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

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Introduction

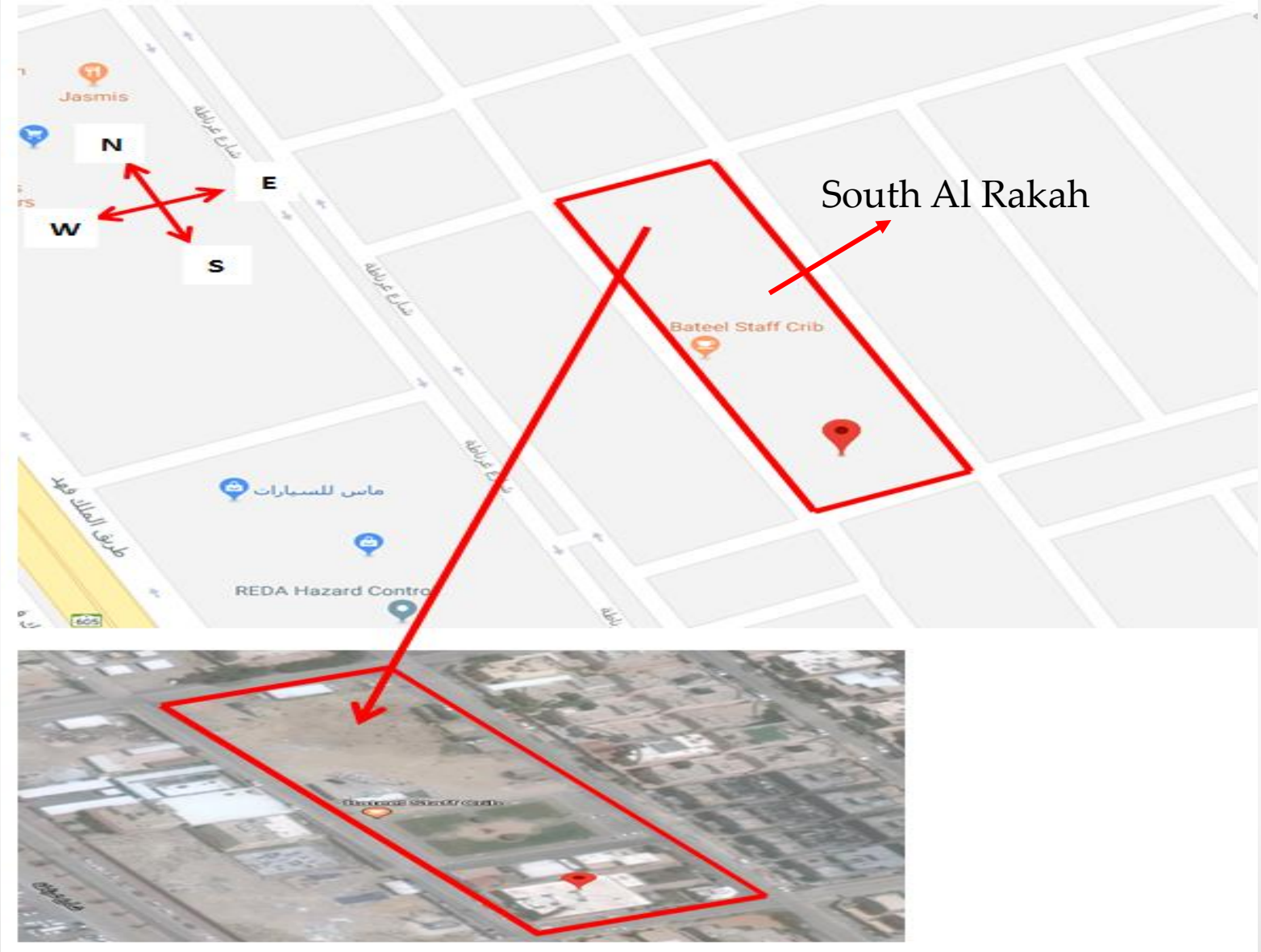
- The water supply industry is vitally important not only to maintain the health of the community, but for the sustainability of industry, business and agriculture. Without adequate water supplies our present society would never have evolved, and our lives today would be unrecognizable

