	L116	900.0	Steel	140.0	False	0.760	1.19	0.001	457
936	P-289	L116	L46	500.0	Ductile Iron	130.0	False	0.539	2.75	0.012	1,331
937	P-288	L116	L36	300.0	Ductile Iron	130.0	False	0.218	3.08	0.027	588
938	P-290	L36	L35	900.0	Steel	100.0	False	0.096	0.15	0.000	213
939	P-293	L40	L41	400.0	Ductile Iron	110.0	False	0.024	0.19	0.000	1,064
940	P-294	L37	L44	300.0	Ductile Iron	110.0	False	0.043	0.60	0.002	2,498
941	P-296	L47	L46	500.0	Steel	140.0	False	-0.526	2.68	0.010	738
942	P-299	L44	L45	200.0	Steel	140.0	False	0.042	1.35	0.008	562
944	P-301	L44	L42	200.0	Steel	140.0	False	-0.007	0.23	0.000	461
946	P-305	L154	J-79	300.0	Ductile Iron	100.0	False	0.007	0.10	0.000	626
947	P-306	J-79	L113	300.0	Ductile Iron	100.0	False	0.034	0.48	0.001	995
948	P-307	L113	L69	300.0	Ductile Iron	100.0	False	0.078	1.10	0.007	2,859
953	P-316	L81	L83	250.0	Ductile Iron	110.0	False	0.063	1.29	0.009	704
954	P-317	L83	L104	250.0	Steel	140.0	False	0.022	0.45	0.001	940
955	P-318	L113	J-70	300.0	Ductile Iron	100.0	False	-0.076	1.07	0.006	57
956	P-319	J-70	J-78	300.0	Ductile Iron	100.0	False	-0.076	1.07	0.006	47
957	P-320	L104	J-70	300.0	Ductile Iron	100.0	False	0.000	0.00	0.000	873
959	P-323	L112	L27	250.0	Ductile Iron	100.0	False	0.055	1.12	0.008	2,008
960	P-324	L20	L24	200.0	Ductile Iron	110.0	False	0.014	0.45	0.002	800
961	P-325	L69	L70	300.0	Ductile Iron	110.0	False	0.073	1.03	0.005	76
962	P-326	L70	L81	300.0	Ductile Iron	100.0	False	0.067	0.95	0.005	856
964	P-328	L20	L19	400.0	Steel	140.0	False	0.111	0.88	0.002	770
965	P-330	L19	L18	250.0	Ductile Iron	110.0	False	0.073	1.49	0.012	607
966	P-332	J-80	L112	900.0	Steel	140.0	False	0.935	1.47	0.002	563
967	P-333	J-80	L26	200.0	Ductile Iron	100.0	False	0.029	0.91	0.007	2,077
977	P-344	L35	L155	400.0	Ductile Iron	100.0	False	0.019	0.15	0.000	455
978	P-345	L155	L154	400.0	Ductile Iron	100.0	False	0.012	0.10	0.000	127
979	P-346	L37	L38	600.0	Ductile Iron	110.0	False	0.049	0.17	0.000	616
980	P-347	L38	L40	600.0	Ductile Iron	110.0	False	0.033	0.12	0.000	345
981	P-348	L155	L38	200.0	Ductile Iron	110.0	False	0.006	0.18	0.000	407
982	P-350	L154	L108	300.0	Steel	140.0	False	0.002	0.03	0.000	796
1014	P-428	J-27	J-138	200.0	Ductile Iron	100.0	False	0.078	2.47	0.047	100
1027	P-460	L130	J-127	450.0	Ductile Iron	130.0	False	0.450	2.83	0.014	2,732
1028	P-461	J-127	J-125	400.0	Ductile Iron	130.0	False	0.146	1.17	0.003	1,458
1029	P-463	J-125	J-126	400.0	Ductile Iron	100.0	False	0.000	0.00	0.000	20
