ABSTRACT

This report covers the water supply, sanitation and sewage system design of an industrial village which was designed for the purpose of the Environmental Engineering Design sessional course. The layout of an industrial village which contains a Textile Industry has been proposed. The organogram of the Textile Industry has been prepared and on the basis of the organogram the total population has been calculated. The water that would be required to serve the population has also been calculated, including the water demand for fire-fighting. Both the population and water demand have been estimated for the current and future condition. The design periods have been taken as **10**, **20** and **30 years**. The source of water is tube wells and they have been designed depending on the geological information of the substrata. For the water supply system pump capacity was calculated and pumping schedules have been prepared. Overhead tanks have been located and pipe networks for the industrial village have been designed. The pipe sizes have also been calculated. The sanitary sewerage system has been designed. For this purpose the amount of waste water has been estimated. The system would be a gravity system and the pipe network and pipe sizes for this have been calculated. Apart from these, the plumbing system of a ten story building has been designed. The drainage system of that building has also been completed. At the end the basic features of the **CETP** (Common Effluent Treatment Plant) located at Savar, Dhaka has been covered.

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CHAPTER - 1

INTRODUCTION

1.1 GENERAL DESCRIPTION:

This report mainly portraits the details about design of sanitation, water supply and sewerage systems. This course **CE-432** has mainly been introduced to us for making us more knowledgeable about those terms. This is basically a sessional course and the total course topics have been divided in **14 weeks**. In this course we have designed the water supply, sanitation and sewerage systems of a typical industrial village, a textile industry to be specific. In this report we have mentioned all the works step by step and chapter wise to make the report more understandable. This report has helped us a lot as environment engineers, how we should start any sanitary design system and most importantly team work. This course has also given us the opportunity to visit the **CETP** (Common Effluent Treatment Plant) situated at Savar and helped us to gain practical knowledge about effluent treatment.

At the very beginning of the report, we have prepared a typical organogram showing all sections of the project, department wise division of people and also how many workers will be working in each section. Next we have prepared a rough layout of the industrial village. For that at first we have divided the whole village in three zones – residential zone, commercial zone and industrial zone. In the layout we have clearly shown all the facilities that will be available in each zone. In the residential zone we have shown all the residential allotments for the people who will be staying in the industrial village, which is a certain percentage of the total work force. In the commercial zone we have included all commercial facilities such as – school, markets, shopping mall, mosque etc. Finally for industrial zone we have shown various sections of the textile industry and also the treatment plant section. In the particular layout we have left reasonable amount of space for any future extensions. At the same time we have also prepared a project Gantt chart for the suitable time division of each part of the report, so that we would be able to complete the report more efficiently and precisely.

1.2 OBJECTIVES AND OUTLINE OF THE REPORT:

The total report consists of **12** chapters mainly. Each chapter represents individual part of the design of the industrial village:

Chapter – 1: This chapter is mainly the introductory portion of the report. The objective of this chapter is to introduce us with all activities of the project step by step and also about the limitations. In this chapter the project Gantt chart is also included showing the time schedule of each section.

Chapter – 2: In this chapter we have prepared a typical organogram for our textile industry specifying all the necessary sectors of the industry. The objective of this chapter is to enlighten us about the importance of preparing an organogram for any project.

Chapter – 3: This chapter illustrates the complete layout of the industrial village. In this chapter the different zones of the village have been mentioned – residential zone, commercial zone and industrial zone. Also various facilities under each zone have also been included here.

Chapter – 4: In this chapter we have estimated the total population for each zone. We have also calculated the future population for **10**, **20** and **30 years** of the village. The population for the residential zone was obtained from the organogram previously prepared and the accommodations for the residents have been allotted in accordance with that.

Chapter – 5: This chapter illustrates the water demand calculation for the predicted population from the previous chapter. The water demand calculation has been divided in four parts – for residential zone, for commercial zone, for industrial zone (including both production purpose and personal consumption) and for fire-fighting. Water demand for future predicted population for **10**, **20** and **30 years** has also been estimated.

Chapter - 6: This chapter includes the development of water source for different zones of the industrial village. Here the grain size analysis at different depth of the soil has been provided. From that data we have selected the appropriate layer for the water source development. Also in this chapter we have calculated the total number of tube-well required for each zone both for present and future.

Chapter – 7: In this chapter we have estimated the pump capacity for each zone both for present and future. Also we have prepared pumping schedule for each zone for present, **10**, and **20 years**. We have also prepared individual demand curve for each pumping schedule and estimated the average demand of each zone.

Chapter - 8: This chapter represents the design of water distribution network showing branch network design for residential and commercial facilities and loop network design for industrial zones. Here the appropriate pipe diameter and pressure have been calculated for the branch network system and for loop network system two trials have been given for designing industrial area and pipe diameter.

Chapter – 9: This chapter illustrates the design of wastewater conveyance system for the industrial village. Trunk sewer design is mainly focused here along with determining the layout of manholes. The waste water collected from residential and the commercial zone and disposal of that water is the main theme of this chapter. Here the peak flow and cumulative flow have been calculated and next the trunk sewer line has been designed in accordance with that calculation.

Chapter – 10: This chapter represents the design of plumbing system for a typical **10** storied residential building. The design includes – determination of fixture unit, design of underground water reservoir, design of over-head tank, design of riser pipe, determination of pump capacity and design of down feed zone pipes.

Chapter – 11: This chapter includes the design of water supply and drainage system for the **10** storied building mentioned before. Here two pipe drainage system has been considered and accordingly we have designed the soil stack, waster stack and vent stack for the building.

Chapter – 12: The final chapter contains a brief discussion regarding the field visit at the CETP, Savar.

1.3 LIMITATIONS OF THE REPORT:

- There were many values (Peak factors, growth rates population for some sectors etc.) which we did assume from personal judgment which is one of the limitations of this report.
- Due to lack of experience and proper knowledge, there might be unavoidable mistakes in the report.

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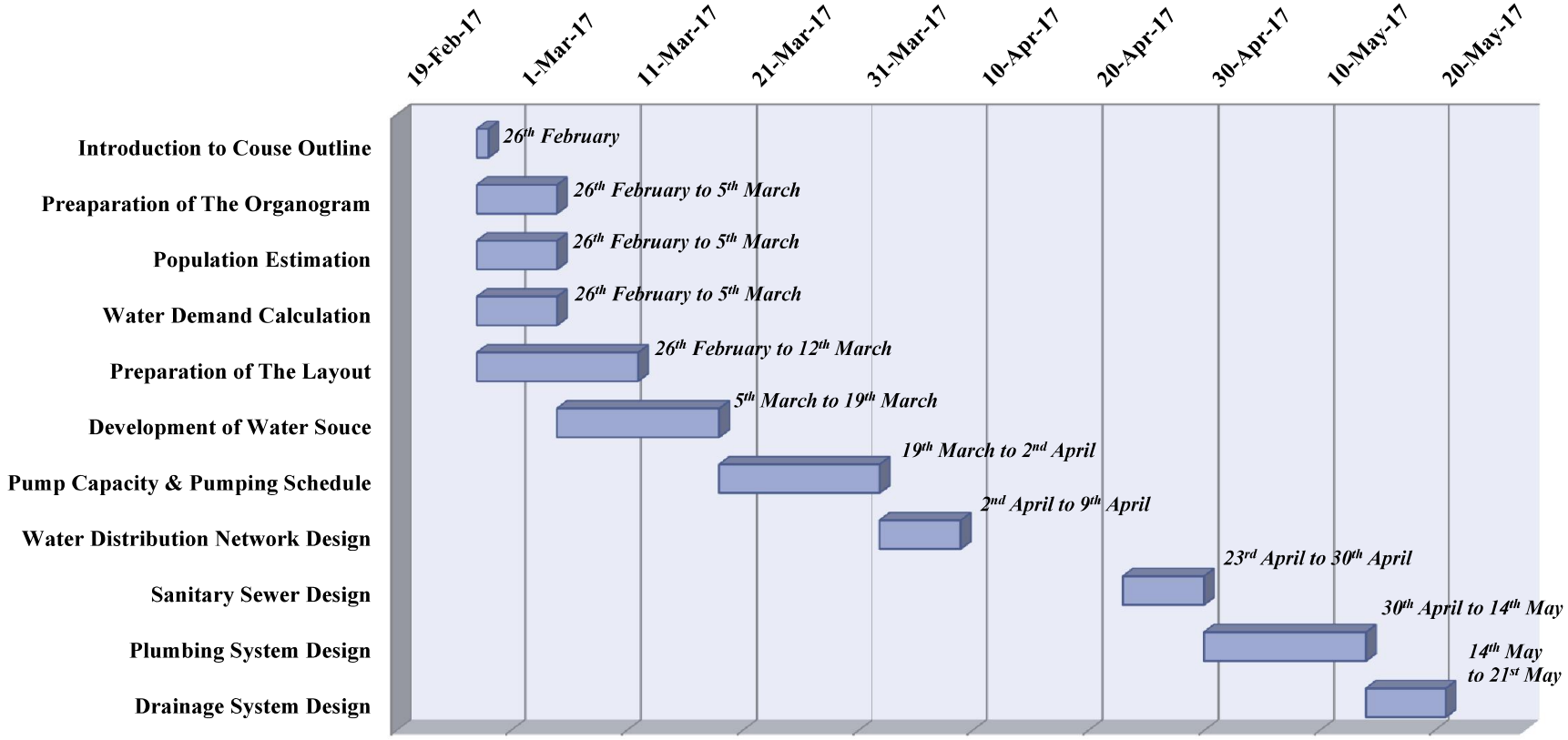
1.4 PROJECT GANTT CHART:

A Gantt chart is a graphical depiction of a project schedule. It is a type of **bar chart** that shows the start and finish dates of several elements of a project that include resources, milestones, tasks and dependencies. Henry Gantt, an American mechanical engineer, designed the Gantt chart. It is the most widely used chart in project management. These charts are useful in planning a project and defining the sequence of tasks that require completion. In most instances, the chart displays as a horizontal bar chart. Horizontal bars of different lengths represent the project timeline that includes task sequences, duration, and start and end dates for each task. The horizontal bar also shows how much of a task requires completion. The horizontal bar length is proportional to the time necessary for a task's completion. In addition, the project tasks are visible on the vertical bar. A Gantt chart aids in scheduling, managing, and monitoring specific tasks and resources in a project.

For our project we have also prepared a typical Gantt chart showing all the necessary elements and their time schedule. In case of performing the work, we did not adhere to the scheduling and duration of the activities strictly, due to unavoidable circumstances. But this project Gantt chart helped us to see what work was scheduled at what time . The Gantt chart also gave an overview of the progress of our work.

The Project Gantt chart prepared by us at the starting of our work is given in the following page:

FIGURE 1.1: PROJECT GANTT CHART (For a Typical Indistrial Village)



	Drainage System Design	Plumbing System Design	Sanitary Sewer Design	Water Distribution Network Design	Pump Capacity & Pumping Schedule	Development of Water Souce	Preparation of The Layout	Water Demand Calculation	Population Estimation	Preaparation of The Organogram	Introduction to Couse Outline
Starting Date	14-May-17	30-Apr-17	23-Apr-17	2-Apr-17	19-Mar-17	5-Mar-17	26-Feb-17	26-Feb-17	26-Feb-17	26-Feb-17	26-Feb-17
Duration (Days)	7	14	7	7	14	14	14	7	7	7	1

CHAPTER - 2

ORGANOGRAM OF THE INDUSTRIAL VILLAGE

2.1 GENERAL DESCRIPTION:

An organizational chart, or Organogram, is a diagram that shows how an organization is structured, and how the positions in the organization are related to each other. An Organogram describes the jobs of each establishment at different levels and describes their relationships. A common name for Organogram is organizational chart.

The Organogram gives us an idea about the structure of the company and an estimate of the total number of working people. A rough estimation of the total population was computed from the Organogram.

For preparing the Organogram we have over viewed the Organogram of BUET[1]. For the different units of the textile industry the units of different textile industries were reviewed[2][3]. To get an idea about the ranks of employees the Organogram of some industries like Niagara Textile and others were taken into consideration[4][5][6].

In our proposed rganogram the Chairman is the head of the textile industry. Below the chairman is the Managing Director followed by the Executive Director. Below the executive director there are **6** Head of the Departments (HoD), each with separate area of responsibility. The HoDs' are directly responsible to the Managing Director and of equal rank with each other.

Below each Head are the positions they supervise. Using the example of the Human Resources, the Head is directly below the Managing Director followed by the **5** Executive Officers. There are **13** Sub-Executive Officers responsible to these **5** Executive Officers who are in turn responsible for the **25** HR officers below them. Each of the Executive officers is responsible for different divisions of HR such as Recruitment, Employee Benefits, Training and Development Division, Employee Assistance Program, Training and Development, Compliance etc. The Organogram in a form of flowchart has been provided in the next segment.

An Organogram is very essential to forming and designing any industry, company or office. It is an important tool for management, owners, stake holders and also for engineers and planners in designing the water supply, sanitation and waste management. Knowledge of the Organogram will help us through in our future service life like it helped in our academic life.

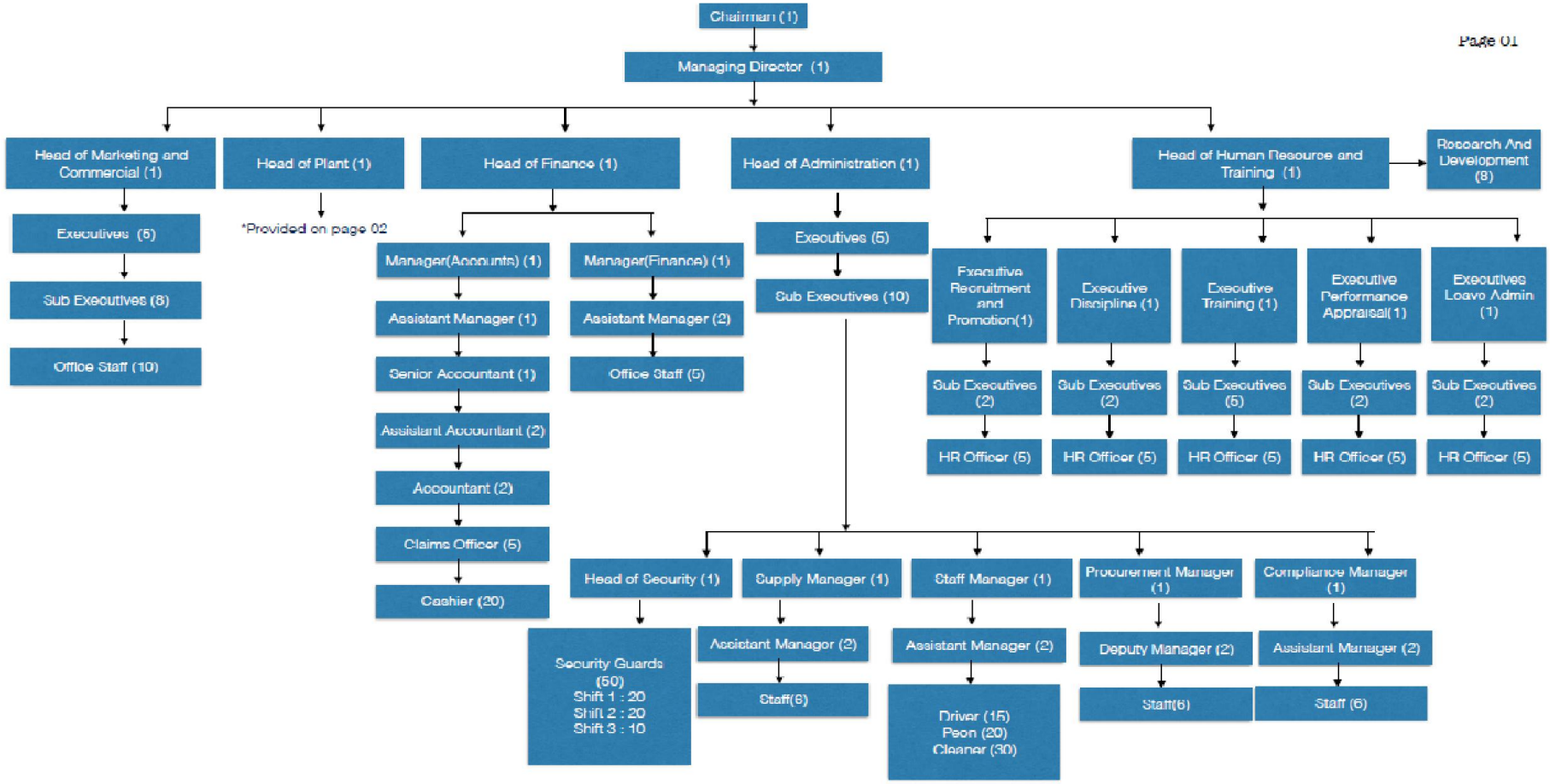


FIGURE 2.1: ORGANOGRAM OF THE INDUSTRIAL VILLAGE

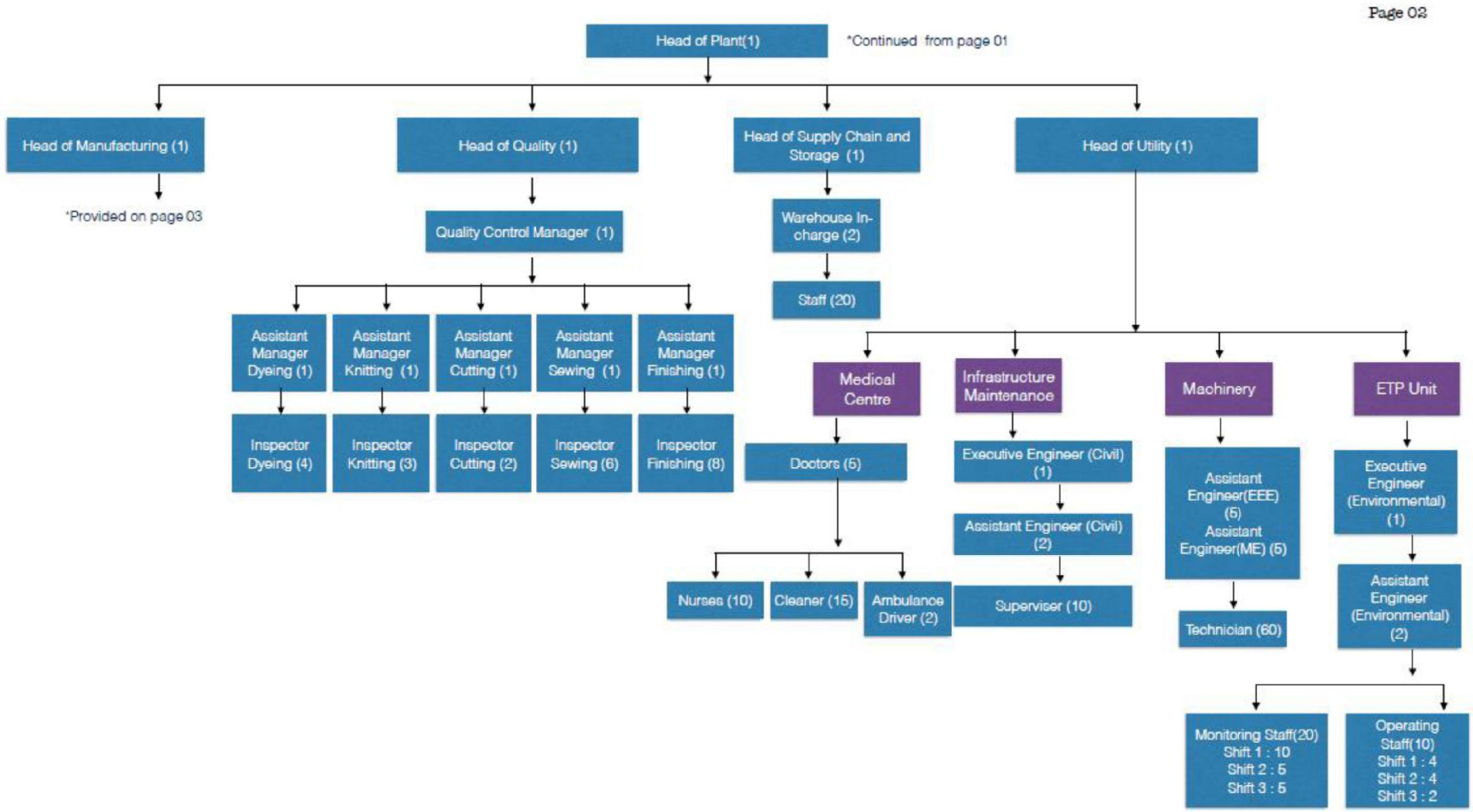


FIGURE 2.1: ORGANOGRAM OF THE INDUSTRIAL VILLAGE (Continued)