- Generally, the distribution system of a small community water supply is designed to cater for the domestic and other household water requirements

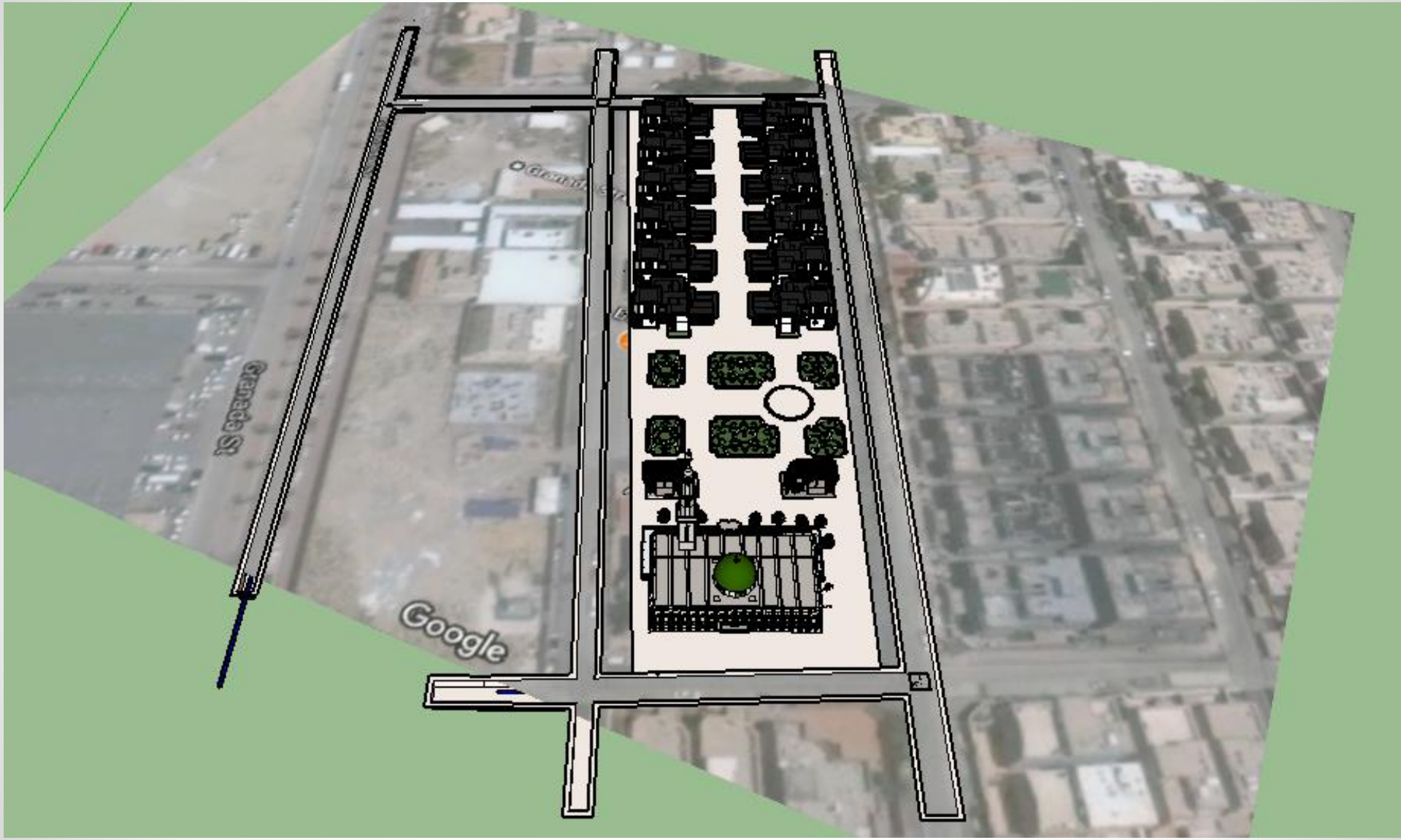
Objectives

- Design the looped network for WSS in the residential area located in Al-Khobar city