1030	P-464	J-126	J-124	350.0	Ductile Iron	130.0	False	-0.039	0.40	0.001	562
1031	P-465	J-125	J-123	150.0	Ductile Iron	130.0	False	-0.024	1.33	0.013	1,365
1032	P-466	J-123	J-124	200.0	Ductile Iron	100.0	False	-0.041	1.32	0.015	1,165
1033	P-467	J-124	J-129	350.0	Ductile Iron	100.0	False	-0.118	1.23	0.007	1,369
1034	P-468	J-129	J-131	350.0	Ductile Iron	100.0	False	-0.158	1.64	0.012	689
1035	P-469	J-129	J-122	150.0	Ductile Iron	130.0	False	0.027	1.53	0.017	1,107
1036	P-470	J-122	J-123	150.0	Ductile Iron	130.0	True	0.027	1.53	0.017	473
1037	P-471	J-122	J-120	250.0	Ductile Iron	100.0	False	-0.010	0.21	0.000	478

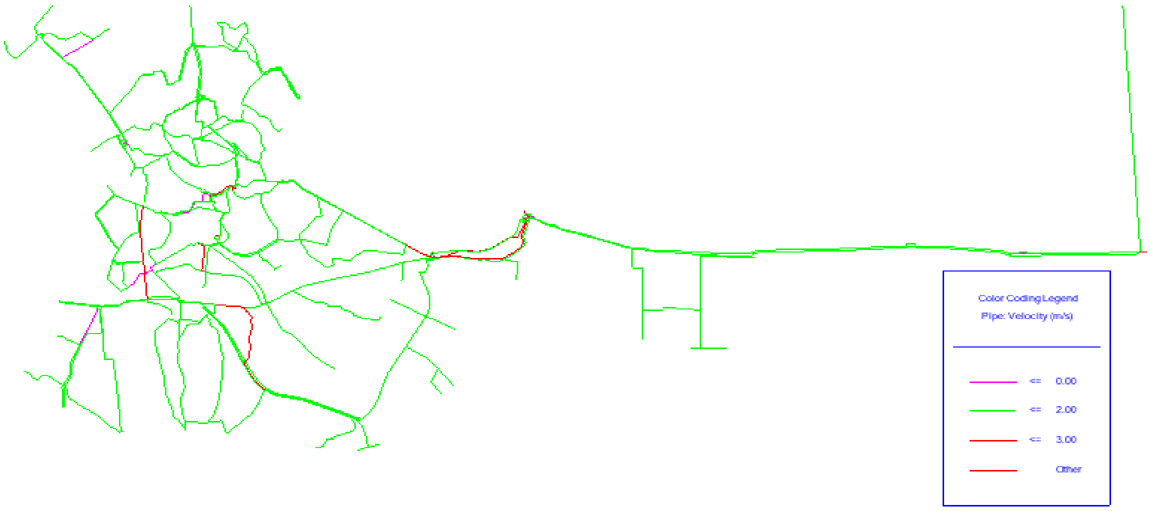
1038	P-472	J-120	J-121	150.0	Ductile Iron	100.0	False	0.110	6.22	0.364	654
1039	P-473	J-120	J-115	350.0	Ductile Iron	130.0	False	-0.242	2.52	0.016	860
1040	P-474	J-115	J-116	550.0	Ductile Iron	100.0	False	-0.505	2.13	0.011	629
1041	P-475	J-116	J-130	550.0	Ductile Iron	100.0	False	-0.509	2.14	0.011	783
1042	P-476	J-118	J-117	200.0	Steel	100.0	False	0.033	1.04	0.010	393
1043	P-478	J-116	J-117	200.0	Ductile Iron	100.0	False	0.000	0.00	0.000	11
1044	P-479	J-130	J-133	800.0	Ductile Iron	100.0	False	-0.514	1.02	0.002	143
1045	P-480	J-133	J-132	400.0	Ductile Iron	100.0	False	0.306	2.43	0.020	44
1046	P-481	J-132	J-131	400.0	Ductile Iron	100.0	False	0.407	3.24	0.035	63
1047	P-483	J-118	J-134	150.0	Steel	140.0	False	0.028	1.56	0.015	526
1048	P-485	J-131	J-119	350.0	Ductile Iron	130.0	False	0.247	2.57	0.016	667
1049	P-487	J-119	T3	200.0	Ductile Iron	130.0	False	0.020	0.65	0.002	1,366
1050	P-488	J-119	J-118	200.0	Ductile Iron	100.0	False	0.063	2.00	0.032	407
1051	P-490	T9	T8	250.0	Ductile Iron	130.0	False	-0.016	0.32	0.000	1,287
1052	P-491	T12	T10	200.0	Ductile Iron	100.0	False	0.024	0.76	0.005	1,222
1053	P-493	T8	T10	150.0	Ductile Iron	130.0	False	0.003	0.17	0.000	960
1054	P-494	T10	T5	150.0	Ductile Iron	130.0	False	0.009	0.53	0.002	260
1055	P-495	T8	T7	250.0	Ductile Iron	130.0	False	-0.030	0.62	0.002	84
1056	P-496	T7	T1	250.0	Ductile Iron	130.0	False	0.022	0.45	0.001	868
1057	P-499	T1	T6	150.0	Ductile Iron	130.0	False	0.013	0.75	0.004	1,131
1058	P-500	T6	T7	250.0	Ductile Iron	130.0	False	-0.068	1.40	0.008	761
1059	P-501	IC5	IC1	200.0	Ductile Iron	130.0	False	-0.006	0.20	0.000	530
1060	P-502	IC1	SP17	350.0	Ductile Iron	130.0	False	-0.067	0.70	0.001	169
1061	P-503	IC1	IC2	350.0	Ductile Iron	130.0	False	0.055	0.57	0.001	359
1062	P-504	IC2	IC3	300.0	Ductile Iron	130.0	False	0.042	0.59	0.001	234
