Prince Mohammad Bin Fahd University
College of Engineering

Department of Civil Engineering

Senior Design Project (ASSE III)

Fall 2017/2018

The Design of Distribution Network for Water Supply System at Al Rakah in Al Khobar City

Presented by

Abdullah Aldali 201201721

Abdulrhman Kojan 201201952

Supervised by

Dr. Saidur Chowdhury

Date: March 18, 2018

Acknowledgment

We would like to express our profound appreciation to our supervisor, Dr. Saidur Chowdhury, for his continuous and enthusiastic guidance and encouragement as well as his invaluable advice and patient throughout this research work particularly and other works generally. In addition, a special thanks to Dr Andi Asiz for his support, motivation, and immense knowledge.

We would like to express our deep appreciation to the civil engineering department including all faculty, secretary, and lab technicians for giving us this opportunity to complete our bachelor degree in civil engineering. We cannot imagine a better university than PMU from which we can complete our degree.

Special and harmful thanks and appreciation for our families for supporting us to study at PMU and overcome all difficulties we faced during the study period.

Abstract

Water distribution system is vitally important not only to maintain the health of the community but also for the sustainability of industry, business and agriculture. This project includes the background study of water distribution system with brief description of all components. In this design project, looped network system has been considered for the distribution of water to the residential area located at South Al Rakah in AL Khobar city. The design was performed using the energy equation or Bernoulli equation. The energy equations determined the pressure, velocity, and flow into the pipe network. Darcy-Weisbach equation was also applied to find out approximate flow into the pipe. All necessary data were collected from the city of Al khobar water department. In this project, WaterCad and WaterGEMS softwares was used to calculate the design parameters and compared results to the design parameters found from manual calculations. The constraints for this project were also carefully verified and project limitation was identified. The results indicated that the difference in total energy at different project location was due to the head losses.

Table of Content

List of Figures

List of Tables

Chapter 1 Introduction

1.1 General

The water supply industry is vitally important not only to maintain the health of the community, but for the sustainability of industry, business and agriculture. Without adequate water supplies our present society would never have evolved, and our lives today would be unrecognizable. Our dependence on treated water is now incalculable, and threats to that supply are comparable to the worst natural and man-made disasters. The volumes of water consumed each day by agriculture, industry and the public are vast, requiring an enormous infrastructure to satisfy the demand. Like the other service providers, electricity, telephone and gas, the water utilities deliver their product to the home, which requires a network of distribution pipes to service each household, but unlike the other utilities these are standalone local or regional networks, rather than integrated national supply networks (Burlingame and Anselme 1995).

Water distribution systems convey water drawn from the water source or treatment facility, to the point where it is delivered to the users. These systems deal with water demand that varies considerably in the course of a day. Water consumption is highest during the hours that water is used for personal hygiene and cleaning, and when food preparation and clothes washing are done. Water use is lowest during the night. This variation in flow can be dealt with by operating pumps in parallel and/or building balancing storage in the system. For small community water supplies the distribution system with water storage (e.g. a service reservoir) is the preferable option, given that supplies of electricity or diesel to power pumps will usually be unreliable. Although it can be kept simple, construction of such a system may represent a substantial capital investment and the design must be done properly. Generally, the distribution system of a small community water supply is designed to cater for the domestic and other household water requirements (Burlingame and Anselme 1995). In water supply system, service reservoirs accumulate and store water during the night so that it can be supplied during the daytime hours of high water demand. It is necessary to maintain sufficient pressure in the distribution system to protect it against contamination by the ingress of polluted seepage water. For small community supplies a minimum pressure of 5-10 mwc (meters of water column) should be adequate in most instances (According to Saudi Building Code). Water Supply System (WSS) generally consists of few parts that are sources, treatment, storage and distribution. In this design process, only distribution system was designed for newly developed residential area. The looped network distribution systems were proposed for the WSS at Al Rakah in Al-Khobar. There are basically two main layouts of a distribution network: Branched configuration, Looped (or grid) configuration. Branched networks are predominantly used for small-capacity community supplies delivering the water mostly through public standpipes and having few house connections, if any. Although adequate, having in mind simplicity and acceptable investment costs, branched networks have some disadvantages:

- Low reliability, which affects all users located downstream of any breakdown in the system
- Danger of contamination caused by the possibility that a large part of network will be without water during irregular situations
- Accumulation of sediments, due to stagnation of the water at the system ends ("dead" ends) occasionally resulting in taste and odour problems
- Fluctuating water demand producing rather large pressure variations

In looped distribution networks, where consumers can be supplied from more than one direction. Looped networks greatly improve the hydraulics of the distribution system. This is of major importance in the event that one of the mains is out of operation for cleaning or repair.

A looped network usually has a skeleton of secondary mains that can also be in a form of branch, one loop ('ring'), or a number of loops. From there, water is conveyed towards the distribution pipes and further to the consumers. The secondary mains are connected to one or more loops or rings.

The responsibility of the water supply system of Dammam, Al-khobar, and Dhahran Cities is divided between the Ministry of Water and Electricity (MWE), General directorate of water in the eastern province and saline water conversion corporation (SWCC). The most water distribution system in Dammam, Al-khobar, and Dhahran Cities are looped network system and it consists of source, reservoir, main, and sub-main pipes. Based on pros and cons of the two network systems, looped distribution network was selected in this project to design the WSS system for the project site. The study included the analyses and design of the water distribution system in Al Khobar city.

1.2 Objectives of the Project

The main objective of this project is to design the looped network for water supply distribution system. This objective requires to satisfy the following conditions: (a) to supply safe and wholesome water to the users, whether these constitute a family, a group of families, or a community; (b) to supply water in adequate quantity; and (c) to make water readily available to the users, in order to encourage personal and household hygiene.

1.3 Organization of the Report

The report includes all work and information related to the conceptualized design of distribution network for water supply system at Al Rakah in Al Khobar.

Chapter one includes the general discussion and the objective of the project. Chapter two highlights the constraint and applicable standard for the project. In Chapter three, background of the WSS are divided into different specific parts: water source, storage tanks, main and sub-main pipes, water distribution systems, water demand, discharge and head losses.

The methodology of this study mentions in the chapter four and is divided into three main parts which are design area, water demand, design and calculation.

Chapter five and six include the design of water supply system and conclusions, respectively. The complete calculations are shown in the appendix.

Chapter 2 Project Constraints and Applicable Standard for the Project

a) Major design constraints for pure water supply

1) Physical and Technical Constraints

Our project site is located at the difficult project sites (e.g. the South Al Rakah in Al-Khobar). It is located in a residential area with no proper water supply facilities. We have established this project to design the distribution system for water supply (in the near future)and the supply would be for newly developed residential area. Because of lack of some technical information, (e.g. existing proper water supply infrastructure, local authority as well as zoning map) we avoided complex design system. In this project, physical and technical constraints considered as one of the major constraints while designing the system.

2) Economic and Financial Constraints

Key economic and financial constraints were also verified. The project did not assess the direct financial effect. The cost of treated water might affect the design processes. The cost of land allocated to the project could be also one of the major constraints. The present values of the land also influences the plans and engineering designs prepared for the project. In the project site, the installation of water facilities in the buildings, civil works, the mosque and the house of Imam could be constraints. The cost of machinery and equipment, supply, installation, shipping, and transport to the site are based on the valuation of the machinery and equipment imported and local condition. This could be constraint for the project. Working capital (operating) represents the financial resources required to operate the project at the planned operating levels and conditions, mainly the minimum inventory required to be maintained, as well as the minimum cash required to cover a full operating cycle. From a financial and accounting point of view, net cost is the difference between the value of current assets and the current liabilities of the project. The level and value of working capital in the project depends on the nature of its activity and financial policies applied by the project management. If we don't consider these issues properly, it might be constraint for the project (while implementing the project).

3) Structural Constraints

We directly or indirectly measure as well as considered these types of constraint while designing the project.

4) Climate constraint

Warm dry areas have higher consumption rates than cooler areas. Al Rakah is located at a warm environment, and its water consumption is always very high. In addition, water use is affected by rainfall levels in the region. The design should consider the climate issues for any sustainable development.

5) The availabilities or accessibility of water sources

South Al Rakah is residential area and water sources are very far from it. The availabilities or accessibility of water sources is one of the constraints.

6) Occupational Safety and Health

The main objective of the implementation of occupational health and safety programs is to reduce the costs resulting from losses and injuries and increase productivity by providing a safe working environment for employees and therefore this goal can be achieved only if the following elements are maintained:

1. Safety and health of the worlds; 2. Machines and machines; and 3. Work environment.

To ensure the safety, the organization of the project work is very important. Lack of proper organization of the work is another constraint for the project implementation. This can achieved by as follows:

- Put a banner showing the name of the project and the contractor.
- Secure entrance and exit sound and clear.
- Determining the location and route of public service lines.
- Do not put offices and sketches under the movement of cranes tower and mobile
- Hazardous and flammable materials must be stored in private and safe places.

- Construction waste should be collected and removed on a timely basis.
- Fire extinguishers and a pharmacy should be placed at the site for safety.

During field application of this project, occupational health and safety issues may be one of the constraints. The proper monitoring can resolve any safety issues.

7) Land availabilities for project implementation

There is no direct constraint for land availabilities for this project. Because of the design project limited for small residential area.

8) Environmental Constraint

The area is located close to the desert region. Water availabilities may be the constraints for the project in case of any unexpected environmental condition

b) <u>Other design constraints for the site</u>

Population

Limited information for past population (before 30 to 40 years ago) hindered the prediction of future population at these localities.

Elevation of the pipe

There is no proper information available for the project. It hindered the measurement of the pressure head for looped network system at the project site.

Volume of soil generated for Excavation

We did not access the amount of soil that can be generated from excavation while placing the pipe network.

Pipe gradient

This information is not included in the design.

Quality of water

Quality of water (Treatment) is not included in our project.

Design did not include reservoir

The information on reservoir design can enhance the project strength. Our project focuses only distribution looped network system. Without proper reservoir information may weaken the project.

Sampling station

The designer should consider the provision of dedicated sampling stations within the distribution system to monitor water quality. In the selection of locations for sampling sites, the designer should consider all challenging conditions within the system such as increased hydraulic retention times and temperature variations,. We did not take any sample for lab test. The missing information regarding water quality was the constraint for this design project.

Soil conditions

Soil geochemical information was not assessed for the project. This information can determine the corrosive quality of soil. Missing of this information considered as a constraint of the project design.

c) Other constraints

Social barrier

The social and political barrier for any project implementation is very common in any project. In case of land occupation, data collection as well as access to the community may extend the project duration. In this project, the team collected data from outside because of unavailability of important technical information. Reaching to responsible people can enhance the quality of the project.

Operation and maintenance

The major objective of operation and maintenance of water supply system is to provide sustainable, equitable, consistent, economic safe and adequate water. Operation of system in general means ensuring effective and continuous operation of the system.

