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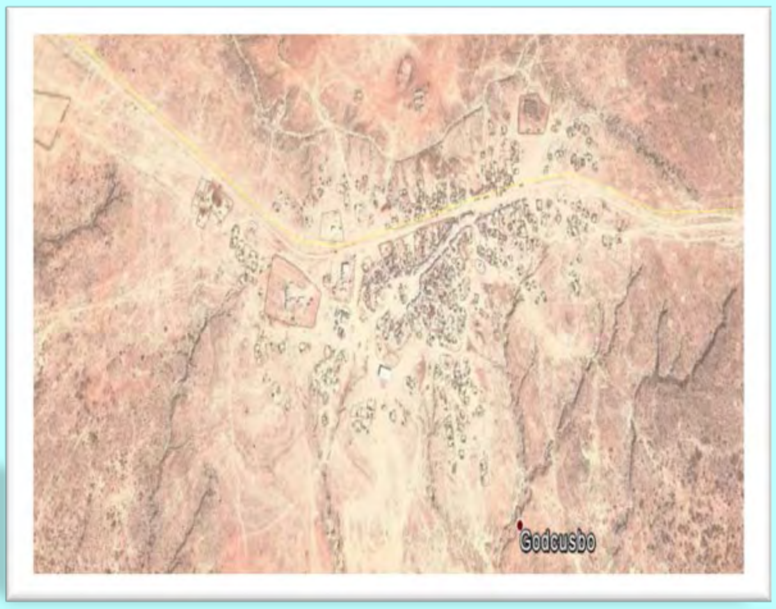
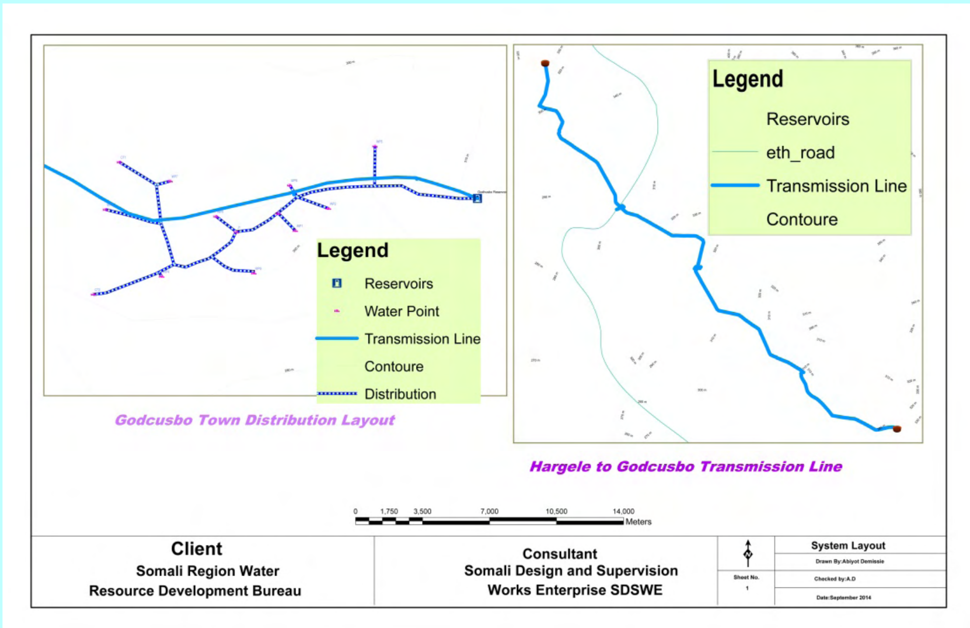
SOMALI NATIONAL REGIONAL STATE

WATER RESOURCES DEVELOPMENT BUREAU

DESIGN REPORT OF

HARGELE GODCUSBO WATER SUPPLY PROJECT





BY

SOMALI DESIGN AND SUPERVISION
WORKS ENTERPRISE

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Jigjiga, Ethiopia

1. Introduction

1.1 General

Every living thing needs certain amount of water to fulfill its requirement and to assure its existence. The amount of water that every human needs per day is very great compared to the other living creature consumptions. This is because human being needs water not only for drinking but also for other purposes too. Such as swimming, washing, sanitation, navigation, Irrigation is some of them. Therefore to fulfill those requirements the sources is obtained for rivers, ground water, lakes and soon.

The world's total water is about $1.37*10^{18}$ m^3. from this amount of the water saline which occurs is about 92.203% and fresh water which is about 2.712%, out of this fresh water 2.519% is surface water and 0.633% is ground water and from this fresh ground water 0.31% can be economically extracted with the present drilling technology up to the depth of 0.8km.

Even if Ethiopian of water tower of east Africa, the exploited potential of water is minimum. For the accomplishment of water supply system we have to pass different steps.

Among these:-

- Determination of people who will be served
- Per capital water consumption
- Analysis of factors that may operate to affect consumption
- Assessment of water for various purposes
    - ✓ Domestic
    - ✓ Commercial
    - ✓ Public and Industrial.

1.2 Back Ground

1.2.1 Location and Topography

Godhusbo is located in Somali regional State. It is one of the Kebele in Afder zone. It is 790km far from Jigjiga in the direction of south west and 190km for from Gode. The road from Gode Godhusbo is an all weather type which needs maintenance during this time. Geographical coordinates of the town are Lat/Lon: 5.07003350° N, 42.34606987° E. It has an altitude raging from 296m to 320m above mean sea level.

1.2.2 Climate

Weather type of Godhusbo is arid with a mean annual precipitation of 400mm. The temperature varies between 21.5 0C and 30 0C with an average of 25.75 0C.

1.3 Objective of the Project.

As any water supply project, the Godhusbo water supply project has its own objective and goal. No living thing can live without safe, adequate and clean water hence, this project is done for the sustainable provision of this natural basis.

According to WHO any mankind should be delivered with clean and safe water for drinking purpose. The Godhusbo Water Supply Project also aimed to fulfill the requirement of clean and safe water for inhabitant of Godhusbo.

1.4 Existing Water Supply

Hargele town has its own water supply even though it has problems while God Husbo town has no any conventional water supply system. The inhabitants of the town are getting untreated pond water that was constructed to collect the surface runoff generated during the rainy season. Formerly, there was only one pond that was constructed by the previous, but as the area gets very few rain falls in a year and due to salt problem it is difficult to cover the ever growing water demand of humans and domestic animals. Currently the community has no access to any clean and safe water supply service.

So before we start the construction of this new project we have to solve the main problems of Hargele and Chereti town water supply projects.

The main problems are;

- the intake (raw water) pump is not working
- Sluice gate is not working
- One of the two clear water pump is non functional
- Diversion weir is filled with silt
- Sand from Settling basin is removed by man power and deposited near the structures.
- Hargele town Reservoir needs maintenance
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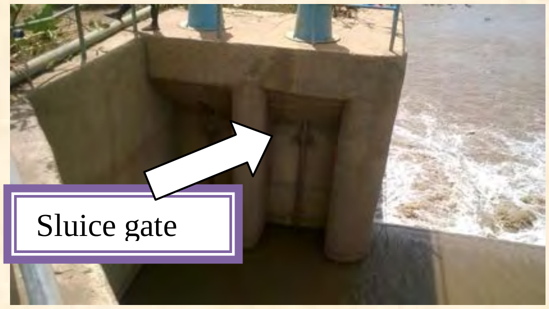

2. Socio Economy

2.1 Housing Condition

Based on the data from the municipality of the town, 66% of the area is covered by house and the central business area occupies 31 ha. Nearly all the houses are built of stone, blocks or bricks. Of those surveyed houses 4.6% have internal plumbing, 85% of the houses are owned by private, 1% is rented from the government and 14% are rented from privates.

2.2 Health Condition

There is one hospital & one health center that serves the community of Godhusbo the percentage of water-born and sanitation-related diseases at Godhusbo are significantly higher than the national averages for outpatient visits as recorded for 1998/99 in heath & health related indicators.

A nine-month record of top ten diseases observed in Godhusbo town in the year 2001, as recorded by the health center, is shown as follows

Table1. Disease at Godhusbo

Disease	Relation to water	Number of Cases	Godhusbo	National Out patients
Amoebic dysentery	Water borne	1425	15.2%	1.9%
Gastritis	Water borne	1115	11.9%	3.6%
Skin diseases	Water washed	870	9.3%	1.7%
Parasites	Some	835	8.9%	2.2%
Malaria	Related	992	10.6%	7.0%
Sub total		5237	55.8%	16.4%
Respiratory disease	None	1832	19.5%	6.2%
Bronchitis	None	939	10.0%	2.2%
Pneumonia	None	794	8.5%	3.8%

Disease	Relation to water	Number of Cases	Godhusbo	National Out patients
Malnutrition	None	590	6.3%	-------
Other				71.4%
Total		9392	100.0 %	100.0%

(Source: Health Center of Godhusbo town)

2.3 Electrical and Water Supply Condition

According to current information Godhusbo town has no hydro electric power supply. Concerning water supply status the town has no access to clean, safe and adequate water supply.

2.4 Educational Status

There are one primary school in the town and two other schools in the Langer and Habtir Kebele.

2.5 Objectives

The specific objectives of the project are:-

- To select appropriate water supply source that can meet the demand of the Town.
- To produce appropriate design of water supply system for the selected source and related structures.

The overall objective of the project is to design safe adequate, accessible and

Sustainable water supply system for Godhusbo town there by improves the health condition of the community and increase productivity.

3. Population Forecasting

3.1 General

A water supply scheme includes huge and costly structures, which cannot be replaced or increased in their capacities easily and conveniently. Hence, all scenarios affecting the water supply system should have to be thoroughly accessed before the system is designed. One of the scenarios that have great impact on estimating the water demand of a particular project is the projection of the population sizes. Hence, the planning of any water supply system has to be based on the forecast of population size, population growth rate and distribution.