1063	P-505	IC3	IC4	200.0	Ductile Iron	130.0	False	0.012	0.38	0.001	205
1064	P-506	SP17	IC6	200.0	Ductile Iron	130.0	False	0.006	0.20	0.000	213
1065	P-507	T6	SP27	500.0	Ductile Iron	100.0	False	0.208	1.06	0.003	1,642
1066	P-508	SP27	MO	500.0	Ductile Iron	100.0	False	0.208	1.06	0.003	57
1076	P-524	L20	L23	200.0	Ductile Iron	100.0	False	0.047	1.48	0.018	637
1077	P-525	L18	L160	150.0	Ductile Iron	130.0	False	0.024	1.38	0.014	483
1078	P-526	L18	L16	150.0	Ductile Iron	100.0	False	0.024	1.38	0.022	640
1079	P-528	L13	L22	900.0	Steel	140.0	False	0.535	0.84	0.001	2,661
1080	P-529	L13	L8	250.0	Ductile Iron	120.0	False	0.128	2.61	0.029	1,548
1081	P-530	L8	L9	200.0	PVC	120.0	False	0.110	3.49	0.064	646
1082	P-531	L8	L7	150.0	PVC	120.0	False	0.009	0.53	0.003	376
1083	P-532	J-7	L11	900.0	Steel	140.0	False	0.972	1.53	0.002	5,178
1084	P-534	L11	L5	350.0	Ductile Iron	100.0	False	0.111	1.16	0.006	1,209
1085	P-535	L5	L6	250.0	PVC	120.0	False	0.009	0.19	0.000	754
1086	P-536	L5	L3	250.0	PVC	120.0	False	0.092	1.88	0.016	839
1087	P-537	L3	L4	250.0	PVC	120.0	False	0.018	0.37	0.001	173
1088	P-538	L11	L10	350.0	Ductile Iron	100.0	False	0.026	0.27	0.000	1,084
1100	P-554	T11	T19	150.0	Ductile Iron	100.0	False	-0.014	0.81	0.008	1,097
1101	P-555	T19	T4	150.0	Ductile Iron	100.0	False	0.010	0.57	0.004	717
1102	P-556	J-133	T19	150.0	Ductile Iron	100.0	False	0.034	1.94	0.042	30
1108	P-666	J-110	J-109	150.0	Ductile Iron	130.0	False	0.010	0.58	0.003	864
1115	P-852	L31	L30	150.0	Ductile Iron	100.0	False	-0.013	0.72	0.007	226
1116	P-654	RK7	RK10	50.0	PVC	110.0	False	-0.002	1.04	0.039	377
1128	P-585	B7	SP26	200.0	Galvanized iron	120.0	False	0.109	3.45	0.067	2,909
1134	P-673	J-107	J-106	150.0	Galvanized iron	120.0	False	-0.021	1.21	0.013	618
1139	P-831	RK15	RK14	100.0	Galvanized iron	120.0	False	-0.024	3.00	0.110	0
1142	P-583	B10	B9	110.0	PVC	110.0	False	0.000	0.00	0.000	699
1144	P-634	J-142	J-143	400.0	Steel	140.0	False	-0.122	0.97	0.002	154
1148	P-671	J-143	J-108	250.0	PVC	110.0	False	0.100	2.04	0.021	1,195
1149	P-660	RK8	RK7	50.0	PVC	110.0	False	-0.001	0.41	0.007	703
1153	P-658	RK9	RK8	50.0	PVC	110.0	False	0.000	0.24	0.006	812
1164	P-685	G1	J-144	150.0	Steel	140.0	False	-0.028	1.56	0.015	97
1165	P-672	J-108	J-107	150.0	Ductile Iron	130.0	False	0.017	0.94	0.007	404
1171	P-830	RK20	RK15	150.0	Galvanized iron	90.0	False	-0.022	1.26	0.026	371
1173	P-576	B8	B1	100.0	PVC	110.0	False	0.011	1.43	0.033	1,647