Applicable Standard for the Project

The requirements of this section of Saudi building code are concerned with water networks and reservoirs, and rationalization in the irrigation of gardens and fountains, Waterfalls and swimming pools, and dual water systems in buildings, which complement the health requirements (SBS 700).

Networks and reservoirs requirements:

1. The pipes and fittings shall be made of materials conforming to the standard specifications contained in health requirements (SBC 701)
2. Health and safety issues during excavation, pipe emplacement, installation of any network connection would be identified and followed according to SBC 701.
3. Pipeline leak testing shall be carried out in accordance with sanitary requirements (SBC 701)
4. Pumps used to raise water shall be installed in a manner that prevents the pumping of water from the reservoirs to the public water network, and the installation of any pump to pull the public network water into the tanks
5. The pressure regulator will be installed in the water network, when feeding the network directly from the ground tank.
6. The water network would be designed according to health requirements (SBC 701).

Chapter 3 Background

Water supply in Saudi Arabia is characterized by challenges and achievements. One of the main challenges is water scarcity. In order to overcome water scarcity, substantial investments have been undertaken in seawater desalination, water distribution, sewerage, and wastewater treatment. Today about 50% of drinking water comes from desalination, 40% from the mining of non-renewable groundwater and only 10% from surface water in the mountainous southwest of the country (Burlingame and Anselme 1995). The capital Riyadh, located in the heart of the country, is supplied with desalinated water pumped from the Arabic Gulf over a distance of 467 km. Water is provided almost for free to residential users. Despite improvements, service quality remains poor, for example in terms of continuity of supply. Another challenge is weak institutional capacity and governance, reflecting general characteristics of the public sector in Saudi Arabia. Among the achievements is a significant increase in desalination, and in access to water, the expansion of wastewater treatment, as well as the use of treated effluent for the irrigation of urban green spaces, and for agriculture (Burlingame, and Anselme. 1995).

Since 2000, the government has increasingly relied on the private sector to operate water and sanitation infrastructure, beginning with desalination and wastewater treatment plants. Since the creation of the National Water Company (NWC) in 2008, the operation of urban water distribution systems in the four largest cities has gradually been delegated to private companies as well. The apparent paradox of very low water tariffs and water privatization is explained by government subsidies. The government buys desalinated water from private operators at high prices and resells the bulk water free. Likewise, the government directly pays private operators that run the water distribution and sewer systems of large cities under management contracts. Furthermore, it fully subsidizes investments in water distribution and sewers. Water utilities are expected to recover an increasing share of their costs from the sale of treated effluent to industries. In January 2016, water and sewer tariffs were increased for the first time in more than a decade, which resulted in discontent and in the sacking of the Minister of Water in April 2016.

In this project, distribution system for WSS at Al Rakah in Al Khobar City. The water supply system has different parts. Those are sources, treatment, storage tank, distribution system (including main, sub-main, fire hydrant and different valves). The section also described the looped distribution system for the project. The figure shows water supply and distribution system in any area.

3.1 Sources for water supply system (WSS)

Water distribution systems are designed to adequately satisfy the water requirements for a combination of the following demands: domestic, commercial, industrial, fire-fighting. The system should be capable of meeting the demands at all times.

Figure 3.1: Water Supply and Distribution System (Villatoro, Water Distribution 2015)

There are three main sources of water: rainwater, surface water, and underground water. Rainwater is used in some areas where water levels in the ground are very deep, surface water that runs in streams or is found in depressions, such as lakes, reservoirs, ponds, or oceans, is called surface water. Most areas ordinarily use surface water for a potable water source, and the underground surface beneath which earth materials, as in soil or rock, are saturated with water is known as the water table (Villatoro, water distribution 2015). Source of water for (WSS) in Al Khobar City is the sea located at southeast portion of the City. After treatment, water is stored into the overhead tank. Then, water is supplied to the project site. The main pipe diameter used in this project is to be 300 mm.

3.2 Treatment

Water which requires no treatment to meet bacteriological, physical, and chemical requirements and which can be delivered to the consumer by a gravity system should be given first consideration. Second-priority consideration water which requires no treatment to meet bacteriological, physical, and chemical requirements but which must be pumped to consumers would be the second choice. Well supplies would fall within this category. Third-priority consideration water which requires simple treatment before it can meet bacteriological, physical, or chemical requirements. Simple treatment is considered to be limited to: (1) storage which would provide plain sedimentation and some reduction in bacteria, (2) chlorination without the use of a mechanically operated chlorinator (Kell, and Doyle, 2006). Water treatment removes contaminants and undesirable components, or reduces their concentration so that the water becomes fit for its desired end-use. Treatment is not included in this project.

3.3 Storage Tanks

Figure 3.2: Water Tank in Al Khobar City (Al-Wabil Group, 2008)

Storage contributes to safeguarding water quality. It is necessary for the supply of peak demands which occur in all systems, whether a simple village well or a large city supply. Storage is most needed where one or two hand-pump supply a relatively large number of people from a single well. Pump can work more or less continuously and thus extend the utility of this minimum facility (Handbook of storage tank systems). The responsibility of the water supply system of Dammam, Al-khobar, and Dhahran Cities is divided and they have storage tank in Al Khobar. Design of storage tank is not included in this project.

3.4 Main Pipes

Pipes which are commonly used in water supply system are Ductile iron Pipes (DI), and Steel Pipes, This pipe can carry high pressure up to 20 bar, diameter between 300 mm to 400 mm as main pipe. In this project we used loop network system.

3.5 Sub-Main Pipes

Plastic or Polythene or PVC Pipes

This sub-main pipe is connected to the main pipe and distributes to the project site. In this project, we proposed the diameter of pipe in the range of 90 mm to 110 mm. It could carry up to 10 bar Pressure at maximum at 60^{o}C.

3.6 Water Distribution Systems

The purpose of distribution system is to deliver water to consumer with appropriate quality, and pressure. Distribution system is used to describe collectively the facilities used to supply water from its source to the point of usage. The distribution pipes are generally laid below the road pavements, and as such their layouts generally follow the layouts of roads. There are, in general, four different types of pipe networks; any one of which either singly or in combinations, can be used for a particular place. They are: Grid, Ring, Radial and Dead End System.

It is suitable for cities with rectangular layout, where the water mains and branches are placed in rectangles.