There are a number of factors that should be taken in to consideration in projecting the future population size of a project. some of which are fertility, mortality, economic activity in and around the project area, availability of natural resources, and status of the area in the region, i.e. its political and economical significance, relative location of the area with respect to main highways and availability of reliable infrastructure facilities and etc.

3.2 Design Period

The expansions in the water works, network of pipelines etc is not easy work while designing and constructing these works, they should have sufficient capacity to meet the future demand of the town for number of years. The number of years for which the designs of water works have to be known and this period is called deign period. The design period should be neither too short nor too long.

3.2.1 Factors Affecting Design Period

The following Factors should be kept in view while fixing the design period.

- If more funds are available design period may be more, but if small funds are available the design period shall be less

- Life of the pipe and other Structural materials is used in the water supply scheme. Design period in no case should have more life than the components and material used in the scheme
- As far as possible, the design period should be nearly equal to the materials used in the water supply works.
- Rate of interest on the loans taken to complete the project. If this rate is less, it will be good to keep design period more. But if the interest rate is high, the design period shall be small.
- Anticipated expansion rate of the town

Taking into consideration the above factors the design period taken to be 25 years.

Table 3.1 Design Period of different unites of water supply system

S.No	Name of unit	Design period in years
1	Pump house	30
2	Electrical motors and pumps	15
3	Water treatment units	15
4	Distribution(pipe lines)	30
5	River intake	20
6	Spring collection chamber	10-20
7	Disinfection units	5
8	Reservoir	20

3.3. Population

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3.4 Base Population

The use of a reliable base population figure is very important for optimizing the project costs and sustaining the project's service year. Over and under estimation of the populations could result in a higher investment cost and a lower service run period respectively. Hence it is very important to initially get a realistic base population figures not to come with the above-mentioned problems.

For this scheme the crude information from the town Municipality is considered as present population of the town and the population figure in year 2013 G.C i.e. 3480 for urban and 2897 for rural is considered as a base population.

Table: 4.3 Base Populations

NO	Village/PA	Urban	Rural
1	Godcusbo	3,480	
2	Habtir		1,591
3	Lanqer		1,306
	Total	**3,480**	**2,897**

3.4 Population Growth

In predicting the future water demand of a community its population growth rate and the existing population should be known. The annual growth rate in Ethiopia for rural and urban areas is shown in the table below.

Table: 4.3 CSA's Country Level Population Growth Rates

Year	Urban	Rural
2005-2010	4.06	2.33
2010-2015	3.88	2.15
2015-2020	3.69	1.98
2020-2025	3.51	1.68
2025-2030	3.35	1.41

3.4.1. Population Projection

The design population projection is done for 20 years lifetime starting from 2015 to 2035 G.C. Based on this the projected populations are shown in the table below

Table: Projected Population

Year	Urban	Rural	Total
2013	3,480	2,897	6,377
2015	3,755	3,023	6,778
2020	4,501	3,334	7,835
2025	5,349	3,624	8,973
2030	6,307	3,887	10,193
2035	7,436	4,169	11,605

4. Water Demand

4.1 General

While designing the water supply scheme for a town or city, it is necessary to determine the total quantity of water required for various purposes by the city.

As a matter fact, the first duty of the engineer is to determine the water demand of the town and to find out the suitable water sources from where the demand can be meet.

Some of the factors that affect water demand are

- Climatic condition
- size of the town
- Culture of people etc.

Climatic condition: - Water consumption during summer is more than winter.

During summer everybody takes shower twice a day, clothes also become dirties, water is used for drinking and in running coolest. This is why we say water consumption is much more in summer than in winter.

Size of the town: - Generally, the demand of water per head will be more on big city than that in small city. In big cities, lot of water is required for maintaining clean and health environments while in small towns more or less small.

Culture of people: - High-class community uses more water due to their better standard of living and high economic status (uses for luxuries purpose).

Middle class people uses water at average rate and for poor people a single water tap may be sufficient for several families.

Industries: - more water is used in highly industrial city

Cost of water: - If cost of water is high, the water demand will be less .Hence the rate at which water is supplied to consumer may affect the rate of demand.

Quality of water: - A water work system having good facility and portable water supply will be more popular with consumers.

Pressure in the distribution system: - There would be of great importance in the case of localities having number of two or three storied buildings. Adequate pressure would mean an uninterrupted and constant supply of water.

System of supply: - The system of water may be continuous or intermittent. In continuous system, water is supplied all 24 hours .while in the case of intermittent system water is supplied for hours of the day only results in some reduction in the consumption. This may be due to decrease in loss and other waste of full use.

Method of charging: - In a town where meters are used less quantity of water will be used than in towns without meters in their system. A metered supply ensures minimum of waste as the consumer then know that he was to pay. For water used by him and consequently. It more carefully in use.

4.2 Water Demand Assessment

In the design of any water supply project, it is necessary to estimate the amount of water that is requiring to be supplied. This involves determining the number of people to be served and their per capita water consumption along with analysis of the factors that may operate to affect consumption.

4.2.1 Domestic Water Demand

The Domestic water demand is the daily water requirement for human need purposes... The domestic water demand required by human being could be supplied or obtained through different arrangements depending on the economic status and facilities owned by the individual. Mainly the water is required to use for drinking, cooking, bathing, and related works. For this particular town piped supply with standpipe and housing connection is taken in to consideration.

In estimating the per capita demand there are different alternatives either using empirical formulae for developing countries or using data of estimated figure for different target year in the region, guideline prepared by ministry of water resource, the minimum per capita requirement for the human established by WHO, or Design criteria set by water work and supervision enterprise for 5-town water supply project. The following methods are selected for this specific design.

a) Empirical formula

For design the following empirical formula is used:

$$Q = \left(\frac{50 + 10 * n}{n} \right)$$

Where Q = demand in l/sec

n = number of family served per house hold

As most of the household's family of the region, God Husbo town possesses an average family size of 5.

$$\Rightarrow Q = \left(\frac{50 + 10 * 5}{5} \right) = 20 \text{ lit/sec}$$

b) Estimated figure for different target year in Somali

The 'improvement of water supply in Somali ' technical design standard manual (model D_1) establish domestic water consumption figure (l/c/day) for deferent target year as shown below. The value of 1997-target year is based on random sampling taken from various water supply systems.

Table 4- 1 Per Capital Demand In Semi - Urban Areas

Year	2015	2020	2025	2030	2035
Demand (l/c/d)	22	24	28	35	49

Table 4- 2 per capital demand in rural areas

Year	2015	2020	2025	2030	2035
Demand (l/c/d)	20	21	22	23	24

c) Guideline prepared by ministry of water resource

The ministry of water resource establishes a guideline for water supply projects in 1999.According to this paper, to estimate the amount of water required for different category of domestic consumers, the figures shown in the following table shall be assumed as reasonable estimate for present day conditions, with applying different adjustment factor to specific communities.

Table 4- 3 Estimate of per capital demand for piped water in l/c/day (1997) for population less than 30,000 (for urban between 2,500 and 30,000)

No	Activity	House connection	Yard connection	Public fountain (stand pipe)	Rural scheme
1	Drinking	1.5	1.5	1.5	1.5
2	Cooking	5.5	3.5	3.5	3.5
3	Ablutions	15	10	6	5
4	Washing dishes	5	2	2	2
5	Laundry	15	8	7	3
6	House cleaning	4	1	-	-
7	Bath and shower	20	4	-	-
8	Toilet	4	-	-	-
	Total	70	30	20	15

d) World Health Organization

For comparison, the WHO has established a minimum requirement of human water consumption of 30 l/c/d.

e) Design criteria set by water work and supervision enterprise for 5-town water supply project

Table 4.2.1 Per Capita Demand For Different Demand Categories

Demand categories	l/c/d
Public tap	15
Yard connection	25
House connection	35

Based on the above information's and from region condition for farther analyses 35l/c/day, 25l/c/d and 22 l/c/d is used for year 2009 G.C for house connection, Yard connection, and public fountain respectively.

Projected Level of Service

Percentage of population to be served by each demand category will vary with time. The variation is caused by changes in living standards, improvement of the Service level and the capacity of the water supply service.

Although the standard approach of projecting would normally involves a detail analysis of past consumption trends by consumers group to which alternative economic development scenarios would be applied to produce future consumption levels, this approach requires detail information on the present consumption pattern and future economic development scenarios. For 85% of the population needs to be served by public taps, 10% of the population need to be served by yard tap connection and 5% needs to be served house connection.

Table 4- 4 Percentage of population by mode of services

Demand categories	Percentage of population	Growth rate	l/c/d
House Tap Users	5.00	2.00	35.00
Yard Tap Users	10.00	2.00	25.00
Public Tap Users	85.00	1.00	22.00

Projected domestic demand

If more people acquired better education and style of living standard, their water consumption rate increase according to their mode of service. For this project the water demand growth rate per annum is taken from other water supply project experience 1%.

Based on the above assumption the projected per capital water demand for each category over the expected design period is given as follow.

Table 4- 5 Projected per capital demand (l/c/d)

Demand category	Design period				
	2015	**2020**	**2025**	**2030**	**2035**
House connection	35.00	35.70	39.42	43.52	47.11
Yard	25.00	25.50	28.15	31.08	33.65
Public	22.00	22.22	23.35	24.54	25.54

Adjusted domestic demand

The domestic demand shall be factored for climatic condition and socio economic condition of specific town. The following grouping is done based on the design criteria set by pervious similar water supply projects.

A) Climatic adjustment factor

The project area climate has an impact for quantities of water consumption. The population living in hot area and less rain consume more water than living in normal climatic condition. The following table shows the climatic adjustment factor.

Table 4- 7 Climatic adjustment factor

Group	Mean annual ppt(mm)	Factor
A	600 or less	1.1
B	601-900	1.0
C	901 or more	0.9

Since the mean annual precipitation of God Husbo is 400mm, the climatic adjustment factor for this area is 1.2

B) Socio economic adjustment factor

The socio-economic activity has a role in determining the water consumption of the project town. The following table shows the Socio economic adjustment factor.