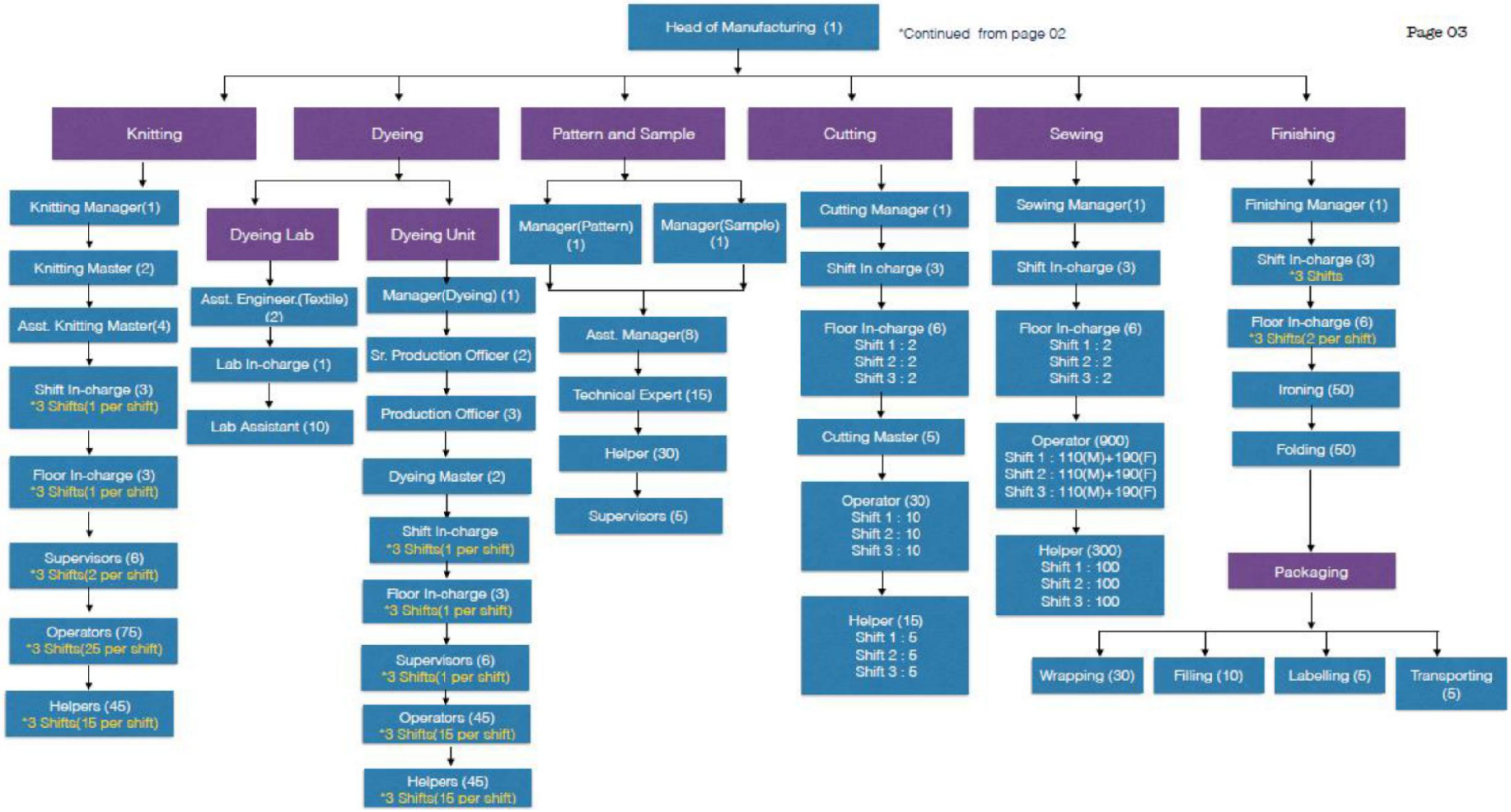


FIGURE 2.1: ORGANOGRAM OF THE INDUSTRIAL VILLAGE (Continued)

CHAPTER - 3

LAYOUT OF THE INDUSTRIAL VILLAGE

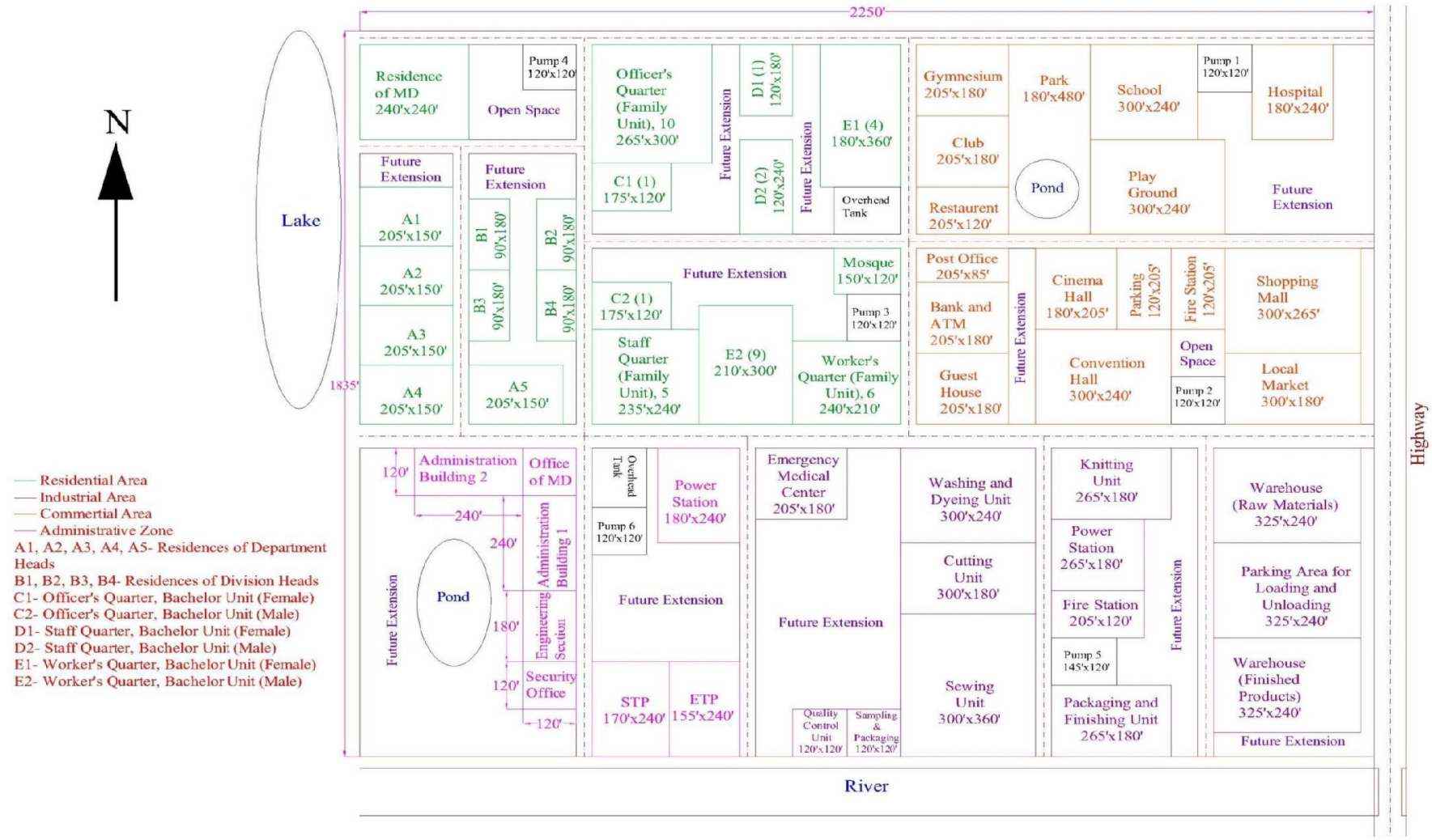


FIGURE 3.1: LAYOUT OF THE INDUSTRIAL VILLAGE

3.1 GENERAL DESCRIPTION:

The industrial village was designed for a Textile Industry. The whole area of the village is about 100 acres. The village is extended **2250 feet** from **West to East** and **1835 feet** from **North to South**. There is a highway on the Eastern side of the village. On the South there is a river. There are three (**3**) entrances to the industrial village from the highway. There are intermediate roads with a width of **35 ft**. The main road that is used by the people of the industrial village is **60 ft** wide.

The designation of different zones was made trying to keep symmetry between road networks for further lying out of pipe networks. There are mainly three parts of the whole industrial village. On the southern part the whole industrial unit is located. On the Northern part the residential block and the commercial zone is situated.

The loading and unloading area for the industry is beside the highway. So the trucks and other heavy vehicles carrying the goods don't need to enter the village. The residence of the workers has been kept close to the industry so that they can easily travel to their work place. The managing director's residence is at the North-Western corner. The commercial facilities have been kept in a completely different block. The effluent treatment plant and sewage treatment plant are located beside the river so that the discharge of treated waste water can be done easily. It is also kept away from the residential zone for avoiding any inconvenience. There are also water bodies for recreation purpose. Provisions for future extensions are also there.

3.2 DESCRIPTION OF ZONES:

There are three zones which are stated below along with the components:

3.2.1 Residential Zone:

- Residence of Managing Director
- Duplex houses for Head of different units
- Officers' Quarter – **1)** Family Unit
  2) Bachelor Unit (Male, Female)
- Staff Quarter – **1)** Family Unit
  2) Bachelor Unit (Male, Female)

3.2.2 Commercial Zone:

- Gymnasium
- Club
- Restaurant
- School
- Playground
- Park
- Hospital
- Post office
- Bank and ATM Booth
- Cinema Hall
- Guest House
- Convention Hall
- Parking lot
- Fire Station
- Shopping Mall
- Local Market

3.2.3 Industrial Zone:

- Administrative Building (1,2)
- Office of Managing Director
- Security Office
- Engineering Section
- Power Station (For Residential And Commercial Zone)
- STP
- ETP
- Emergency Medical Centre
- Washing and Dying Unit
- Cutting Unit
- Sewing Unit
- Knitting Unit
- Power Station (For Industry)
- Fire Station
- Packaging and Finishing Unit
- Showroom
- Sampling Unit
- Loading and Unloading Area
- Ware House (For Raw Materials)
- Ware House (For Finished Goods)

The dimensions of different areas were assumed depending on the population of different zones. The facilities in the commercial zones have been provided by keeping the needs of the residents in mind.

CHAPTER - 4

POPULATION ESTIMATION OF THE INDUSTRIAL VILLAGE

4.1 INTRODUCTION:

Our industrial village is a medium sized village. For complete design of the village calculating the population is very important. Later on the water demand and other facilities will be determined depending on this population. There are three different zones and these will have different populations.

The whole population was obtained from the organogram. The organogram shows the ranks of the employees. For the residential zone, there are different categories of buildings which are designated according to the ranks of the employees. There is managing director's residence, duplex type flats for head of units, Officers' quarter, Staff Quarter and Quarter for workers. There are also provisions for separate bachelor units for male and female employees and workers. But all the people of the organogram were not facilitated with residential facilities. A certain percentage was accommodated. We have assumed that the rest of the people will stay near the industrial village and will commute on a daily basis. The present population was calculated and the future population after **10**, **20** and **30 years** were also calculated. For calculating the population growth of the residential zone we have assumed a growth rate. Different growth rates were assumed for different classes. All the employees have a designated category as shown in the **Table 4.1.**

For the commercial zone the populations were assumed for different facilities. Calculation of the future population was done thinking that the increase will be linear. Different percentage of growth was assumed.

For the industrial population increase of population was also linear as here the population depends on the increase of production. The percentage of growth was assumed. All the assumptions are stated in **Table 4.2**.

TABLE 4.1: BUILDING TYPE

Category	Designation	Housing Allocation
A	Managing Director Head of Marketing and Commercial, Head of Plant, Head of Finance, Head of Administration, Head of HR and Training Head of Manufacturing, Head of Quality, Head of Supply Chain and Storage, Head of Utility	Duplex Type Type 1
B	Engineer Doctor Executives Sub-Executives Manager Assistant Manager Senior Accountant Assistant Accountant Head of Security	Officers Quarter Apartment Type (Family unit & Bachelor unit) Type 2

TABLE - 4.1: BUILDING TYPE (Continued)

Category	Designation	Housing Allocation
C	Unit In-charges Office Staff Officers Cashier Accountants Inspectors Supervisors Knitting Master, Dyeing Master, Cutting Master Assistant Knitting Master, Assistant Dyeing Master, Assistant Cutting Master	Staff Quarter Apartment Type (Family unit & Bachelor unit) Type 3
D	Drivers Cleaners Technicians Workers Nurses Security Guards Operators Helpers Peon	Flat Type (Family) Mess (Bachelor) Type 4

TABLE - 4.2: ASSUMPTIONS

Residential Zone:

From Bangladesh Bureau of Statistics we obtained the Growth Rate (National) = **1.37** (2014) [7]

For Employee category (A, B, C) the growth rate will be lower. So we assumed it as **1** and **1.2**.

For Employee category D the growth rate will be higher. So we assumed it as **1.5**.

Employee Category	Family Members	Percentage Provided with Accommodation	Percentage Of Family Unit	Percentage Of Bachelor Unit	Number Of Employees	Population Growth Rate
A	5	100%	100%	-	10	1.0%
B	5	60%	80%	20% Male - 59% Female - 41%	119	1.0%
C	5	60%	60%	40% Male - 85% Female - 15%	256	1.2%
D	5	50%	30%	70% Male - 32% Female - 68%	1852	1.5%

Industrial Zone:

Population Growth Rate After 10 Years	Population Growth Rate After 20 Years	Population Growth Rate After 30 Years
25%	30%	35%

Commercial Zone:

Population Growth After 10 Years	Population Growth After 20 Years	Population Growth After 30 Years
27%	32%	38%

***All the operation times for commercial facilities were assumed.**

4.2 SAMPLE CALCULATION FOR POPULATION PREDICTION:

4.2.1 Residential Zone:

- **TYPE-1:**

Present Population	=	10
Accommodation Provided	=	100%
Family Unit	=	10
Bachelor Unit	=	0
Assumed Family member	=	5 persons/family
Residential Population	=	10 * 5 = 50
Growth Rate	=	1% (Bangladesh Bureau of Statistics)
Population after 10 years	=	$50 * (1+1/100)^{10} = 55$
Population after 20 years	=	$50 * (1+1/100)^{20} = 61$
Population after 30 years	=	$50 * (1+1/100)^{30} = 67$

- **TYPE – 2:**

Present Population	=	119
Accommodation Provided	=	100%
Family Unit	=	80% = 0.8 * 119 = 95
Bachelor Unit	=	20% = 0.2 * 119 = 24 (Male = 14, Female = 10)
Assumed Family member	=	5 persons/family
Residential population	=	(95 * 5) + 24 = 499
Growth Rate	=	1% (Bangladesh Bureau of Statistics)
Population after 10 years	=	$499 * (1+1/100)^{10} = 551$
Population after 20 years	=	$499 * (1+1/100)^{20} = 609$
Population after 30 years	=	$499 * (1+1/100)^{30} = 673$

- **TYPE – 3:**

Present Population	=	256
Accommodation Provided	=	60% = 0.6 * 256 = 154
Family Unit	=	60% = 0.6 * 154 = 92
Bachelor Unit	=	405 = 0.4 * 154 = 62 (Male = 52, Female = 10)
Assumed Family member	=	5 persons/family
Residential population	=	(92 * 5) + 62 = 522
Growth Rate	=	1.2% (Bangladesh Bureau of Statistics)
Population after 10 years	=	$522 * (1+1.2/100)^{10} = 588$
Population after 20 years	=	$522 * (1+1.2/100)^{20} = 663$
Population after 30 years	=	$522 * (1+1.2/100)^{30} = 745$

- **TYPE – 4:**

Present Population	=	1852
Accommodation Provided	=	50% = 0.5 * 1852 = 926
Family Unit	=	30% = 0.3 * 926 = 278
Bachelor Unit	=	40% = 0.7 * 926 = 648 (Male = 207, Female = 441)
Assumed Family member	=	5 persons/family
Residential population	=	(278 * 5) + 648 = 2038
Growth Rate	=	1.5% (Bangladesh Bureau of Statistics)
Population after 10 years	=	$2038 * (1+1.5/100)^{10} = 2365$
Population after 20 years	=	$2038 * (1+1.5/100)^{20} = 2745$
Population after 30 years	=	$2038 * (1+1.5/100)^{30} = 3185$

4.2.2 Commercial Zone:

- **FOR HEALTH CARE CENTRE:**

Present Population	=	450
Growth after 10 years	=	27%
Growth after 20 years	=	32%
Growth after 30 years	=	38%

So,

Population after 10 years	=	1.27*450 = 571
Population after 20 years	=	1.32*450 = 594
Population after 30 years	=	1.38*450 = 621

4.2.3 Industrial Zone:

- **FOR SEWING UNIT:**

Present Population	=	1210
Growth after 10 years	=	25%
Growth after 20 years	=	30%
Growth after 30 years	=	35%

So,

Population after 10 years	=	1.25*1210 = 1512
Population after 20 years	=	1.30*1210 = 1573
Population after 30 years	=	1.35*1210 =16

POPULATION OF RESIDENTIAL ZONE

Type of Building	Present Population	Percentage of Employees Provided with Accommodations	Residential Employees	Family Unit	Bachelor Unit	Number of Persons per Family	Residential Population	Growth Rate* %	Future Population**			Remarks
									After 10 Years	After 20 Years	After 30 Years	
Type 1	10	100	10	10	---	5	50	1	55	61	67	---
Type 2	119	100	119	95 (80%)	24 (20%)	5	499	1	551	609	673	In bachelor unit: Male 14 (59%), Female 10 (41%)
Type 3	256	60	154	92 (60%)	62 (40%)	5	522	1.2	588	663	747	In bachelor unit: Male 52 (85%), Female 10 (15%)
Type 4	1852	50	926	278 (30%)	648 (70%)	5	2038	1.5	2365	2745	3186	In bachelor unit: Male 207 (32%), Female 441 (68%)
Total	**2237**	**---**	**1209**	**---**	**---**	**---**	**3109**	**---**	**3559**	**4078**	**4671**	**---**

***Assumed**

****Future Population = Present Population * (1+(growth rate/100))^n , n= Number of years**

POPULATION OF COMMERCIAL ZONE

Type of Facility/Building	Present Population	Population after 10 Years*	Population after 20 Years*	Population after 30 Years*	Remarks
School	435	552	574	600	Including Teachers, Students, Guards and Other Staffs
Mosque	180	229	238	248	Including Imam, Mass People, Cleaner and Other Staffs
Play Ground	10	13	13	14	Including Gardeners, Cleaners and Vendors
Gymnasium	25	32	33	35	Including Instructors, Trainees, Manager and Other Staffs
Park	25	32	33	35	Including Gardeners, Mass People, Cleaners and Vendors
Bank & ATM Booth	50	64	66	69	Including Manager, Official Staffs, Customers, Cleaners, Peons and Guards
Recreation Centre/Club	40	51	53	55	Including Manager, Club Members, Guards and Other Staffs
Guest House	20	25	26	28	Including Manager, Assistants, Customers and Other Staffs
Shopping Mall	55	70	73	76	Including Sellers, Buyers, Guards, Cleaners and Other Staffs
Supermarket	100	127	132	138	Including Sellers, Buyers, Guards, Cleaners and Other Staffs

POPULATION OF COMMERCIAL ZONE (Continued)

Type of Facility/Building	Present Population	Population after 10 Years*	Population after 20 Years*	Population after 30 Years*	Remarks
Health Care Centre	450	572	594	621	Including Doctors, Patients, Nurses, Cleaners and Other Staffs
Fire Station	60	76	79	83	Including Trainers, Trainees, Fire Fighters and Other Staffs
Sub/Power Station	50	64	66	69	Including Monitors, Experts, Assistants and Other Staffs
Post Office	35	44	46	48	Including Manager, Cashier, Office Staffs, Customers and Other Staffs
Restaurant	150	191	198	207	Including Chefs, Assistants, Waiters, Customers, Cashier and Other Staffs
Parking Lot	15	19	20	21	Including Drivers, Car Mechanics and Other Staffs
Convention Centre	40	51	53	55	Including Managers, Guests, Guards, Assistants and Other Staffs
Cinema Hall	55	70	73	76	Including Ticket Sellers, Guards, Cleaners, Mass People and Other Staffs
Total	**1795**	**2282**	**2372**	**2475**	

***Population Growth, (i) After 10 Years = 27%, (i) After 20 Years = 32%, (i) After 30 Years = 38%**

Formula for,

Future Population = Present Population + Present Population * Growth Rate

POPULATION OF INDUSTRIAL ZONE

Type of Facility/Building	Present Population	Population after 10 Years*	Population after 20 Years*	Population after 30 Years*
Office of Chairman & Managing Director	2	2	2	2
Admin Building :				
➢ Administration	95	119	124	128
➢ Marketing	24	30	31	32
➢ Finance & Accounts	40	50	52	54
➢ Human Resource	52	65	68	70
Health Care Center(Worker)	30	38	39	41
Engineer Section	83	104	108	112
Knitting Unit	139	174	181	188
Dyeing & Washing Unit	123	154	160	166
Cutting Unit	60	75	78	81
Sewing Unit	1210	1513	1573	1634
Finishing & Packaging Unit	160	200	208	216
Pattern & Sampling Unit	62	78	81	84
Quality Control Unit	23	29	30	31

POPULATION OF INDUSTRIAL ZONE (Continued)

Type of Facility/Building	Present Population	Population after 10 Years*	Population after 20 Years*	Population after 30 Years*
Warehouse Monitoring :				
➢ Raw Material	11	14	14	15
➢ Finished Products	11	14	14	15
Showroom	20	25	26	27
STP Unit	30	38	39	41
ETP Unit	33	41	43	45
Parking Lot & Garage	17	21	22	23
Security Office	51	64	66	69
Total	**2276**	**2845**	**2958**	**3072**

***Population Growth, (i) After 10 Years = 25%, (i) After 20 Years = 30%, (i) After 30 Years = 35%**
Formula for,
Future Population = Present Population + Present Population * Growth Rate

SUMMARY OF POPULATION PREDICTION

Zone	Present Population	Future Population		
		After 10 Years	After 20 Years	After 30 Years
Residential	3109	3559	4078	4671
Industrial	2276	2845	2958	3072
Commercial	1795	2282	2372	2475
Total	**7180**	**8686**	**9408**	**10218**

CHAPTER - 5

WATER DEMAND CALCULATION FOR INDUSTRIAL VILLAGE

5.1 INTRODUCTION:

The water supply is one of the most essential facilities for the industrial village. To design the water supply facility we need to know the water demand first. For calculating the water demand we need the following information,

- The present population for all the zones
- The design period of the industrial village
- The growth rates and the future populations
- The water requirement for each zone

In the industrial village the water demand is classified as,

1) Residential Water Demand
2) Commercial Water Demand
3) Industrial Water Demand
4) Water Demand for Fire Fighting

5.2 ASSUMPTIONS:

- Peak factor for different zones,
  - Residential Zone = 2.5
  - Commercial Zone = 4
  - Industrial Zone = 1.2
  - Fire Fighting = 1
- All the operation time of the commercial facilities are assumed.
- The growth of industrial production was assumed.
- For Water Demand for Fire Fighting:
  - Diameter of nozzle of hydrant = 3 inch
  - Velocity = 3 fps
  - Flow occurs for 30 minutes
  - Fire incident occurs once in a day.
  - Number of hydrants working at a time = 2

5.3 STEPS FOR CALCULATING WATER DEMAND:

5.3.1 Residential Zone:

1) We need to calculate the present population which is done in the previous chapter.
2) From the assumed growth rate we need to calculate the future population.
   The formula for future population is,
   Future Population = $P * (1+r)^n$
   Here P= Present Population, r = Growth Rate, n= Design Period (years)

3) Water consumption per capita needs to be determined. It is taken from **BNBC '93**[8] (**Table 8.6.1**). Here the water demand per capita depends on occupancy type. There are also different facilities. Some are provided with full facility and some have restricted facility.
4) Multiplying the total population with lpcd (Liter per capita per day) we can obtain the total water demand lpd (Liter per day)
5) Multiplying the total demand by a peak factor we will obtain the peak water demand.

5.3.2 Commercial Zone:

The commercial zone has school, restaurant, local market, shopping mall, guest house, cinema hall, post office, fire station, mosque, convention hall etc. For this zone water demand is calculated by using a peak factor and a time factor. The time factor is calculated based on the operation time of the facility.