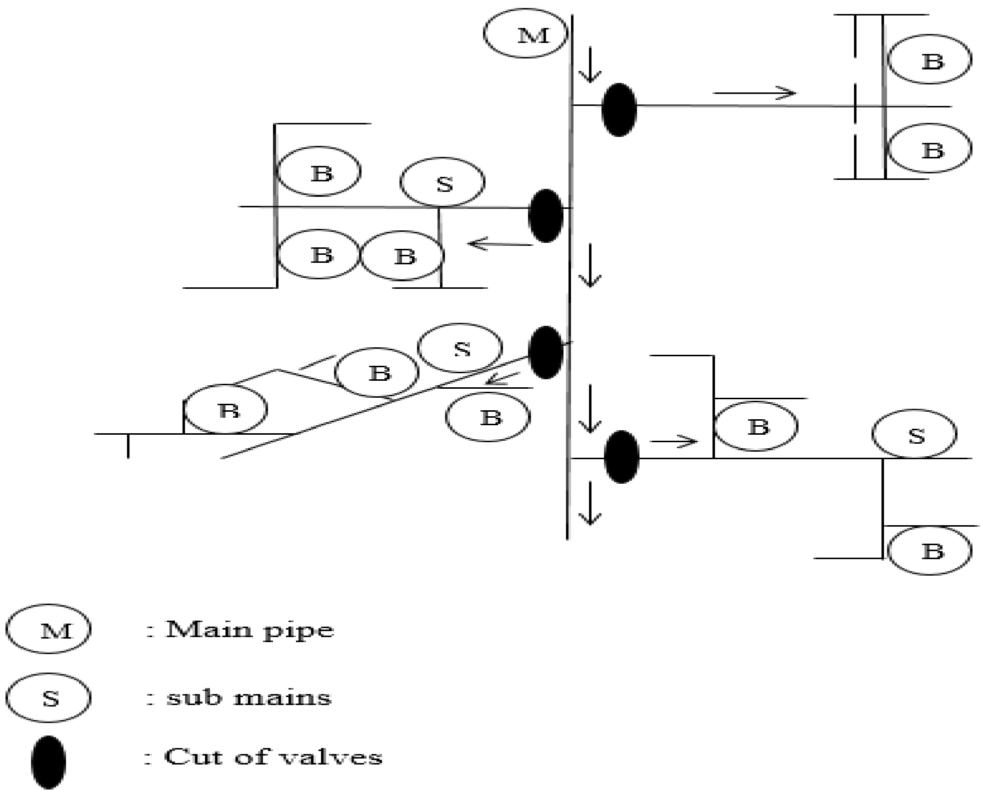

Figure 3.3: Water Supply Grid Network

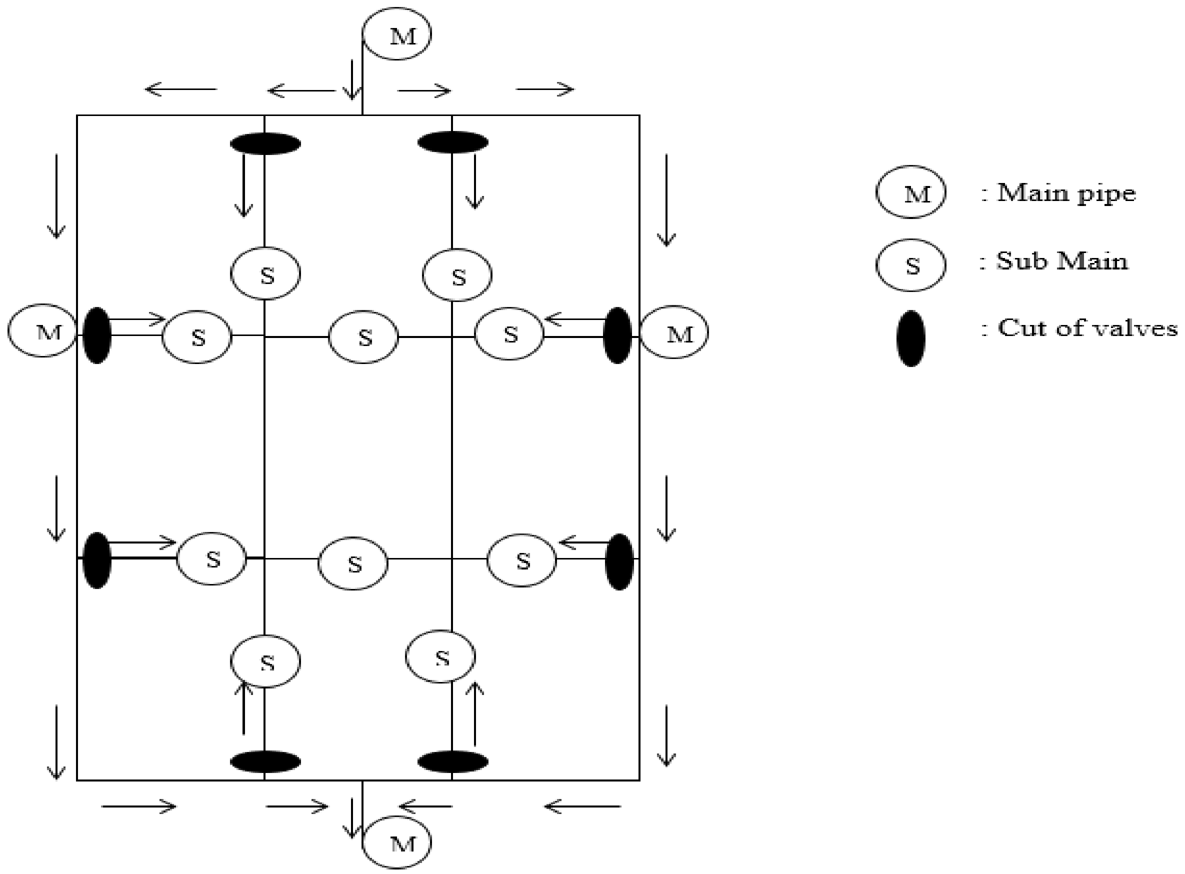

Figure 3.4: Looped Network Distribution Ring System

Figures 3.3 and 3.4 show different network system. In the project, we designed the loop network system because, a) no stagnation of water, b) consumption of water at any point activates flow in the whole network and, c) continuity of water supply anywhere in the system despite any repair work to a main or sub-main. The loop system provides very good control over flow of water. But branch network creates stagnant water, particularly at dead-ends, promotes sedimentation and water contamination. Frequent blow-off flushing is needed to keep the system clean.

3.7 Losses

It is the amount of water lost from the water system due to water leakage from the supply pipe network. In some countries, especially where water systems are old, the losses can be as high as 40%. In the project, losses considered to be 5%.

3.8 Fire Demand for WSS

Fire demand is an emergency event that may potentially happen anywhere. Given enough time, the occurrence of fire events is inevitable. Given enough time, the occurrence of fire events is inevitable. Thus implementing efficient systems to protect human lives and properties in urban areas for fire events is essential. Fire protection planning in urban areas has multiple components such as fire prevention, education, inspection, engineering and suppression.

Fire hydrant is an active fire protection measure, and a source of water provided in most urban, suburban and rural areas with municipal water service to enable firefighters to tap into the municipal water supply to assist in extinguishing a fire.

Figure 3.5: Fire Demand (Benedict et.al.1966)

$NFF_i = C_i O_i (X+P)$

NFFi = the needed fire flow in gallons per minute. C is the construction factor based on the size of the building and its construction. O is the occupancy factor reflecting the kinds of materials stored in the building (ranging from 0.75 to 1.25). (X+P) is the sum of the exposure factor and the communication factor that reflect the proximity and exposure of the other buildings.

$C_i = 220\ F\sqrt{A_i}$

C_i (L/min)

A (m^2) is the effective floor area, typically equal to the area of the largest floor plus 50% of all other floors. F is a coefficient based on the class of construction. To calculate the needed fire flow of a building, you will need to determine the predominant type (class) of construction, size (effective area) of the building, predominant type (class) of occupancy, exposure from the property, and the factor for communication to another building. There are two fire hydrant in this project, one for the northern area and the other for southern arera.

3.9 Valves

Valves are multi-use devices that regulate or control the flow of fluids. Some of the fluids controlled or regulated by valves include, water, liquids, and fluidized solids. In this project, check valves and Gate valve are used. Two valve rooms are provided to control the water flow in this project.

Figure 3.7: Gate Valve (Beasley, July 1990)

Figure 3.6: Check Valve (Dickenson, 1999)

Chapter 4 Project Description and Methodology

4.1 Description of the Site

The study area is located on the west side of “King Fahd and Granada”, specifically at south Al Rakah in Al Khober city. The Figure 4.1 is used to locate and select the specific area required for the distribution network system for water supply system (WSS). The area (selected for water supply) contains future houses, schools, mosques, restaurants, and hospitals as shown in Figure 4.1. The topography of the selected area is also shown in the Figures 4.1, and 4.2.

4.1.1 Project Design

The total area is 10152.4875 m^2

The number of homes = 5590/465=12 homes

The average number of persons per home = 10

The equations for the calculation of the population are

▪ N = N_O(e)kt . When e = 2.71828 N = Future population N_O = present population K = rate of growth t = number of years	▪ Pn=P+n.c When: Pn = future population P = current population N= number of years C= rate of change of population with respect to time

The site is bounded to the north by market of household utensils and at 34227 Road, to the west by King Fahd and Granada Roads, to the south and west by Saudi airlines, and to the east by Ouf Ibn Qast and Al-Andalus Roads. The area is also located in a residential area at south Al Rakah in Al Khober city. Distance from the main street Al-Andalus Road is approximately 1.5 km.

The elevations of the ground surface are not available. Thus we are unable to assess the gradient of water flow and the direction of the pipe slope. The pipe elevation can be obtained from the city of Al Khobar.

4.1.2 Design Assumption

Every project has assumption and these are as follows:

1. Minor calculation was not included in this design calculation
2. Maximum 2 bar pressure considered for the pipe flow
3. Diameter of main pipe was 300 mm, and 110 mm for sub-main
4. Roughness size of pipe (e) = 0.001524
5. Rate of change of population with respect to time, C = 2.05%
6. Number of Person = 10 Persons per home
7. Water demand for other fire, emergency, loss [5%] was considered to be 7000 L/d
8. Consumption per capita per day [LPCD] = 220 Liters/person/day
9. Safety factor S.F = 1.5
10. Design life cycle was considered to be 30 years in this study