Background of The Project



Background



Background

- Water distribution systems are designed to adequately satisfy the water requirements for a combination of the following demands:

- **Domestic**
- **Residential**
- **Firefighting**

- The system should be capable of meeting the demands at all times and at satisfactory pressure

Background

- $N = N_O(e)kt$.

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:

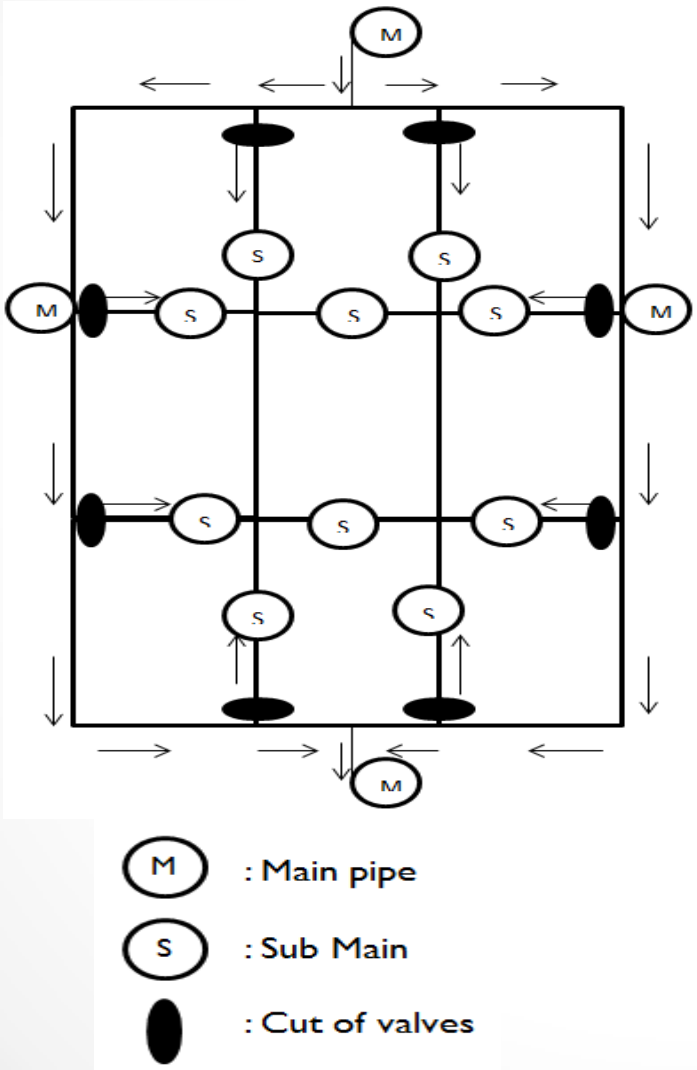
P_n = future population

P = current population

N= number of years

C= rate of change of population with respect to time

Background



Loop network:

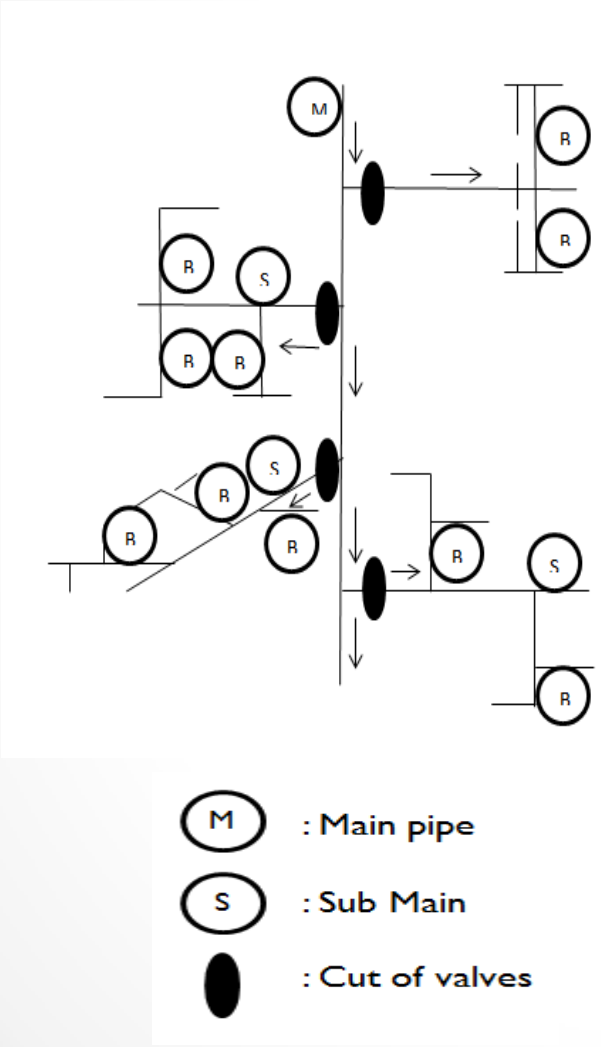
Advantages:

- Reduce the dead ends
- There are valves on the lateral pipes to control the network
- It is easy to extend the network
- The water can reach every point in two directions

Disadvantages:

- Relatively high initial cost
- A large number of valves is needed

Background



Branch network:

Advantages:

- Simple in design and construction.
- Low cost

Disadvantages:

- Dead ends tend to reduce the pressure and pollute water
- There are not enough valves to control the network
- Difficulties in extension of the network

Backgound

- Darcy-Weisbach Equation

1. head loss :

$$h_l(\text{pipe}) = KQ^n$$

$$n = 2$$

$$K = f\frac{8}{g\pi^2}\frac{L}{D^5}$$

h_l = Head loss
K = The constant depending on the length
Q = Flow discharge
f = Fraction
L = Length of pipe
D = Diameter of pipe