The steps for water demand calculation is same as the residential zone. But the formula for future population is,
Future Population= P + P * Growth Rate

5.3.3 Industrial Zone:

For the industrial zone there are two types of water demand,

1) Water demand for personal consumption
2) Water demand for production

1) Water Demand for Personal Consumption:
- The total population (present and future) needs to be calculated in the way ot was done for commercial zone.
- The water requirement per capita is obtained from **BNBC'93**.
- Multiplying the population with the per unit consumption we obtain the water demand.
- Multiplying it with peak factor we obtain the peak water demand.

2) Water Demand for Production Purpose:
- The weight of finished product needs to be assumed.
- Water requirement per 1000lb of finished product is obtained from the book. **(A Text Book of Water Supply Engineering by Dr. M. A. Aziz** [9] **)**
- Multiplying these two we will obtain the water requirement.
- Multiplying the peak factor we obtain the peak water demand for production.

5.4 SAMPLE CALCULATION:

5.4.1 Water Requirement for Residential Zone:

- **TYPE 3:**

Type of occupancy = A1 (Bangladesh National Building Code'93, Table 8.6.1)

Residential Population = 522

Per Capita consumption (lpcd) = 135 (Bangladesh National Building Code'93, Table8.6.1)

Present Water demand (lpd) = 522*135 = 70470

Growth Rate = 1.2%

Water Demand after 10 years (lpd) = $70470 * (1+1.2/100)^{10} = 79398$

Water Demand after 20 years (lpd) = $70470 * (1+1.2/100)^{20} = 89457$

Water Demand after 30 years (lpd) = $70470 * (1+1.2/100)^{30} = 100790$

Assumed Peak factor = 2.5

Same calculations for Type-1, Type-2 & Type-4 are applicable.

So, total present residential water demand = 345405 lpd

Total residential water demand after 10 years = 391073 lpd

Total residential water demand after 20 years = 443000 lpd

Total residential water demand after 30 years = 502066 lpd

Now,

Total present residential water demand including peak factor (lpd) = 863512

Total residential water demand after 10 years including peak factor (lpd) = 977682

Total residential water demand after 20 years including peak factor (lpd) = 1107500

Total residential water demand after 30 years including peak factor (lpd) = 1255165

5.4.2 Water Requirement for Commercial Zone:

Occupancy Type = D1

Present Population = 450

Per Capita Consumption (lpcd) = 450 (From BNBC'93, Table 8.6.1)

Time Factor = 24/24 = 1

Present Water Requirement (lpd) = 450*450*1 = 202500

Water Requirement after 10 years (lpd) = 1.27 * 202500

= 257175 (assumed growth 27%)

Water Requirement after 20 years (lpd) = 1.32 * 202500

= 267300 (assumed growth 32%)

Water Requirement after 30 years (lpd) = 1.38 * 202500

= 279450 (assumed growth 38%)

Assumed Peak factor = 4

Same calculations for all other commercial facilities are applicable.

So, Total present commercial water demand (lpd) = 378809

Total commercial water demand after 10 years (lpd) = 481088

Total commercial water demand after 20 years (lpd) = 500028

Total commercial water demand after 30 years (lpd) = 522757

Now, including peak factor

Total present commercial water demand (lpd) = 1515276

Total commercial water demand after 10 years factor (lpd) = 1924352

Total commercial water demand after 20 years factor (lpd) = 2000114

Total commercial water demand after 30 years factor (lpd) = 2091028

5.4.3 Water Requirement for Industrial Zone:

- **For Production Purpose**

Weight of finished Product per day = 5400 lb

Water Required Per 1000lb Finished Product = 25000 gal

(A Text Book of Water Supply Engineering by Dr. M.A. Aziz)

Time factor = 24/24 (3 shifts) = 1

Present Water Demand (gal/day) = (5400/1000) * 25000

= 135000 gal/day

= 510975 lpd

Growth Rate after 10 years = 25%

Growth Rate after 20 years = 30%

Growth Rate after 30 years = 35%

Future Water Demand after 10 years (lpd) = 1.25 * 510975 = 638719

Future Water Demand after 10 Years (lpd) = 1.30 * 510975 = 664268

Future Water Demand after 10 Years (lpd) = 1.35 * 510975 = 689816

Assuming peak factor = 1.4

Now, including peak factor,

Future Water Demand after 10 Years (lpd) = 1.4 * 638719 = 894206

Future Water Demand after 10 Years (lpd) = 1.4 * 664268 = 929975

Future Water Demand after 10 Years (lpd) = 1.4 * 689816 = 965742

- **For Personal Consumption:**

- **HEALTH CARE CENTRE:**

Occupancy Type	=	D2
Present Population	=	30
Per Capita Consumption (lpcd)	=	300 (BNBC'93, Table 8.6.1)
Present Water Demand (lpd)	=	30 * 300 = 9000
Growth Rate after 10 years	=	25%
Growth Rate after 20 years	=	30%
Growth Rate after 30 years	=	35%
Water Demand After 10 Years (lpd)	=	1.25 * 9000 = 11250
Water Demand After 20 Years (lpd)	=	1.30 * 9000 = 11700
Water Demand After 30 Years (lpd)	=	1.35 * 9000 = 12150
Assuming Peak factor	=	1.4

Same calculations for other Industrial facilities are applicable.

So, Including peak factor,

Total Present Water Demand (lpd)	=	109040
Total Water Demand After 10 Years (lpd)	=	136300
Total Water Demand After 20 Years (lpd)	=	141753
Total Water Demand After 30 Years (lpd)	=	147204

5.4.4 Water Requirement for Fire Fighting:

Q = A*V

A = Area,

V = Velocity

T = Time

Total volume of water flowing through one hydrant = Q*t

= A*V*t

= π x $(3/12)^2$/4x 3fps x 30 x 60

= 265.07 ft3

Total number of fire hydrants = 2

Total volume of water required for firefighting = 2 * 265.07

= 530.14 ft^3 * 28.317

= 15012 liters

It remains the same in future.

The distance between two fire hydrants should be maximum **600 ft** and distance from any point of the road should not exceed **300 ft**. (Water Requirement, Chapter 3, Water and Environmental Engineering by Dr. M. Habibur Rahman)[10]

WATER DEMAND OF RESIDENTIAL ZONE

Type of Building	Type of Occupancy*	Residential Population	Per Capita Consumption (lpcd)*	Present Water Demand (lpd)	Growth Rate** %	Water Demand After 10 Years	Water Demand After 20 Years	Water Demand After 30 Years	Remarks
Type 1	A1	50	400	20000	1	22092	24404	26957	Single Family Dwelling. Duplex Type. Full Facility. (10)
Type 2	A2	499	225	112275	1	124021	136997	151330	Flats. Full Facility. For Family Unit- 5 story building, 2 units per floor (10). For Bachelors' Unit- 2 story building {7 units per floor (Male-1), 5 units per floor (Female-1)}
Type 3	A2	522	135	70470	1.2	79398	89457	100790	Flats. Restricted Facility. For Family Unit- 5 story building, 4 units per floor (5). For Bachelors' Unit- 4 story building {7 units per floor (Male-2), 5 units per floor (Female-1)}
Type 4	A3	2038	70	142660	1.5	165562	192142	222989	Mess for workers. Restricted Facility. For Family unit- 5 story building, 10 units per floor (6). For Bachelors' Unit- 5 story building {10 units per floor (Male-9), 10 units per floor (Female-4)}
Total				**345405**		**391073**	**443000**	**502066**	**Without applying peak factor**
Total	**Peak Factor = 2.5**			**863512**		**977683**	**1107500**	**1255165**	**Peak factor obtained from class notes**

***Bangladesh National Building Code '93, Table 8.6.1**
****Assumed**

WATER DEMAND OF COMMERCIAL ZONE

Building Type	Occupancy Type***	Present member	Per Capita Consumption (lpcd)	Time Factor	Present Water Requirement (lpd)	Future Water Requirement (lpd)**			Remarks (Operation Time)
						After 10 Years	After 20 Years	After 30 Years	
School	B1	435	70	3	91350	116015	120582	126063	8 hrs
Mosque	E3	180	5	8	7200	9144	9504	9936	3 hrs
Play ground		10	2	6	120	153	159	166	4 hrs
Gymnasium	E5	25	8	6	1200	1524	1584	1656	4 hrs
Park		25	3	6	450	572	594	621	4 hrs
Bank and ATM booth	F1	50	30	2	3000	3810	3960	4140	12 hrs*
Recreation center/club	E3	40	8	3	960	1220	1267	1325	8 hrs
Guest house	A2	20	225	1	4500	5715	5940	6210	24 hrs
Shopping Mall	F3	55	30	2	3300	4191	4356	4554	12 hrs*
Supermarket	F3	100	30	2	6000	7620	7920	8280	12 hrs*
Health Care center	D1	450	450	1	202500	257175	267300	279450	24 hrs
Fire station	F5	60	45	1	2700	3429	3564	3726	24 hrs*

WATER DEMAND OF COMMERCIAL ZONE (Continued)

Building Type	Occupancy Type***	Present member	Per Capita Consumption (lpcd)	Time Factor	Present Water Requirement (lpd)	Future Water Requirement (lpd)**			Remarks (Operation Time)
						After 10 Years	After 20 Years	After 30 Years	
Sub/power Station		50	45	1	2250	2858	2970	3105	24 hrs
Post office	F5	35	45	2	3150	4001	4158	4347	12 hrs*
Restaurant	E2	150	90	2	27000	34290	35640	37260	12 hrs
Parking lot		15	25	1	375	476.25	495	518	24 hrs
Convention center	E3	40	90	2.67	855	1085	1129	1180	9 hrs
Cinema Hall	E2	55	45	2	4950	6287	6534	6831	12 hrs*
Total					**361860**	**459565**	**477656**	**499368**	**Without Peak Factor**
Total	**Peak Factor=4**				**1447440**	**1838261**	**1910624**	**1997472**	**Peak Factor obtained from class notes**

***Restricted Facility**
****Growth Rate: (i) After 10 Years = 27%, (ii) After 20 Years = 32%, (iii) After 30 Years = 38% (Assumed)**
*****Bangladesh National Building Code '93. Table 8.6.1**
All Operation Times are Assumed

WATER DEMAND FOR INDUSTRIAL ZONE (Production Purpose)

Per Day Finished Product Weight (lb)	Water Required Per 1000lb Finished Product (gal/1000lb)**	Present Water Demand (gal/day)	Present Water Demand (lpd)***	Future Water Demand (10 Years) (lpd)*	Future Water Demand (20 Years) (lpd)*	Future Water Demand (30 Years) (lpd)*	Remarks
5400	25000	135000	510975	638719	664268	689816	**Without Peak Factor**
Peak Factor=1.4		189000	715365	894206	929975	965742	**With Peak Factor**

***Assumed**

****A Text Book of Water Supply Engineering by Dr. M.A. Aziz**

*****1 gal=3.785 liters**

WATER DEMAND OF INDUSTRIAL ZONE (Personal Consumption)

Type of Facility/Building	Occupancy Type	Present population	Per Capita Consumption (lpcd)	Present Water Demand (lpd)	Water Demand After 10 Years*	Water Demand After 20 years*	Water Demand After 30 years*
Office of Chairman & Managing Director	F1	2	45	90	112.5	117	121.5
Admin Building :							
➢ Administration	F1	95	45	4275	5343.75	5557.5	5771.25
➢ Marketing		24		1080	1350	1404	1458
➢ Finance & Accounts		40		1800	2250	2340	2430
➢ Human Resource		52		2340	2925	3042	3159
Health Care Center(Worker)	D2	30	300	9000	11250	11700	12150
Engineer Section	F1	83	45	3735	4668.75	4855.5	5042.25
Knitting Unit	F1	139	30	4170	5212.5	5421	5629.5
Dyeing & Washing Unit	F1	123	30	3690	4612.5	4797	4981.5
Cutting Unit	F1	60	30	1800	2250	2340	2430
Sewing Unit	F1	1210	30	36300	45375	47190	49005
Finishing & Packaging Unit	F1	160	30	4800	6000	6240	6480
Pattern & Sampling Unit	F1	62	30	1860	2325	2418	2511
Quality Control Unit	F1	23	30	690	862.5	897	931.5

WATER DEMAND OF INDUSTRIAL ZONE (Personal Consumption - Continued)

Type of Facility/Building	Occupancy Type	Present population	Per Capita Consumption (lpcd)	Present Water Demand (lpd)	Water Demand After 10 Years*	Water Demand After 20 years*	Water Demand After 30 years*
Warehouse Monitoring :							
➢ Raw Material	H1	11	6	66	82.5	85.8	89.1
➢ Finished Products	H1	11	6	66	82.5	85.8	89.1
Showroom	F1	20	30	600	750	780	810
STP Unit	J2	30	8	240	300	312	324
ETP Unit	J2	33	8	264	330	343.2	356.4
Parking Lot & Garage	F4	17	45	765	956.25	994.5	1032.75
Security Office	K1	51	5	255	318.75	331.5	344.25
Total (Without Peak Factor)		**2276**		**77886**	**97357**	**101252**	**105146**
Total (With Peak Factor=1.4)		**2276**		**109040**	**136300**	**141753**	**147204**

*** Population Growth Rate: i) After 10 Years = 25%, ii) After 20 Years = 30%, iii)After 30 Years = 35% (Assumed)**
Formula for,
Future Water Demand = Present Water Demand (lpd) * (1+Growth Rate)

SUMMARY OF WATER DEMAND

Zone	Present Water Demand (Without Peak Factor) (lpd)	Present Water Demand (With Peak Factor) (lpd)	Future Water Demand (Without Peak Factor) (lpd)			Future Water Demand (With Peak Factor) (lpd)		
			After 10 Years	After 20 Years	After 30 Years	After 10 Years	After 20 Years	After 30 Years
Residential	345405	863512	391073	443000	502066	977683	1107500	1255165
Commercial	361860	1447440	459565	477656	499368	1838261	1910624	1997472
Industrial:								
➢ Production	510975	715365	638719	664268	689816	894206	929975	965742
➢ Personal Use	77886	109040	97357	101252	105146	136300	141753	147204
Fire Fighting	15012	15012	15012	15012	15012	15012	15012	15012
Total	**1311138**	**3150369**	**1601726**	**1701188**	**1811408**	**3861462**	**4104864**	**4380595**

CHAPTER - 6

DEVELOPMENT OF WATER SOURCE FOR THE INDUSTRIAL VILLAGE

6.1 INTRODUCTION:

Well design basically means,

- Selection of the proper dimensional factors for well structure.
- Choosing the materials to be used in its construction.

Good design should assure an optimum combination of:

- Performance,
- Long service life
- Reasonable cost

6.2 WATER SOURCE (GROUND WATER):

- Tube-well is used to extract ground water.
- Grain size analysis needs to be done for different soil layers.
- Thickness of aquifer needs to be determined.
- Aquifer material needs to be analyzed.
- Screen length needs to be determined.
- Gravel pack needs to be designed.
- Slot number needs to be determined.
- Yield of tube-well needs to be calculated.
- Number of tube-well required is determined.

6.3 DESIGN OF TUBE-WELL:

The main component of a production well design involves determination of:

- Well depth
- Well casing pipe length, diameter, and pipe material
- Screen transmitting capacity
- Number of tube-well pumps required

A properly constructed well screen,

- Allows water to enter the well freely at low velocity.
- Prevents sand from entering with the water.
- Serves as the structural retainer to support the loose formation material.

The main components of a production well design involve determination of

- Well depth
- Well casing/ housing pipe length, diameter & pipe material
- Screen (strainer) length, diameter & screen material
- Screen transmitting capacity
- Number of tube well pumps required

6.4 STEPS FOR DESIGNING THE WATER WELL:

1. Grain size distribution for different soil layers
2. Locating the aquifer and the water bearing strata
3. Design of gravel pack material
4. Determination of strainer length and position
5. Selection of strainer size
6. Yield of well

6.4.1 Grain Size Distribution for Different Soil Layers:

To locate the expected depth of water bearing layer, drilling is done and sieve analyses of various layers are found out. The layer with higher FM, greater uniformity coefficient (**Cu**) & higher percentage of coarse & medium sand is the expected layer for water extraction. Next grain size distribution curves are drawn for different soil layers using soil data and effective grain size ($\mathbf{D_{10}}$, $\mathbf{D_{30}}$, $\mathbf{D_{60}}$) and uniformity coefficient are found for each layer. From the grain size distribution curves, relative percentage of different particles are found using MIT classification of soil.

The characteristics to be found:

- Fineness Modulus –
  = cumulative % retained on sieve # 4, 8, 16, 30, 50 & 100) /100
- Effective Size ($\mathbf{D_{10}}$) –
  Size that represents **10 %** finer and **90%** coarser of soil sample
- Co-efficient of Uniformity = D_{60}/D_{10}
  Higher value of **U > 2.0** indicates well graded sample
- D_{30} and
- Size classifications (Coarse, Medium, Fine) (from **Table 6(a)**)

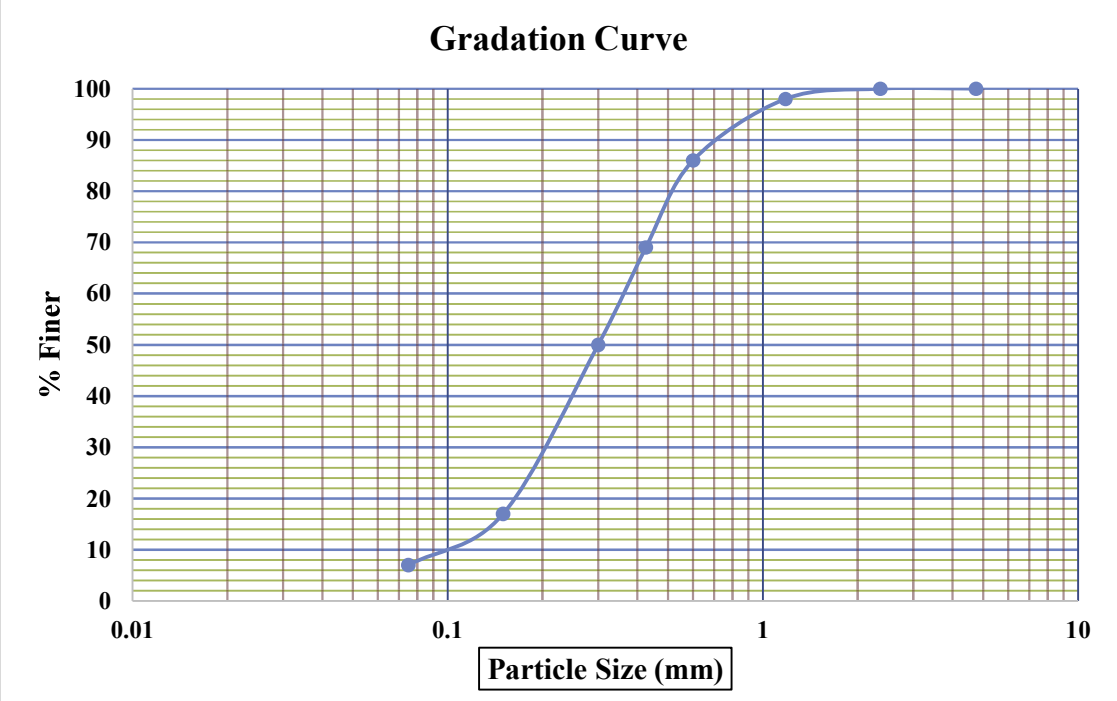
SIEVE ANALYSIS OF DIFFERENT SOIL LAYERS (Provided Data)

Depth(ft)	240-250	250-260	260-270	270-280	280-290	290-300	300-310
Sieve Size (mm)	**Material Retained (gm)**						
No.4(4.75)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No.8(2.36)	0.0	1.7	4.6	0.0	9.0	8.1	8.1
No.16(1.18)	2.3	3.7	10.4	0.9	16.7	20.2	18.5
No.30(0.6)	11.8	17.9	18.6	6.1	16.0	19.7	23.1
No.40(0.425)	17.3	36.7	12.6	28.7	9.1	11.1	13.7
No.50(0.3)	19.3	23.9	24.5	37.7	14.9	17.5	18.4
No.100(0.15)	33.1	11.7	23.9	20.0	30.4	20.8	16.3
No.200(0.075)	9.8	2.8	3.6	4.1	3.4	2.1	1.5
Pan	6.4	1.6	1.8	2.5	0.5	0.5	0.4
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

SIEVE ANALYSIS AT DEPTH 240'- 250'

Sieve No.	Sieve Size (mm)	Retained Material (gm)	Retained Material %	Cumulative % Retained	% Finer	Results	
4	4.75	0	0	0	100		
8	2.36	0	0	0	100		
16	1.18	2.3	2	2	98		
30	0.6	11.8	12	14	86	F.M = 1.49	Fine Sand = 28%
40	0.425	17.3	17	31	69	D_{60} = 0.36 mm	
50	0.3	19.3	19	50	50	D_{30} = 0.21 mm	Medium Sand = 58%
100	0.15	33.1	33	83	17	D_{10} = 0.12 mm	
200	0.075	9.8	10	93	7	C_U = 3.0	Coarse Sand = 14%
PAN	0.0001	6.4	7	100	0		
Total		**100**	**100**				

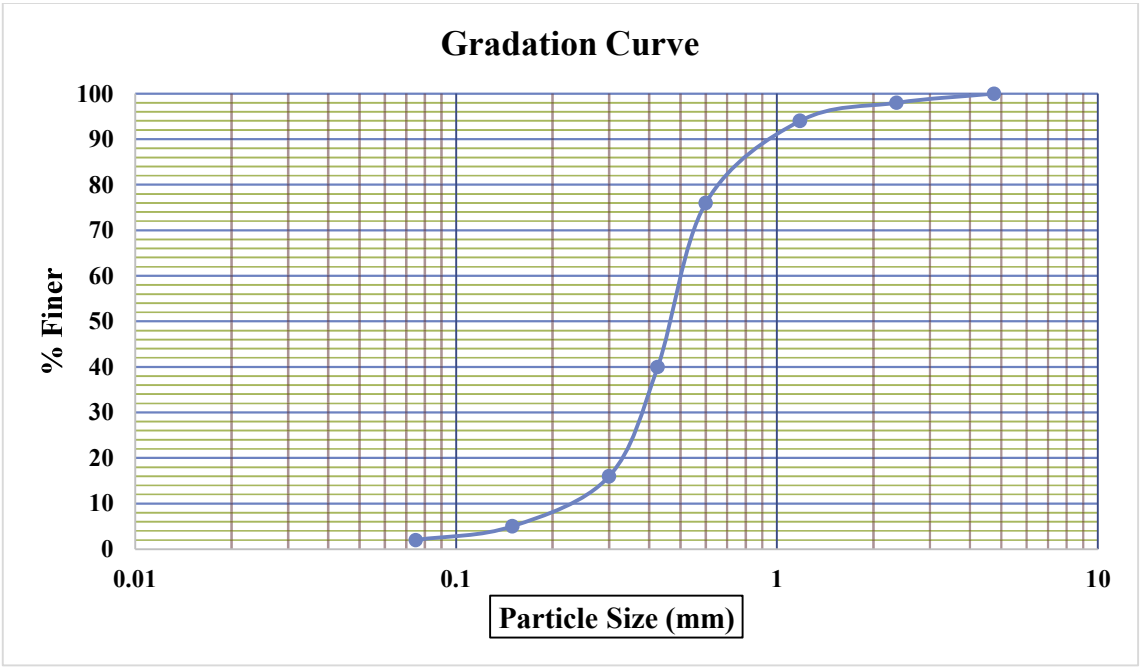
GRADATION CURVE OF SIEVE ANALYSIS AT DEPTH 240'- 250'