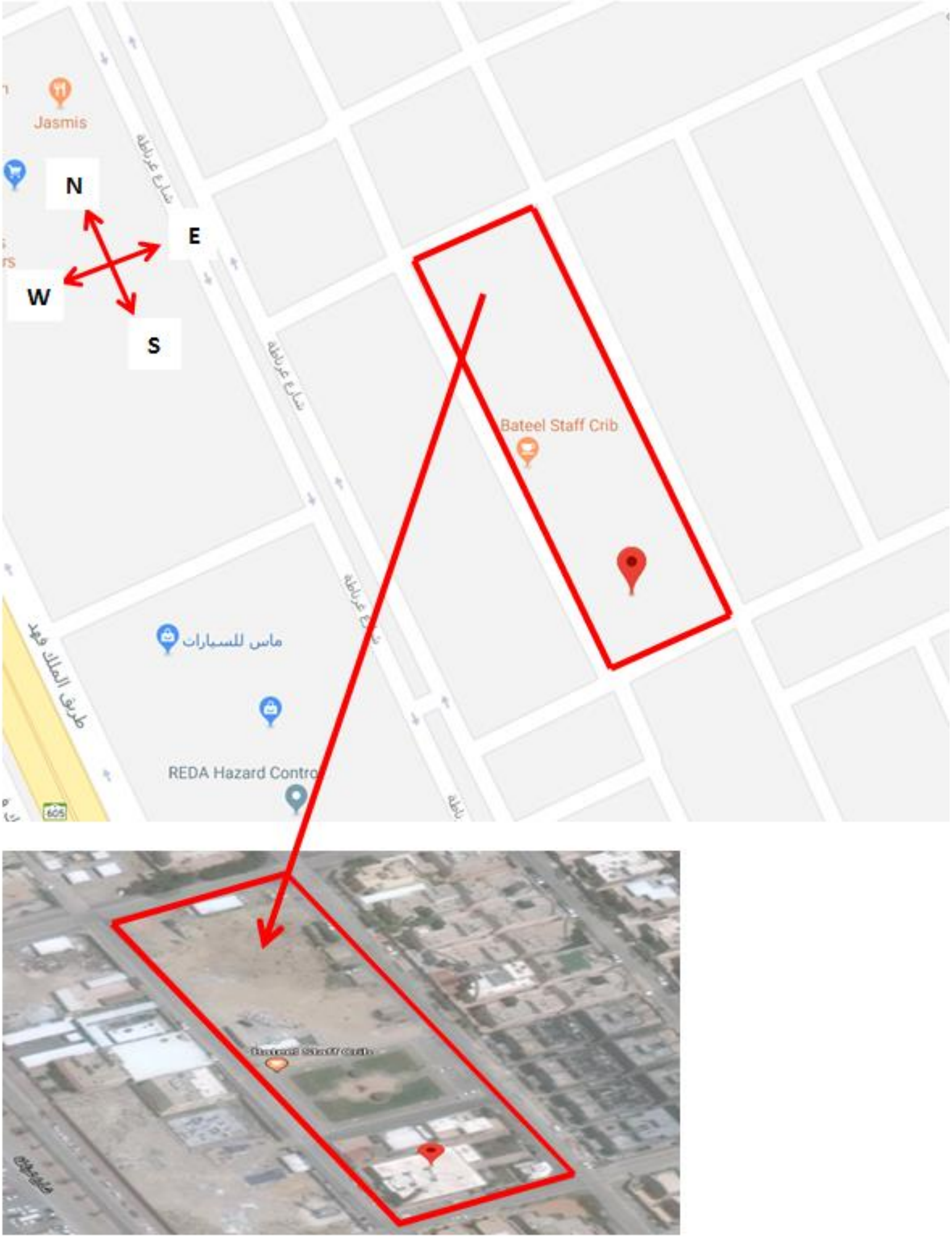

Figure 4.1: The location of selected project site

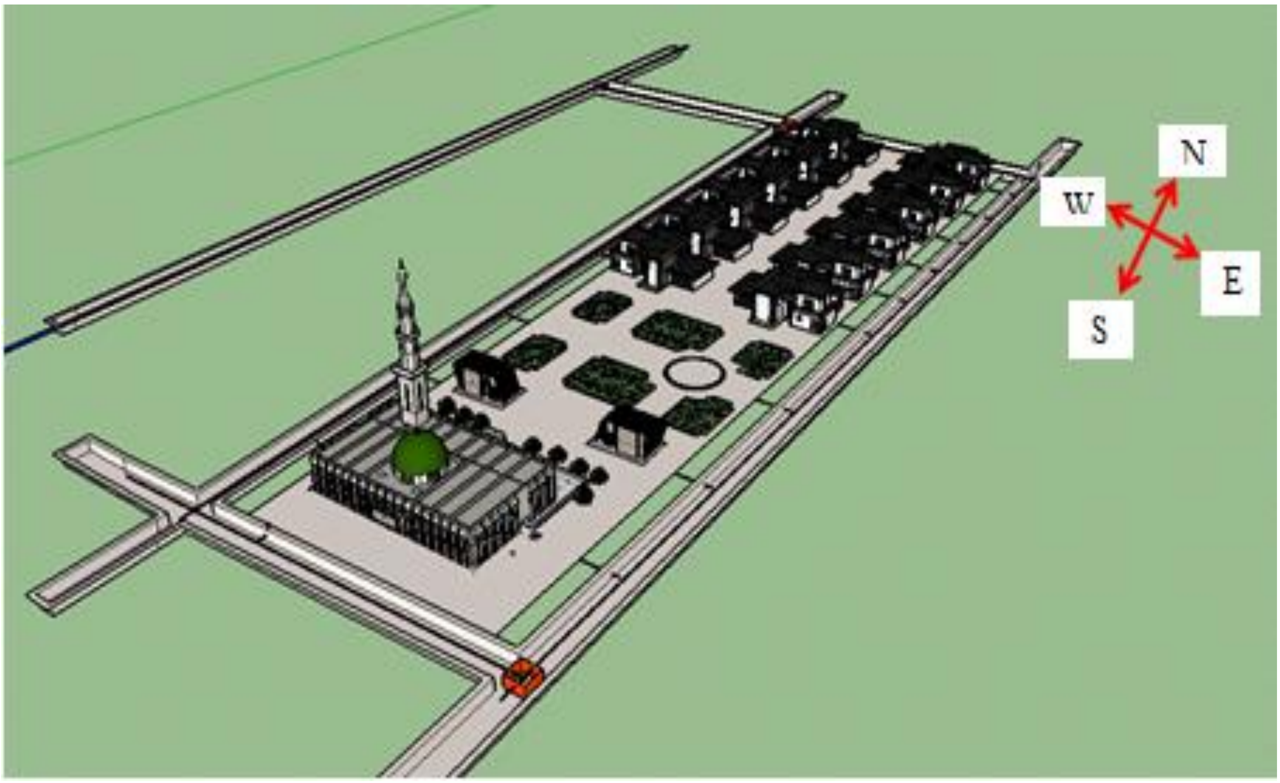

Figure 4.2: Selected Project Area in Al Khobar City

Our area is divided into two parts, such as south side and north side. South side which would covered mosque, garden, and Imam house. In addition, there is one room of valve and one firefighting. The north sides which will be cover residential area (12 houses), one room of valve and one firefighting. Based on our prediction, the demand for water will be higher at the north side than south side. The variation of water demand also depends on hours, seasons, and special occasions.

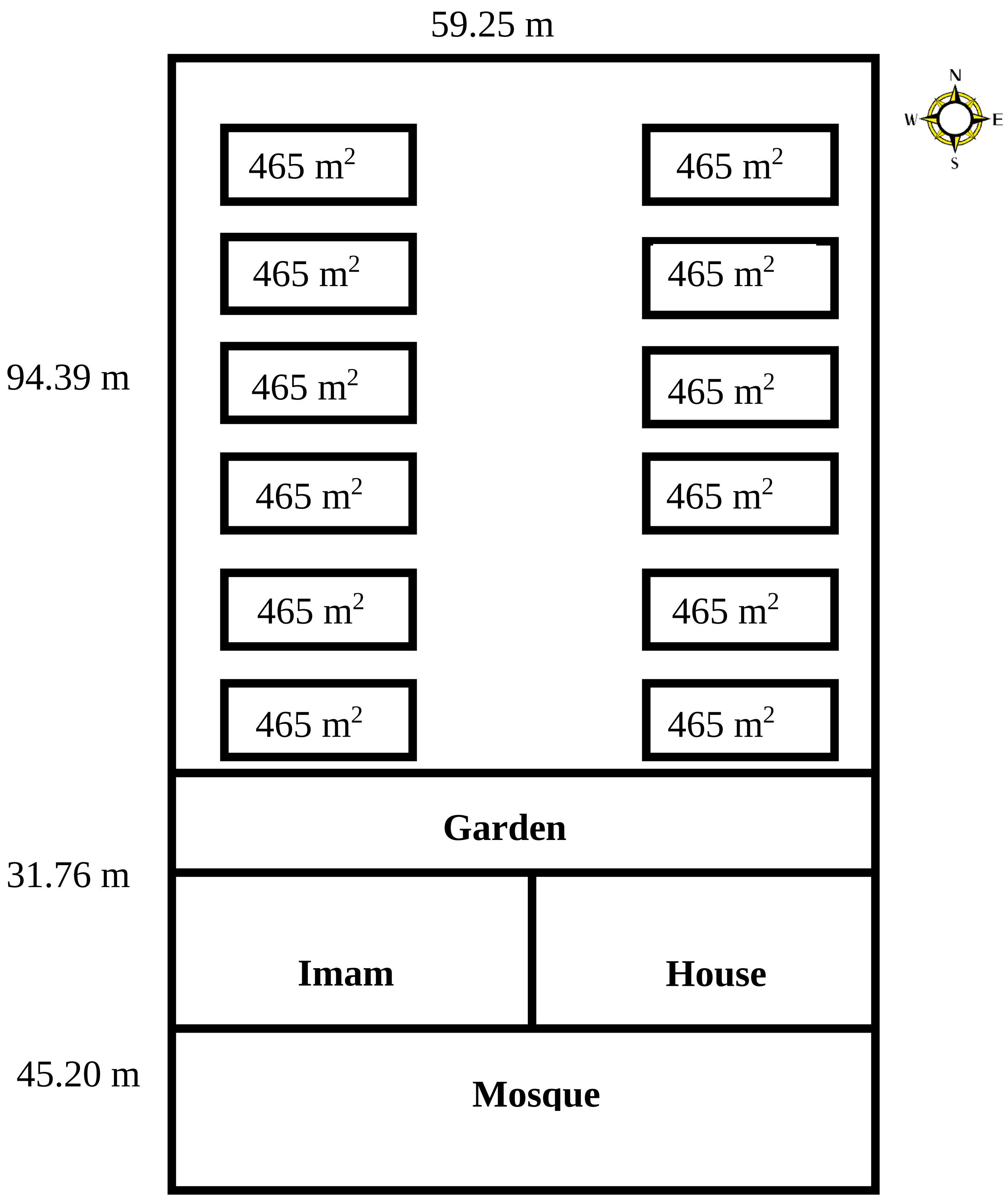

Figure 4.3: The Conceptualized Design of the Site

Our site area located at south Al Rakah in Al Khober city is 10152.4875 m^2. The project site is divided into two parts e.g. north portion and south portion. The length of north side is 94.39 m and the width side is 59.25 m and every house the area of each house is 465 m^2. In south portion, the length of garden is 31.76 m and the width is 59.25 m the length of Imam house, and mosque 45.20 m and width is 59.25 m.

4.1.3 Design Limitations

Major design limitation for the site

1. Population

Limited information about the past population (before 30 to 40 years ago) was available

2. Elevation of the pipe

From the Saudi building code, the elevation of pipe to be (1 m – 1.5 m) was considered

3. Volume of soil generated for Excavation

The volume was considered in this design project

4. Pipe gradient

Our land is flat. There is no slope in pipe

5. Quality of water

Quality of water (Treatment) was not determined in our project

6. Design did not include reservoir

The project focused only distribution loop network system

7. Sampling station

We did not take any sample for lab test

8. Soil conditions

We did not determine the type of soil conditions

4.2 Water Demand

Water demand is important to perform the design of water supply network. One should follow the international standard to assess water demand for different usages such as the per capita water consumption, fire demand, energy production, agriculture, industry, and domestic/municipal users. It is important to estimate the population of the selected area in order to assess the human consumption. However, others water consumption can be estimated roughly as per the recommendations from the municipality. Finally, water demand including the different usages should be represented by the flow rate which is the volume of water per unit time.

4.2.1 Emergency

The first priority is to provide an adequate quantity of water and to protect water sources from contamination. A minimum of 15 litres per person per day was assumed for emergency.

Design and Calculation

The actual design process can be performed after specifying the total flow rate based on water demand, the pressure at the main pipe source, and the elevations of all junction point in the network.

4.3 Steps for Design

- Step-1) Data collection

  We collected our information from municipal Al Khober and Saudi building code as well as books which were related to water supply system, and same articles

- Step-2) Population calculation

  This formula was used to design the population after 30 years as shown in below.

▪ $N = N_O (e)^{kt}$. When e = 2.71828 N = Future population N_O = present population K = rate of growth t = number of years	▪ P_n=P+n.c When: P_n = future population P = current population N= number of years C= rate of change of population with respect to time

(The best answer we would use for the design)

- Step-3) Design calculation

  1) Discharge calculation

  - Assumed discharge Q_a and direction for each pipe. Applied Continuity equation at each node e.g. Total inflow = Total Outflow

  2) Calculate equivalent resistance K for each pipe

We used Darcy Weisbach equation to calculate the design parameters

$$k = f * \frac{8}{g\,\pi^2} * \frac{L}{D^5}$$

To find f $$\frac{1}{\sqrt{f}} = -2Log\left(\frac{e/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right)$$

3) Calculate head loss for each pipe

$h_f = K\,Q_a^{\,n}$

4) Correction factor

$$\Delta = -\frac{\sum KQ_a^{\,n}}{\sum\left|nKQ_a^{\,n-1}\right|}$$

$\Delta = correction\ of\ pipe$

Qa = assumption of flow

$Q_{actual} = Qa + \Delta$

The constant used in the equation, n = 2

- Step-4) WaterCAD and WaterGEMS

WaterCAD is one of the water network system analysis programs with the ability to draw, design and the high possibility of reviewing the results and producing the report for all elements of the network. WaterGEMS provides with a comprehensive and easy-to-use decision-support tool for water distribution networks. The software helps improve your knowledge of how infrastructure behaves as a system, how it reacts to operational strategies, and how it should grow as population and demands increase. The figures 4.4 and 4.5 show the WaterCAD and WaterGEMS softwares' screen.