Table 4- 8 Socio economic adjustment factor

Group	Description	Factor
A	Town enjoying high living standard with very high potential for development	1.1
B	Town having a very high potential for development but lower living standard at present	1.05
C	Town under normal Ethiopian condition	1.0
D	Advanced rural town	0.9

God Husbo town is classified under towns under normal Ethiopia condition, with adjustment factor 1.0.

Table 4- 9 Adjusted per capital demand

Demand category	**Design period**				
	2015	**2020**	**2025**	**2030**	**2035**
House connection	34.65	35.34	39.02	43.08	46.63
Yard	24.75	25.25	27.87	30.77	33.31
Public	21.78	22.00	23.12	24.30	25.29

The total domestic water demand shall be equal to the adjusted per - capita water demand multiplied by their respective population growth.

4.2.2. Institutional Water Demand

Institutional water demand includes demand of Hospitals, Schools, initiative offices, etc. The demand varies with the nature, number and type of the institution centers.

Most of the time in the water supply design projects the institutional water demand is expressed as a percentage of the adjusted daily domestic water demand. Therefore, for this project 4 % is adopted for the institutional water demand throughout the design period.

4.2.3. Industrial Water Demand

Presently, in the town, there is no such big industry and no information regarding the establishment of any big industries in the near future. There is a plan to establish small - scale cottage industries (like Abattoir and veterinaries) in the coming years. Therefore, water demand estimates based on their specific water demand is taken.

4.2.4. Commercial Water Demand

Commercial water demand comprises the needs of hotels, restaurants, shops, etc. The demand depends on the nature, number of employee or visitors, etc. of the commercial unit. For design purpose in semi - urban towns, the commercial demand can be estimated as 4 % of the adjusted domestic water demand.

4.2.5 Livestock Water Demand

Livestock water demand may be required if there is no other water sources to the proximity of the town. From the information and observation made around the town there are water sources at reasonable distance for livestock water consumption so, livestock demand is not considered in the new system.

4.2.6. Water Losses (unaccounted for water)

All the water that goes in the distribution pipe does not reach the consumer. Some portion of this is wasted in the pipelines due to defective pipe joints, cracked and broken pipes, faulty valve and fittings. Some consumer keep open their taps or public taps even when they are not using the water and allow continuous wastage of water which also includes illegal connection, unlettered usages such as flushing, firefighting, cleaning the system and overflow from components of the water supply system and etc. unaccounted for water is expressed as a percentage of the total water production for the system. . For design purpose tentative value for loss as percentage in different age and different size of distribution network can be used. For this project it is taken 15%, 17%, 19%, 22%, and 25% for each target year of the total consumption

Table 4- 10 Water losses (UN – accounted for water) of the total consumption

Water Losses	Design period				
	2015	**2020**	**2025**	**2030**	**2035**
Percentage Of Total Demand	15	17	19	22	25

4.2.7. Total Water Demand

The average total demand is sum of all adjusted domestic, institutional, and commercial, livestock demand and other demands including water losses.

4.2.8. Total Average Day Demand (TADD)

It is the total annual water demand divided by 365 days. This includes all demands and their losses considered above.

4.2.9. Maximum Daily Demand

The maximum water demand is the higher of any one - day period over any specific year. The ration of the maximum daily consumption to the mean annual daily consumption is the maximum day factor. Maximum day factor usually varies from place to place and ranges from 1.2 to 1.25 of total average day demand

Table 4- 11 Daily peak factor

Population	Peak day factor
For population 0-2,000	1.25
For population 2,000-20,000	1.2

The peak day factor (PFD) for population between 2000 and 20,000 is taken as 1.2. The maximum daily demand is determined by multiplying peak day factor (PFD) by the average daily demand.

4.2.10. Peak Hour Demand, Qmax, h (PHD)

The peak hour demand is the highest demand of any one - hour over a peak day. The size of the towns, mode of services and social activities in the town usually influence the peak hour demand. Previous experience from the studies shows that the smaller the number of consumer, the higher the peak hour factors.

Table 4.2.10 Hourly peak factor

Population	Hourly Peak factor
For population 0-2,000	2.2
For population 2,000-20,000	2.0

The peak hour factor (PHF) for this project is taken as 2. The maximum hourly consumption is found by multiplying hourly factor (PHF) by the total average day demand.

4.2.11. Summary of total demand

The following table shows summary of water demand up to year 2035 for the different demand category. To design different elements of the water supply scheme, different demand conditions with respective factor such as Average day demand, maximum day demand and peak hour demand should be taken in to consideration.

Table: 4.2.11 Summary of Total Water Demands for Urban					
Year	2015	2020	2025	2030	2035
Maximum Day Demand of Urban in (m3/d)	138.92	155.59	180.87	209.44	245.66
(l/s)	1.61	1.80	2.09	2.42	2.84
Total Design Water Demand (m^3/d)	138.92	155.59	180.87	209.44	245.66
(l/s)	1.61	1.80	2.09	2.42	2.84
Table: 4.2.12 Summary of Total Water Demands for Rural Villages					
Year	2015	2020	2025	2030	2035
Maximum Day Demand of Rural Areas (m3/sec)	145.96	168.96	194.44	220.38	258.91
Lit/Sec	1.69	1.96	2.25	2.55	3.00

Total Design Water Demand (m^3/d)	145.96	168.96	194.44	220.38	258.91
Lit/Sec	1.69	1.96	2.25	2.55	3.00

5 Water Resources

Water Resource is the critical part of any water supply system that needs to be investigated thoroughly. It is important that sources of supply be capable of providing service for both the short-term and long-term demands being projected. The characteristic of the source being proposed is fundamental to its ability to provide service. Surface sources are entirely dependent upon climatic influences from year to year, spring sources are possibly less weather-dependent but still greatly influenced by precipitation levels in their recharge area, and ground water sources, (except in some instances where localized "lenses" of recharge occur), being the least dependent upon annual weather conditions.

Hence, it is important to study water resources that are viable to cover both the current and the future maximum day water requirement of the system. In selecting the source of water considerations have been given that an adequate quantity of water will be available, and that the water, which is to be delivered to the consumers, should be feasible economically and should meet the hydrologic and environmental requirements.

For Hargele Godcusbo water supply project the proposed water source is the existing Hargele and Chereti town water supply project source which is the river intake constructed on Weyib River near Chereti town.

But due to some problems this project needs some maintenance. Some of the problems and solutions required are as described below

Hargele and Chereti Town Water Supply Project Problems

Two design horizons are fixed; the years 2016 and 2026. In this design Hargele & Chereti towns were designed & constructed in the first phase, however rural villages that are found along the Chereti – Hargele transmission line were not included in estimation of initial water demands of the project area. But, during construction going at the project site some rural areas are included to have water supply schemes.

Then, rural areas like (Gebrile, Elemad, Maroges, Labo weren, Babured, Gumiasle).
Hence, the recorded population figure of Chereti and Hargele town as per the CSA count in the year 1997 is 5,967 and 5,515 respectively. The projected population for Hargele and Chereti in the 2026 is 16,659 and 18,023 respectively.

The source for Hargele town water supply project is the river intake constructed on Weyib River near Chereti town. As per the information we have collected from zone administration, District administration, Chereti and Hargele Town water supply project office representative and as per our visit the following problems are observed

- the intake (raw water) pump is not working
- Sluice gate is not working
- One of the two clear water pump is non-functional
- Diversion weir is filled with silt
- Sand from Settling basin is removed by man power and deposited near the structures.
- Hargele town Reservoir needs maintenance

Measures to Be Taken

- ⇨ complete maintenance of sluice gate
- ⇨ Removal of silt deposited on upstream apron
- ⇨ maintenance of clear water and Raw water pump
- ⇨ supply of one Loader and dump truck for the project office

- ⇨ Construction of one 300m3 Storage Reservoir for Hargele town

6. Distribution Reservoirs

Distribution reservoirs are also called service reservoirs. They are mainly provided for storing the treated water, for supplying water to the town or city. These reservoirs are provided for meeting the water demand during breakout of fires, break down of pumps, repair etc. The reservoirs avoid the hourly fluctuations in the water demand.

Functions of service reservoirs;

It stores treated water till it is distributed

- It meets variation of demand
- It meets emergency of demand as a case of fire
- It avoids continuous operation of pumps which means the pumping of water in shift is possible
- It brings economy in distribution system by reducing the size of the pumps, pipe lines & treatment units.

6.1 Types of reservoirs

6.1.1 Based on support

Surface reservoir (resting on ground):-these reservoirs are constructed on the earth by excavating to the required depth below the ground surface and are constructed when there is sufficient high ground above the distribution is available.

Elevated reservoir:-when sufficient high ground above the distribution is not available for the construction of ground reservoirs from where water can flow under gravitational force in the distribution system, elevated reservoirs are constructed.

In this specific project surface reservoir is selected for the following reasons

- ⇨ Surface reservoirs are economical than elevated reservoirs
- ⇨ Design is simple as compared to elevated tank
- ⇨ Maintenance is less

6.1.2 Based on geometry

- ⇨ Circular
- ⇨ Rectangular

In this project circular reservoir is adopted due to the following advantages

- ⇨ It is geometrically the most economical
- ⇨ It gives the least amount of walling for a given depth
- ⇨ The water pressure is evenly distributed throughout the wall

6.2 Site of Distribution Reservoir

Generally distribution reservoirs are located near the central portion of the distribution area. It is always better to construct them on high ground of city or town at such place where it can be constructed economically and also by considering the elevation of the highest building to be supplied.

It is also necessary to site the service reservoir at such elevation that a steady pressure is maintained at all points of the distribution system, together with sufficient additional pressure to enable a good flow to be maintained to those top most points.

It is, of course not always possible to find a high point, which in the center of the distribution area and the best must be done in the circumstance. For Godhusbo town water supply project the location of service reservoir is at an elevation of 1556m a.s.l.