SIEVE ANALYSIS AT DEPTH 250'- 260'

Sieve No.	Sieve Size (mm)	Retained Material (gm)	Retained Material %	Cumulative % Retained	% Finer	Results	
4	4.75	0	0	0	100		
8	2.36	1.7	2	2	98		
16	1.18	3.7	4	6	94		
30	0.6	17.9	18	24	76	F.M = 2.09	Fine Sand = 9%
40	0.425	36.7	36	60	40	D_{60} = 0.50 mm	
50	0.3	23.9	24	84	16	D_{30} = 0.39 mm	Medium Sand = 67%
100	0.15	11.7	11	95	5	D_{10} = 0.21 mm	
200	0.075	2.8	3	98	2	C_U = 2.38	Coarse Sand = 22%
PAN	0.0001	1.6	2	100	0		
Total		**100**	**100**				

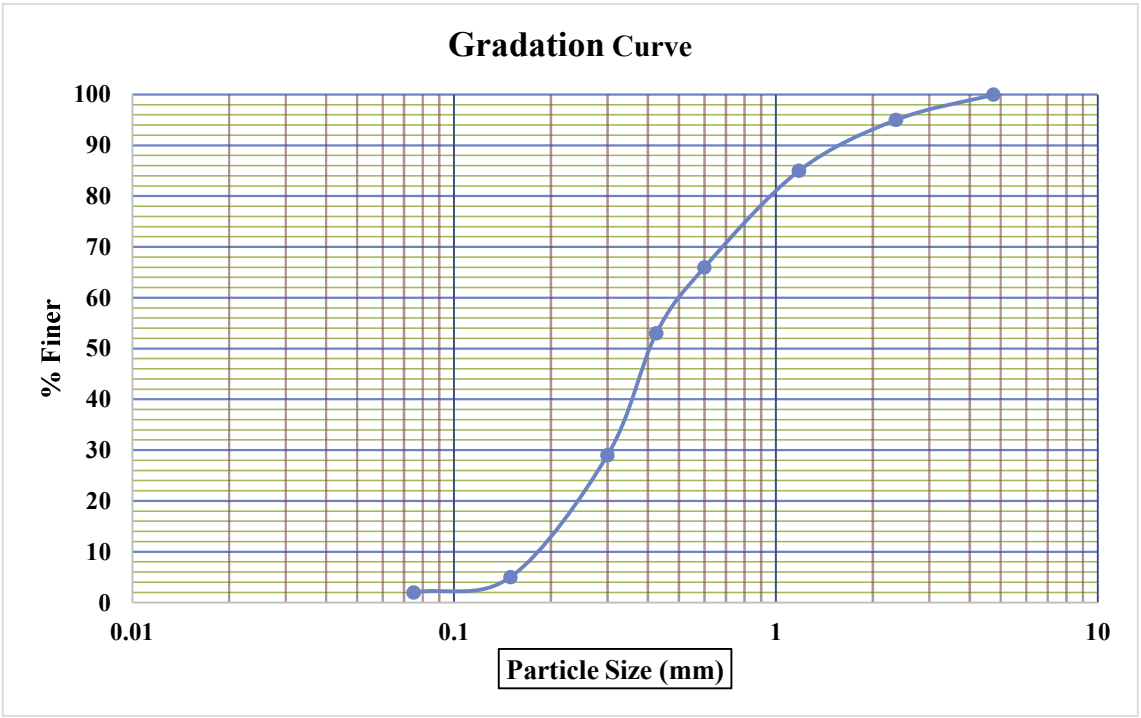
GRADATION CURVE OF SIEVE ANALYSIS AT DEPTH 250'- 260'



SIEVE ANALYSIS AT DEPTH 260'- 270'

Sieve No.	Sieve Size (mm)	Retained Material (gm)	Retained Material %	Cumulative % Retained	% Finer	Results	
4	4.75	0	0	0	100		
8	2.36	4.6	5	5	95		
16	1.18	10.4	10	15	85		
30	0.6	18.6	19	34	66	F.M = 2.17	Fine Sand = 12%
40	0.425	12.6	13	47	53	D_{60} = 0.51 mm	
50	0.3	24.5	24	71	29	D_{30} = 0.31 mm	Medium Sand = 54%
100	0.15	23.9	24	95	5	D_{10} = 0.19 mm	
200	0.075	3.6	3	98	2	C_U = 2.68	Coarse Sand = 27%
PAN	0.0001	1.8	2	100	0		
Total		**100**	**100**				

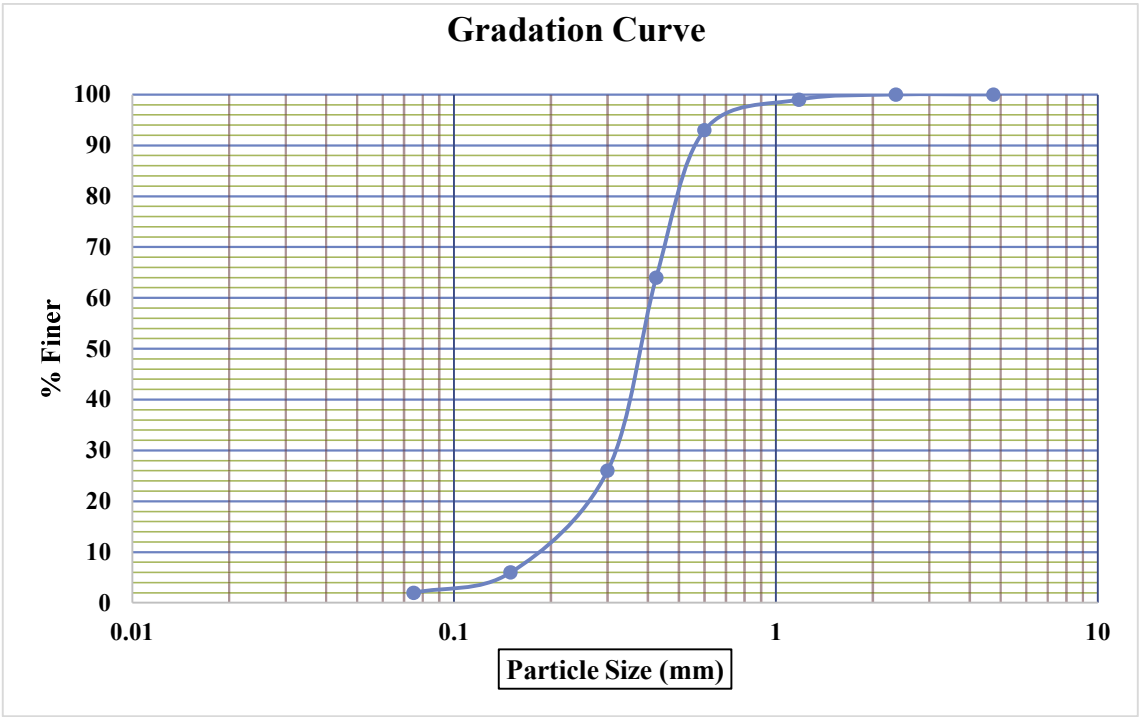
GRADATION CURVE OF SIEVE ANALYSIS AT DEPTH 260'- 270'



SIEVE ANALYSIS AT DEPTH 270'- 280'

Sieve No.	Sieve Size (mm)	Retained Material (gm)	Retained Material %	Cumulative % Retained	% Finer	Results	
4	4.75	0	0	0	100		
8	2.36	0	0	0	100		
16	1.18	0.9	1	1	99		
30	0.6	6.1	6	7	93	F.M = 1.76	Fine Sand = 13%
40	0.425	28.7	29	36	64	D_{60} = 0.41 mm	
50	0.3	37.7	38	74	26	D_{30} = 0.32 mm	Medium Sand = 80%
100	0.15	20	20	94	6	D_{10} = 0.18 mm	
200	0.075	4.1	4	98	2	C_U = 2.28	Coarse Sand = 7%
PAN	0.0001	2.5	2	100	0		
Total		**100**	**100**				

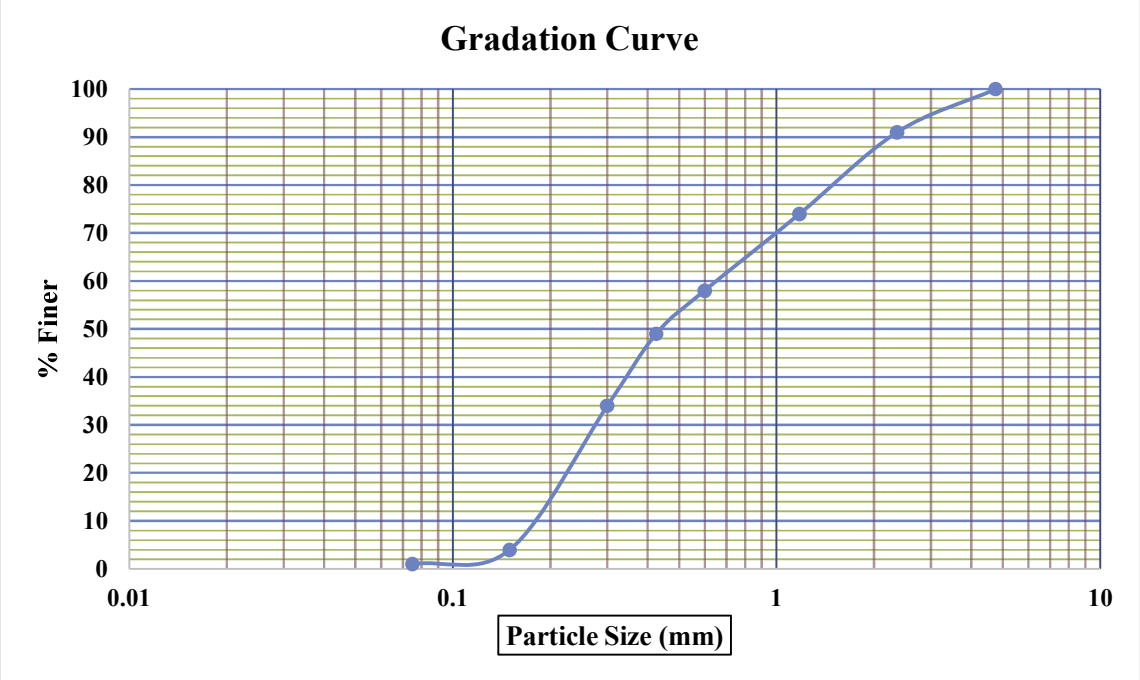
GRADATION CURVE OF SIEVE ANALYSIS AT DEPTH 270'- 280'



SIEVE ANALYSIS AT DEPTH 280'- 290'

Sieve No.	Sieve Size (mm)	Retained Material (gm)	Retained Material %	Cumulative % Retained	% Finer	Results	
4	4.75	0	0	0	100		
8	2.36	9	9	9	91		
16	1.18	16.7	17	26	74		
30	0.6	16	16	42	58	F.M = 2.39	Fine Sand = 14%
40	0.425	9.1	9	51	49	D_{60} = 0.66 mm	
50	0.3	14.9	15	66	34	D_{30} = 0.28 mm	Medium Sand = 43%
100	0.15	30.4	30	96	4	D_{10} = 0.18 mm	
200	0.075	3.4	3	99	1	C_U = 3.70	Coarse Sand = 30%
PAN	0.0001	0.5	1	100	0		
Total		**100**	**100**				

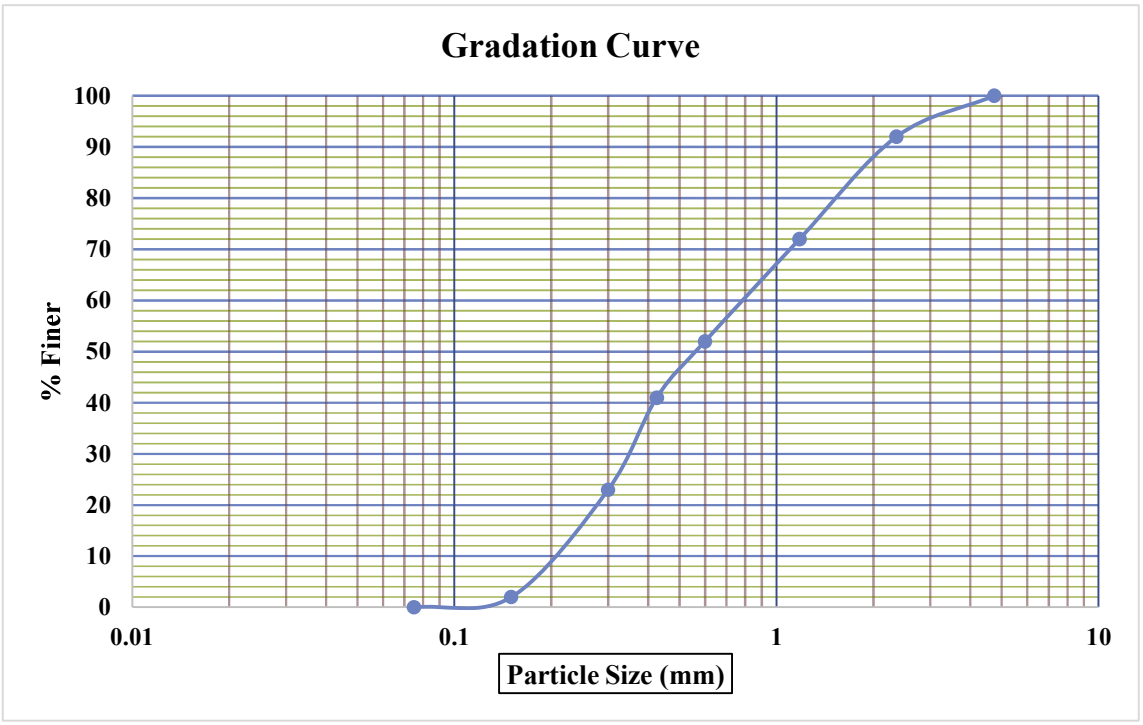
GRADATION CURVE OF SIEVE ANALYSIS AT DEPTH 280'- 290'



SIEVE ANALYSIS AT DEPTH 290'- 300'

Sieve No.	Sieve Size (mm)	Retained Material (gm)	Retained Material %	Cumulative % Retained	% Finer	Results	
4	4.75	0	0	0	100		
8	2.36	8.1	8	8	92		
16	1.18	20.2	20	28	72		
30	0.6	19.7	20	48	52	F.M = 3.56	Fine Sand = 10%
40	0.425	11.1	11	59	41	D_{60} = 0.80 mm	
50	0.3	17.5	18	77	23	D_{30} = 0.33 mm	Medium Sand = 42%
100	0.15	20.8	21	98	2	D_{10} = 0.21 mm	
200	0.075	2.1	2	100	0	C_U = 3.80	Coarse Sand = 38%
PAN	0.0001	0.5	0	100	0		
Total		**100**	**100**				

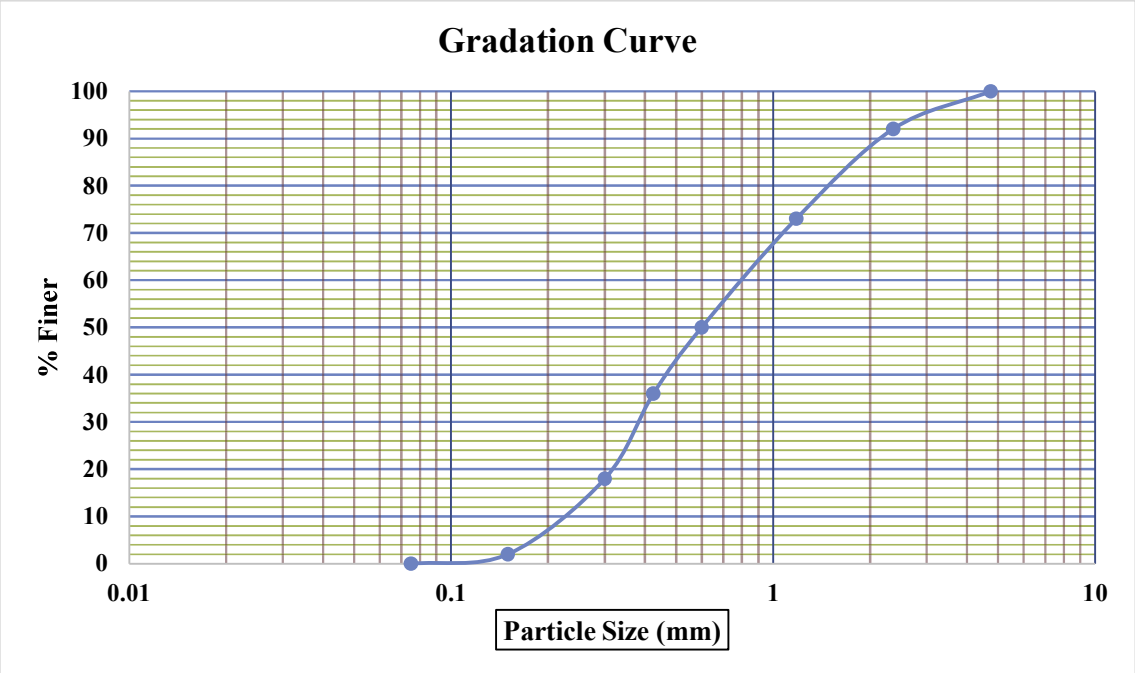
GRADATION CURVE OF SIEVE ANALYSIS AT DEPTH 290'- 300'



SIEVE ANALYSIS AT DEPTH 300'- 320'

Sieve No.	Sieve Size (mm)	Retained Material (gm)	Retained Material %	Cumulative % Retained	% Finer	Results	
4	4.75	0	0	0	100		
8	2.36	8.1	8	8	92		
16	1.18	18.5	19	27	73		
30	0.6	23.1	23	50	50	F.M = 2.56	Fine Sand = 8%
40	0.425	13.7	14	64	36	D_{60} = 0.78 mm	
50	0.3	18.4	18	82	18	D_{30} = 0.375 mm	Medium Sand = 42%
100	0.15	16.3	16	98	2	D_{10} = 0.215 mm	
200	0.075	1.5	2	100	0	C_U = 3.63	Coarse Sand = 38%
PAN	0.0001	0.4	0	100	0		
Total		**100**	**100**				

GRADATION CURVE OF SIEVE ANALYSIS AT DEPTH 300'- 320'



SUMMARY TABLE FOR GRAIN SIZE DISTRIBUTION ANALYSIS

Sampling Depth (ft)	Fineness Modulus	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_U	Fine Sand %	Medium Sand %	Coarse Sand %
240 – 250	1.49	0.36	0.21	0.12	3.0	28	58	14
250 – 260	2.09	0.50	0.39	0.21	2.38	9	67	22
260 – 270	2.17	0.51	0.31	0.19	2.68	12	54	27
270 – 280	1.76	0.41	0.32	0.18	2.28	13	80	7
280 – 290	2.39	0.66	0.28	0.18	3.70	14	43	30
290 – 300	3.56	0.80	0.33	0.21	3.80	10	42	38
300 - 320	2.56	0.78	0.375	0.215	3.63	8	42	38

6.4.2 Locating the Aquifer and Water Bearing Strata:

(a) Factors to be considered for locating water bearing strata:

- Higher percentage of coarse and medium sand indicates higher water carrying capacity.
- Greater uniformity coefficient indicates higher permeability.
- Higher fineness modulus means bigger soil particle having good permeability and presence of water.

(b) Well Casing /Housing Pipe Material:

Usually seamless MS pipe is used for bigger diameter (**12" to 18"**) casing pipe
For small diameter (**4" to 6"**) production well uPVC material is also used now days.

(c) Well Casing /Housing Pipe Length:

Length of casing pipe must be sufficient enough so that well pump remain submerged all the time sufficiently below the maximum pumping water level even after a reasonable operation period (**10-20 years**) of well.

Length of casing depends on following four factors-

- Static water level at present
- Assumed drawdown of **10-20 ft** while pumping
- Average rate of water level declination per year * design period
- Extra allowance of **10-15 ft** depth for safety

(1) Calculation for Well Casing Pipe Length:

Diameter = 16 inch

Material = Mild steal pipe

Length:

- Static water level at present = 180 ft
- Assumed drawdown = 15 ft
- Design period = 20 year
- Assumed depletion per year = 2 ft
- Extra allowance = 15 ft

Length of casing pipe = 180'+15'+15'+ (2'* 20)

= 250 ft

(d) Well Screen (Strainer):

(1) Well Screen Length:

The optimum length of well screen is chosen in relation to the thickness of the aquifer available drawdown and stratification of the aquifer. As it is very difficult to maintain vertical alignment of a long strainer, it will not be practical to go beyond **100'** screening. Strainer should not be extended up to the bottom of the aquifer to allow upward converging flow of water during pumping.

(2) Well Screen Diameter:

Screen openings depend upon -

- The gradation of the sand
- The requirement of water

Usually **4"** and **6"** diameter are common. Screen diameter is selected to satisfy an essential basic principle, i.e. enough total area of screen openings so that the entrance velocity is equal or less than **0.1 ft/sec**.

(3) Well Screen Material:

- Usually bridge-type stainless steel screen is preferable,
- Recently continuous slot-type stainless steel screen are manufactured locally.

(4) Where Blank Pipe is Necessary:

- Between two strainers of a discontinuous aquifer **10'** blank pipe is placed at the bottom to trap soil particles that may enter the pipe through upward converging flow

(5) Calculation for Well Screen:

From the summary table selected aquifer depth = 250 ft – 320 ft

The length of casing pipe = 250 ft

So, Available aquifer thickness = (320-250) ft
= 70 ft

The thickness is greater than 50 ft.