1175	P-854	L30	L29	125.0	Galvanized iron	100.0	False	0.013	1.03	0.016	247
1177	P-678	J-112	J-113	350.0	Ductile Iron	100.0	False	-0.173	1.79	0.014	938
1183	P-849	L33	L32	200.0	Ductile Iron	100.0	False	-0.013	0.40	0.002	420
1184	P-686	J-144	L109	100.0	Galvanized iron	120.0	False	0.002	0.31	0.002	1,042

1195	P-758	L1	L2	125.0	Ductile Iron	100.0	False	-0.025	2.00	0.055	470
1198	P-677	J-106	J-112	300.0	Ductile Iron	130.0	False	0.000	0.00	0.000	900
1199	P-584	B10	B11	200.0	Ductile Iron	130.0	False	0.005	0.14	0.000	404
1202	P-703	J-143	J-84	400.0	Steel	140.0	False	-0.231	1.84	0.006	384
1203	P-704	J-84	J-137	500.0	Ductile Iron	130.0	False	-0.017	0.09	0.000	455
1205	P-706	R3	E2	50.0	PVC	110.0	False	0.000	0.00	0.000	281
1206	P-708	E3	R2	100.0	Ductile Iron	130.0	False	0.000	0.00	0.000	157
1207	P-710	R1	E4	200.0	PVC	110.0	False	0.024	0.77	0.005	90
1208	P-711	E1	R3	75.0	Galvanized iron	120.0	False	0.000	0.00	0.000	262
1209	P-712	EN	E16	100.0	Galvanized iron	120.0	False	0.008	0.99	0.014	293
1210	P-718	RK10	RK9	75.0	Galvanized iron	120.0	False	0.007	1.65	0.041	358
1211	P-713	RK	RK14	100.0	Galvanized iron	120.0	False	0.000	0.00	0.000	769
1212	P-716	RK21	RK13	150.0	Ductile Iron	130.0	False	0.003	0.20	0.000	1,101
1213	P-717	RK13	RK22	150.0	Ductile Iron	130.0	False	0.026	1.47	0.015	1,945
1214	P-719	RK	RK13	250.0	Ductile Iron	130.0	False	0.000	0.00	0.000	307
1215	P-720	RK13	RK21	150.0	Ductile Iron	130.0	False	-0.003	0.20	0.000	1,122
1216	P-721	RK20	RK21	150.0	Galvanized iron	120.0	False	0.020	1.12	0.014	180
1217	P-722	B7	T-14	250.0	Ductile Iron	130.0	False	0.000	0.00	0.000	62
1218	P-723	B7	B9	125.0	Galvanized iron	120.0	False	0.006	0.48	0.000	659
1237	P-749	J-142	J-86	400.0	Steel	140.0	False	0.076	0.61	0.001	482
1238	P-750	J-86	J-110	200.0	Ductile Iron	130.0	False	0.023	0.72	0.003	580
1239	P-751	J-86	J-110	250.0	Ductile Iron	130.0	False	0.040	0.81	0.003	611
1240	P-752	J-110	J-109	250.0	Ductile Iron	130.0	False	0.039	0.79	0.003	903
1241	P-753	J-109	J-105	250.0	Ductile Iron	100.0	False	0.073	1.48	0.014	1,101
1242	P-754	J-105	J-106	300.0	Ductile Iron	130.0	False	0.045	0.64	0.001	165
1243	P-755	J-108	J-79	200.0	Ductile Iron	130.0	False	0.069	2.19	0.023	833
1244	P-756	J-108	J-107	150.0	Ductile Iron	130.0	False	0.011	0.61	0.003	899
1245	P-757	J-142	J-111	300.0	Ductile Iron	130.0	False	0.038	0.54	0.001	361
1246	P-759	J-111	J-109	200.0	Ductile Iron	130.0	False	0.030	0.95	0.005	839
1247	P-760	J-84	J-112	350.0	Ductile Iron	130.0	False	-0.051	0.53	0.001	1,487