The elevation at which it is desirable to position a service reservoir depends up on both the distance of the reservoir from the distribution area and the elevation of the highest building to be supplied. Pressure control valves are sometimes installed in inlet mains from service reservoir in order to reduce the pressure to low laying zones, or to limit increase of pressure at night to reduce leakage.

7. System Design

7.1 General

After the water is treated completely, it becomes necessary to distribute it to a number of houses, estates, industries, and public places by means of a network of distribution system. The distribution system consists of pipes of various sizes, valves, meters, pumps, distribution reservoirs etc. The pipelines carry the water to every street and road. Valves control the flow of water through the pipes. Pumps are provided to pump the water to the elevated service reservoirs or directly in the water mains to obtain the required pressure in the pipe lines. Meters are provided to measure the quantity of water consumed by individual as well as by the town.

The requirement of a good distribution system includes the following.

⇨ It should convey the treated water up to the consumers with the same degree of purity.
⇨ The water should reach to every consumer with the required pressure head and with sufficient quantity.
⇨ It should transport sufficient quantity of water during emergency such as firefighting.
⇨ It should be economical and easy to maintain and to operate

7.2 Distribution system

Water to reach every consumer with required rate of flow needs a sufficient pressure in pipelines. Depending up on the methods of distribution, the distribution system is classified as follows:

1. Gravity system
2. Pumping system
3. Dual system or combined gravity and pumping system

1. Gravity system

This system is suitable when source of supply is at sufficient height than the city. The water flows in the mains due to gravitational force .As no pumping is required, therefore it is the most reliable system for the distribution of water.

2. Pumping system

In this system, water is directly pumped from Hargele Reservoir to the main line to Godcusbo using one surface pump. Since the pumps have to work at different rates in a day, the maintenance cost increases. It is preferred to have number of pumps and only the required numbers may work at various times to meet the varying demand, in place of providing pump of variable speed. High lift pumps are required and their operations are continuously watched. If the power fails, the whole supply of the town will be stopped. Therefore, it is better to have diesel pumps also in addition to the electric pumps as stand – bye.

7.3 Types of layout of the distribution system

Depending up on their layout and direction of supply there are four different types of system exists in practice: These are;

I. Dead-end or tree-system
II. Grid iron system
III. Circular or ring system
IV. Radial system.

I) Dead-end system

In this system the direction of the water flow in all the pipes and flow rate can be readily determined.

A central tank main is which takes its supply from the storage reservoir and to which are connected a numbers of the sub-main or branches in both direction, and which have no inter-connections expect at the beginning, thus, making dead-end.

Due to no circulations in pipes lines, the unused water remains and stagnates at the dead-end of the pipeline is out and water supply has to be stopped when a pipe line is out operation due to the break down at any section or cleaning purpose. This system generally uses for small scale of water supply such as community water supply.

II) Grid-iron system

This system is most convenient for towns having rectangular layout of roads. All the dead ends are interconnected with each other and water circulates freely throughout the system. Main lines are laid along the main line road. Sub-main are takes in both the direction along other minor roads and Streets.

III) Circular or ring system

In this system each locality is division into square or circular blocks and water mains are laid around all the four sides of the square or round the circle. The branches, sub-mains are laid along the inner roads. All the sub-main and branches are taken off from the boundary main and are inter connected. In this way every point receives its supply from two directions. Sometime it is used as "LOOPED FEEDOR" & pranced centrally around a high demand area, along with the grid iron system. In such case, it increases the capacity of the grid iron system and also increases the water pressure at various points. Generally this system is more common for larger distribution system such as urban water supply with well planned locality of cities.

IV) Radial system

In this system water flows towards the outer periphery from the center radically. The entire districts divided into various zones and one reservoir provided for each zone, which is in the center of the zone.

7.4 Methods of supplying water

Water supplied to the consumers by the following systems

1) Intermittent system:

When the water available is not sufficient, the supply of water is divided in to zones and each zone is supplied with water for the fixed hours in day.

2) Continuous system:

This system is possible when there is adequate quantity of water for supply. It is the best system for which the water is supplied for all the 24 hrs. In this system ample water is always available for firefighting and due to continuous circulation water always remains fresh.

7.5 Design Pipe Line

Since flow will be turbulent in pipe used for water supply the friction deepened up on the roughness of the pipe and also up on Reynolds number, which in terms depends on the velocity in the pipe and its diameter.

Various pipe flow formula are available to predict head losses as a function of velocity in pipes, and of these;

- ⇨ Darcy-Weisbach
- ⇨ Hazen-Williams formulas, and
- ⇨ Manning formula

The Hazen- Williams and Manning formula are used in the designing of a water supply distribution system. Generally, Hazen-Williams formula for pressure conduits and Manning equation for open-channel problem, and the Darcy-Weisbach for pressure conduits.

Head Loss

Head loss using each formula is calculated as follows:

- Darcy-Weisbach formula,

$$Hf = f * L/D * V^2/2g$$

Where, Hf-Head loss in meter

F-Friction factor

L-Length of pipe in meter

V-Velocity of flow, in meter per sec.

G-Acceleration due to gravity.

- Hazen- Williams formula

$$Q = 0.278CD^{0.63}\ S^{0.54}$$

S= Hf/L & Hf= S* L

Where, C= Coefficient that depends on the material and age of the pipe given.

S= Hydraulic gradient; m/m

Q= Quantity of flow, m^3/m

D =Internal diameter of pipe

- Manning formula

$$Q = 1/n * A * R^{2/3}\ S^{1/2}$$

R= P/4 & S= Hf/L

Where, n= coefficient of roughness depending on pipe material, usually n depend on the type of material.

From these, Hazen- William's equation or formula is the commonly and mostly used in the design of water distribution.

Design Consideration

The pipe lines is designed by taking the water demand at each mode (junction) which is determined based on the following procedures,

- The total water demand computed
- The total population within the node area is computed
- The demand ratio is obtained diving 'I 'by 'II'
- Finally the modal demands are computed by multiplying the population of each node with the demand ratio.

For our case we have adopted Hazen Williams's formula for the head loss via pressure line from Hargele to Godcusbo reservoir

- Hazen- Williams formula

$$h_{fl} = 1.22*10^{10}*L*(Q/C)^{1.852}/D^{4.87}$$

Where, C= Coefficient that depends on the material and age of the pipe given=145

L= Length in m=30890m

Q= Flow in lit/sec

D =Internal diameter of pipe in mm=150mm

From the above formula we can get a head loss of 94.3m

7.6 Analysis of distribution system

The distribution system is analyzed using EPANET-2.0 SOFTWARE. The analysis is made for peak hour demand of 1.9 * average daily demand. From the analysis, the pipe network is shown on Annexes, and the velocity, head loss and other parameter shown on Annexes. The analysis is began by feeding assumed diameter of distribution pipes in to computer and the pressure, velocity and head loss are checked for peak flow. The analysis is presented in table for all conditions. The velocity should be from 0.6m/s-1.8m/s and the pressure should be from 7m-75m.

Appurtenances

The different devices required for controlling the flow of water for preventing leakage and other similar purposes in water distribution net work. These are the following.

1. Valves

Valves are required to control the flow of water, to regulate pressures, to release or to admit air, to prevent flow of water in opposite direction and other purposes.

2. Fire hydrants

These devices are used for tapping water from mains for fire extinguishing, street washing, watering gardens, and flushing sewer lines and for other purposes. These are provided at all junctions of roads and at 100 to 130 meters apart along the roads.

3. Pipe fittings

Various types of pipe fittings such as unions, caps, plugs, flanges, nipples, crosses, tees, elbows, bends etc are used during lying of distribution pipes.

4. Water meters

Meters are required to determine the quantity of water flowing through pipes and quantities of water supplied to private houses, industries, public buildings etc.

5. Service connections

A service connection is primarily a connection from the distribution system to the consumer.

6. Man holes

At every change of alignment, manholes are constructed for giving access for inspection, cleaning, repairs and maintenance.

8. Hydraulic Simulation Result

Table 8.1: Nodal Reports

Label	X (m)	Y (m)	Elevation (m)	Hydraulic Grade (m)	Pressure (m H2O)
Godcusbo	206446.59	560961.29	328.96	329.46	0.5
65.2	206386.07	560985.48	316.78	329.52	13
158.4	206297.15	561013.49	313.65	329.6	16
217.7	206240.15	561029.99	310.95	329.65	19
282.6	206175.36	561032.06	307.05	329.71	23
342.5	206115.53	561028.78	303.88	329.76	26
417.5	206040.59	561024.43	301.82	329.83	28
522.0	205943.41	561012.47	299.87	329.92	30
645.5	205817.56	560978.27	298.83	330.03	31
743.2	205722.17	560956.86	298.17	330.12	32
881.8	205587.11	560925.74	297.52	330.24	33
1006.7	205465.68	560896.77	297.46	330.35	33
1108.2	205364.55	560887.36	296.43	330.44	34
1192.7	205283.36	560910.69	296.84	330.52	34
1304.0	205186.34	560965.26	297.6	330.62	33
1413.2	205093.45	561022.59	297.6	330.71	33
1513.0	205004.62	561068.13	296.97	330.8	34