So, the screening length will be 80% of the thickness of the aquifer **(**from **Table 6(b)**)

Screening length = 0.8 * 70 ft = 56 ft

Screen diameter = 6 inch

Well screen material = Bridge type stainless steal

(e) Screen Slot Opening:

- For an available depth of aquifer where strainer will be placed comparatively finest sand layer is identified from the soil characteristics on the basis of sieve analysis results.
- For naturally developed wells, well-screen slot openings are selected as the size that will retain from **40% -50%** of the finest sand.

6.4.3 Design of Gravel Pack Material:

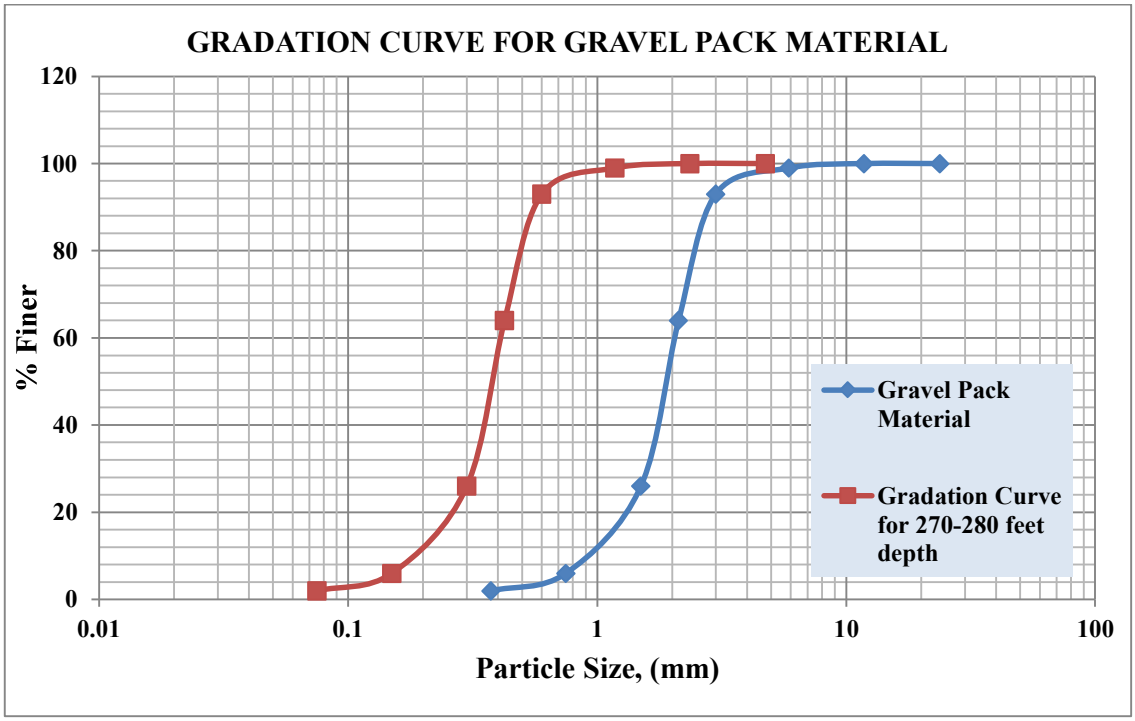
- Grain size distribution curve of the comparatively finest sand layer (lowest FM among all soil depths where the strainer to be installed) is drawn on a fresh semi-log graph paper.
- **70%** (D30) size of that finest sand is multiplied by a factor between 4 (fine and uniform) and 6 (coarser and non-uniform).
  Cu ≤ 1.5 use multiplying factor = **4**
  Cu ≥ 2.5 use multiplying factor = **6**
  Interpolate for in between values
- Place the result of this multiplication on the graph as the **70%** size of the gravel. This first point on the curve that represents the grading of the artificial gravel pack materials.
- Through the initial point on the gravel-pack curve, a smooth curve nearly parallel with the aquifer material curve is drawn by trial and error, representing a material with a uniformity coefficient of **2.5 or less**.

The finest sand layer within the selected aquifer thickness is 270 ft -280 ft with a F.M = 1.76

GRADATION CURVE OF SIEVE ANALYSIS AT DEPTH 270'- 280'

Sieve No.	Sieve Size (mm)	Retained Material (gm)	Retained Material %	Cumulative % Retained	% Finer	Results	
4	4.75	0	0	0	100		
8	2.36	0	0	0	100		
16	1.18	0.9	1	1	99		
30	0.6	6.1	6	7	93	F.M = 1.76	Fine Sand = 13%
40	0.425	28.7	29	36	64	D_{60} = 0.41 mm	
50	0.3	37.7	38	74	26	D_{30} = 0.32 mm	Medium Sand = 80%
100	0.15	20	20	94	6	D_{10} = 0.18 mm	
200	0.075	4.1	4	98	2	C_U = 2.28	Coarse Sand = 7%
PAN	0.0001	2.5	2	100	0		
Total		**100**	**100**				

Let the multiplying factor be **5**, the gradation curve for the gravel pack material is as follows,



SIEVE ANALYSIS OF THE GRAVEL PACK MATERIAL

Sieve No.	Seive Size (mm)	% Finer (From Graph)	Cumulative % Retained	% Retained Material	Range of % Retained
4	4.75	98	2	2	0-10
8	2.36	76	24	22	14-30
16	1.18	14	86	62	54-70
30	0.6	4	96	10	2-18
40	0.425	3	97	1	0-9
50	0.3	0	100	3	0-11
100	0.15	0	100	0	-
200	0.075	0	100	0	-

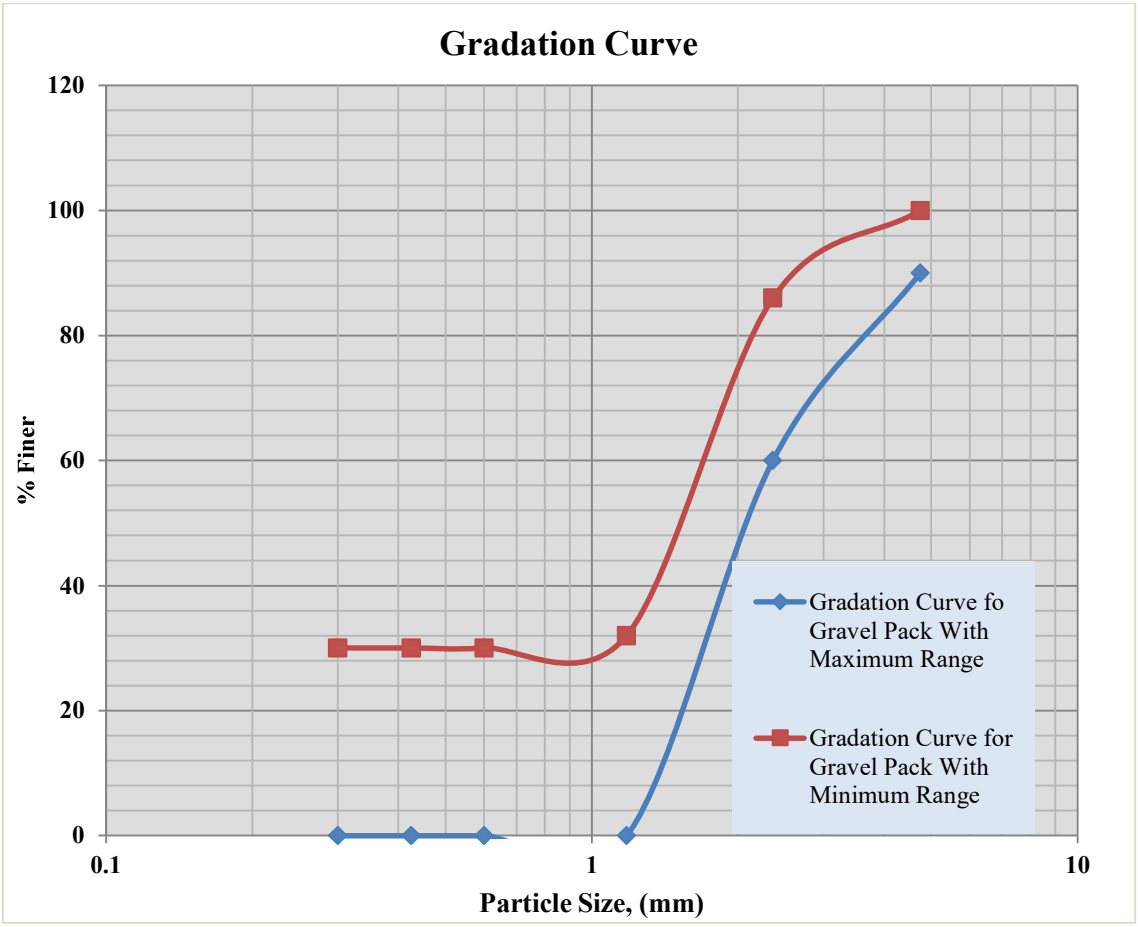
GRADATION CHART OF GRAVEL PACK MATERIAL WITH MINIMUM RANGE

Sieve No.	Sieve Size (mm)	Minimum Retained Material %	Cumulative % Retained	% Finer
4	4.75	0	0	100
8	2.36	14	14	86
16	1.18	54	68	32
30	0.6	2	70	30
40	0.425	0	70	30
50	0.3	0	70	30

GRADATION CHART OF GRAVEL PACK MATERIAL WITH MAXIMUM RANGE

Sieve No.	Sieve Size (mm)	Retained Material %	Cumulative % Retained	% Finer
4	4.75	10	10	90
8	2.36	30	40	60
16	1.18	70	100	0
30	0.6	18	100	0
40	0.425	9	100	0
50	0.3	11	100	0

GRADATION CURVE FOR GRAVEL PACK MATERIAL



From the gradation curve,

D_{10} = 0.9 mm
D_{60} =2.1 mm

U = 2.1/.9 = 2.33 < 2.5 (**OK**)

6.4.4 Determination of Strainer Length, Position and Selection of Strainer Size:

Size of the well screen openings are selected that will retain **90% or more** of the gravel-pack material (i.e. $\mathbf{D_{10}}$).
Slot number = slot size (in mm) * 1000 / 25.4

Specification for the gravel pack material is prepared by first selecting **4 to 5** sieve sizes that cover the spread of the curve and then set down a permissible range (**± 8%**) for the percent retained on each of the selected sieves. Gravel pack material should be clean and well-rounded.

To ensure that an envelope of gravel will surrounded the entire screen, a thickness from **3- 8 inch** can be maintained.

Here, Screen opening (slot number) = (0.9/ 25.4) * 1000

= 35.43

= 30

6.4.5 Calculation of Yield of Well:

Well yield or Screen Transmitting Capacity = $\pi * D * L_s * v * BF * A$

v = Maximum entrance velocity = 0.1 fps
A = Available opening of the screen
As slot number is 30, A = 15% (from **Table 6(c)**)
L_s = Length of screen (ft)
D = Diameter of screen (ft)
BF = Screen blockage factor =0.4

Well yield = $\pi * (6/12) * 56 * 0.15 * 0.1 * 0.4$

= 0.53 ft^3/s

= 53845 lph

For one pump,

Pumping hour per day = 16 hour continuous

Total capacity = (53, 854 * 16) lpd

= 861520 lpd

6.5 NUMBER OF TUBE-WELL REQUIRED:

Water Demand for present = 3150369 lpd

Number of tube-well = (3150369/861520)
= 3.65
= 4

Water demand after 10 years = 3861462 lpd

Number of tube-well = (3861462/861520)

= 4.48
= 5

Water demand after 20 years = 4104864 lpd

Number of tube-well = (4104864/861520)

= 4.76
= 5

Water demand after 30 years = 4380595 lpd

Number of tube-well = (4380595/861520)
= 5

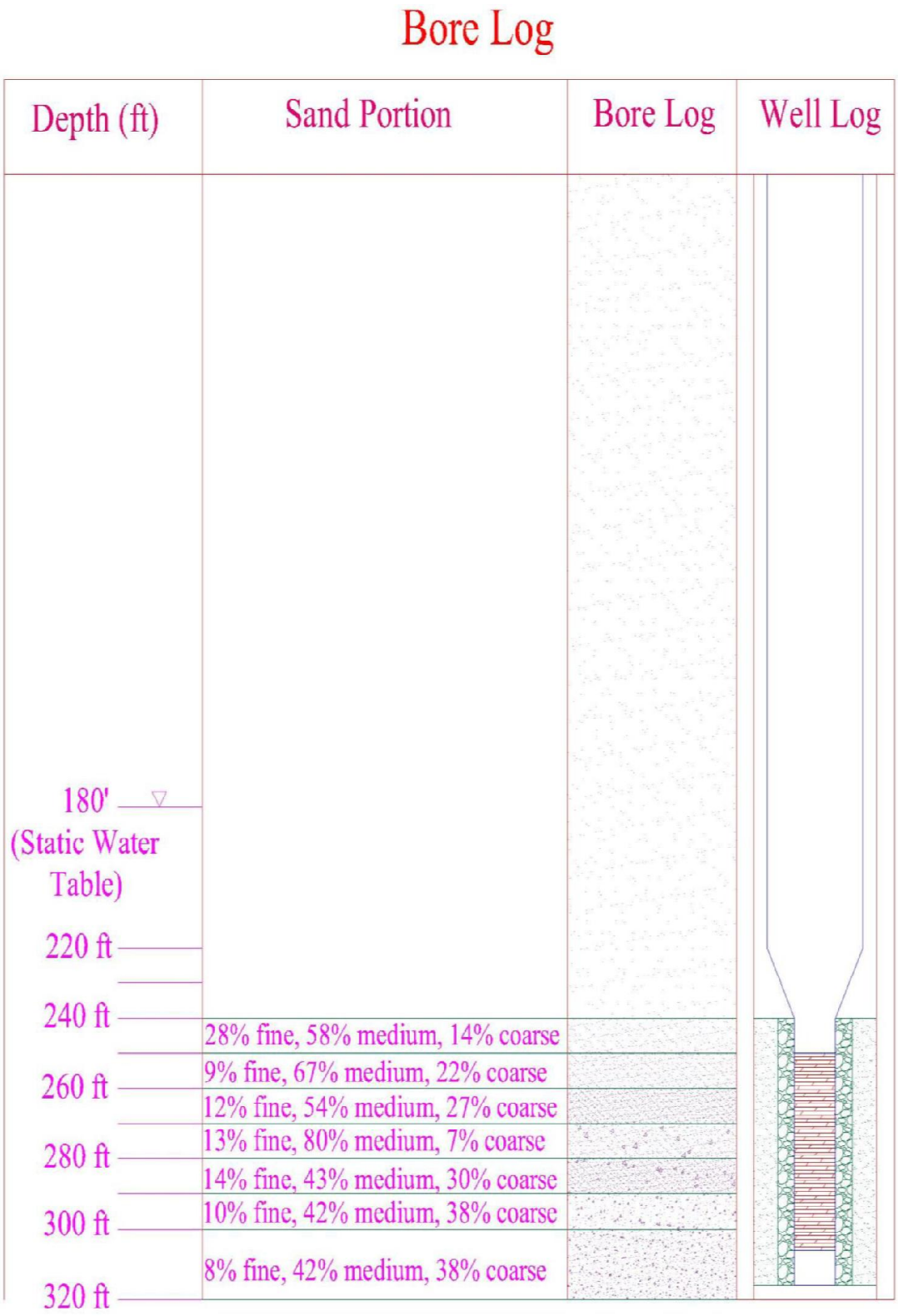


FIGURE 6.1: BORE LOG

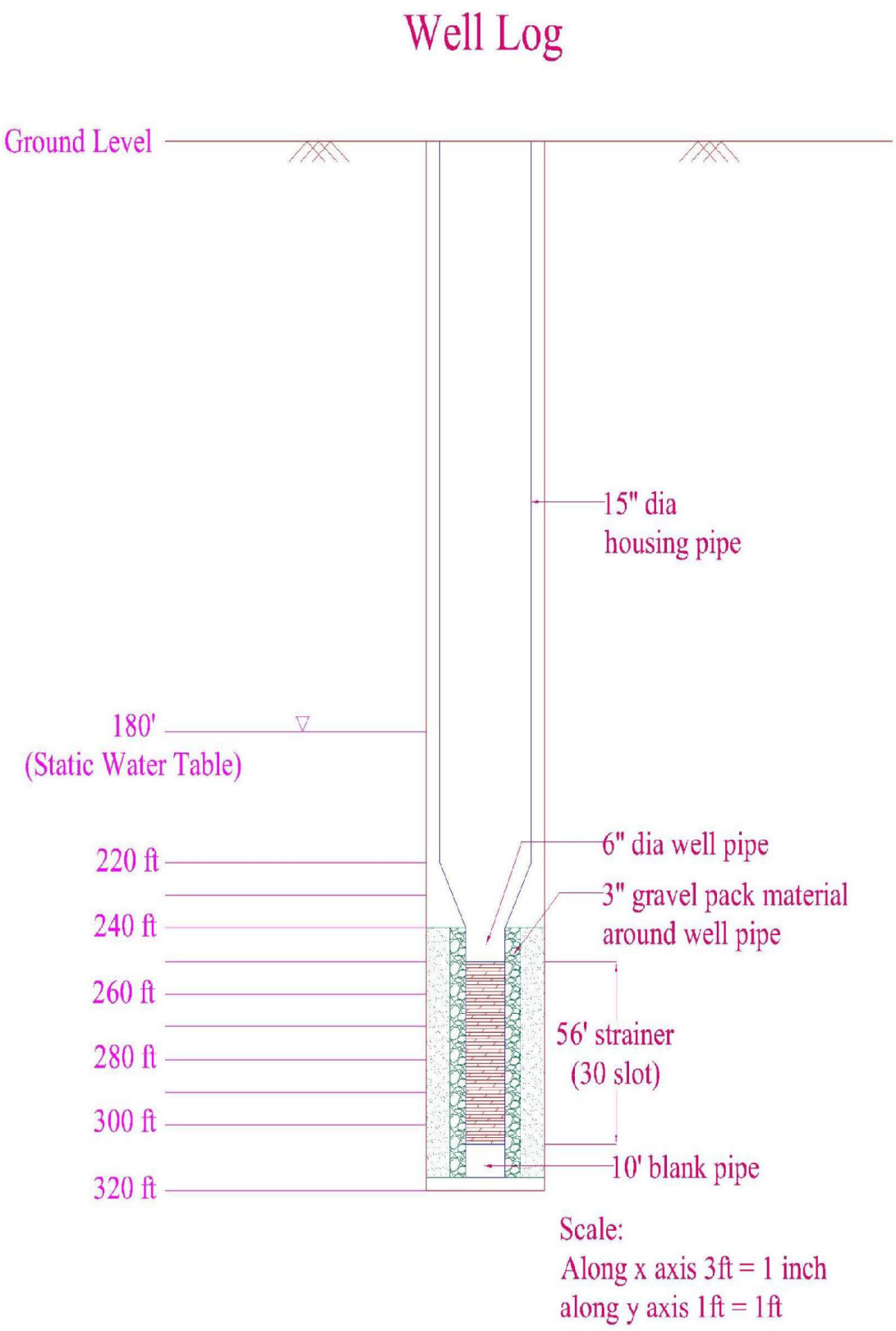


FIGURE 6.2: WELL LOG

CHAPTER - 7

DETERMINATION OF PUMP CAPACITY & PUMPING SCHEDULE

7.1 INTRODUCTION:

Water supply system mainly includes:

- Pumps and necessary equipments
- Storage reservoirs
- Various pipes that convey water to the consumers

Pump is a primary unit of water distribution system. Pump and pumping machineries lift water from the source to overhead tank so that water can flow by gravity to the distribution system. Design of pumping devices includes:

- Determining pump capacity &
- Pumping Schedule

7.1.1 Types of Pumps:

- Submersible Pump
- Turbine Pump
- Centrifugal Pump etc.

Each type of pump has certain advantages and disadvantages. For this particular industrial village design, submersible pump has been used.

7.2 ASSUMPTIONS:

- Pump efficiency = 70%
- Velocity for water supply, v = 3fps
- Friction loss is assumed to be 10% of maximum pipe length
- Maximum building height = 60 ft
- Height of the overhead tank = 15 ft

7.3 STEPS FOR DETERMINING PUMP CAPACITY:

- The whole industrial village has been divided into 2 zones:

  Zone 1: Residential & Commercial Zone

  Zone 2: Industrial Zone

- The number of well or pump required for each zone is calculated.
- The capacity of each pump is determined.

7.3.1 Pump Capacity:

- **Working Horse Power,**

$$WHP = HQ/3960$$

Where, H = Total head or lift of the pump (ft)

Q = Yield of well (gpm)

- **Breaking Horse Power,**

$$BHP = WHP/\eta$$

Where, η = Pump Efficiency

- **Total Head / Total Lift of Pump,**

H = Static head + Velocity head + Friction head

- **Static Head,**

h = Suction head (h_s) + Delivery head (h_d)

Where, Suction head, $h_s = 0$ (for submersible pump)

Delivery head, h_d = Static water level + Maximum building height

- **Velocity Head,**

$$h_v = v^2/ 2g$$

- **Friction Head,**

h_f = 0.1*(Maximum horizontal distance + Maximum height of the building + Height of overhead tank)

7.4 SAMPLE CALCULATION:

- **FOR PUMP – 1:**

Suction head, h_s = 0

Delivery head, h_d = (180 + 60) ft = 240 ft

Velocity head, h_v = $3^2/(2*32)$ = 0.14 ft

Maximum horizontal distance = 3063 ft

Friction head, h_f = 0.1*(3063 + 60 + 15) ft

= 313.8 ft

So, Total Head, H = (0 + 240 + 0.14 + 313.8) ft

= 553.94 ft

Yield of well, Q = 53845 lph

= 236.9 gpm

Working horse power, WHP = 553.94*236.9/3960 = 33 HP

Breaking horse power, BHP = 33/0.7 = 47 HP

DETERMINATION OF PUMP CAPACITY

Zone	Design Period	Pump	Yield of the Source, Q		Maximum Horizontal distance	Suction Head, h_s	Delivery Head, h_d	Velocity Head, h_v	Friction Head, h_f	Total Head, H	WHP	BHP
			lph	gpm	ft	ft	ft	ft	ft	ft	hp	hp
Zone 1	Present	P1	53845	236.9	3063.0	0	240	0.14	313.8	553.94	33	47
		P2	53845	236.9	2998.0	0	240	0.14	307.3	547.44	33	47
		P3	53845	236.9	2655.0	0	240	0.14	273	513.14	31	44
	After 10 years & 20 years	P4	53845	236.9	1994.0	0	240	0.14	206.9	447.04	27	38
Zone 2	Present	P5	53845	236.9	2228.0	0	240	0.14	230.3	470.44	28	40
	After 10 years & 20 years	P6	53845	236.9	2118.0	0	240	0.14	219.3	459.44	27	39

7.5 STEPS FOR DETERMINING PUMPING SCHEDULE:

- The total present and future water demand for each zone is calculated.
- Pumping chart is prepared.
- Demand curve for each zone is prepared.