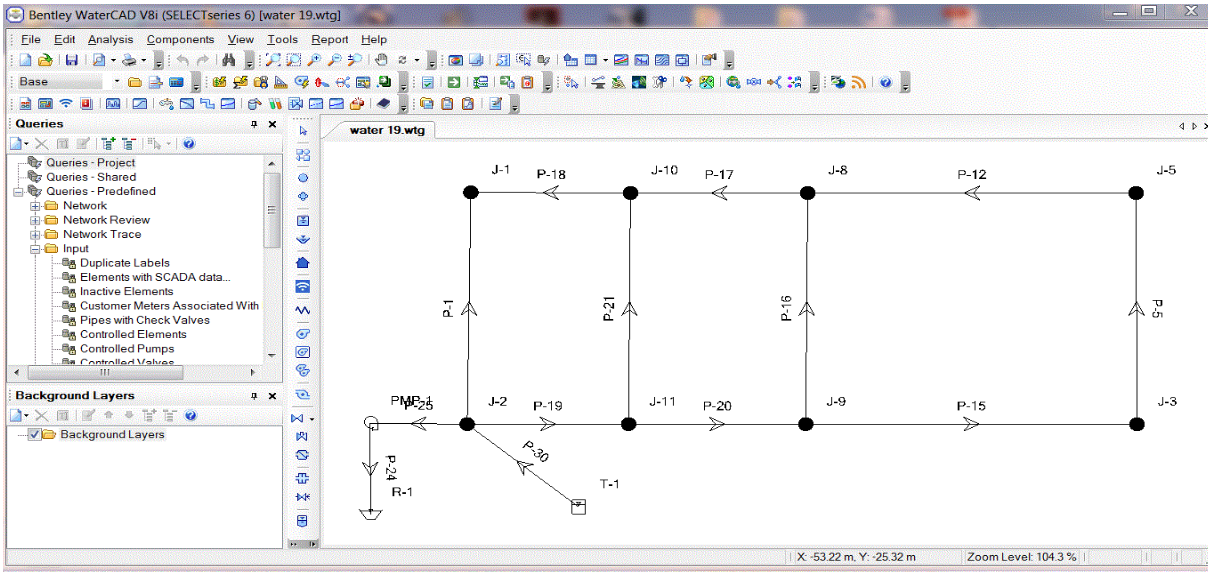

Figure 4.4: WaterCAD

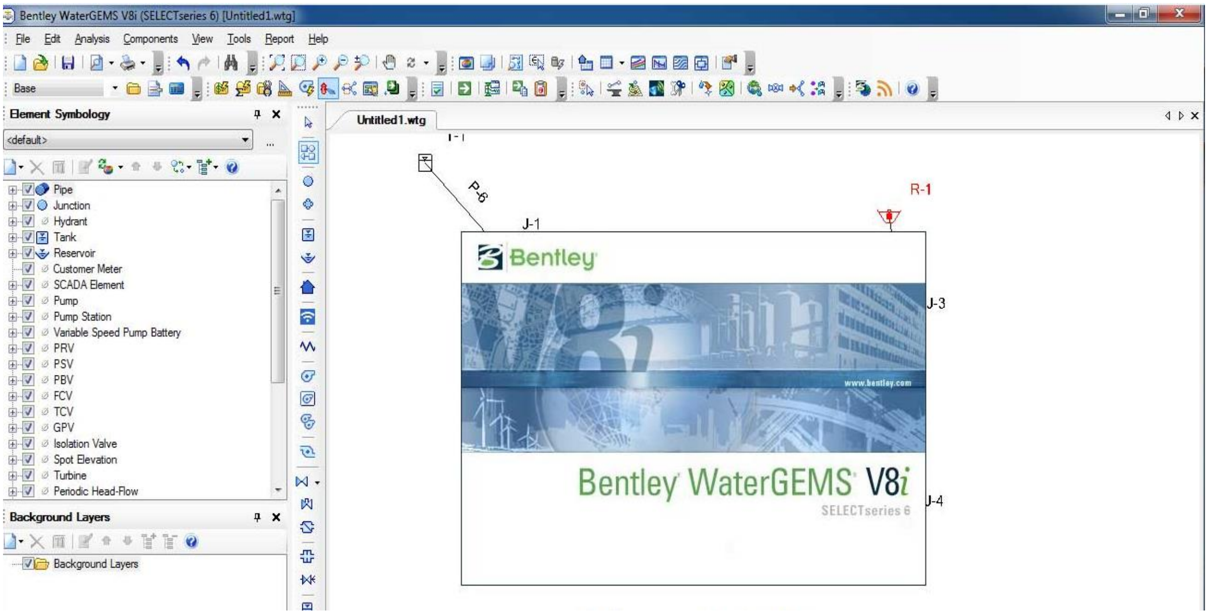

Figure 4.5: WaterGEMS

Chapter 5 Design of the Water Supply System

5.1 Manual Calculations

The design of the looped network water system was based on the energy equations. The energy equation was used to estimate the head losses in each pipe. The pressure provided by the municipality at the main pipe was 2 bars and the head losses are mainly due to friction loss. The required diameter of the pipe increases as the flow rate increase. The main pipes (which are very close to the water source) have larger diameter than those which are far away from the main water source. Here, our Q which we took it from Al Khobar city. We calculate the Q based on population. The equation that was used to predict the future population is as follows: N = $N_O(e)^{kt}$

e = 2.71828

N = Future population

N_O = present population

K = rate of growth = 0.0205 (Source: City of Al-khobar)

t = number of years. In this project, design life is 30 years.

We considered the population in the project area after 30 years to be 222 persons.

Thus, Q= 220 Liter per capita per day $\times$ 222 our design population = 48840 L/d

Q depends on losses, emergency, firefighting and garden.

According to municipal Al Kohber, the flow rate is 7000 L/d; but we assumed to be 20000 L/d after 30 years.

Total design Q is 48840 + 20000 × 1.5 = 103260 L/d.

These tables 5.1, 5.2, 5.3 show our design calculations based on three loops we calculated friction factor, Reynold's number, velocity, and the correction on pipe, we tried to reach almost zero error in each pipe.

For Loop 1, we got close to zero, and also loops 2 and 3, the calculated values for correction factor was close to zero indicating the corrected Q in each pipe.

Table 5.1 shows design results of loop 1 from first iteration. The table include the flowrate (Q), constant (K), head loss, Reynold's number, friction factor, and the final correction.

Table 5.1: Design results for loop one

Pipe	Length	Dia (m)	Q (m^3/sec)	K	H (m)	H/Q (1/m^2)	Correction (m^3/Sec)	e/d	A (m^2)	V m/sec	R_e	f
AB	40	0.11	0.00059	973768.3	0.3477	581.89	-0.00029	0.0140	0.0094	0.062	6920	0.04
BE	30	0.11	0.00014	944159	0.0201	138.17	-7.3090	0.0140	0.0094	0.015	1692	0.06
EF	40	0.11	0.00036	1040173	0.1394	380.79	-0.00018	0.0140	0.0094	0.038	4239	0.05
FA	30	0.11	0.00059	730326.2	0.2607	436.42	-0.00085	0.0140	0.0094	0.062	6920	0.04
					0.768	1537.1						

Table 5.2 shows the results of loop 2 from first iteration. The table includes the flowrate (Q), constant (K), head loss, Reynold's number, friction factor, and the final correction.

Table 5.2: Design results for loop two

Pipe	Length	Dia (m)	Q (m^3/sec)	K	H (m)	H/Q ($1/m^2$)	Correction (m^3/Sec)	e/d	A (m^2)	V m/sec	R_e	f
BC	41	0.11	0.00033	1081300	0.1218	362.93	-0.00016	0.0140	0.0094	0.035	3887	0.05
CD	30	0.11	0.00046	1386118	0.0029	64.172	-2.3148	0.0140	0.0094	0.004	536	0.09
DE	30	0.11	0.00033	790021.8	0.0906	267.54	-0.00016	0.0140	0.0094	0.035	3921	0.05
EB	30	0.11	0.00014	944159	0.0201	138.017	-7.30903	0.0140	0.0094	0.015	1692	0.06
					0.235	832.67	-0.00014					
							0.00057					

Table 5.3 shows design results of loop 3 from first iteration. The table include the flowrate (Q), constant (K), head loss, Reynold's number, friction factor, and the final correction.

Table 5.3: Design results for loop three

Pipe	Length	Dia (m)	Q (m^3/sec)	K	H (m)	H/Q ($1/m^2$)	Correction (m^3/Sec)	e/d	A (m^2)	V m/sec	R_e	f
CH	76.96	0.11	0.00011	2582958	0.0346	298.95	-5.78704	0.0140	0.0094	0.012	1340	0.06
HI	59.25	0.11	0.00010	2051657	0.0222	213.71	-5.20833	0.0140	0.0094	0.010	1206	0.06
ID	76.96	0.11	0.00015	2391836	0.0563	367.08	-7.67361	0.0140	0.0094	0.016	1777	0.06
DC	30	0.11	0.00046	1386118	0.0029	64.172	-2.31481	0.0140	0.0094	0.004	536	0.09
					0.116	0.116						

5.2 WaterCAD and WaterGEMS

WaterCAD used for designed our parameters in loops and analysis our draw, WaterGEMS provides you with a comprehensive yet easy-to-use decision-support tool for water distribution networks.

A. Average Demand:

This tables show average demand for Pipe, Junction, and Isolation, of our software design

Table 5.4: Pipe Table of Average Demand

FlexTable: Pipe Table

Current Time: 0.000 hours

ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
48	EF	40.00	E	F	110.0	PVC	130.0	0.06761	0.01
51	ED	41.00	D	E	110.0	PVC	130.0	0.11082	0.01
53	BE	59.26	B	E	110.0	PVC	130.0	0.02971	0.00
55	AF	59.27	F	A	110.0	PVC	130.0	-0.00530	0.00
57	CD	59.27	C	D	110.0	PVC	130.0	0.11730	0.01
59	HI	59.25	H	I	110.0	PVC	130.0	-0.40245	0.04
62	DI	76.96	I	D	110.0	PVC	130.0	0.56079	0.06
63	CH	76.97	C	H	110.0	PVC	130.0	-0.40245	0.04
66	AB	40.00	A	B	110.0	PVC	130.0	-0.07822	0.01
67	BC	41.05	B	C	110.0	PVC	130.0	-0.18085	0.02
69	TI	46.73	R-1	I	110.0	PVC	130.0	0.96324	0.10

Table 5.5: Junction Table of Average Demand

FlexTable: Junction Table

Current Time: 0.000 hours

ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Hydraulic Grade (m)	Pressure (bars)	Unit Demand Collection	Unit Demand Collection <Count>
56	A	0.00	<None>	<Collection: 0 items>	0.07292	29.99	2.93	<Collection: 1 items>	1
54	B	0.00	<None>	<Collection: 0 items>	0.07292	29.99	2.93	<Collection: 1 items>	1
58	C	0.00	<None>	<Collection: 1 items>	0.10431	29.99	2.93	<Collection: 1 items>	1
52	D	0.00	<None>	<Collection: 1 items>	0.56727	29.99	2.93	<Collection: 2 items>	2
49	E	0.00	<None>	<Collection: 0 items>	0.07292	29.99	2.93	<Collection: 1 items>	1
50	F	0.00	<None>	<Collection: 0 items>	0.07292	29.99	2.93	<Collection: 1 items>	1
60	H	0.00	<None>	<Collection: 0 items>	0.00000	29.99	2.94	<Collection: 0 items>	0
61	I	0.00	<None>	<Collection: 0 items>	0.00000	29.99	2.94	<Collection: 0 items>	0