1248	P-761	J-84	J-135	150.0	Steel	140.0	False	-0.004	0.21	0.000	461
1249	P-764	J-135	J-134	150.0	Steel	140.0	False	-0.025	1.43	0.013	195
1250	P-769	J-141	J-137	500.0	Ductile Iron	130.0	False	0.000	0.00	0.000	898
1251	P-770	J-137	J-135	150.0	Ductile Iron	130.0	False	-0.019	1.09	0.009	18
1252	P-771	J-119	J-136	300.0	Ductile Iron	130.0	False	0.162	2.29	0.016	766
1253	P-773	J-136	J-84	300.0	Ductile Iron	100.0	False	0.159	2.25	0.025	468
1254	P-775	J-135	J-136	150.0	Ductile Iron	130.0	False	0.000	0.00	0.000	21
1255	P-778	J-117	J-114	200.0	Steel	100.0	False	0.029	0.92	0.008	379
1256	P-781	J-114	PG	200.0	Steel	100.0	False	0.030	0.97	0.008	108
1257	P-783	J-114	J-120	150.0	Ductile Iron	100.0	False	-0.010	0.54	0.004	1,063
1258	P-784	J-120	J-122	150.0	Ductile Iron	100.0	False	0.003	0.15	0.000	490
1259	P-785	J-144	J-113	200.0	Ductile Iron	100.0	False	-0.073	2.31	0.042	716
1260	P-786	J-113	J-115	400.0	Ductile Iron	100.0	False	-0.255	2.03	0.015	521
1261	P-787	G2	G1	200.0	Ductile Iron	100.0	False	-0.053	1.70	0.024	376
1262	P-804	PG	G1	250.0	Ductile Iron	100.0	False	0.092	1.86	0.022	942
1263	P-806	L38	L157	200.0	Ductile Iron	110.0	False	0.015	0.49	0.002	378
1264	P-807	L157	L42	200.0	Ductile Iron	110.0	False	0.015	0.48	0.002	1,878
1265	P-808	L157	L37	150.0	Steel	140.0	False	-0.006	0.35	0.001	829
1266	P-805	L36	L153	600.0	Ductile Iron	110.0	False	0.120	0.42	0.000	290
1267	P-809	L153	L37	600.0	Ductile Iron	110.0	False	0.097	0.34	0.000	84
1268	P-810	L35	L34	400.0	Ductile Iron	100.0	False	0.024	0.19	0.000	139
1269	P-811	L153	L34	200.0	Ductile Iron	100.0	False	-0.007	0.21	0.000	174
1270	P-813	L34	L153	200.0	Ductile Iron	100.0	False	0.007	0.21	0.000	177
1271	P-814	L153	L37	150.0	Steel	140.0	False	0.003	0.16	0.000	102
1272	P-815	L34	L153	200.0	Steel	140.0	False	0.008	0.27	0.000	207
1273	P-816	L153	L47	200.0	Ductile Iron	100.0	False	0.019	0.62	0.004	2,046
1274	P-817	L47	L45	350.0	Ductile Iron	100.0	False	0.050	0.52	0.001	1,234
1275	P-818	L153	L47	200.0	Ductile Iron	100.0	False	0.019	0.62	0.004	2,070
1276	P-819	L153	L46	250.0	Ductile Iron	100.0	False	0.000	0.00	0.000	1,291
1277	P-820	L30	L28	250.0	Ductile Iron	100.0	False	-0.038	0.78	0.004	604
1278	P-821	L19	L32	400.0	Ductile Iron	100.0	False	0.025	0.20	0.000	2,787
1279	P-822	L28	L47	200.0	Ductile Iron	100.0	False	-0.004	0.14	0.000	2,055
1280	P-823	L42	L43	200.0	Ductile Iron	110.0	False	0.000	0.00	0.000	159
1282	P-825	L43	L41	150.0	Ductile Iron	100.0	False	-0.008	0.45	0.003	1,455