7.5.1 Method of Supply:

- Continuous supply
- Intermittent supply

Continuous supply is preferred because,

- During non-supply hours, in an intermittent system, distribution lines may suffer from partial vacuum, sucking in contaminated water from sewage lines which run close to the water supply lines.
- Supply is well metered in continuous system
- Constant supply of water for fire-fighting is always available

7.5.2 Method of Distribution:

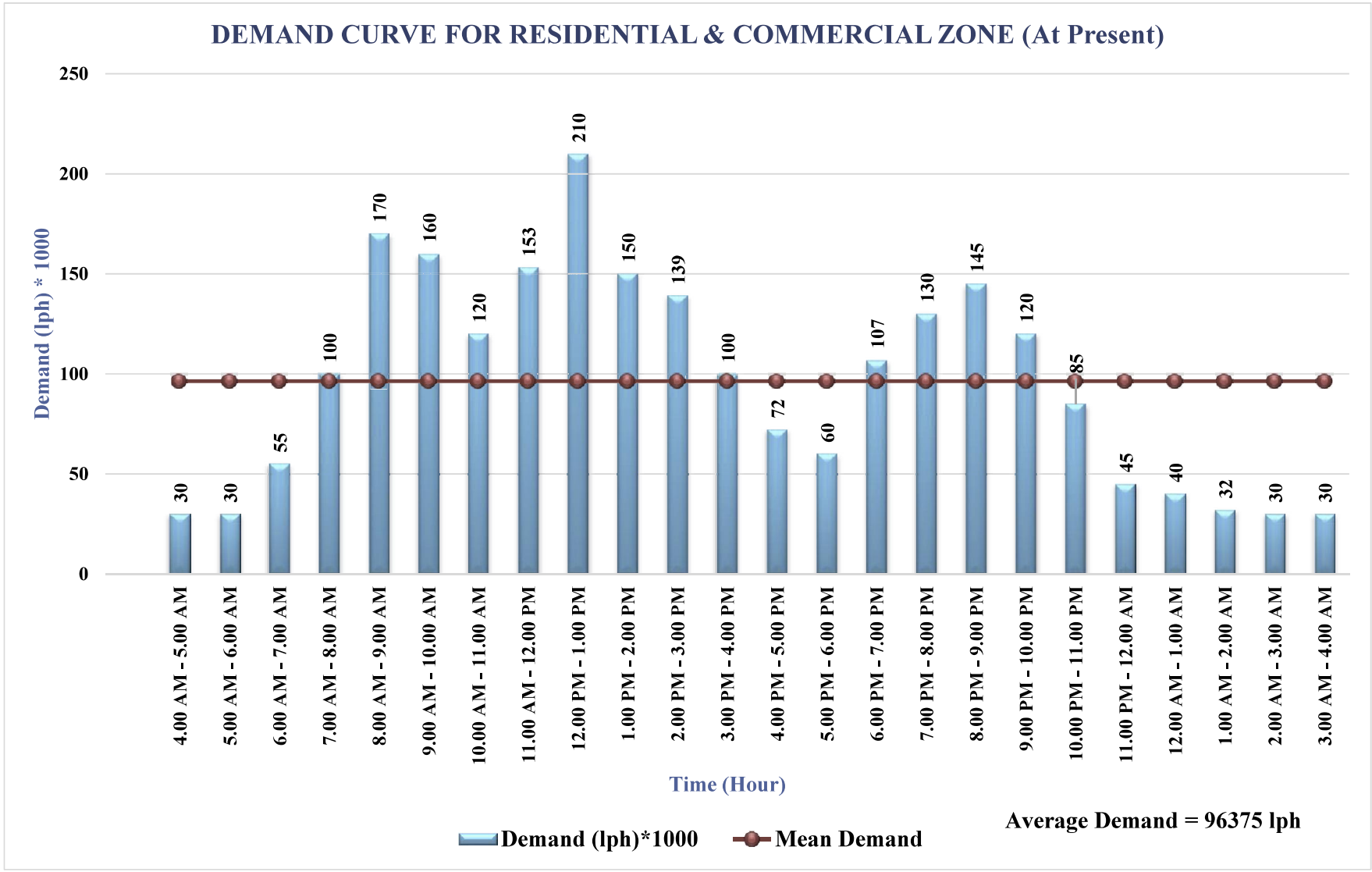
- **System with direct pumping**
  1) If there is power failure then it will cause failure of the whole distribution system
  2) Difficult to maintain minimum pressure, especially in varying rate of consumption

- **System with pumping and storage**
  1) Operation is economic
  2) Minimum pressure can be maintained even at varying rate of consumption
  3) Initial cost is higher

We will design the system for continuous water supply with pumping and storage.

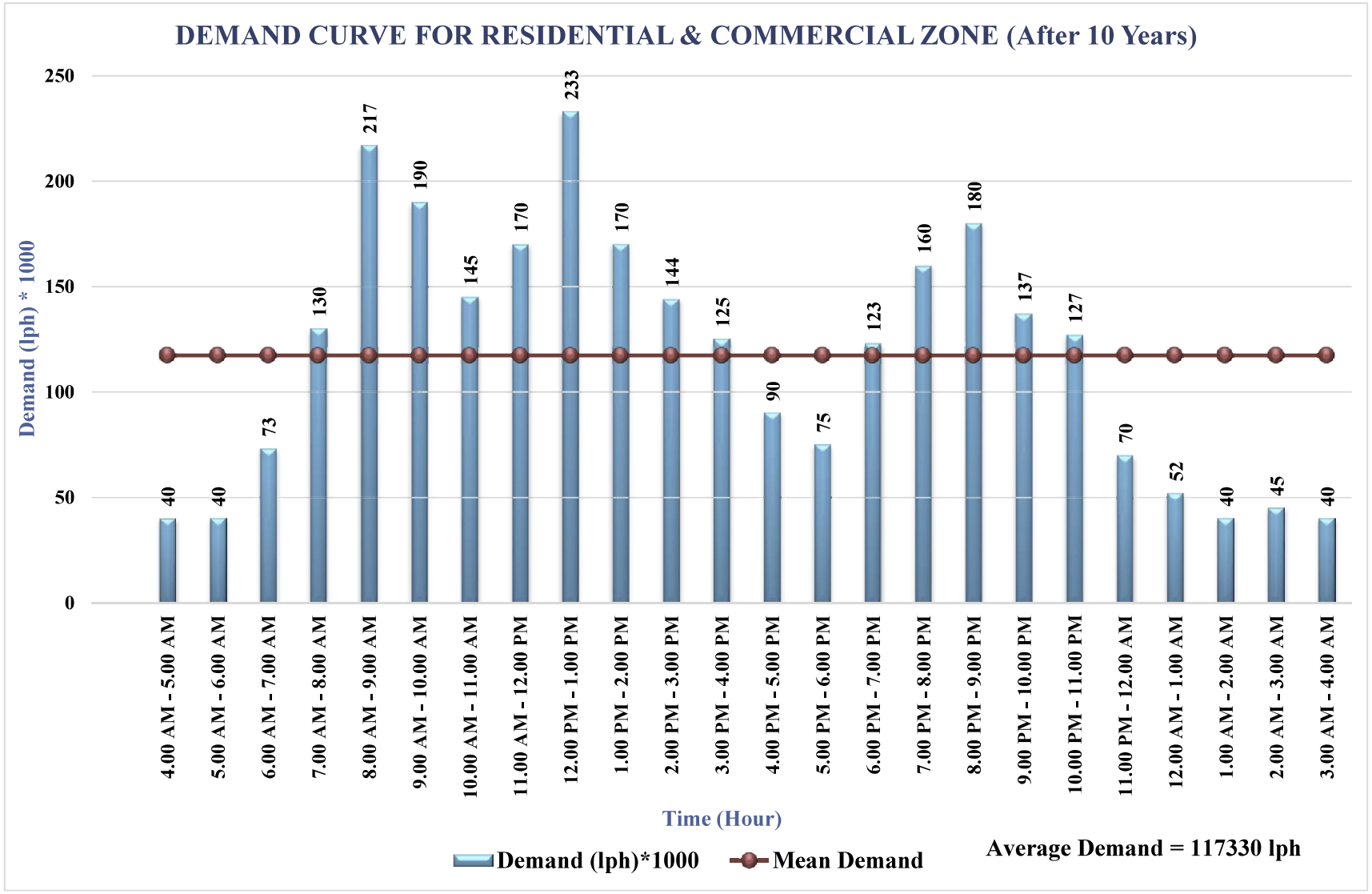
PUMPING SCHEDULE FOR RESIDENTIAL & COMMERCIAL ZONE (At Present)

Time	Demand (lph)*1000	Supply (lph)*1000	Net Storage (lph)*1000	Pumping Required	Remarks
			15+30		
4.00 AM - 5.00 AM	30	53.8	68.8	Yes	Pump-1
5.00 AM - 6.00 AM	30	53.8	92.6	Yes	Pump-1
6.00 AM - 7.00 AM	55	0	37.6	No	No Pumping Required
7.00 AM - 8.00 AM	100	107.6	45.2	Yes	Pump-2, Pump-3
8.00 AM - 9.00 AM	170	161.4	36.6	Yes	Pump-1, Pump-2, Pump-3
9.00 AM - 10.00 AM	160	161.4	38	Yes	Pump-1, Pump-2, Pump-3
10.00 AM - 11.00 AM	120	161.4	79.4	Yes	Pump-1, Pump-2, Pump-3
11.00 AM - 12.00 PM	153	161.4	87.8	Yes	Pump-1, Pump-2, Pump-3
12.00 PM - 1.00 PM	210	161.4	39.2	Yes	Pump-1, Pump-2, Pump-3
1.00 PM - 2.00 PM	150	161.4	50.6	Yes	Pump-1, Pump-2, Pump-3
2.00 PM - 3.00 PM	139	107.6	19.2	Yes	Pump-1, Pump-3
3.00 PM - 4.00 PM	100	107.6	26.8	Yes	Pump-1, Pump-3
4.00 PM - 5.00 PM	72	107.6	62.4	Yes	Pump-2, Pump-3
5.00 PM - 6.00 PM	60	53.8	56.2	Yes	Pump-1
6.00 PM - 7.00 PM	107	107.6	56.8	Yes	Pump-1, Pump-2
7.00 PM - 8.00 PM	130	107.6	34.4	Yes	Pump-1, Pump-3
8.00 PM - 9.00 PM	145	161.4	50.8	Yes	Pump-1, Pump-2, Pump-3
9.00 PM - 10.00 PM	120	107.6	38.4	Yes	Pump-2, Pump-3
10.00 PM - 11.00 PM	85	107.6	61	Yes	Pump-2, Pump-3
11.00 PM - 12.00 AM	45	53.8	69.8	Yes	Pump-1
12.00 AM - 1.00 AM	40	0	29.8	No	No Pumping Required
1.00 AM - 2.00 AM	32	53.8	51.6	Yes	Pump-2, Pump-3
2.00 AM - 3.00 AM	30	53.8	75.4	Yes	Pump-2
3.00 AM - 4.00 AM	30	0	45.4	No	No Pumping Required
Summation	**2313**				


DEMAND CURVE FOR RESIDENTIAL & COMMERCIAL ZONE (At Present)
Demand (lph) * 1000
250
200
150
100
50
0
30
30
55
100
170
160
120
153
210
150
139
100
72
60
107
130
145
120
85
45
40
32
30
30
4.00 AM - 5.00 AM
5.00 AM - 6.00 AM
6.00 AM - 7.00 AM
7.00 AM - 8.00 AM
8.00 AM - 9.00 AM
9.00 AM - 10.00 AM
10.00 AM - 11.00 AM
11.00 AM - 12.00 PM
12.00 PM - 1.00 PM
1.00 PM - 2.00 PM
2.00 PM - 3.00 PM
3.00 PM - 4.00 PM
4.00 PM - 5.00 PM
5.00 PM - 6.00 PM
6.00 PM - 7.00 PM
7.00 PM - 8.00 PM
8.00 PM - 9.00 PM
9.00 PM - 10.00 PM
10.00 PM - 11.00 PM
11.00 PM - 12.00 AM
12.00 AM - 1.00 AM
1.00 AM - 2.00 AM
2.00 AM - 3.00 AM
3.00 AM - 4.00 AM
Time (Hour)
Demand (lph)*1000
Mean Demand
Average Demand = 96375 lph

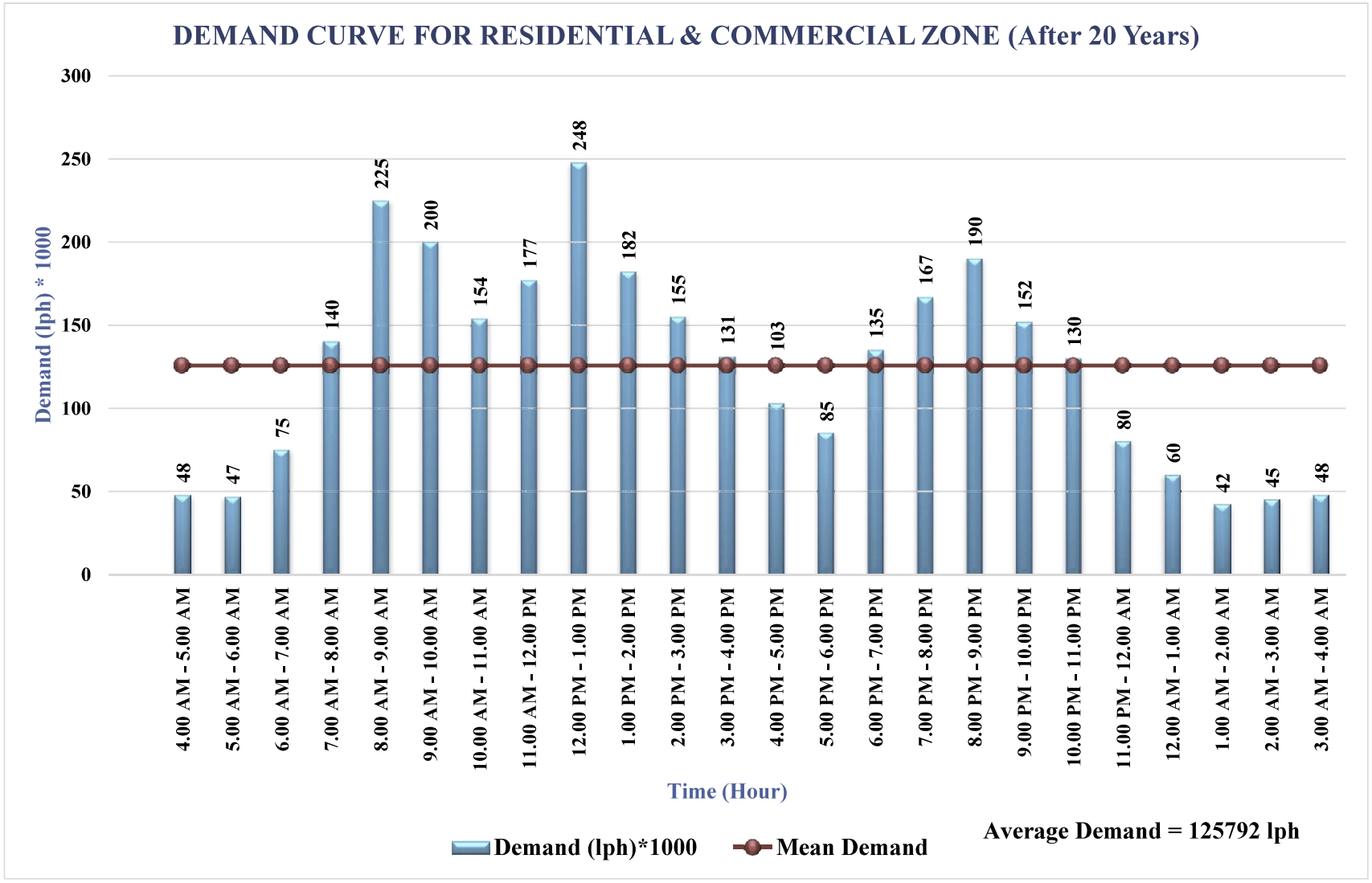
PUMPING SCHEDULE FOR RESIDENTIAL & COMMERCIAL ZONE (After 10 Years)

Time	Demand (lph)*1000	Supply (lph)*1000	Net Storage (lph)*1000	Pumping Required	Remarks
			15+40		
4.00 AM - 5.00 AM	40	53.8	68.8	Yes	Pump-4
5.00 AM - 6.00 AM	40	53.8	82.6	Yes	Pump-1
6.00 AM - 7.00 AM	73	53.8	63.4	Yes	Pump-1
7.00 AM - 8.00 AM	130	107.6	41	Yes	Pump-3
8.00 AM - 9.00 AM	217	215.2	39.2	Yes	Pump-1, Pump-2, Pump-3, Pump-4
9.00 AM - 10.00 AM	190	215.2	64.4	Yes	Pump-1, Pump-2, Pump-3, Pump-4
10.00 AM - 11.00 AM	145	107.6	27	Yes	Pump-1, Pump-2
11.00 AM - 12.00 PM	170	215.2	72.2	Yes	Pump-1, Pump-2, Pump-3, Pump-4
12.00 PM - 1.00 PM	233	215.2	54.4	Yes	Pump-1, Pump-2, Pump-3, Pump-4
1.00 PM - 2.00 PM	170	215.2	99.6	Yes	Pump-1, Pump-2, Pump-3, Pump-4
2.00 PM - 3.00 PM	144	161.4	117	Yes	Pump-2, Pump-3, Pump-4
3.00 PM - 4.00 PM	125	107.6	99.6	Yes	Pump-3, Pump-4
4.00 PM - 5.00 PM	90	107.6	117.2	Yes	Pump-1, Pump-4
5.00 PM - 6.00 PM	75	0	42.2	No	No Pumping Required
6.00 PM - 7.00 PM	123	161.4	80.6	Yes	Pump-1, Pump-2, Pump-3
7.00 PM - 8.00 PM	160	161.4	82	Yes	Pump-2, Pump-3, Pump-4
8.00 PM - 9.00 PM	180	215.2	117.2	Yes	Pump-1, Pump-2, Pump-3, Pump-4
9.00 PM - 10.00 PM	137	107.6	87.8	Yes	Pump-2, Pump-4
10.00 PM - 11.00 PM	127	107.6	68.4	Yes	Pump-2, Pump-3
11.00 PM - 12.00 AM	70	80.7	79.1	Yes	Pump-1 (30 min), Pump-4 (1 hr)
12.00 AM - 1.00 AM	52	53.8	80.9	Yes	Pump-4
1.00 AM - 2.00 AM	40	0	40.9	No	No Pumping Required
2.00 AM - 3.00 AM	45	53.8	49.7	Yes	Pump-4
3.00 AM - 4.00 AM	40	53.8	63.5	Yes	Pump-4
Summation	**2816**				


DEMAND CURVE FOR RESIDENTIAL & COMMERCIAL ZONE (After 10 Years)
Demand (lph) * 1000
250
200
150
100
50
0
40
40
73
130
217
190
145
170
233
170
144
125
90
75
123
160
180
137
127
70
52
40
45
40
4.00 AM - 5.00 AM
5.00 AM - 6.00 AM
6.00 AM - 7.00 AM
7.00 AM - 8.00 AM
8.00 AM - 9.00 AM
9.00 AM - 10.00 AM
10.00 AM - 11.00 AM
11.00 AM - 12.00 PM
12.00 PM - 1.00 PM
1.00 PM - 2.00 PM
2.00 PM - 3.00 PM
3.00 PM - 4.00 PM
4.00 PM - 5.00 PM
5.00 PM - 6.00 PM
6.00 PM - 7.00 PM
7.00 PM - 8.00 PM
8.00 PM - 9.00 PM
9.00 PM - 10.00 PM
10.00 PM - 11.00 PM
11.00 PM - 12.00 AM
12.00 AM - 1.00 AM
1.00 AM - 2.00 AM
2.00 AM - 3.00 AM
3.00 AM - 4.00 AM
Time (Hour)
Demand (lph)*1000
Mean Demand
Average Demand = 117330 lph

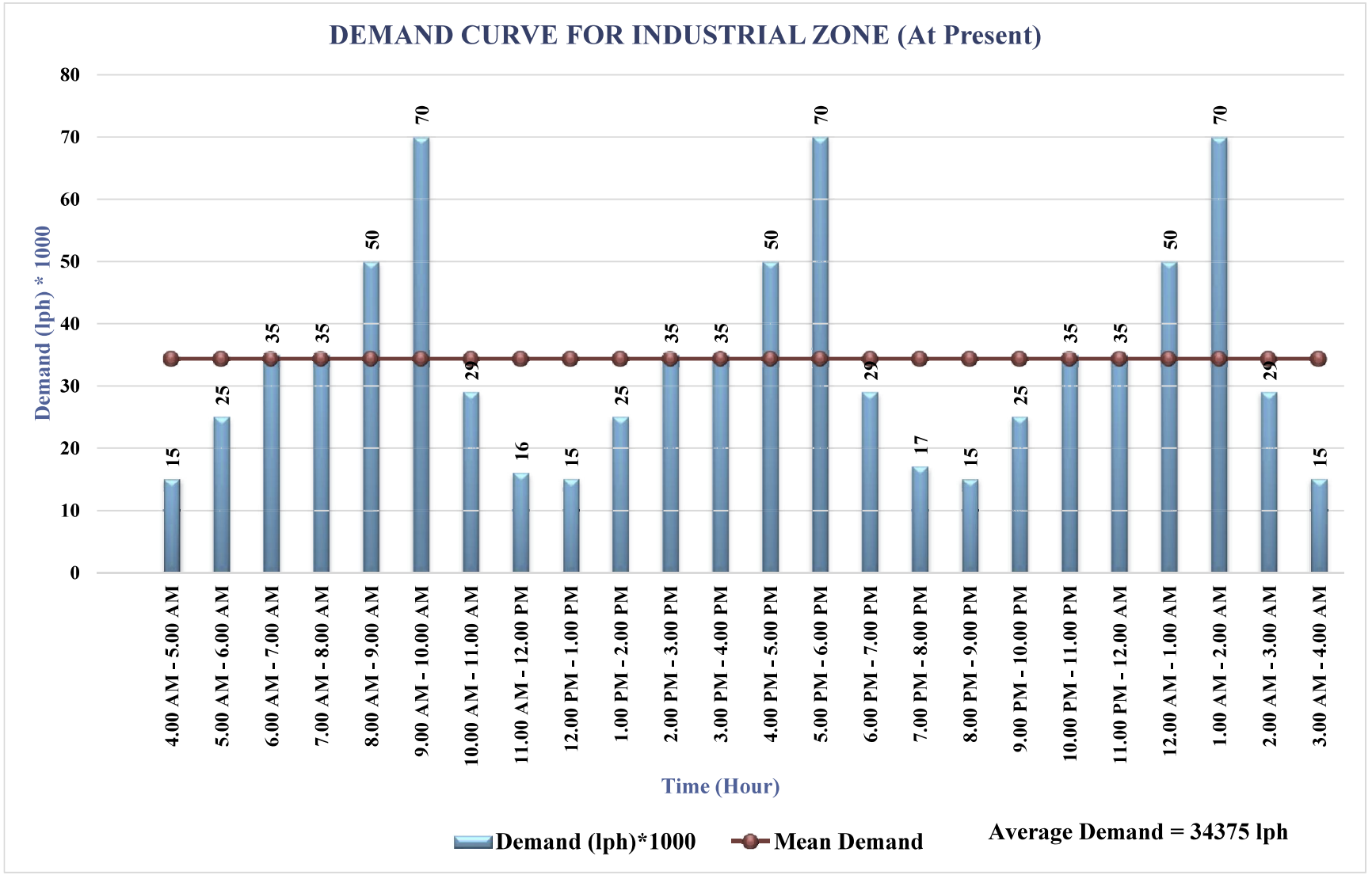
PUMPING SCHEDULE FOR RESIDENTIAL & COMMERCIAL ZONE (After 20 Years)