Table 5.6: Isolation Valve Table of Average Demand

FlexTable: Isolation Valve Table

Current Time: 0.000 hours

ID	Label	Is Operable?	Diameter (Valve) (mm)	Elevation (m)	Referenced Pipe	Flow (L/s)	Hydraulic Grade (m)	Pressure (bars)	Velocity (m/s)
70	ISO-1	True	152.4	0.00	EF	0.06761	29.99	2.93	0.00
71	ISO-2	True	152.4	0.00	BE	0.02971	29.99	2.93	0.00
72	ISO-3	True	152.4	0.00	DI	0.56079	29.99	2.93	0.03
73	ISO-4	True	152.4	0.00	CD	0.11730	29.99	2.93	0.01
74	ISO-5	True	152.4	0.00	CH	0.40245	29.99	2.93	0.02
75	ISO-6	True	152.4	0.00	CD	0.11730	29.99	2.93	0.01
76	ISO-7	True	152.4	0.00	HI	0.40245	29.99	2.94	0.02
77	ISO-8	True	152.4	0.00	BC	0.18085	29.99	2.93	0.01
78	ISO-9	True	152.4	0.00	BE	0.02971	29.99	2.93	0.00
79	ISO-10	True	152.4	0.00	AF	0.00530	29.99	2.93	0.00
80	ISO-11	True	152.4	0.00	AF	0.00530	29.99	2.93	0.00

B. Firefighting Demand:

This tables show firefighting demand for Pipe, Junction, and Isolation, of our software design

Table 5.7: Pipe Table of Firefighting Demand

FlexTable: Pipe Table

Current Time: 0.000 hours

ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
48	EF	40.00	E	F	110.0	PVC	130.0	1.96115	0.21
51	ED	41.00	D	E	110.0	PVC	130.0	5.01034	0.53
53	BE	59.26	B	E	110.0	PVC	130.0	-2.93981	0.31
55	AF	59.27	F	A	110.0	PVC	130.0	1.85178	0.19
57	CD	59.27	C	D	110.0	PVC	130.0	-6.56397	0.69
59	HI	59.25	H	I	110.0	PVC	130.0	-20.97964	2.21
62	DI	76.96	I	D	110.0	PVC	130.0	12.38522	1.30
63	CH	76.97	C	H	110.0	PVC	130.0	11.02036	1.16
66	AB	40.00	A	B	110.0	PVC	130.0	1.74240	0.18
67	BC	41.05	B	C	110.0	PVC	130.0	4.57284	0.48
69	TI	46.73	R-1	I	110.0	PVC	130.0	33.36486	3.51

Table 5.8: Junction Table of Firefighting Demand

FlexTable: Junction Table

Current Time: 0.000 hours

ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Hydraulic Grade (m)	Pressure (bars)	Unit Demand Collection	Unit Demand Collection <Count>
56	A	0.00	<None>	<Collection: 0 items>	0.10937	23.23	2.27	<Collection: 1 items>	1
54	B	0.00	<None>	<Collection: 0 items>	0.10937	23.21	2.27	<Collection: 1 items>	1
58	C	0.00	<None>	<Collection: 1 items>	0.11646	23.09	2.26	<Collection: 1 items>	1
52	D	0.00	<None>	<Collection: 1 items>	0.81090	23.42	2.29	<Collection: 2 items>	2
49	E	0.00	<None>	<Collection: 0 items>	0.10937	23.28	2.28	<Collection: 1 items>	1
50	F	0.00	<None>	<Collection: 0 items>	0.10937	23.26	2.28	<Collection: 1 items>	1
60	H	0.00	<None>	<Collection: 0 items>	32.00000	21.99	2.15	<Collection: 1 items>	1
61	I	0.00	<None>	<Collection: 0 items>	0.00000	24.79	2.43	<Collection: 0 items>	0

Table 5.9: Isolation Valve Table of Firefighting Demand

FlexTable: Isolation Valve Table

Current Time: 0.000 hours

ID	Label	Is Operable?	Diameter (Valve) (mm)	Elevation (m)	Referenced Pipe	Flow (L/s)	Hydraulic Grade (m)	Pressure (bars)	Velocity (m/s)
70	ISO-1	True	152.4	0.00	EF	1.96115	23.28	2.28	0.11
71	ISO-2	True	152.4	0.00	BE	2.93981	23.28	2.28	0.16
72	ISO-3	True	152.4	0.00	DI	12.38522	23.46	2.30	0.68
73	ISO-4	True	152.4	0.00	CD	6.56397	23.40	2.29	0.36
74	ISO-5	True	152.4	0.00	CH	11.02036	23.06	2.26	0.60
75	ISO-6	True	152.4	0.00	CD	6.56397	23.11	2.26	0.36
76	ISO-7	True	152.4	0.00	HI	20.97964	22.12	2.16	1.15
77	ISO-8	True	152.4	0.00	BC	4.57284	23.20	2.27	0.25
78	ISO-9	True	152.4	0.00	BE	2.93981	23.21	2.27	0.16
79	ISO-10	True	152.4	0.00	AF	1.85178	23.26	2.28	0.10
80	ISO-11	True	152.4	0.00	AF	1.85178	23.23	2.27	0.10

C. Peak Demand:

This tables show peak demand for Pipe, Junction, and Isolation, of our software design

Table 5.10: Pipe Table of Peak Demand

FlexTable: Pipe Table

Current Time: 0.000 hours

ID	Label	Length (Scaled) (m)	Start Node	Stop Node	Diameter (mm)	Material	Hazen-Williams C	Flow (L/s)	Velocity (m/s)
48	EF	40.00	E	F	110.0	PVC	130.0	0.15099	0.02
51	ED	41.00	D	E	110.0	PVC	130.0	0.24469	0.03
53	BE	59.26	B	E	110.0	PVC	130.0	0.07036	0.01
55	AF	59.27	F	A	110.0	PVC	130.0	-0.01308	0.00
57	CD	59.27	C	D	110.0	PVC	130.0	0.27266	0.03
59	HI	59.25	H	I	110.0	PVC	130.0	-0.81891	0.09
62	DI	76.96	I	D	110.0	PVC	130.0	1.14838	0.12
63	CH	76.97	C	H	110.0	PVC	130.0	-0.81891	0.09
66	AB	40.00	A	B	110.0	PVC	130.0	-0.17714	0.02
67	BC	41.05	B	C	110.0	PVC	130.0	-0.41156	0.04
69	TI	46.73	R-1	I	110.0	PVC	130.0	1.96729	0.21

Table 5.11: Junction Table of Peak Demand

FlexTable: Junction Table

Current Time: 0.000 hours

ID	Label	Elevation (m)	Zone	Demand Collection	Demand (L/s)	Hydraulic Grade (m)	Pressure (bars)	Unit Demand Collection	Unit Demand Collection <Count>
56	A	0.00	<None>	<Collection: 0 items>	0.16406	29.95	2.93	<Collection: 1 items>	1
54	B	0.00	<None>	<Collection: 0 items>	0.16406	29.96	2.93	<Collection: 1 items>	1
58	C	0.00	<None>	<Collection: 1 items>	0.13469	29.96	2.93	<Collection: 1 items>	1
52	D	0.00	<None>	<Collection: 1 items>	1.17635	29.96	2.93	<Collection: 2 items>	2
49	E	0.00	<None>	<Collection: 0 items>	0.16406	29.96	2.93	<Collection: 1 items>	1
50	F	0.00	<None>	<Collection: 0 items>	0.16406	29.95	2.93	<Collection: 1 items>	1
60	H	0.00	<None>	<Collection: 0 items>	0.00000	29.97	2.93	<Collection: 1 items>	1
61	I	0.00	<None>	<Collection: 0 items>	0.00000	29.97	2.93	<Collection: 0 items>	0

Table 5.12: Isolation valve Table of Peak Demand

FlexTable: Isolation Valve Table

Current Time: 0.000 hours

ID	Label	Is Operable?	Diameter (Valve) (mm)	Elevation (m)	Referenced Pipe	Flow (L/s)	Hydraulic Grade (m)	Pressure (bars)	Velocity (m/s)
70	ISO-1	True	152.4	0.00	EF	0.15099	29.96	2.93	0.01
71	ISO-2	True	152.4	0.00	BE	0.07036	29.96	2.93	0.00
72	ISO-3	True	152.4	0.00	DI	1.14838	29.96	2.93	0.06
73	ISO-4	True	152.4	0.00	CD	0.27266	29.96	2.93	0.01
74	ISO-5	True	152.4	0.00	CH	0.81891	29.96	2.93	0.04
75	ISO-6	True	152.4	0.00	CD	0.27266	29.96	2.93	0.01
76	ISO-7	True	152.4	0.00	HI	0.81891	29.97	2.93	0.04
77	ISO-8	True	152.4	0.00	BC	0.41156	29.96	2.93	0.02
78	ISO-9	True	152.4	0.00	BE	0.07036	29.96	2.93	0.00
79	ISO-10	True	152.4	0.00	AF	0.01308	29.95	2.93	0.00
80	ISO-11	True	152.4	0.00	AF	0.01308	29.95	2.93	0.00

There are some small differences between velocity and flow, the result in software is more accurate than manual calculation, but it is steel close result.

Table 5.13: Comparison tables for Manual and Software

Manual		Software	
Flow (m^3/sec)	Velocity (m/s)	Flow (L/s)	Velocity (m/s)
0.00059	0.062	0.067	0.01
0.00014	0.015	0.11	0.01
0.00036	0.038	0.029	0.00
0.00059	0.062	0.005	0.00

5.3 Partial Cost of the Project

Table 5.14: Cost Estimation

Type of material	Size	Cost form factory	Cost after enforcement
Pipe (DI)	300 mm	270 R.S for 1 meter	500 R.S for 1 meter
Pipe (HDPE)	110 mm	46 R.S for 1 meter	150 R.S for 1 meter
Pipe house connection	From 40 to 60 mm	It will cost as one piece from start point to last point from 600 – 800 R.S.	
Firefighting	150 mm	4300 R.S	
Valve	150 mm	1820 R.S	
Bend	Depend on shape		
Labour cost for Installation		15-30 R.S per meter	

Total cost for pipes:

Total pipes meters = 461.2

Cost for 1 m = 46 R.S

So 461.2 * 500 = 231000 R.S for all pipes

Total cost for firefighting:

Total firefighting = 2

Cost for one firefighting = 4300 R.S

So 2 * 4300 = 8600 R.S

Total cost for valve = 1820 * 7 = 12740 R.S

The total cost estimation for project is 231000 + 8600 + 12740 = 252340 R.S

Approximate Unit Cost = 252340 / 461.2 = 547.14 R.S/m

Chapter 6 Conclusions

Water distribution system is vitally important not only to maintain the health of the community but also for the sustainability of industry, business and agriculture. This project also includes the background study of water distribution system with brief description of all components. In this design project, looped network system has been considered for the distribution of water to the residential area located at South Al Rakah in AL Khobar city. The design was performed using the energy equation or Bernoulli equation. The energy equations determined the pressure, velocity, and flow into the pipe network. Darcy-Weisbach equation was also applied to find out approximate flow into the pipe. All necessary data were collected from the city of Al khobar water department. In this project, WaterCad and WaterGEMS softwares was used to calculate the design parameters and compared results to the design parameters found from manual calculations. The constraints for this project were also carefully verified and project limitation was identified. The results indicated that the difference in total energy at different project location was due to the head losses.