1283	P-826	J-79	L156	150.0	Galvanized iron	120.0	False	0.001	0.08	0.000	691
1284	P-827	L113	L82	200.0	Ductile Iron	100.0	False	0.027	0.87	0.007	2,150
1285	P-828	L82	L79	125.0	Steel	100.0	False	0.019	1.54	0.034	385
1286	P-829	L83	L79	150.0	Ductile Iron	100.0	False	-0.010	0.57	0.004	490
1293	P-838	L83	L84	200.0	Ductile Iron	130.0	False	0.009	0.28	0.000	944
1308	P-868	L104	L105	150.0	Ductile Iron	100.0	False	0.018	1.02	0.013	505
1325	P-885	J-78	M18	300.0	Ductile Iron	100.0	False	0.003	0.04	0.000	778
1327	P-887	SP27	J-76	300.0	Ductile Iron	100.0	False	0.000	0.00	0.000	173
1329	P-889	J-76	SP12	300.0	Ductile Iron	120.0	False	0.105	1.49	0.008	854
1337	P-898	IC7	J-86	400.0	Steel	140.0	False	-0.014	0.11	0.000	257
1338	P-897	L114	L115	900.0	Steel	140.0	False	0.973	1.53	0.002	611
1339	P-899	L115	J-80	900.0	Steel	140.0	False	0.963	1.51	0.002	2,300
1340	P-900	J-91	L115	150.0	Steel	140.0	False	0.000	0.00	0.000	409
1341	P-901	J-87	J-128	150.0	Galvanized iron	90.0	False	0.009	0.53	0.005	2,182
1342	P-902	L14	L114	900.0	Steel	140.0	False	1.480	2.33	0.004	1,423
1343	P-903	L15	L14	150.0	Ductile Iron	100.0	False	-0.015	0.85	0.009	700
1344	P-904	L11	L12	900.0	Steel	140.0	False	0.765	1.20	0.001	906
1345	P-905	L12	L13	900.0	Steel	140.0	False	0.697	1.10	0.001	781
1405	P-965	J-141	J-130	800.0	Ductile Iron	100.0	False	-0.003	0.01	0.000	384
1406	P-966	B7	B13	200.0	Ductile Iron	130.0	False	0.047	1.51	0.025	794
1407	P-967	B13	B4	200.0	Ductile Iron	130.0	False	0.041	1.31	0.000	464
1408	P-968	J-127	J-139	150.0	Ductile Iron	100.0	False	0.014	0.80	0.008	984
1409	P-969	J-139	J-140	150.0	Ductile Iron	100.0	False	-0.008	0.44	0.003	996
1410	P-970	J-140	J-123	150.0	Ductile Iron	100.0	False	-0.024	1.33	0.021	868
1411	P-971	J-55	G3	200.0	Ductile Iron	100.0	False	-0.002	0.06	0.000	520
1412	P-972	G3	G1	200.0	Ductile Iron	100.0	False	-0.040	1.26	0.014	1,005
1413	P-973	G4	G5	200.0	Ductile Iron	130.0	False	-0.012	0.38	0.001	928
1414	P-974	G5	G6	200.0	Ductile Iron	130.0	False	-0.038	1.20	0.008	768
1415	P-975	G6	PG	200.0	Ductile Iron	130.0	False	-0.049	1.55	0.012	374
1416	P-976	T13	T15	150.0	DI	100.0	False	0.019	1.05	0.014	431
1417	P-977	T15	T1	150.0	Ductile Iron	100.0	False	0.000	0.01	0.000	587
1418	P-978	T13	T14	400.0	Ductile Iron	100.0	False	0.152	1.21	0.006	427
1419	P-979	T14	T7	400.0	Ductile Iron	100.0	False	0.133	1.06	0.004	604
1420	P-980	J-29	T16	500.0	Ductile Iron	100.0	False	0.157	0.80	0.002	590
1421	P-981	T16	T6	500.0	Ductile Iron	100.0	False	0.137	0.70	0.002	495