Time	Demand (lph)*1000	Supply (lph)*1000	Net Storage (lph)*1000	Pumping Required	Remarks
			15+48		
4.00 AM - 5.00 AM	48	53.8	68.8	Yes	Pump-4
5.00 AM - 6.00 AM	47	53.8	75.6	Yes	Pump-4
6.00 AM - 7.00 AM	75	53.8	54.4	Yes	Pump-1
7.00 AM - 8.00 AM	140	161.4	75.8	Yes	Pump-1, Pump-2, Pump-3
8.00 AM - 9.00 AM	225	215.2	66	Yes	Pump-1, Pump-2, Pump-3, Pump-4
9.00 AM - 10.00 AM	200	161.4	27.4	Yes	Pump-2, Pump-3, Pump-4
10.00 AM - 11.00 AM	154	161.4	34.8	Yes	Pump-1, Pump-3, Pump-4
11.00 AM - 12.00 PM	177	215.2	73	Yes	Pump-1, Pump-2, Pump-3, Pump-4
12.00 PM - 1.00 PM	248	215.2	40.2	Yes	Pump-1, Pump-2, Pump-3, Pump-4
1.00 PM - 2.00 PM	182	215.2	73.4	Yes	Pump-1, Pump-2, Pump-3, Pump-4
2.00 PM - 3.00 PM	155	134.5	52.9	Yes	Pump-1 (30 min), Pump-2, 4 (1 hr)
3.00 PM - 4.00 PM	131	107.6	29.5	Yes	Pump-2, Pump-3
4.00 PM - 5.00 PM	103	107.6	34.1	Yes	Pump-1, Pump-3
5.00 PM - 6.00 PM	85	107.6	56.7	Yes	Pump-2, Pump-4
6.00 PM - 7.00 PM	135	107.6	29.3	Yes	Pump-1, Pump-2
7.00 PM - 8.00 PM	167	161.4	23.7	Yes	Pump-1, Pump-3, Pump-4
8.00 PM - 9.00 PM	190	215.2	48.9	Yes	Pump-1, Pump-2, Pump-3, Pump-4
9.00 PM - 10.00 PM	152	179.3	76.2	Yes	Pump-1, 2 (40 min), Pump-3, 4 (1 hr)
10.00 PM - 11.00 PM	130	80.7	26.9	Yes	Pump-2 (1 hr), Pump-3 (30 min)
11.00 PM - 12.00 AM	80	107.6	54.5	Yes	Pump-1, Pump-4
12.00 AM - 1.00 AM	60	53.8	48.3	Yes	Pump-4
1.00 AM - 2.00 AM	42	107.6	113.9	Yes	Pump-2, Pump-3
2.00 AM - 3.00 AM	45	0	68.9	No	No Pumping Required
3.00 AM - 4.00 AM	48	44.8	71.7	Yes	Pump-4 (50 min)
Summation	**3019**				


DEMAND CURVE FOR RESIDENTIAL & COMMERCIAL ZONE (After 20 Years)
Demand (lph) * 1000
300
250
200
150
100
50
0
48
47
75
140
225
200
154
177
248
182
155
131
103
85
135
167
190
152
130
80
60
42
45
48
4.00 AM - 5.00 AM
5.00 AM - 6.00 AM
6.00 AM - 7.00 AM
7.00 AM - 8.00 AM
8.00 AM - 9.00 AM
9.00 AM - 10.00 AM
10.00 AM - 11.00 AM
11.00 AM - 12.00 PM
12.00 PM - 1.00 PM
1.00 PM - 2.00 PM
2.00 PM - 3.00 PM
3.00 PM - 4.00 PM
4.00 PM - 5.00 PM
5.00 PM - 6.00 PM
6.00 PM - 7.00 PM
7.00 PM - 8.00 PM
8.00 PM - 9.00 PM
9.00 PM - 10.00 PM
10.00 PM - 11.00 PM
11.00 PM - 12.00 AM
12.00 AM - 1.00 AM
1.00 AM - 2.00 AM
2.00 AM - 3.00 AM
3.00 AM - 4.00 AM
Time (Hour)
Demand (lph)*1000
Mean Demand
Average Demand = 125792 lph

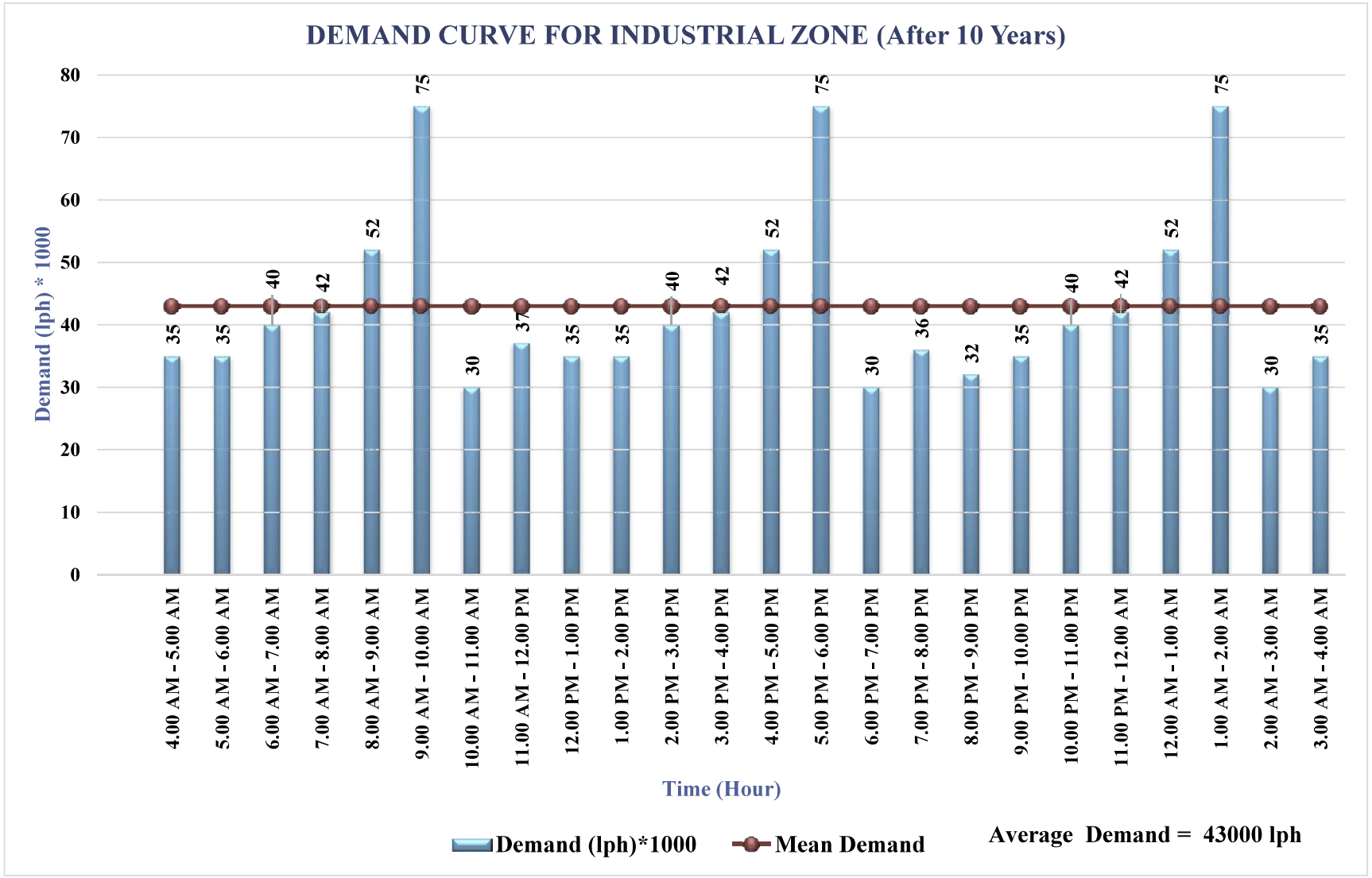
PUMPING SCHEDULE FOR INDUSTRIAL ZONE (At Present)

Time	Demand (lph)*1000	Supply (lph)*1000	Net Storage (lph)*1000	Pumping Required	Remarks
			15+15		
4.00 AM - 5.00 AM	15	0	15	No	No Pumping Required
5.00 AM - 6.00 AM	25	53.8	43.8	Yes	Pump-1
6.00 AM - 7.00 AM	35	53.8	62.6	Yes	Pump-1
7.00 AM - 8.00 AM	35	53.8	81.4	Yes	Pump-1
8.00 AM - 9.00 AM	50	53.8	85.2	Yes	Pump-1
9.00 AM - 10.00 AM	70	53.8	69	Yes	Pump-1
10.00 AM - 11.00 AM	29	0	40	No	No Pumping Required
11.00 AM - 12.00 PM	16	0	24	No	No Pumping Required
12.00 PM - 1.00 PM	15	53.8	62.8	Yes	Pump-1
1.00 PM - 2.00 PM	25	0	37.8	No	No Pumping Required
2.00 PM - 3.00 PM	35	53.8	56.6	Yes	Pump-1
3.00 PM - 4.00 PM	35	53.8	75.4	Yes	Pump-1
4.00 PM - 5.00 PM	50	53.8	79.2	Yes	Pump-1
5.00 PM - 6.00 PM	70	53.8	63	Yes	Pump-1
6.00 PM - 7.00 PM	29	0	34	No	No Pumping Required
7.00 PM - 8.00 PM	17	53.8	70.8	Yes	Pump-1
8.00 PM - 9.00 PM	15	53.8	109.6	Yes	Pump-1
9.00 PM - 10.00 PM	25	0	84.6	No	No Pumping Required
10.00 PM - 11.00 PM	35	0	49.6	No	No Pumping Required
11.00 PM - 12.00 AM	35	53.8	68.4	Yes	Pump-1
12.00 AM - 1.00 AM	50	53.8	72.2	Yes	Pump-1
1.00 AM - 2.00 AM	70	53.8	56	Yes	Pump-1
2.00 AM - 3.00 AM	29	26.9	53.9	Yes	Pump-1 (30 min)
3.00 AM - 4.00 AM	15	0	38.9	No	No Pumping Required
Summation	**825**				


DEMAND CURVE FOR INDUSTRIAL ZONE (At Present)
Demand (lph) * 1000
80
70
60
50
40
30
20
10
0
15
25
35
35
50
70
29
16
15
25
35
35
50
70
29
17
15
25
35
35
50
70
29
15
4.00 AM - 5.00 AM
5.00 AM - 6.00 AM
6.00 AM - 7.00 AM
7.00 AM - 8.00 AM
8.00 AM - 9.00 AM
9.00 AM - 10.00 AM
10.00 AM - 11.00 AM
11.00 AM - 12.00 PM
12.00 PM - 1.00 PM
1.00 PM - 2.00 PM
2.00 PM - 3.00 PM
3.00 PM - 4.00 PM
4.00 PM - 5.00 PM
5.00 PM - 6.00 PM
6.00 PM - 7.00 PM
7.00 PM - 8.00 PM
8.00 PM - 9.00 PM
9.00 PM - 10.00 PM
10.00 PM - 11.00 PM
11.00 PM - 12.00 AM
12.00 AM - 1.00 AM
1.00 AM - 2.00 AM
2.00 AM - 3.00 AM
3.00 AM - 4.00 AM
Time (Hour)
Demand (lph)*1000
Mean Demand
Average Demand = 34375 lph

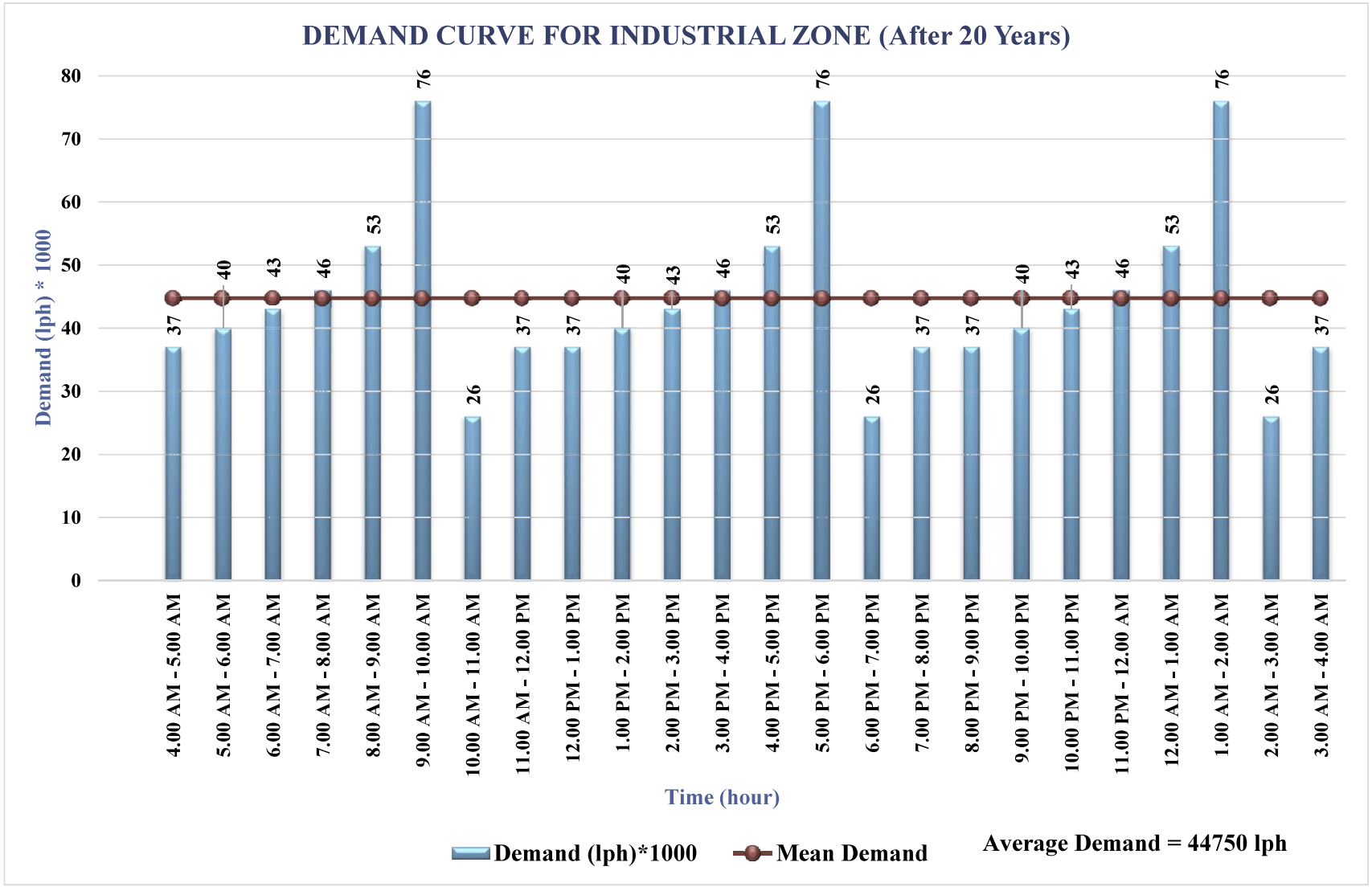
PUMPING SCHEDULE FOR INDUSTRIAL ZONE (After 10 Years)

Time	Demand (lph)*1000	Supply (lph)*1000	Net Storage (lph)*1000	Pumping Required	Remarks
			15+35		
4.00 AM - 5.00 AM	35	53.8	68.8	Yes	Pump-2
5.00 AM - 6.00 AM	35	53.8	87.6	Yes	Pump-2
6.00 AM - 7.00 AM	40	53.8	101.4	Yes	Pump-2
7.00 AM - 8.00 AM	42	53.8	113.2	Yes	Pump-2
8.00 AM - 9.00 AM	52	53.8	115	Yes	Pump-1
9.00 AM - 10.00 AM	75	107.6	147.6	Yes	Pump-1, Pump-2
10.00 AM - 11.00 AM	30	0	117.6	No	No Pumping Required
11.00 AM - 12.00 PM	37	0	80.6	No	No Pumping Required
12.00 PM - 1.00 PM	35	53.8	99.4	Yes	Pump-2
1.00 PM - 2.00 PM	35	53.8	118.2	Yes	Pump-2
2.00 PM - 3.00 PM	40	53.8	132	Yes	Pump-1
3.00 PM - 4.00 PM	42	0	90	No	No Pumping Required
4.00 PM - 5.00 PM	52	107.6	145.6	Yes	Pump-1, Pump-2
5.00 PM - 6.00 PM	75	0	70.6	No	No Pumping Required
6.00 PM - 7.00 PM	30	0	40.6	No	No Pumping Required
7.00 PM - 8.00 PM	36	53.8	58.4	Yes	Pump-2
8.00 PM - 9.00 PM	32	53.8	80.2	Yes	Pump-2
9.00 PM - 10.00 PM	35	53.8	99	Yes	Pump-2
10.00 PM - 11.00 PM	40	53.8	112.8	Yes	Pump-1
11.00 PM - 12.00 AM	42	0	70.8	No	No Pumping Required
12.00 AM - 1.00 AM	52	0	18.8	No	No Pumping Required
1.00 AM - 2.00 AM	75	80.7	24.5	Yes	Pump-1 (1hr), Pump-2 (30min)
2.00 AM - 3.00 AM	30	98.6	93.1	Yes	Pump-1 (50 min), Pump-2 (1 hr)
3.00 AM - 4.00 AM	35	0	58.1	No	No Pumping Required
Summation	**1032**				


DEMAND CURVE FOR INDUSTRIAL ZONE (After 10 Years)
Demand (lph) * 1000
80
70
60
50
40
30
20
10
0
35
35
40
42
52
75
30
37
35
35
40
42
52
75
30
36
32
35
40
42
52
75
30
35
4.00 AM - 5.00 AM
5.00 AM - 6.00 AM
6.00 AM - 7.00 AM
7.00 AM - 8.00 AM
8.00 AM - 9.00 AM
9.00 AM - 10.00 AM
10.00 AM - 11.00 AM
11.00 AM - 12.00 PM
12.00 PM - 1.00 PM
1.00 PM - 2.00 PM
2.00 PM - 3.00 PM
3.00 PM - 4.00 PM
4.00 PM - 5.00 PM
5.00 PM - 6.00 PM
6.00 PM - 7.00 PM
7.00 PM - 8.00 PM
8.00 PM - 9.00 PM
9.00 PM - 10.00 PM
10.00 PM - 11.00 PM
11.00 PM - 12.00 AM
12.00 AM - 1.00 AM
1.00 AM - 2.00 AM
2.00 AM - 3.00 AM
3.00 AM - 4.00 AM
Time (Hour)
Demand (lph)*1000
Mean Demand
Average Demand = 43000 lph

PUMPING SCHEDULE FOR INDUSTRIAL ZONE (After 20 Years)

Time	Demand (lph)*1000	Supply (lph)*1000	Net Storage (lph)*1000	Pumping Required	Remarks
			15+37		
4.00 AM - 5.00 AM	37	53.8	68.8	Yes	Pump-1
5.00 AM - 6.00 AM	40	53.8	82.6	Yes	Pump-1
6.00 AM - 7.00 AM	43	53.8	93.4	Yes	Pump-1
7.00 AM - 8.00 AM	46	53.8	101.2	Yes	Pump-2
8.00 AM - 9.00 AM	53	53.8	102	Yes	Pump-2
9.00 AM - 10.00 AM	76	107.6	133.6	Yes	Pump-1, Pump-2
10.00 AM - 11.00 AM	26	0	107.6	No	No Pumping Required
11.00 AM - 12.00 PM	37	0	70.6	No	No Pumping Required
12.00 PM - 1.00 PM	37	0	33.6	No	No Pumping Required
1.00 PM - 2.00 PM	40	53.8	47.4	Yes	Pump-2
2.00 PM - 3.00 PM	43	53.8	58.2	Yes	Pump-2
3.00 PM - 4.00 PM	46	53.8	66	Yes	Pump-1
4.00 PM - 5.00 PM	53	53.8	66.8	Yes	Pump-1
5.00 PM - 6.00 PM	76	107.6	98.4	Yes	Pump-1, Pump-2
6.00 PM - 7.00 PM	26	53.8	126.2	Yes	Pump-2
7.00 PM - 8.00 PM	37	0	89.2	No	No Pumping Required
8.00 PM - 9.00 PM	37	0	52.2	No	No Pumping Required
9.00 PM - 10.00 PM	40	0	12.2	No	No Pumping Required
10.00 PM - 11.00 PM	43	53.8	23	Yes	Pump-2
11.00 PM - 12.00 AM	46	53.8	30.8	Yes	Pump-2
12.00 AM - 1.00 AM	53	53.8	31.6	Yes	Pump-2
1.00 AM - 2.00 AM	76	107.6	63.2	Yes	Pump-1, Pump-2
2.00 AM - 3.00 AM	26	53.8	91	Yes	Pump-2
3.00 AM - 4.00 AM	37	0	54	No	No Pumping Required
Summation	**1074**				