References

- Burlingame, G. A., and C. Anselme. 1995. Distribution system tastes and odors. In Advances in Taste-and-Odor Treatment and Control. AWWA Research Foundation Cooperative Research Report. Denver, CO: AWWARF.
- Geldreich, E. E., and M. W. LeChevallier. 1999. Microbial water quality in distribution systems. Pp. 18.1–18.49 In: Water Quality and Treatment, 5th edition. R. D. Letterman (ed.). New York: McGraw-Hill.
- Handbook of storage tank systems, Codes, Regulations, and Designs, Steel Tank Institute, Lake Zurich, Illinois.
- Manufacturers of Cast Iron Soil Pipe and Fittings, 7825 San Leandro Street Oakland, California 94621.
- Panguluri, s., w. M. Grayman, r. M. Clark, l. M. Garner, and R, Haught. 2005. Water distribution system analysis: field studies, modeling and management. U.S. environmental protection agency, Washington, DC, EPA/600/R-06/028, 2005.
- California. Governor's Office of Emergency Services. 2007. "Multi-Agency Response Guidance for Emergency Drinking Water Procurement & Distribution." 2nd Edition. Accessed January 14, 2011.
- Roberson, J. A., Cassidy, J and Chaudhry, M.H., 1997. Hydraulic Engineering, 2nd Edition. New York: John Wiley & Sons, Inc., 1997. ISBN: 047124664
- http://www.oes.ca.gov/Operational/OESHome.nsf/PDF/Drinking%20Water%20Guidance/$file/Drink WaterGd.pdf Connecticut. Department of Public Health. Drinking Water Section. 2008. "Bulk Water Hauling Guidelines." Revision December 18, 2007. Effective February 1, 2008. Accessed May 10, 2010.

- http://www.ct.gov/dph/lib/dph/drinking_water/pdf/Bulk_Water_Hauling_Guidelines.pdf Federal Emergency Management Agency (FEMA). 2008. "Emergency Support Function #3 – Public Works and Engineering Annex." Accessed January 14, 2011.
- New Jersey. Department of Environmental Protection. 2007. "Interconnection Study Mitigation of Water Supply Emergencies – Public Version." Prepared by Gannett Fleming, and Black and Veatch. Oxfam.
- Water and Sanitation. Maintaining Standards. [Web page] Accessed February 10, 2011.
- "Water Supply Handbook; 2008. A Handbook on Water Supply Planning and Resource Management." USACE Institute for Water Resources, Water Resource Support Center: Revised Report 96-PS-4. Planning for Emergency Drinking Water Supply 35 U.S. Environmental Protection Agency (EPA). 2008.
- "Water Security Initiative: Interim Guidance on Developing Consequence Management Plans for Drinking Water Utilities." 2004. Washington, D.C.: U.S. Environmental Protection Agency, Office of Water, EPA 817-R-08-001. U.S. Environmental Protection Agency.
- http://www.epa.gov/safewater/watersecurity/pubs/small_medium_ERP_guidance040704.pdf U.S. Environmental Protection Agency. 2003.
- U.S. Department of Homeland Security. 2009. "Ready.gov – Prepare. Plan. Stay Informed." Accessed January 14, 2011. http://www.ready.gov/
- World Health Organization (WHO). 2005. "Cleaning and disinfecting water storage tanks and tankers." Technical Notes for Emergencies, Technical Note No. 3. Revised July 1, 2005.

- American Society of Civil Engineers ASCE. 1969. Design and construction of sanitary and storm sewers. Manuals and Reports of Civil Engineering Practise 37. ASCE: New York.
- Blevins, R.D. 1984. Applied fluid dynamics handbook. Van Nostrand Reinhold: New York.
- Miller, D.S. (1971). Internal flow. BHRA: Cranfield-Bedford.
- Miller, D.S. (1978). Internal flow systems. BHRA Fluid Engineering: Cranfield-Bedford.
- Miller, D.S., ed. (1994). Discharge characteristics. IAHR Hydraulic Structures Design Manual 8. Balkema: Rotterdam.
- Zigrang, D.J., Sylvester, N.D. (1985). Discussion to "A simple explicit formula for the estimation of pipe friction factor", by J.J.J. Chen. Proc. Institution Civil Engineers 79: 218–219.
- Warren, V and Mark J. Hammer, M.J., 2001. Water Supply and Pollution Control, 6th Edition. Addison-Wesley Publishing Company.