1422	P-982	Jan Meda	T17	800.0	Ductile Iron	100.0	False	0.876	1.74	0.005	539
1423	P-983	T17	J-133	800.0	Ductile Iron	100.0	False	0.856	1.70	0.005	442
1424	P-984	T10	T18	200.0	Ductile Iron	100.0	False	0.008	0.26	0.001	520
1425	P-985	T18	T9	200.0	Ductile Iron	100.0	False	-0.001	0.04	0.000	586
1431	P-991	L28	L110	400.0	Ductile Iron	110.0	False	-0.027	0.21	0.000	1,334
1432	P-992	L110	L47	400.0	Ductile Iron	110.0	False	-0.037	0.29	0.000	638
1433	P-993	L47	L111	400.0	Ductile Iron	100.0	False	0.030	0.24	0.000	1,492
1434	P-994	L111	L28	400.0	Ductile Iron	100.0	False	0.020	0.16	0.000	516
1437	P-997	L125	J-87	200.0	Galvanized iron	90.0	False	0.009	0.30	0.001	43
1438	P-998	L2	L3	200.0	Ductile Iron	100.0	False	-0.053	1.68	0.023	36
1441	P-636	J-65	E12	150.0	Ductile Iron	100.0	False	0.036	2.04	0.046	99
1442	P-637	E12	B14	150.0	Ductile Iron	100.0	False	0.026	1.47	0.025	1,783
1447	P-643	L117	FCV-1	900.0	Steel	100.0	False	1.510	2.37	0.008	16
1448	P-644	FCV-1	L14	900.0	Steel	140.0	False	1.510	2.37	0.004	1,046
1449	P-646	J-101	RK10	150.0	Galvanized iron	140.0	False	0.011	0.60	0.008	622
1450	P-645	RK	PMP-47	200.0	Galvanized iron	140.0	False	0.000	0.00	0.000	21
1451	P-647	PMP-47	J-101	150.0	Galvanized iron	140.0	False	0.074	4.17	0.000	19
1452	P-648	T-14	PMP-48	200.0	Ductile Iron	100.0	False	0.000	0.00	0.000	23
1453	P-649	PMP-48	B8	150.0	Ductile Iron	130.0	False	0.057	3.25	0.000	24
1454	P-650	RK	PMP-49	150.0	Ductile Iron	100.0	False	0.000	0.00	0.000	27
1455	P-651	PMP-49	J-101	150.0	Ductile Iron	100.0	False	0.037	2.09	0.000	29
1456	P-652	T-14	PMP-50	100.0	Steel	100.0	False	0.000	0.00	0.000	29
1457	P-653	PMP-50	B8	200.0	Steel	100.0	False	0.057	1.83	0.000	34
1460	P-582a	B7	J-104	200.0	Ductile Iron	130.0	False	0.077	2.44	0.000	16
1461	P-582	J-104	B10	250.0	Ductile Iron	130.0	False	0.077	1.56	0.017	1,161
1478	P-1	R-1	LAGA TANK	600.0	Ductile Iron	130.0	False	0.238	0.84	0.001	0
1479	P-2	R-2	LAGA TANK	900.0	Ductile Iron	130.0	False	2.932	4.61	0.016	0
2357	P-2	J-128	AN	152.4	Ductile Iron	130.0	False	-0.011	0.63	0.003	0

Figure.B.13 Links Velocity Map for New Optimized Design Run of the Proposed System (EPS) Analysis

Scenario: New Optimized Design Run - 1 - 1



Existing Water System of Legedadi sub system 4+AN+
Proposal.wtg
6/5/2014

Bentley Systems, Inc. Haestad Methods Solution Center
27 Siemon Company Drive Suite 200 W Watertown, CT 06795
USA +1-203-755-1666

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