1693.9	204846.77	561156.53	294.93	330.96	36
1813.3	204742.26	561214.19	291.82	331.07	39
1940.7	204629.66	561273.76	290.94	331.18	40
2031.9	204546.01	561310.08	289.47	331.26	42
2205.5	204393.90	561393.69	285.61	331.42	46
2372.8	204240.20	561459.84	284.58	331.57	47
2606.8	204007.76	561487.25	285.82	331.77	46
2658.6	203956.20	561491.73	286.08	331.82	46
2708.1	203908.32	561504.26	286.08	331.86	46
2903.6	203714.30	561528.09	286.85	332.04	45
3013.8	203604.81	561541.39	287.28	332.14	45
3570.1	203056.71	561636.45	281.82	332.63	51
3858.9	202883.54	561867.56	273.14	332.89	60
4377.2	202538.63	562254.38	281.51	333.35	52
4653.6	202338.44	562445.03	287.5	333.59	46
4697.9	202302.55	562470.93	287.59	333.63	46
4799.5	202221.53	562532.20	284.77	333.72	49
4908.2	202125.69	562583.58	281.99	333.82	52
5085.7	201972.98	562673.90	280.05	333.97	54
5190.8	201896.79	562746.40	283.41	334.07	51
5310.3	201812.39	562830.92	287.42	334.17	47
5423.0	201751.55	562925.83	289.26	334.27	45
5789.3	201661.72	563280.89	291.98	334.6	43
5879.6	201613.40	563357.23	292.93	334.68	42
5984.6	201561.43	563448.43	294.44	334.77	40
6092.4	201506.05	563540.87	296.44	334.87	38
6224.0	201448.09	563659.07	299.23	334.98	36
6277.4	201442.60	563712.20	300.68	335.03	34
6393.9	201428.81	563827.92	300.09	335.14	35
6483.6	201466.85	563909.08	300.25	335.21	35
6513.9	201469.97	563939.22	299.87	335.24	35
6529.6	201466.14	563954.51	299.86	335.26	35
6588.0	201431.10	564001.22	300.37	335.31	35
6643.4	201383.14	564028.92	299.29	335.36	36
6684.6	201350.95	564054.57	298.96	335.39	36
6821.8	201230.72	564120.61	296.23	335.52	39
6890.2	201172.13	564155.94	294.25	335.58	41
6953.1	201119.66	564190.61	293.12	335.63	42
7023.7	201060.80	564229.68	292.17	335.69	43
7064.5	201024.84	564249.00	290.77	335.73	45
7146.8	200954.85	564292.34	291.71	335.8	44

7212.1	200900.10	564327.92	291.95	335.86	44
7285.3	200835.01	564361.34	290.33	335.93	45
7353.8	200777.46	564398.47	289.26	335.99	47
7418.0	200719.99	564427.07	287.68	336.04	48
7496.8	200646.48	564455.37	284.95	336.11	51
7589.5	200559.54	564487.55	282.35	336.2	54
7822.8	200344.84	564578.86	274.63	336.4	62
8003.4	200175.79	564642.61	272.63	336.56	64
8042.4	200150.89	564672.61	275.97	336.6	60
8072.9	200123.35	564685.68	275.71	336.63	61
8156.1	200045.00	564713.50	275.03	336.7	62
8164.3	200036.90	564712.24	274.89	336.71	62
8242.8	199966.76	564747.68	277.98	336.78	59
8391.7	199831.94	564810.70	283.4	336.91	53
8475.5	199786.28	564880.96	282.83	336.98	54
8547.0	199757.06	564946.30	280.98	337.05	56
8638.0	199721.71	565030.14	279.43	337.13	58
8783.2	199663.64	565163.21	277.3	337.26	60
8833.2	199648.78	565210.90	275.64	337.3	62
8910.6	199613.64	565279.96	278.85	337.37	58
9012.2	199573.42	565373.22	280.12	337.46	57
9116.8	199532.13	565469.33	282.19	337.55	55
9210.3	199494.05	565554.71	283.02	337.63	54
9328.2	199444.80	565661.78	284.43	337.74	53
9442.7	199399.18	565766.47	286.26	337.84	51
9556.6	199350.13	565869.27	287.87	337.94	50
9668.1	199306.63	565971.93	290.76	338.04	47
9784.9	199260.94	566079.50	293.9	338.14	44
9867.0	199217.77	566149.34	295.83	338.22	42
9956.5	199143.89	566199.74	296.86	338.3	41
10079.5	199043.55	566270.95	295.42	338.41	43
10273.8	198879.19	566374.58	296.88	338.58	42
10421.9	198758.67	566460.67	298.96	338.71	40
10556.9	198650.24	566541.02	303.14	338.83	36
10667.7	198557.17	566601.20	307.76	338.93	31
10778.9	198470.28	566670.53	312.29	339.03	27
10898.9	198377.58	566746.76	314.39	339.13	25
11129.7	198191.00	566882.69	318.17	339.34	21
11133.9	198190.42	566878.53	317.8	339.34	21
11215.9	198111.82	566901.85	313.65	339.41	26
11270.5	198059.46	566917.16	312.29	339.46	27

11334.2	197996.82	566928.73	311.53	339.52	28
11405.7	197926.90	566943.55	311.8	339.58	28
11452.4	197881.07	566952.52	312.4	339.62	27
11522.8	197812.76	566969.79	312.82	339.69	27
11587.1	197749.80	566982.68	312.8	339.74	27
11655.6	197682.63	566996.28	312.32	339.8	27
11760.6	197579.48	567015.92	310.83	339.9	29
11839.8	197502.78	567035.48	309.92	339.97	30
11925.0	197419.09	567051.44	308.71	340.04	31
12031.8	197314.46	567073.23	307.5	340.14	33
12227.9	197123.36	567117.10	304.08	340.31	36
12323.3	197048.86	567176.59	303.8	340.4	37
12357.0	197030.29	567204.81	303.46	340.43	37
12420.5	197002.94	567262.09	301.51	340.48	39
12490.0	196968.71	567322.54	298.79	340.55	42
12546.0	196945.25	567373.39	295.46	340.6	45
12568.8	196933.05	567392.65	295.09	340.62	45
12582.5	196926.14	567404.55	294.87	340.63	46
12638.2	196898.19	567452.61	294.24	340.68	46
12719.1	196858.02	567522.79	293.09	340.75	48
12786.5	196825.57	567581.86	293.36	340.81	47
12835.0	196801.16	567623.80	292.79	340.85	48
12916.4	196760.60	567694.33	293.29	340.92	48
12970.5	196733.16	567741.02	293.33	340.97	48
13030.2	196703.82	567792.93	293.39	341.02	48
13072.3	196682.61	567829.35	294.88	341.06	46
13143.7	196647.09	567891.24	295.81	341.13	45
13190.6	196623.93	567932.13	296.28	341.17	45
13254.8	196591.45	567987.44	297.47	341.22	44
13322.1	196558.00	568045.88	298.48	341.28	43
13396.2	196520.37	568109.66	299.85	341.35	41
13462.6	196487.57	568167.41	300.84	341.41	40
13504.0	196466.48	568203.02	301.49	341.45	40
13588.0	196422.95	568274.90	302.05	341.52	39
13662.7	196385.24	568339.40	303.16	341.59	38
13732.8	196350.68	568400.39	303.92	341.65	38
13796.9	196319.00	568456.06	304.24	341.71	37
13867.7	196282.56	568516.73	305.02	341.77	37
13919.0	196256.16	568560.76	304.33	341.81	37
13972.0	196229.05	568606.28	305.41	341.86	36
14107.4	196167.68	568727.02	307.43	341.98	34

14292.7	196077.94	568889.10	308.14	342.15	34
14398.4	196023.40	568979.68	308.77	342.24	33
14454.4	195997.00	569029.10	309.5	342.29	33
14612.0	195925.22	569169.36	310.66	342.43	32
14824.6	196014.91	569362.03	310.67	342.62	32
14974.3	196049.08	569507.78	311.34	342.89	31
15107.9	196081.32	569637.50	311.89	343.14	31
15233.4	196113.30	569758.87	311.92	343.37	31
15314.8	196134.07	569837.51	311.87	343.52	32
15389.3	196151.97	569909.88	311.21	343.66	32
15509.5	196176.41	570027.53	309.56	343.88	34
15589.2	196191.34	570105.86	308.21	344.03	36
15704.1	196222.92	570216.35	309.1	344.24	35
15831.2	196247.80	570340.99	309.91	344.48	34
16023.7	196298.00	570526.76	309.73	344.83	35
16123.1	196329.09	570621.18	309.48	345.01	35
16181.7	196335.27	570679.42	308.81	345.12	36
16303.6	196300.14	570796.22	306.57	345.35	39
16321.9	196282.26	570799.86	305.12	345.38	40
16398.2	196223.63	570848.70	307.54	345.52	38
16471.9	196162.07	570889.23	309.74	345.66	36
16711.3	195952.14	571004.29	314.52	346.1	32
16810.9	195852.98	571013.71	316.32	346.28	30
16920.2	195743.76	571017.07	318.09	346.49	28
17028.6	195635.27	571015.91	318.7	346.69	28
17090.5	195573.58	571019.71	318.91	346.8	28
17399.5	195264.56	571017.24	316.3	347.37	31
17516.0	195148.08	571021.04	314.57	347.59	33
17776.3	194888.13	571033.04	312.79	348.07	35
17873.3	194791.58	571023.50	312.11	348.24	36
17986.3	194679.09	571034.34	311.4	348.45	37
18109.8	194573.31	571098.09	310.23	348.68	38
18254.1	194449.46	571172.13	309.32	348.95	40
18431.7	194296.18	571261.80	308.72	349.28	40
18679.3	194082.16	571386.47	308.02	349.73	42
18854.9	193929.68	571473.37	307.53	350.06	42
18874.7	193912.23	571482.89	306.95	350.09	43
19078.3	193733.74	571580.70	307.59	350.47	43
19241.6	193592.92	571663.46	308.24	350.77	42
19413.6	193444.04	571749.56	308.38	351.09	43
19605.8	193276.56	571843.84	308.29	351.44	43