Appendix A Design Calculation

Total area = 10152.4875 m^2

Number of homes = 5590/465 = 12 homes

Average number of persons per home =10 persons

N = N0 e^{kt} = 120 * $2.71828^{0.0205*30}$ = 222

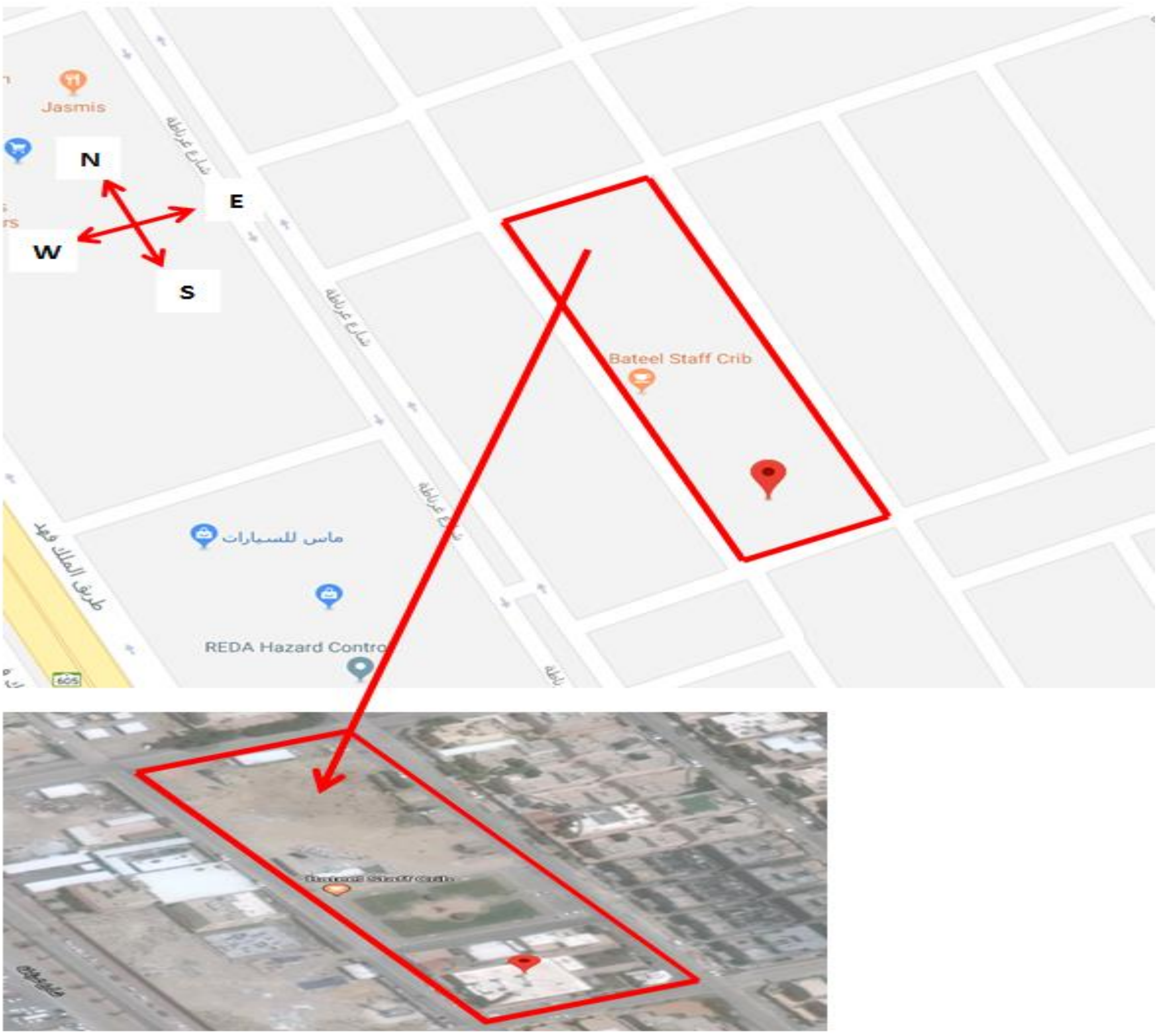

Figure A.1: The location of selected project site

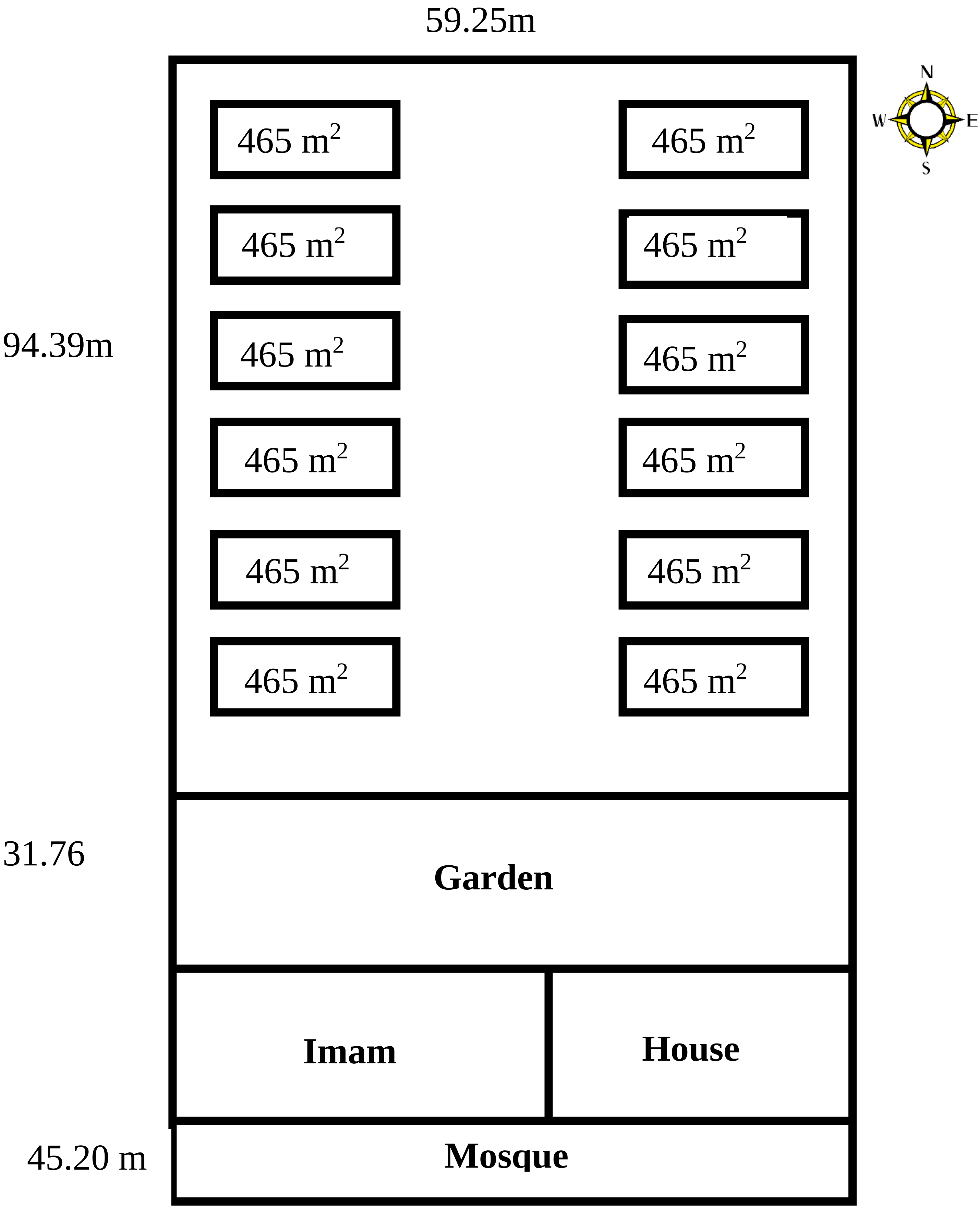

Figure A.2: The conceptualized design of the site

Figure A.3: Design Loop Network System

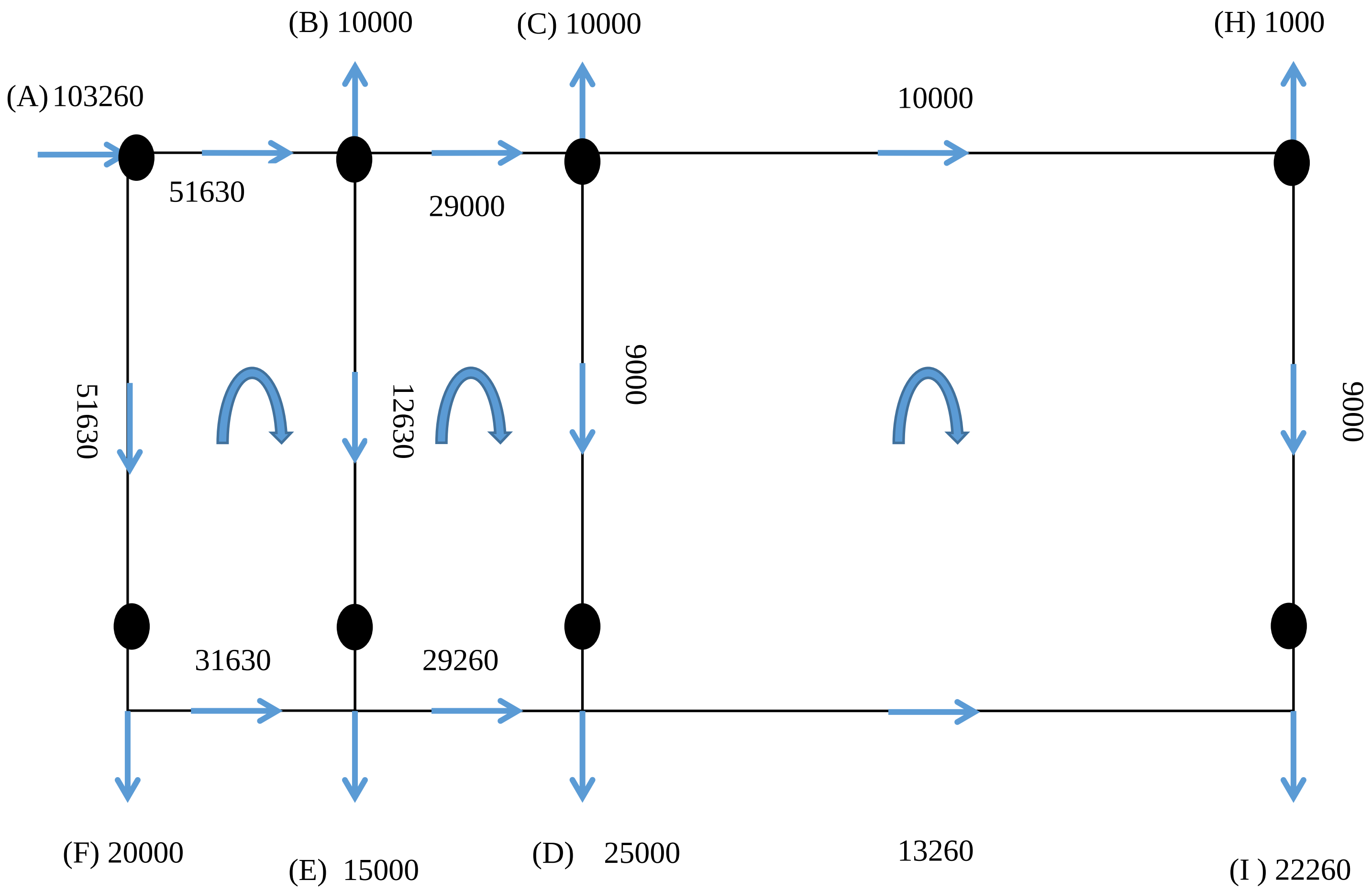

Table A.1: Length and diameter of each pipe

Pipe	AB	BC	CD	DE	EF	AF	BE	CH	HI	ID
L(m)	40	41	30	30	40	30	30	76.96	59.25	76.96
D(mm)	110	110	110	110	110	110	110	110	110	110

Darcy Weisbach equation:

To find k n=2 $k = f * \frac{8}{g\,\pi^2} * \frac{L}{D^5}$

To find $\frac{1}{\sqrt{f}} = -2Log\left(\frac{e/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right)$

E=0.001524 [0.000060 in to mm 0.001524]

To find Re $Re = \frac{v*D}{\nu}$ $\nu\ for\ water = 1.00 * 10^{-6}\ at\ t =$

Velocity v=Q/A A=$\pi D^2/4$

h=$K*Q^2$

Loop 1:

A=π(0.11)^2/4=0.009499 mm^2

Pipe AB

v=Q/A =0.000597569/0.009499 = 0.06291198 m/s

$Re = \frac{2.81*110}{1.00*10^{-6}}$ =6920.31782

$$\frac{1}{\sqrt{f}} = -2Log\left(\frac{0.001524/0.11}{3.7} + \frac{2.51}{6920.31782\sqrt{f}}\right)$$

f =0.048761694

k =973768.3

$h = k * Q^2$ =0.34772218

$\frac{h}{Q}$ = 581.894173

Pipe BE

v=Q/A =0.015389857 m/s

Re =1692.884257$turbulent$

f =0.063038667

h =0.0201755

$\frac{h}{Q}$ =138.0176846

Pipe EF

v= 0.038541661 m/s

Re =4239.582663

f =0.052086913

k =1040173

h =0.13940436

$\frac{h}{Q}$ =380.7947151

Pipe FA

v= 0.06291198 m/s

Re =6920.317828

f =0.048761694

k =730326.2

h =0.26079163

$\frac{h}{Q}$ =436.4206297

Loop 2:

1st iteration

Pipe BC

A=π/4*0.11^2=0.009499

v=Q/A =0.035336964 m/s

$Re = \frac{0.035336964 * 0.11}{1.00*10^{-6}} = 3887.065989$

$$\frac{1}{\sqrt{f}} = -2Log\left(\frac{0.001524/110}{3.7} + \frac{2.51}{3887.065989\sqrt{f}}\right)$$

f =0.052825708

$k = f * \frac{8}{g\pi^2} * \frac{L}{D^5}$ =1081300

$h = k * Q^2$ =0.12181886

$\frac{h}{Q}$ =362.9361979

Pipe CD

Re =536.14696

f =0.092546972

K=1386118

h =0.00297093

$\frac{h}{Q}$ =64.17213816

Pipe DE

Re =3921.915546

f =0.052747391

k =790021.8

h =0.09060669

$\frac{h}{Q}$ =267.5467447

Pipe EB

v=0.015389857 m/s

Re =1692.884257

f =0.063038667

k =944159

h =0.0201755

$\frac{h}{Q}$ =138.0176846

Loop 3:

Pipe CH

v=Q/A = 0.01218516 m/s

$Re = \frac{0.01218516 * 0.11}{1.00 * 10^{-6}}$ =1340.367582

f =0.067225706

$k = f * \frac{8}{g\pi^2} * \frac{L}{D^5}$ = 2582958

$h = k * Q^2$ =0.03460109

$\frac{h}{Q}$ =298.9534274

Pipe HI

v=Q/A =0.010966644m/s

Re =1206.330824

f =0.06935848

K=2051657

h =0.0222619

$\frac{h}{Q}$ =213.7142786

Pipe ID

v=0.016157522 m/s

Re =1777.327414

f =0.062251464

k =2391836

h =0.05633665

$\frac{h}{Q}$ =367.0804518

Pipe CD

v=0.004874064 m/s

Re =536.147033

f =0.092546967

k =1386118

h =0.00297093

$\frac{h}{Q}$ =64.1721433

Appendix B Project Management

B.1 Project Plan

Activity	**September 2017 - January 2018**														
	Week number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Setting Objectives	■														
Literature Review		■	■												
Writing The Proposal		■	■												
Choose A Residential Area			■	■											
Comparative Study Among Different Systems				■	■	■	■								
Prepare Mid Term Report				■	■	■	■	■	■						
Prepare Mid Term Presentation							■	■	■						
Finalize The Design Calculations									■	■	■				
Finalize The Design Drawings											■	■			
Prepare Final Detailed Report													■	■	
Prepare Final Presentation														■	■

B.2 Contribution of Team Members

The work has been evenly divided among the team members. Each team participated in writing the report and planning the project. Abdullah Aldali is interested in the chapter one Introduction, chapter two Literary Review, chapter three Methodology, chaper four Results and Discussion done by Abdulrhman Kojan, and chapter fifth Conclusions done by Abdullah Aldali. Abdulrhman Kojan is interested in the Calculation, and Abdullah Aldali is interested in the software WaterCad.

- Abdullah Aldali: did the Report writing, Collect data, and WaterCad (50%)
- Abdulrhman Kojan: did the Report writing, Collect data, and Calculation (50%)

B.3 Project Execution Monitoring:

List various activities:

Meeting:

- The meeting with Dr Saidur Chowdhury was at the beginning of the semester to re-explain some of the articles that relate to the project. The meetings were weekly with Dr Saidur Chowdhury to see the progress of the team.

Team meeting:

The Team is daily meeting because the schedule is made the same for them in order to stay together and work properly.

B.4 Challenges and Decision Making

- The availability of the data was challenging to find, so the team collected similar data from outside.

- Reaching to people, required from the team a lot of effort and time, to find the responsible people.

- Organizing the work between Abdullah Aldali and Abdulrhman Kojan was challenging, where each member lives in a different city.