Background

2. Fraction:

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

$$Re = \frac{V * D}{\nu}$$

Re= Reynolds number
ν= viscosity of water
V= velocity
e=0.001524

Methodology

- **Project Description**

- Select area
- The project has the following main features

- Located in Al khobar City

- Land area is 10152.48 m^2

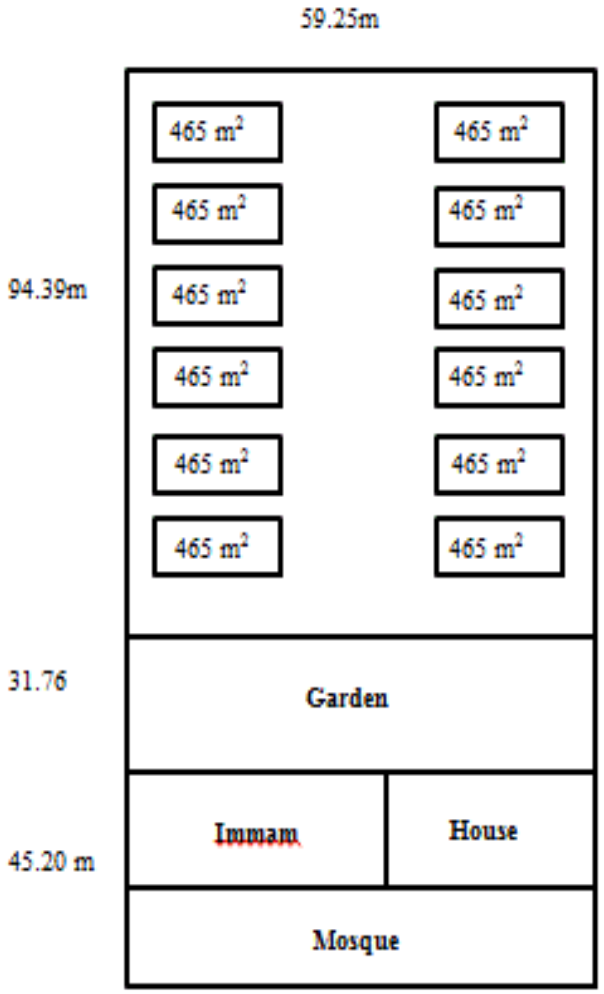


Figure 5: The Design of Project Site

Methodology

- Number of homes = 5592/465 = 12 homes
- Average number of persons per home = 10
- Design of population
- $N = N0\ e^{kt} = 120 * 2.71828^{0.0205*30} = 222$

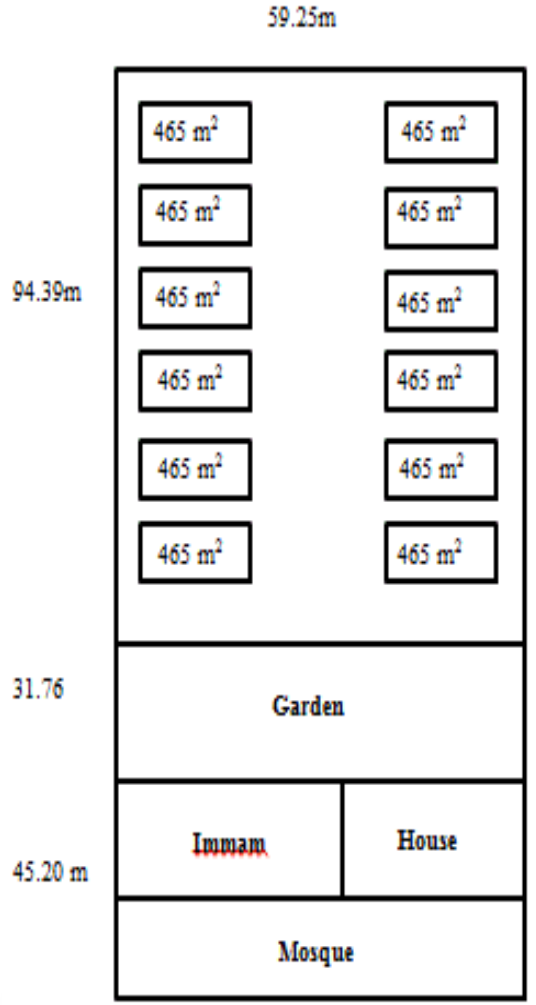


Figure 5: The Design of Project Site

Design

- **Assumptions**

- Minor calculation did not included in this project

- Design life cycle was considered 30 years in this design project

- Maximum 2 bar pressure considered for pipe flow

  [Source : City of Al khobar]

- Diameter of main pipe = 300mm
  and Sub-main = 110 mm

- Roughness size of pipe, e = 0.001524

  [Source : City of Al khobar]

Design

- **Assumptions**

- Rate of change of population with respect to time constant, [C] = 2.05 [Source : City of Al khobar]

- Number of Person = 10 Persons per home

- Water demand for other fire, emergency, loss [5%] was considered to be 7000 L/d [Source : City of Al khobar]

- Consumption per capita per day [LPCD] = 220 [Source : City of Al khobar]

- Safety factor S.F = 1.5 [Source: City of Al khobar]

Design Limitations

1) Population
2) Elevation of the pipe
3) Volume of soil generated for Excavation
4) Pipe gradient
5) Quality of water
6) Design did not include reservoir
7) Sampling station
8) Soil conditions
9) Location and other site specific factors
10) Pressure of the pipe
11) Operating and Maintenance cost
12) Energy conservation