19710.2	193182.00	571888.09	308.32	351.64	43
19800.9	193103.53	571933.67	307.72	351.8	44
19906.5	193011.66	571985.65	305.7	352	46
20020.3	192915.53	572046.50	303.88	352.21	48
20100.7	192841.56	572078.09	302.56	352.36	50
20199.3	192745.95	572102.06	300.79	352.54	52
20309.9	192639.45	572132.07	299.48	352.74	53
20384.9	192567.06	572151.49	299.06	352.88	54
20486.0	192469.83	572179.43	298.72	353.07	54
20626.4	192335.15	572219.09	298.1	353.33	55
20695.4	192276.86	572255.95	297.53	353.45	56
20900.7	192123.87	572392.91	296.46	353.83	57
21008.1	192043.89	572464.56	294.71	354.03	59
21071.0	191998.06	572507.63	293.22	354.15	61
21301.8	191834.15	572670.19	295.53	354.87	59
21347.7	191800.72	572701.61	295.48	355.01	59
21417.5	191756.05	572755.23	294.42	355.23	61
21508.0	191737.73	572843.88	294.77	355.51	61
21622.6	191731.95	572958.26	296.47	355.87	59
21713.7	191730.80	573049.41	297.79	356.15	58
21809.0	191713.73	573143.13	299.1	356.45	57
21904.4	191674.69	573230.22	300.35	356.74	56
22010.7	191622.63	573322.92	301.79	357.08	55
22102.8	191576.71	573402.73	302.85	357.36	54
22227.5	191517.27	573512.34	304.35	357.75	53
22335.3	191465.80	573607.05	305.61	358.09	52
22520.3	191378.08	573769.98	307.72	358.66	51
22588.8	191344.08	573829.38	308.45	358.88	50
22703.7	191288.69	573930.09	309.58	359.24	50
23003.2	191141.54	574190.94	311.07	360.17	49
23120.4	191087.54	574294.97	310.48	360.53	50
23219.8	191037.54	574380.91	310.06	360.84	51
23320.0	190989.98	574469.04	308.88	361.16	52
23445.9	190929.50	574579.48	307.15	361.55	54
23543.3	190881.98	574664.43	306.01	361.85	56
23723.2	190788.69	574818.32	303.48	362.41	59
23823.6	190715.69	574887.31	302.49	362.72	60
23972.9	190596.81	574977.56	300.88	363.19	62
24068.0	190517.01	575029.25	299.86	363.49	63
24158.0	190440.41	575076.54	298.64	363.77	65
24249.2	190365.71	575128.81	298.17	364.05	66

24331.5	190300.88	575179.52	299.41	364.31	65
24430.6	190218.73	575234.99	299.34	364.62	65
24533.8	190132.65	575291.90	298.31	364.94	66
24619.5	190062.01	575340.35	297.76	365.2	67
24687.4	190006.41	575379.31	297.12	365.42	68
24859.4	189854.06	575459.36	296.4	365.95	69
25015.9	189726.64	575550.18	297.7	366.44	69
25118.1	189640.99	575605.95	297.6	366.76	69
25244.8	189535.16	575675.61	297.97	367.15	69
25333.6	189468.57	575734.38	299.91	367.43	67
25442.4	189377.33	575793.11	299.77	367.77	68
25547.0	189290.31	575851.22	300.56	368.09	67
25702.3	189160.27	575936.16	301.95	368.58	66
25806.9	189075.05	575996.80	303.48	368.9	65
25858.9	189027.32	576017.48	304.27	369.06	65
25964.0	188937.87	576072.67	305.19	369.39	64
26026.0	188889.01	576110.85	305.78	369.59	64
26052.5	188872.49	576131.49	306.15	369.67	63
26119.0	188842.04	576190.57	306.62	369.87	63
26176.2	188819.17	576243.07	306.76	370.05	63
26246.2	188781.16	576301.88	307.23	370.27	63
26323.4	188771.73	576378.42	307.81	370.51	63
26372.6	188801.73	576417.50	308.1	370.67	62
26458.2	188795.30	576502.84	308.67	370.93	62
26484.5	188797.60	576528.99	308.77	371.01	62
26546.8	188824.95	576585.01	309.01	371.21	62
26654.6	188869.06	576683.41	309.83	371.54	62
26769.4	188916.39	576787.99	310.21	371.9	62
26868.9	188955.73	576879.40	310	372.21	62
26970.4	188970.95	576979.76	310.1	372.53	62
27052.6	188929.53	577050.71	310.64	372.78	62
27134.9	188883.97	577119.21	310.34	373.04	63
27221.8	188845.69	577197.24	309.14	373.31	64
27316.7	188800.72	577280.86	309.39	373.61	64
27398.3	188768.17	577355.66	309.09	373.86	65
27615.7	188639.47	577530.89	306.8	374.54	68
27709.8	188549.75	577559.06	305.55	374.83	69
27785.7	188474.96	577572.23	304.17	375.07	71
27890.8	188373.93	577601.34	301.26	375.4	74
28073.5	188195.76	577641.46	296.55	375.96	79
28241.1	188031.89	577676.81	294.52	376.49	82

28383.7	187901.66	577735.03	294.57	376.93	82
28445.6	187849.85	577768.80	294.35	377.12	83
28546.8	187753.12	577798.70	293.59	377.44	84
CT1	205165.30	560641.22	297.81	314.07	16
CT2	205251.80	561082.91	301.63	315.57	14
CT3	196195.75	569394.23	309.9	341.95	32
CT4	195863.19	569299.86	309.7	341.92	32
CT5	192177.29	572519.82	292.05	353.42	61
CT6	191795.69	572391.67	292	353.31	61
J1	206153.96	560942.28	301.26	326.26	25
J2	205781.30	560911.16	301.73	316.94	15
J3	205642.10	560849.03	300.99	315.8	15
J4	205749.27	560987.49	298.98	316.7	18
WP1	206104.56	561135.43	301.01	325.51	24
WP2	205949.12	560927.70	298	320.7	23
WP3	205838.90	560854.18	302.02	316.64	15
WP4	205819.71	561006.04	298.83	316.43	18
WP5	205700.13	560712.41	300.47	315.24	15
WP6	205573.58	560901.09	299.29	315.47	16
WP7	205393.07	560701.36	297.5	314.95	17
WP8	205204.94	560924.12	298.01	313.86	16
WP9	205420.55	561019.42	298.48	316.25	18
WP10	196143.24	569315.08	315.83	342.39	26
WP11	195928.64	569397.27	312.59	342.46	30
WP12	192088.16	572589.95	299.86	353.94	54
WP13	191936.89	572443.69	300.98	354	53

Table 8.2: Link Reports

Label	Length(m)	Start Node	Stop Node	Diam (mm)	Material	C	Vel (m/s)	Flow (L/s)
P-521	105	27890.83	27785.7	150	uPVC	145	0.69	12
P-520	76	27785.7	27709.75	150	uPVC	145	0.69	12
P-519	126	15107.93	15233.44	150	uPVC	145	0.52	-9
P-518	134	15107.93	14974.26	150	uPVC	145	0.52	9
P-517	59	16123.08	16181.65	150	uPVC	145	0.52	-9
P-516	99	16023.68	16123.08	150	uPVC	145	0.52	-9
P-515	47	13190.65	13143.66	150	uPVC	145	0.35	6
P-514	71	13143.66	13072.3	150	uPVC	145	0.35	6
P-513	34	12357.03	12323.26	150	uPVC	145	0.35	6
P-512	95	12323.26	12227.91	150	uPVC	145	0.35	6
P-511	174	2205.454	2031.878	150	uPVC	145	0.35	6
P-510	91	2031.878	1940.682	150	uPVC	145	0.35	6
P-509	65	7212.144	7146.846	150	uPVC	145	0.35	6
P-508	82	7146.846	7064.526	150	uPVC	145	0.35	6
P-507	64	11334.18	11270.49	150	uPVC	145	0.35	6
P-506	55	11270.49	11215.93	150	uPVC	145	0.35	6
P-505	8	8164.255	8156.064	150	uPVC	145	0.35	6
P-504	83	8156.064	8072.921	150	uPVC	145	0.35	6
P-503	91	8638.017	8547.038	150	uPVC	145	0.35	6
P-502	72	8547.038	8475.455	150	uPVC	145	0.35	6
P-501	117	9784.944	9668.07	150	uPVC	145	0.35	6
P-500	111	9668.07	9556.572	150	uPVC	145	0.35	6
P-499	53	13971.98	13918.99	150	uPVC	145	0.35	6
P-498	51	13918.99	13867.66	150	uPVC	145	0.35	6
P-497	95	23972.91	24067.99	150	uPVC	145	0.69	-12
P-496	149	23823.65	23972.91	150	uPVC	145	0.69	-12
P-495	113	5423.03	5310.292	150	uPVC	145	0.35	6
P-494	119	5310.292	5190.846	150	uPVC	145	0.35	6
P-493	68	7353.798	7285.312	150	uPVC	145	0.35	6
P-492	73	7212.144	7285.312	150	uPVC	145	0.35	-6
P-491	52	25806.92	25858.93	150	uPVC	145	0.69	-12
P-490	105	25702.32	25806.92	150	uPVC	145	0.69	-12
P-489	91	19710.18	19800.93	150	uPVC	145	0.52	-9
P-488	104	19605.78	19710.18	150	uPVC	145	0.52	-9
P-487	74	13396.18	13322.14	150	uPVC	145	0.35	6

P-486	67	13322.14	13254.79	150	uPVC	145	0.35	6
P-485	49	2708.078	2658.584	150	uPVC	145	0.35	6
P-484	52	2658.584	2606.832	150	uPVC	145	0.35	6
P-483	105	9116.811	9012.208	150	uPVC	145	0.35	6
P-482	102	9012.208	8910.645	150	uPVC	145	0.35	6
P-481	114	9556.572	9442.672	150	uPVC	145	0.35	6
P-480	114	9442.672	9328.157	150	uPVC	145	0.35	6
P-479	50	8833.165	8783.207	150	uPVC	145	0.35	6
P-478	145	8783.207	8638.017	150	uPVC	145	0.35	6
P-477	60	13030.15	12970.53	150	uPVC	145	0.35	6
P-476	54	12970.53	12916.37	150	uPVC	145	0.35	6
P-475	64	11587.08	11522.81	150	uPVC	145	0.35	6
P-474	70	11522.81	11452.36	150	uPVC	145	0.35	6
P-473	115	22588.78	22703.71	150	uPVC	145	0.69	-12
P-472	68	22520.33	22588.78	150	uPVC	145	0.69	-12
P-471	58	6588.034	6529.636	150	uPVC	145	0.35	6
P-470	16	6529.636	6513.879	150	uPVC	145	0.35	6
P-469	135	14107.42	13971.98	150	uPVC	145	0.35	6
P-467	99	24331.48	24430.6	150	uPVC	145	0.69	-12
P-466	82	24249.17	24331.48	150	uPVC	145	0.69	-12
P-465	67	12786.49	12719.09	150	uPVC	145	0.35	6
P-464	81	12719.09	12638.22	150	uPVC	145	0.35	6
P-463	74	16398.18	16471.88	150	uPVC	145	0.52	-9
P-462	76	16321.87	16398.18	150	uPVC	145	0.52	-9
P-461	105	5984.585	5879.618	150	uPVC	145	0.35	6
P-460	90	5879.618	5789.279	150	uPVC	145	0.35	6
P-459	70	13732.83	13662.73	150	uPVC	145	0.35	6
P-458	75	13662.73	13588.01	150	uPVC	145	0.35	6
P-457	68	6890.163	6821.75	150	uPVC	145	0.35	6
P-456	137	6821.75	6684.579	150	uPVC	145	0.35	6
P-454	84	13588.01	13503.99	150	uPVC	145	0.35	6
P-453	127	1940.682	1813.292	150	uPVC	145	0.35	6
P-452	119	1813.292	1693.937	150	uPVC	145	0.35	6
P-451	123	10079.52	9956.481	150	uPVC	145	0.35	6
P-450	89	9956.481	9867.049	150	uPVC	145	0.35	6
P-449	126	23319.99	23445.91	150	uPVC	145	0.69	-12
P-448	100	23219.85	23319.99	150	uPVC	145	0.69	-12
P-447	70	21347.72	21417.51	150	uPVC	145	0.69	-12
P-446	46	21301.84	21347.72	150	uPVC	145	0.69	-12
P-445	79	8242.847	8164.255	150	uPVC	145	0.35	6
P-443	91	21622.56	21713.72	150	uPVC	145	0.69	-12

P-442	115	21508.03	21622.56	150	uPVC	145	0.69	-12
P-441	111	10778.88	10667.72	150	uPVC	145	0.35	6
P-440	111	10667.72	10556.9	150	uPVC	145	0.35	6
P-438	91	24158	24249.17	150	uPVC	145	0.69	-12
P-437	59	217.7357	158.3979	150	uPVC	145	0.35	6
P-436	93	158.3979	65.16904	150	uPVC	145	0.35	6
P-435	53	6277.405	6223.991	150	uPVC	145	0.35	6
P-434	132	6223.991	6092.35	150	uPVC	145	0.35	6
P-432	30	8072.921	8042.433	150	uPVC	145	0.35	6
P-431	65	282.5648	217.7357	150	uPVC	145	0.35	6
P-428	231	21070.99	21301.84	150	uPVC	145	0.69	-12
P-427	192	19413.59	19605.78	150	uPVC	145	0.52	-9
P-426	172	19241.6	19413.59	150	uPVC	145	0.52	-9
P-425	110	3013.846	2903.554	150	uPVC	145	0.35	6
P-424	195	2903.554	2708.078	150	uPVC	145	0.35	6
P-423	75	15314.78	15389.33	150	uPVC	145	0.52	-9
P-422	81	15233.44	15314.78	150	uPVC	145	0.52	-9
P-421	109	4908.207	4799.463	150	uPVC	145	0.35	6
P-420	102	4799.463	4697.888	150	uPVC	145	0.35	6
P-419	20	18854.85	18874.73	150	uPVC	145	0.52	-9
P-418	176	18679.35	18854.85	150	uPVC	145	0.52	-9
P-417	181	8003.446	7822.781	150	uPVC	145	0.35	6
P-416	233	7822.781	7589.466	150	uPVC	145	0.35	6
P-415	71	13867.66	13796.89	150	uPVC	145	0.35	6
P-414	64	13796.89	13732.83	150	uPVC	145	0.35	6
P-413	366	5789.279	5423.03	150	uPVC	145	0.35	6
P-411	127	15704.15	15831.24	150	uPVC	145	0.52	-9
P-410	115	15589.23	15704.15	150	uPVC	145	0.52	-9
P-409	114	19906.48	20020.26	150	uPVC	145	0.52	-9
P-408	106	19800.93	19906.48	150	uPVC	145	0.52	-9
P-407	309	17090.46	17399.48	150	uPVC	145	0.52	-9
P-406	62	17028.65	17090.46	150	uPVC	145	0.52	-9
P-405	115	26654.63	26769.43	150	uPVC	145	0.69	-12
P-404	108	26546.8	26654.63	150	uPVC	145	0.69	-12
P-403	41	7064.526	7023.701	150	uPVC	145	0.35	6
P-402	71	7023.701	6953.055	150	uPVC	145	0.35	6
P-401	108	16920.15	17028.65	150	uPVC	145	0.52	-9
P-400	109	16810.88	16920.15	150	uPVC	145	0.52	-9
P-399	95	21713.72	21808.98	150	uPVC	145	0.69	-12
P-397	205	20695.39	20900.72	150	uPVC	145	0.52	-9
P-396	69	20626.41	20695.39	150	uPVC	145	0.52	-9

P-394	44	4697.888	4653.627	150	uPVC	145	0.35	6
P-392	63	6953.055	6890.163	150	uPVC	145	0.35	6
P-391	68	24619.46	24687.35	150	uPVC	145	0.69	-12
P-390	86	24533.8	24619.46	150	uPVC	145	0.69	-12
P-389	125	22102.81	22227.5	150	uPVC	145	0.69	-12
P-388	92	22010.73	22102.81	150	uPVC	145	0.69	-12
P-387	71	11405.66	11334.18	150	uPVC	145	0.35	6
P-385	30	6513.879	6483.576	150	uPVC	145	0.35	6
P-384	90	6483.576	6393.944	150	uPVC	145	0.35	6
P-383	63	12420.52	12357.03	150	uPVC	145	0.35	6
P-379	55	6643.417	6588.034	150	uPVC	145	0.35	6
P-377	69	11655.62	11587.08	150	uPVC	145	0.35	6
P-375	556	3570.133	3013.846	150	uPVC	145	0.35	6
P-372	117	6393.944	6277.405	150	uPVC	145	0.35	6
P-371	120	10898.9	10778.88	150	uPVC	145	0.35	6
P-369	98	521.9708	417.5449	150	uPVC	145	0.35	6
P-368	75	417.5449	342.4796	150	uPVC	145	0.35	6
P-367	143	28383.75	28241.1	150	uPVC	145	0.69	12
P-366	168	28241.1	28073.46	150	uPVC	145	0.69	12
P-365	107	12031.84	11924.97	150	uPVC	145	0.35	6
P-364	85	11924.97	11839.77	150	uPVC	145	0.35	6
P-362	106	21904.42	22010.73	150	uPVC	145	0.69	-12
P-360	63	21008.1	21070.99	150	uPVC	145	0.52	-9
P-359	139	881.844	743.2455	150	uPVC	145	0.35	6
P-358	98	743.2455	645.4758	150	uPVC	145	0.35	6
P-357	100	26769.43	26868.94	150	uPVC	145	0.69	-12
P-355	100	1513.021	1413.198	150	uPVC	145	0.35	6
P-354	109	1413.198	1304.032	150	uPVC	145	0.35	6
P-353	107	20900.72	21008.1	150	uPVC	145	0.52	-9
P-348	234	2606.832	2372.778	150	uPVC	145	0.35	6
P-347	105	11760.62	11655.62	150	uPVC	145	0.35	6
P-345	99	20100.69	20199.26	150	uPVC	145	0.52	-9
P-344	80	20020.26	20100.69	150	uPVC	145	0.52	-9
P-342	140	20486.02	20626.41	150	uPVC	145	0.52	-9
P-341	149	8391.664	8242.847	150	uPVC	145	0.35	6
P-339	163	19078.26	19241.6	150	uPVC	145	0.52	-9
P-338	204	18874.73	19078.26	150	uPVC	145	0.52	-9
P-337	144	18109.79	18254.08	150	uPVC	145	0.52	-9
P-336	124	17986.28	18109.79	150	uPVC	145	0.52	-9
P-334	111	1304.032	1192.724	150	uPVC	145	0.35	6
P-333	56	14454.45	14398.42	150	uPVC	145	0.35	6