Constrains

1) Physical and Technical Constraints
2) Economic and Financial Constraints
3) Institutional Constraints
4) Structural Constraints
5) Climate constraint
6) The availabilities or accessibility of water sources
7) Safety
8) Land availabilities for project implementation
9) Environmental Constraint

Steps Required for the Looped Network Design

- **Steps for design:**

Step-1) Data collection

We collected our all necessary information from municipal of Al Khobar, website and Saudi building code. Also the books which were related to water supply system, and some published articles

Step-2) Population calculation

This formulas we used to design the population (after 30 years) were as follows:

- Step-3) Design calculation

1. Discharge calculation

- Assumed discharge Q_a and direction for each pipe.
- Applied continuity equation at each node,

  Total inflow = Total Outflow

2. Calculate equivalent resistance K for each pipe

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

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

$$Re = \frac{V * D}{\nu}$$

Re = Reynolds number
ν = viscosity of water
V = velocity
e = 0.001524

3. Calculate head loss for each pipe

$h_f = K\, Q_a^{\,n}$ $\qquad k = f * \frac{8}{g\,\pi^2} * \frac{L}{D^5}$

4. Correction factor

$\Delta = correction\ of\ pipe$

Q_a= assumption of flow

N= 2

Design Materials

Table1 : Pipe Materials

Types	
Pipe Main	(DI) Ductile Iron
Sub main	(HDPE) High Density Polyethylene
Valves	Check and Gate Valve
Fire Hydrant	Fire Hydrant FHUL
Bend pipe	90 Degree Bend Pipe, T pipe

Design of the Water Supply System

Total water demand calculation

- Based on population:

- N = $N_O e^{kt}$

  When,
- e = 2.71828
- N = Future population
- N_O = present population
- K = rate of growth
- t = number of years

Total population = N = $N_0\ e^{kt}$ = $120 * 2.71828^{0.0205*30}$ = 222

So Q based on population = 222×220 = 48840 L/d

Design of the Water Supply System

Total water demand calculation

Water demand for other fire, emergency and losses = 7000 L/d

Total demand= 48840 + 20000 × 1.5 = 103260 L/d

This design showing total nodes, three loops, total Q which calculated based on population and loss, emergency, firefighting, also showing the assuming (Q_a)