P-332	106	14398.42	14292.69	150	uPVC	145	0.35	6
P-331	79	7496.76	7417.994	150	uPVC	145	0.35	6
P-330	64	7417.994	7353.798	150	uPVC	145	0.35	6
P-328	18	16303.62	16321.87	150	uPVC	145	0.52	-9
P-326	94	27709.75	27615.71	150	uPVC	145	0.69	12
P-325	56	12638.22	12582.54	150	uPVC	145	0.35	6
P-324	14	12582.54	12568.78	150	uPVC	145	0.35	6
P-323	23	12568.78	12545.98	150	uPVC	145	0.35	6
P-322	56	12545.98	12489.98	150	uPVC	145	0.35	6
P-320	113	17873.27	17986.28	150	uPVC	145	0.52	-9
P-317	69	12489.98	12420.52	150	uPVC	145	0.35	6
P-315	127	25118.13	25244.83	150	uPVC	145	0.69	-12
P-314	102	25015.92	25118.13	150	uPVC	145	0.69	-12
P-313	299	22703.71	23003.21	150	uPVC	145	0.69	-12
P-311	49	26323.35	26372.62	150	uPVC	145	0.69	-12
P-310	77	26246.24	26323.35	150	uPVC	145	0.69	-12
P-305	66	26052.49	26118.95	150	uPVC	145	0.69	-12
P-304	26	26026.04	26052.49	150	uPVC	145	0.69	-12
P-303	122	16181.65	16303.62	150	uPVC	145	0.52	-9
P-300	100	23723.21	23823.65	150	uPVC	145	0.69	-12
P-299	150	14974.26	14824.56	150	uPVC	145	0.52	9
P-298	213	14824.56	14612	150	uPVC	145	0.35	6
P-297	156	24859.44	25015.92	150	uPVC	145	0.69	-12
P-296	172	24687.35	24859.44	150	uPVC	145	0.69	-12
P-295	101	26868.94	26970.44	150	uPVC	145	0.69	-12
P-292	105	5190.846	5085.675	150	uPVC	145	0.35	6
P-286	41	13503.99	13462.6	150	uPVC	145	0.35	6
P-285	178	18254.08	18431.67	150	uPVC	145	0.52	-9
P-283	167	2372.778	2205.454	150	uPVC	145	0.35	6
P-281	77	8910.645	8833.165	150	uPVC	145	0.35	6
P-279	47	11452.36	11405.66	150	uPVC	145	0.35	6
P-275	101	20384.85	20486.02	150	uPVC	145	0.52	-9
P-274	75	20309.9	20384.85	150	uPVC	145	0.52	-9
P-273	120	15389.33	15509.49	150	uPVC	145	0.52	-9
P-271	518	4377.178	3858.918	150	uPVC	145	0.35	6
P-270	289	3858.918	3570.133	150	uPVC	145	0.35	6
P-269	64	13254.79	13190.65	150	uPVC	145	0.35	6
P-267	217	27615.71	27398.3	150	uPVC	145	0.69	12
P-266	82	27316.72	27398.3	150	uPVC	145	0.69	-12
P-265	118	9328.157	9210.294	150	uPVC	145	0.35	6
P-264	93	9210.294	9116.811	150	uPVC	145	0.35	6

P-262	93	7589.466	7496.76	150	uPVC	145	0.35	6
P-257	130	645.4758	521.9708	150	uPVC	145	0.35	6
P-254	39	8042.433	8003.446	150	uPVC	145	0.35	6
P-251	181	1693.937	1513.021	150	uPVC	145	0.35	6
P-250	185	14292.69	14107.42	150	uPVC	145	0.35	6
P-245	248	18431.67	18679.35	150	uPVC	145	0.52	-9
P-243	99	23120.42	23219.85	150	uPVC	145	0.69	-12
P-240	102	1108.242	1006.679	150	uPVC	145	0.35	6
P-239	125	1006.679	881.844	150	uPVC	145	0.35	6
P-238	103	24430.6	24533.8	150	uPVC	145	0.69	-12
P-235	95	21808.98	21904.42	150	uPVC	145	0.69	-12
P-234	260	17516.02	17776.26	150	uPVC	145	0.52	-9
P-233	117	17399.48	17516.02	150	uPVC	145	0.52	-9
P-232	185	22335.29	22520.33	150	uPVC	145	0.69	-12
P-231	108	22227.5	22335.29	150	uPVC	145	0.69	-12
P-230	101	28546.84	28445.6	150	uPVC	145	0.69	12
P-229	62	28445.6	28383.75	150	uPVC	145	0.69	12
P-228	70	26176.21	26246.24	150	uPVC	145	0.69	-12
P-227	57	26118.95	26176.21	150	uPVC	145	0.69	-12
P-225	155	25547	25702.32	150	uPVC	145	0.69	-12
P-224	95	27221.78	27316.72	150	uPVC	145	0.69	-12
P-223	87	27134.87	27221.78	150	uPVC	145	0.69	-12
P-221	62	26484.46	26546.8	150	uPVC	145	0.69	-12
P-220	105	25858.93	25964.04	150	uPVC	145	0.69	-12
P-215	192	15831.24	16023.68	150	uPVC	145	0.52	-9
P-213	97	17776.26	17873.27	150	uPVC	145	0.52	-9
P-207	66	13462.6	13396.18	150	uPVC	145	0.35	6
P-205	108	6092.35	5984.585	150	uPVC	145	0.35	6
P-202	80	15509.49	15589.23	150	uPVC	145	0.52	-9
P-194	100	16711.27	16810.88	150	uPVC	145	0.52	-9
P-193	239	16471.88	16711.27	150	uPVC	145	0.52	-9
P-192	4	11133.94	11129.75	150	uPVC	145	0.35	6
P-191	231	11129.75	10898.9	150	uPVC	145	0.35	6
P-188	49	12835.01	12786.49	150	uPVC	145	0.35	6
P-183	180	23543.25	23723.21	150	uPVC	145	0.69	-12
P-182	276	4653.627	4377.178	150	uPVC	145	0.35	6
P-180	117	23003.21	23120.42	150	uPVC	145	0.69	-12
P-172	91	21417.51	21508.03	150	uPVC	145	0.69	-12
P-170	111	20199.26	20309.9	150	uPVC	145	0.52	-9
P-168	86	26372.62	26458.21	150	uPVC	145	0.69	-12
P-164	79	11839.77	11760.62	150	uPVC	145	0.35	6

P-161	135	10556.9	10421.94	150	uPVC	145	0.35	6
P-159	158	14612	14454.45	150	uPVC	145	0.35	6
P-155	62	25964.04	26026.04	150	uPVC	145	0.69	-12
P-153	60	342.4796	282.5648	150	uPVC	145	0.35	6
P-150	42	13072.3	13030.15	150	uPVC	145	0.35	6
P-149	194	10273.82	10079.52	150	uPVC	145	0.35	6
P-144	90	24067.99	24158	150	uPVC	145	0.69	-12
P-139	148	10421.94	10273.82	150	uPVC	145	0.35	6
P-134	84	1192.724	1108.242	150	uPVC	145	0.35	6
P-131	82	11215.93	11133.94	150	uPVC	145	0.35	6
P-129	81	12916.37	12835.01	150	uPVC	145	0.35	6
P-126	196	12227.91	12031.84	150	uPVC	145	0.35	6
P-123	84	8475.455	8391.664	150	uPVC	145	0.35	6
P-120	82	9867.049	9784.944	150	uPVC	145	0.35	6
P-117	105	25442.36	25547	150	uPVC	145	0.69	-12
P-112	183	28073.46	27890.83	150	uPVC	145	0.69	12
P-107	97	23445.91	23543.25	150	uPVC	145	0.69	-12
P-102	82	27052.6	27134.87	150	uPVC	145	0.69	-12
P-84	177	5085.675	4908.207	150	uPVC	145	0.35	6
P-81	26	26458.21	26484.46	150	uPVC	145	0.69	-12
P-64	65	65.16904	Godcusbo	150	uPVC	145	0.35	6
P-47	89	25244.83	25333.64	150	uPVC	145	0.69	-12
P-42	109	25333.64	25442.36	150	uPVC	145	0.69	-12
P-25	82	26970.44	27052.6	150	uPVC	145	0.69	-12
P-24	41	6684.579	6643.417	150	uPVC	145	0.35	6
P-22	2,350	PMP-1	28546.84	150	uPVC	145	0.69	12
P-21	2	R-1	PMP-1	150	uPVC	145	0.69	12
P-20	199	J1	WP1	50	uPVC	145	0.38	1
P-19	205	J1	WP2	80	uPVC	145	1.49	7
P-18	293	Godcusbo	J1	100	uPVC	145	1.05	8
P-17	292	WP7	WP8	50	uPVC	145	0.38	1
P-16	180	WP9	CT2	50	uPVC	145	0.38	1
P-15	330	J4	WP9	80	uPVC	145	0.3	1
P-14	73	J4	WP4	50	uPVC	145	0.38	1
P-13	83	J2	J4	80	uPVC	145	0.45	2
P-12	81	J2	WP3	50	uPVC	145	0.38	1
P-11	86	J3	WP6	50	uPVC	145	0.38	1
P-10	148	J3	WP5	50	uPVC	145	0.38	1
P-9	236	WP7	CT1	50	uPVC	145	0.38	1
P-8	150	WP13	CT6	50	uPVC	145	0.38	1
P-8	290	J3	WP7	80	uPVC	145	0.45	2

P-7	88	21070.99	WP13	80	uPVC	145	0.3	1
P-7	152	J2	J3	80	uPVC	145	0.75	4
P-6	113	WP12	CT5	50	uPVC	145	0.38	1
P-6	169	WP2	J2	80	uPVC	145	1.34	7
P-5	122	21070.99	WP12	80	uPVC	145	0.3	1
P-4	117	WP11	CT4	50	uPVC	145	0.38	1
P-3	93	14824.56	WP11	80	uPVC	145	0.3	1
P-2	95	WP10	CT3	50	uPVC	145	0.38	1
P-1	137	14824.56	WP10	80	uPVC	145	0.3	1

9. Cost Estimation

In every construction project cost estimation plays a vital role by

- ⇨ Providing financial guidelines for making preliminary decisions on water supply schemes
- ⇨ Officials to check whether cost estimates are allowing reasonable.
- ⇨ Assessing the general level of capital and recurrent costs as a tool for planning.

By taking consideration the present cost of materials the Godhusbo water supply cost estimation done as follows.

Table 9.1.Total cost summary

Part	Description	Quan	Amount Birr
1	General Items		2,900,000.00
2	Supply Of Pipes		11,233,745.30
3	Construction Of Transmission Main		7,637,245.49
4	Construction Of 100 M3reservoir Rcc (#1)	1	747,639.05
5	Construction Of 300 M3reservoir Rcc (#1)	1	2,926,662.17
6	Construction Of Cattle Troughs (#5)	5	388,992.83
7	Construction Of Public Fountains (#10)	10	904,023.47
8	Construction Of Latrine(#5)	5	226,538.81
9	Construction Of Generator House(#1)	1	513,105.78

10	Supply and Installation of Pump & Generator(#2)	2	1,000,000.00
	Total		**28,477,952.90**
	15% VAT		**4,271,692.93**
	Contingency 6%		**1,708,677.17**
	Grand Total Project Cost (Birr)		**34,458,323.00**