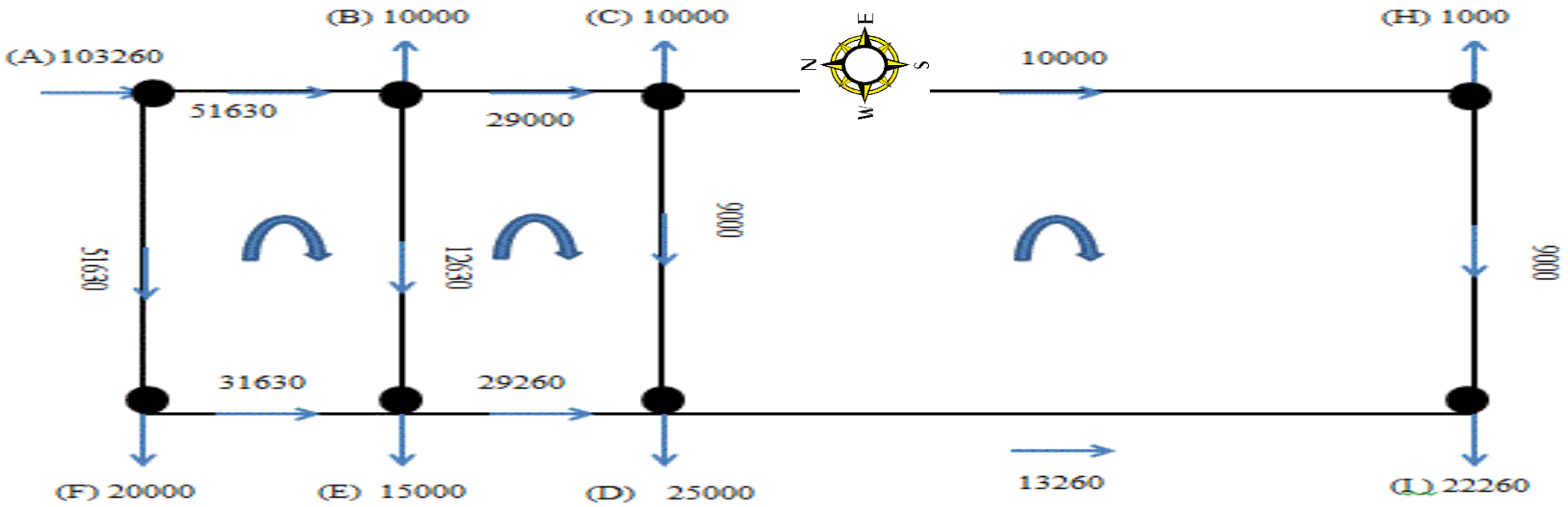


Figure 6: The looped distribution network for WSS

The node (A) 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

Table (2) : The length and diameter for all pipes

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

LOOP 1 **Table 3: Design calculation from Ist Trial**

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						

LOOP 2 **Table 4: Design calculation from 1st Trial**

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	4.62963	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: Design calculation from 1st Trial

LOOP 3

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	4.62963	1386118	0.0029	64.172	-2.31481	0.0140	0.0094	0.004	536	0.09
					0.116	0.116						

WaterCAD

- 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

Bentley WaterCAD V8i (SELECTseries 6) [water 19.wtg]

File Edit Analysis Components View Tools Report Help

Base

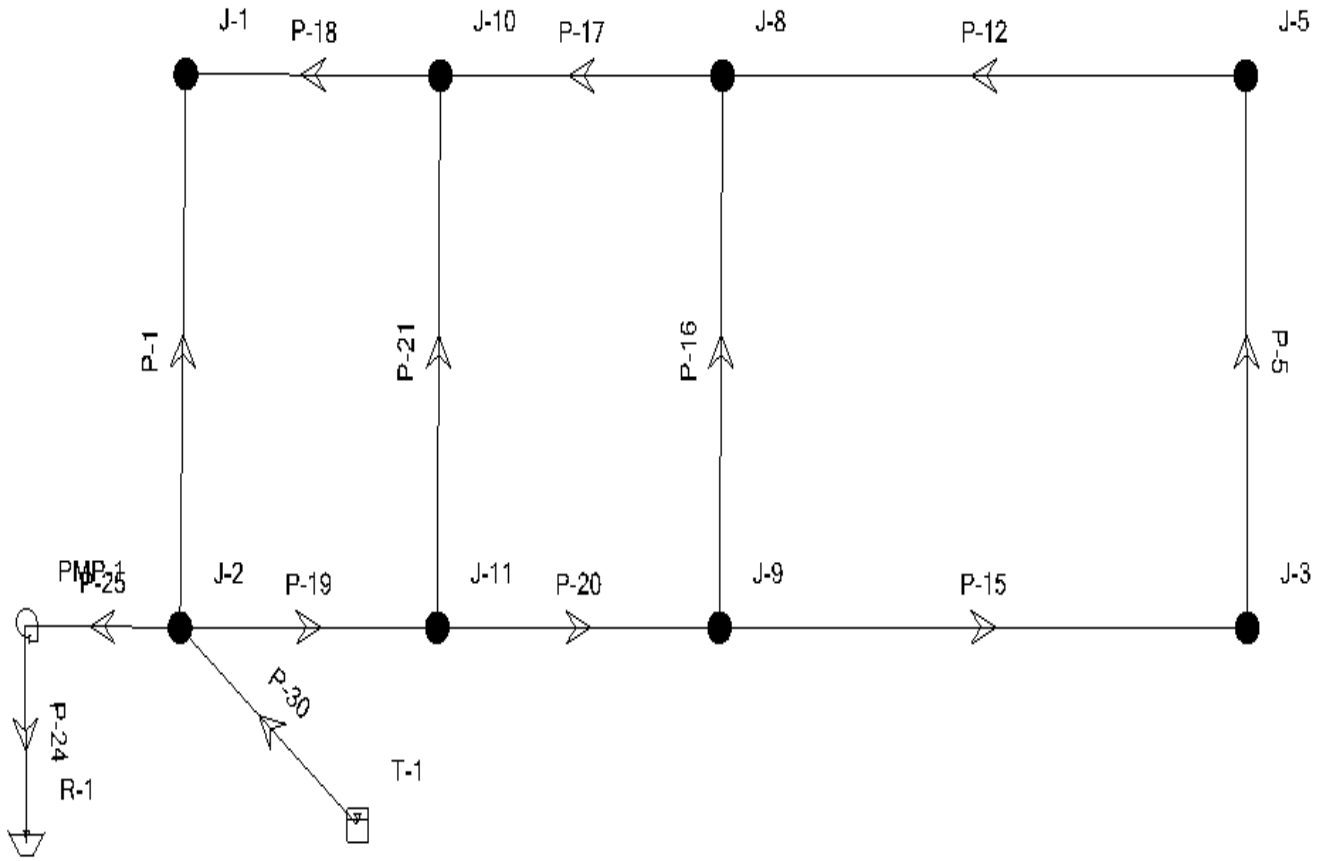
Queries

- Queries - Project
- Queries - Shared
- Queries - Predefined
  - Network
  - Network Review
  - Network Trace
  - Input
    - Duplicate Labels
    - Elements with SCADA data...
    - Inactive Elements
    - Customer Meters Associated With
    - Pipes with Check Valves
    - Controlled Elements
    - Controlled Pumps
    - Controlled Valves

Background Layers

- Background Layers

water 19.wtg



X: -53.22 m, Y: -25.32 m

Zoom Level: 104.3 %

Average

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

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

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

Firefighting

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

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

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

Peak

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

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

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

Partial Cost Estimation

Type of material	Size	Cost form factory	Cost after enforcement
Pipe (DI)	300mm	270 R.S for 1 meter	500 R.S for 1 meter
Pipe (HDPE)	110mm	46 R.S for 1 meter	150 R.S for 1 meter
Pipe house connection	From 40 to 60mm	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	

Cost Estimation

- 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

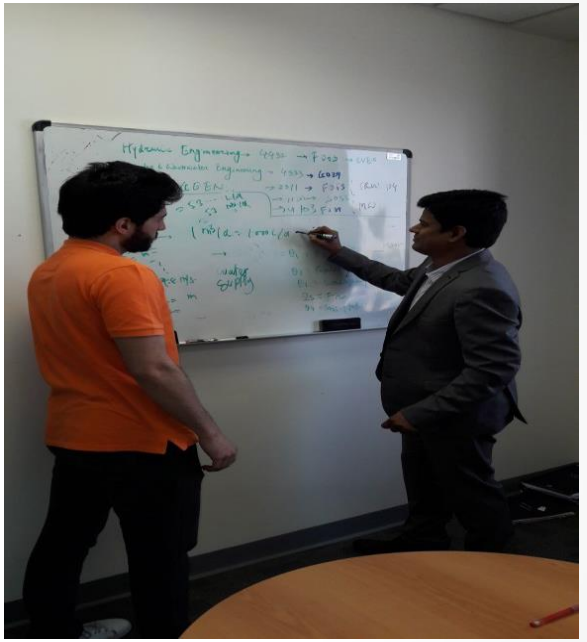
- Total cost for valve = 1820 * 7 = 12740 R.S
- The total cost estimation for project is 231000 + 8600 + 12740 = 252340 R.S

- Approximate Unit Cost = 252340 / 461.2 = 547.14 R.S per meter of the length

Conclusions

- Looped network system was considered for the distribution system to the considered area located in AL Khobar city

- The design was based on the common equation which is the energy equation



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