DEMAND CURVE FOR INDUSTRIAL ZONE (After 20 Years)
Demand (lph) * 1000
80
70
60
50
40
30
20
10
0
37
40
43
46
53
76
26
37
37
40
43
46
53
76
26
37
37
40
43
46
53
76
26
37
4.00 AM - 5.00 AM
5.00 AM - 6.00 AM
6.00 AM - 7.00 AM
7.00 AM - 8.00 AM
8.00 AM - 9.00 AM
9.00 AM - 10.00 AM
10.00 AM - 11.00 AM
11.00 AM - 12.00 PM
12.00 PM - 1.00 PM
1.00 PM - 2.00 PM
2.00 PM - 3.00 PM
3.00 PM - 4.00 PM
4.00 PM - 5.00 PM
5.00 PM - 6.00 PM
6.00 PM - 7.00 PM
7.00 PM - 8.00 PM
8.00 PM - 9.00 PM
9.00 PM - 10.00 PM
10.00 PM - 11.00 PM
11.00 PM - 12.00 AM
12.00 AM - 1.00 AM
1.00 AM - 2.00 AM
2.00 AM - 3.00 AM
3.00 AM - 4.00 AM
Time (hour)
Demand (lph)*1000
Mean Demand
Average Demand = 44750 lph

SUMMARY TABLE FOR PUMPING SCHEDULE

Zone		At Present	After 10 years	After 20 years
Residential + Commercial	**Water Demand**	2313000 lpd	2816000 lpd	3019000 lpd
	Pump Required	3	4	4
	Pumping Hour	**Pump 1 :** 15 hr **Pump 2 :** 14 hr **Pump 3 :** 15 hr	**Pump 1 :** 11 hr 30min **Pump 2 :** 12 hr **Pump 3 :** 12 hr **Pump 4 :** 16 hr	**Pump 1 :** 13 hr 10 min **Pump 2 :** 13 hr 40 min **Pump 3 :** 13 hr 30 min **Pump 4 :** 15 hr 50 min
Industrial	**Water Demand**	825000 lpd	1032000 lpd	1074000 lpd
	Pump Required	1	2	2
	Pumping Hour	**Pump 1 :** 15 hr 30 min	**Pump 1 :** 6 hr 50 min **Pump 2 :** 12 hr 30 min	**Pump 1 :** 8 hr **Pump 2 :** 12 hr

CHAPTER - 8

DESIGN OF WATER DISTRIBUTION NETWORK (BRANCH & LOOP NETWORK)

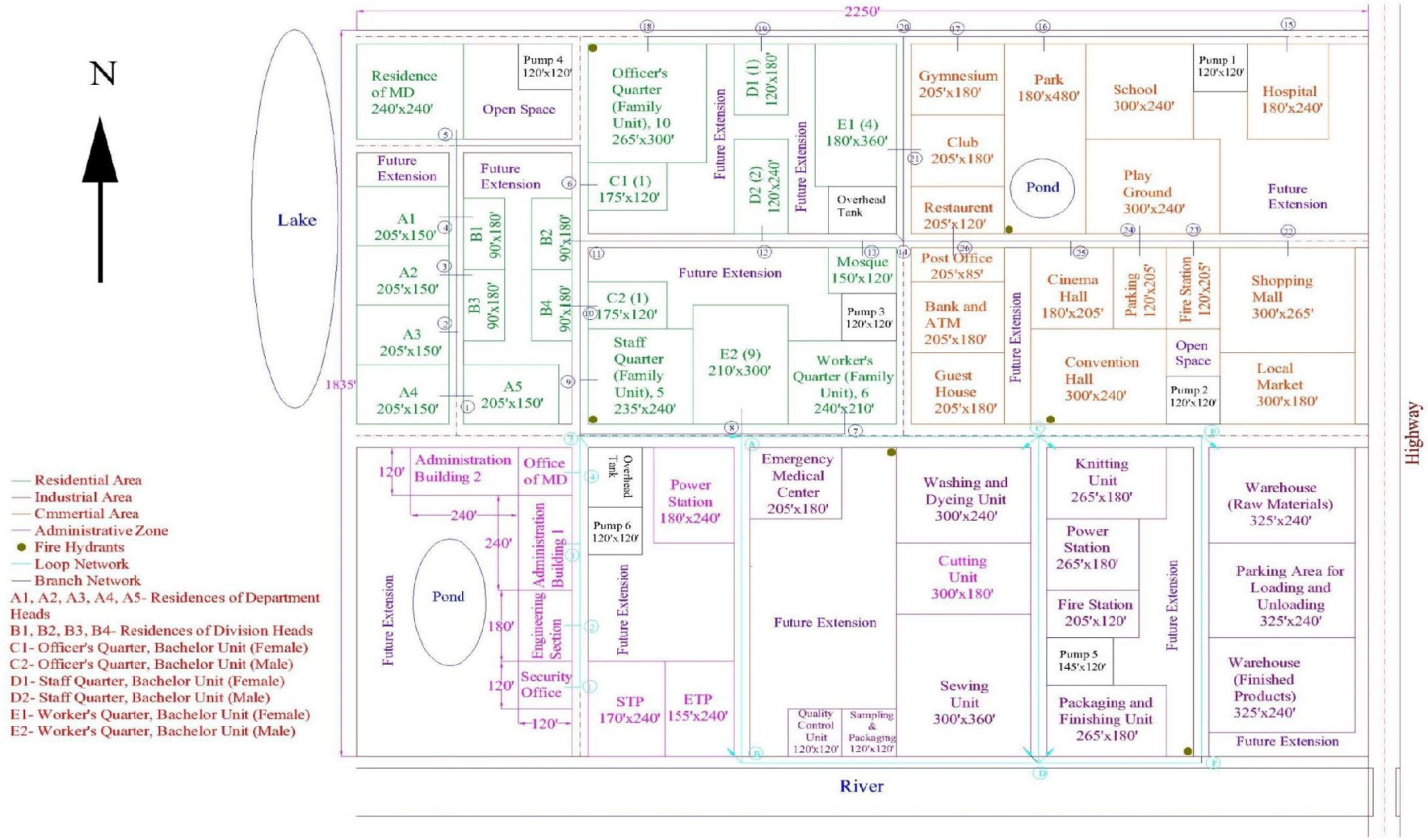


FIGURE 8.1: LAYOUT OF WATER DISTRIBUTION NETWORK THE INDUSTRIAL VILLAGE

8.1 INTRODUCTION:

The purpose of distribution system is to deliver water to consumer with appropriate quality, quantity and pressure. Distribution system is used to describe collectively the facilities used to supply water from its source to the point of usage.

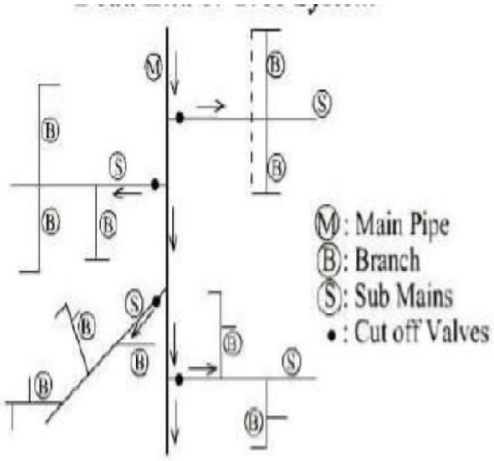
The transmission of water from the sources to the consumers is usually done in two stages: distribution and reticulation.

8.1.1 Layouts of Distribution Network:

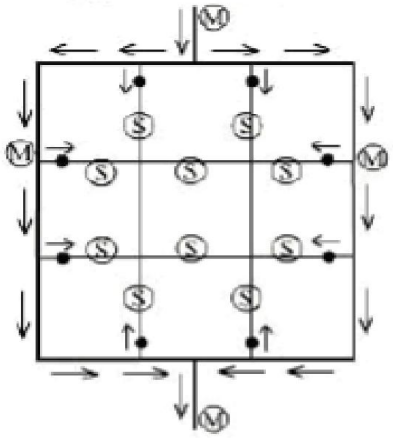
There are four different types of pipe networks:
1) Branched Network - Dead End System
2) Looped network –

- Grid Iron System
- Ring System
- Radial System

We used Dead End system for our network design of residential and commercial zone and used a loop network for industrial zone.



Branched or Dead End System



Loop Network (Ring System)

8.2 DESIGN OF BRANCH NETWORK FOR RESIDENTIAL & COMMERCIAL ZONE:

8.2.1 Advantages:

- Relatively cheap as length of pipe required is less.
- Determination of discharges and pressure is easier due to less number of valves.
- Can easily be expanded to connect newly developed area with the distribution system.

8.2.2 Disadvantages:

- Due to many dead ends, stagnation of water occurs in pipes which in turn promote sedimentation and water contamination.
- Frequent blow-off or flushing is needed to keep the system clean.
- Repair work in mains and sub-mains cuts off water supply downstream.

8.2.3 Assumptions:

- A transmission main serving half of the residential & commercial zone was laid out along the main road.
- Quantity flowing in each section of the network was taken from the peak daily demand previously calculated.
- The water distribution system was designed to maintain operating pressures within the system between **40** and **75 psi**.
- The velocity in pipe is assumed to be around **1m/s** or **3 fps**.
- Friction factor is assumed to be **0.01**

8.2.4 Design Procedure for Distribution Layout System (Branched Network):

- A layout of mains, sub mains, branches along with valves and other accessories prepared.
- Peak flows at different points estimated from previous **Chapter 6** and **7**.
- The pipe size is then calculated from the following formula

$$Q = A * v$$

Where,

v is assumed to be 3 fps

- Now, frictional head loss per unit length of pipe is calculated.

  Pressure loss due to friction, $h_f = 4fLv^2/2gd$ (ft)

- Pressure loss in psi = h_f (ft) * 62.4 (lb/ft^3)/144

Where,

L = length of pipe
V = velocity (fps)
f = Friction Factor, 0.01 (assumed)
D = diameter of the pipe (ft)

- Pressure requirement at the farthest point from the source is checked.

8.3 SAMPLE CALCULATION FOR BRANCH SYSTEM:

8.3.1 Determination of Pipe Diameter:

- **FOR NODE 1, 2:**

Peak Demand, Q = 10000 lpd

= $(10000*10^{-3} * 3.28^3)/(3600*24)$ ft^3/s

= 0.0041 ft^3/s

Length, L = 163 ft

Assume, Velocity, V = 3 fps

We know, Q = A * V

So, 0.0041 = $3.1416*(D^2)/(4*3)$ fps

So, Required Diameter = 0.500 inch

So, Provided Diameter = 1.5 inch

8.3.2 Check for Pressure:

- **For Path - 1:**

Node 1, 2: Length = 163 ft

Diameter = 1.5 inch

Head loss h_f = $(4fLv^2)/ 2gD$

Here, Friction factor, f = 0.01

So, h_f = $(4 * 0.01 * 163 * 3^2)/(2 * 32.3 * 1.5)$ ft

= 7.289 ft

= $(7.289 * 62.4 \text{ lb}/ft^3)/144$ psi

= 3.159 psi

Similar calculation for other nodes of the path - 1

Pressure drop = 3.159+3.391+2.655+3.256+7.5+3.527+2.863+1.388+0.552

= 28.291 psi

Initial Pressure at overhead tank = 45 psi

So, available pressure = 45 psi - 28.291 psi = 16.709 psi < 30 psi

So **NOT OK**, the pipe diameter needs to be revised.

After increasing the pipe diameter the head loss = 14.762 psi

So, available pressure = (45 -14.762) psi = 30.238 psi

Which is greater than 30 psi.

So, Pressure check is **Satisfied**.

For all the other paths same calculation was repeated and pressure was checked.

For other paths the pressure check was ok in first trial, no further revision of pipe diameter was required.

CALCULATION OF PIPE DIAMETER FOR RESIDENTIAL AND COMMERCIAL AREA BY BRANCH NETWORK

Node	Peak Demand (lpd)	Peak Demand (ft^3/s)	Length (ft)	Area of Pipe Required ($inch^2$)	Diameter of Pipe Required (inch)	Diameter of Provided Pipe (inch)
1,2	10000	0.0041	163	0.1968	0.5000	1.5
2,3	15000	0.00615	175	0.2952	0.6100	1.5
3,4	25000	0.01025	137	0.4920	0.7900	1.5
4,5	35000	0.01435	168	0.6888	0.9400	1.5
5,6	40000	0.0164	387	0.7872	1.0000	1.5
7,8	243250	0.0997325	245	4.7872	2.4700	3
8,8A	279500	0.114595	130	5.5006	2.6500	3
8A,9	288500	0.118285	427	5.6777	2.6900	3
9,10	443750	0.1819375	170	8.7330	3.3300	4
10,11	456625	0.18721625	127	8.9864	3.3800	4
6,11	45625	0.01870625	182	0.8979	1.0700	1.5
11,12	507200	0.207952	394	9.9817	3.5600	4
12,13	524750	0.2151475	191	10.3271	3.6300	4
13,14	553550	0.2269555	76	10.8939	3.7200	4
22,23	37200	0.015252	153	0.7321	0.9700	1.5
23,24	48000	0.01968	84	0.9446	1.1000	1.5
24,25	415380	0.1703058	221	8.1747	3.2300	4
25,26	438600	0.179826	255	8.6316	3.3200	4
26,14	589200	0.241572	114	11.5955	3.8400	4
18,19	267200	0.109552	296	5.2585	2.5900	3
19,20	270600	0.110946	313	5.325408	2.6000	3
15,16	810000	0.3321	532	15.9408	4.5100	5
16,17	811800	0.332838	241	15.976224	4.5100	5
17,20	816600	0.334806	76	16.070688	4.5200	5
20,21	1087200	0.445752	296	21.396096	5.2200	6
21,14	1168215	0.47896815	116	22.9904712	5.4100	6

BRANCH NETWORK DESIGN

Path	Node	Length (ft)	Diameter of Provided Pipe (inch)	Diameter of Provided Pipe (ft)	Head Loss (ft)	Head Loss (psi)	Total Head Loss (psi)	Available Pressure (psi)	Comment
Path - 1	1,2	163	1.5	0.125	7.289	3.159	28.291	16.709	NOT OK, Diameter Of Pipes Need To Be Revised
	2,3	175	1.5	0.125	7.826	3.391			
	3,4	137	1.5	0.125	6.127	2.655			
	4,5	168	1.5	0.125	7.513	3.256			
	5,6	387	1.5	0.125	17.307	7.500			
	6,11	182	1.5	0.125	8.139	3.527			
	11,12	394	4	0.333	6.607	2.863			
	12,13	191	4	0.333	3.203	1.388			
	13,14	76	4	0.333	1.275	0.552			
Path - 2	7,8	245	3	0.250	5.478	2.374	14.733	30.267	OK
	8,8A	130	3	0.250	2.907	1.260			
	8A,9	427	3	0.250	9.548	4.137			
	9,10	170	4	0.333	2.851	1.235			
	10,11	127	4	0.333	2.130	0.923			
	11,12	394	4	0.333	6.607	2.863			
	12,13	191	4	0.333	3.203	1.388			
	13,14	76	4	0.333	1.275	0.552			

BRANCH NETWORK DESIGN (Continued)

Path	Node	Length (ft)	Diameter of Provided Pipe (inch)	Diameter of Provided Pipe (ft)	Head Loss (ft)	Head Loss (psi)	Total Head Loss (psi)	Available Pressure (psi)	Comment
Path - 3	22,23	153	1.5	0.125	6.842	2.965	8.880	36.120	**OK**
	23,24	84	1.5	0.125	3.757	1.628			
	24,25	221	4	0.333	3.706	1.606			
	25,26	255	4	0.333	4.276	1.853			
	26,14	114	4	0.333	1.912	0.828			
Path - 4	15,16	532	5	0.417	7.137	3.093	6.932	38.068	**OK**
	16,17	241	5	0.417	3.233	1.401			
	17,20	76	5	0.417	1.020	0.442			
	20,21	296	6	0.500	3.309	1.434			
	21,14	116	6	0.500	1.297	0.562			
Path - 5	18,19	296	3	0.250	6.619	2.868	7.897	37.103	**OK**
	19,20	313	3	0.250	6.999	3.033			
	20,21	296	6	0.500	3.309	1.434			
	21,14	116	6	0.500	1.297	0.562			

BRANCH NETWORK DESIGN (Revised)

Path	Node	Length (ft)	Diameter of Provided Pipe (inch)	Diameter of Provided Pipe (ft)	Head Loss (ft)	Head Loss (psi)	Total Head Loss (psi)	Available Pressure (psi)	Comment
Path - 1	1,2	163	3	0.250	3.645	1.579	14.762	30.238	**OK**
	2,3	175	3	0.250	3.913	1.696			
	3,4	137	3	0.250	3.063	1.327			
	4,5	168	4	0.333	2.817	1.221			
	5,6	387	4	0.333	6.490	2.812			
	6,11	182	4	0.333	3.052	1.323			
	11,12	394	4	0.333	6.607	2.863			
	12,13	191	4	0.333	3.203	1.388			
	13,14	76	4	0.333	1.275	0.552			
Path - 2	7,8	245	3	0.250	5.478	2.374	14.733	30.267	**OK**
	8,8A	130	3	0.250	2.907	1.260			
	8A,9	427	3	0.250	9.548	4.137			
	9,10	170	4	0.333	2.851	1.235			
	10,11	127	4	0.333	2.130	0.923			
	11,12	394	4	0.333	6.607	2.863			
	12,13	191	4	0.333	3.203	1.388			
	13,14	76	4	0.333	1.275	0.552			

BRANCH NETWORK DESIGN (Revised - Continued)

Path	Node	Length (ft)	Diameter of Provided Pipe (inch)	Diameter of Provided Pipe (ft)	Head Loss (ft)	Head Loss (psi)	Total Head Loss (psi)	Available Pressure (psi)	Comment
Path - 3	22,23	153	1.5	0.125	6.842	2.965	8.880	36.120	**OK**
	23,24	84	1.5	0.125	3.757	1.628			
	24,25	221	4	0.333	3.706	1.606			
	25,26	255	4	0.333	4.276	1.853			
	26,14	114	4	0.333	1.912	0.828			
Path - 4	15,16	532	5	0.417	7.137	3.093	6.932	38.068	**OK**
	16,17	241	5	0.417	3.233	1.401			
	17,20	76	5	0.417	1.020	0.442			
	20,21	296	6	0.500	3.309	1.434			
	21,14	116	6	0.500	1.297	0.562			
Path - 5	18,19	296	3	0.250	6.619	2.868	7.897	37.103	**OK**
	19,20	313	3	0.250	6.999	3.033			
	20,21	296	6	0.500	3.309	1.434			
	21,14	116	6	0.500	1.297	0.562			

8.4 DESIGN OF LOOP NETWORK FOR INDUSTRIAL ZONE:

A loop network is designed around the industrial units. Two loops were assumed to supply the facilities such as washing, dying, sewing, warehouses etc.

8.4.1 Classification of Looped Network:

(a) Grid Iron System:

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

Advantages:

- Water is kept in good circulation due to the absence of dead ends.
- In the cases of a breakdown in some section, water is available from some other direction.
- Have good control over flow of water.

Disadvantages:

- Initial cost is relatively high.
- A large number of valves needed to control the flow.
- Exact calculation of sizes of pipes is not possible due to provision of valves on all branches.

(b) Ring System:

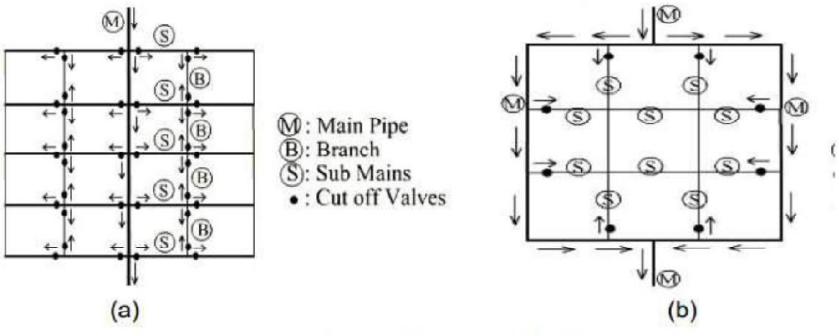
The supply main is laid all along the peripheral roads and sub mains branch out from the mains. Thus, this system also follows the grid iron system with the flow pattern similar in character to that of dead end system. So, determination of the size of pipes is easy.

Advantages:

- In addition to the advantages of grid iron system, in ring system water can be supplied to any point from at least two directions.

Disadvantages:

- Initial cost is relatively high.
- A large number of valves needed to control the flow.



Grid Iron System **Ring System**

(c) Radial System:

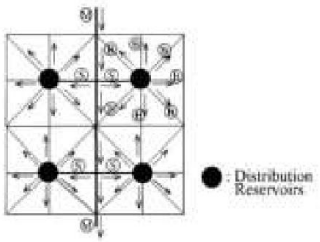
The area is divided into different zones. The water is pumped into the distribution reservoir kept in the middle of each zone and the supply pipes are laid radially ending towards the periphery.

Advantages:

- It gives quick service.
- Calculation of pipe sizes is easy.
- Presence of several reservoirs makes it easy to meet the emergency water demand.

Disadvantages:

- Presence of a number of distribution reservoirs increases the cost of the system.



Radial System

8.4.2 Assumptions:

A loop network around the industrial zone was chosen for calculation. Hardy Cross method of approximation was used to calculate flow of water in each pipe section.

In the looped network following conditions were satisfied:

- Flow entering into a junction must equal the flow leaving it.
- Algebraic sum of head loss in a closed loop will be zero.
- Value of Hazen William constant k is assumed **1**.
- Value of x in Hazen- William Equation is considered **1.85**.

8.4.3 Design Procedure for Distribution Layout System (Loop Network):

- The Hazen - William equation for Hardy Cross method is,
  $H = kQ^x$

Where,

H = Head loss
k = is a constant depending on length, diameter and roughness of the pipe as well as fluid property. Here, we are assuming k = 1
Q = Assumed flow in the pipe
X = 1.85 for Hazen-Williams equation

- Reasonable rate of flows were assumed in each pipe such that inflow equals outflow at each junction.
- For each loop head loss, H and H/Q were determined for each pipe

- Total head loss ΣH around each circuits were calculated with due consideration of the sign.
- Correction Δ to each loop was calculated $\Delta = - \Sigma H / (x \Sigma H/Q_a)$

Here,

- When the sign of Δ is negative, '-', decrease the clockwise flows and increase the counterclockwise flows.
- When the sign is positive '+' increase clockwise flows and decrease counterclockwise flows.
- Pipes that are common to two loops require double correction

- With adjusted flows, the procedure is repeated for the second approximation. The procedure is continued until the desired accuracy is attained.

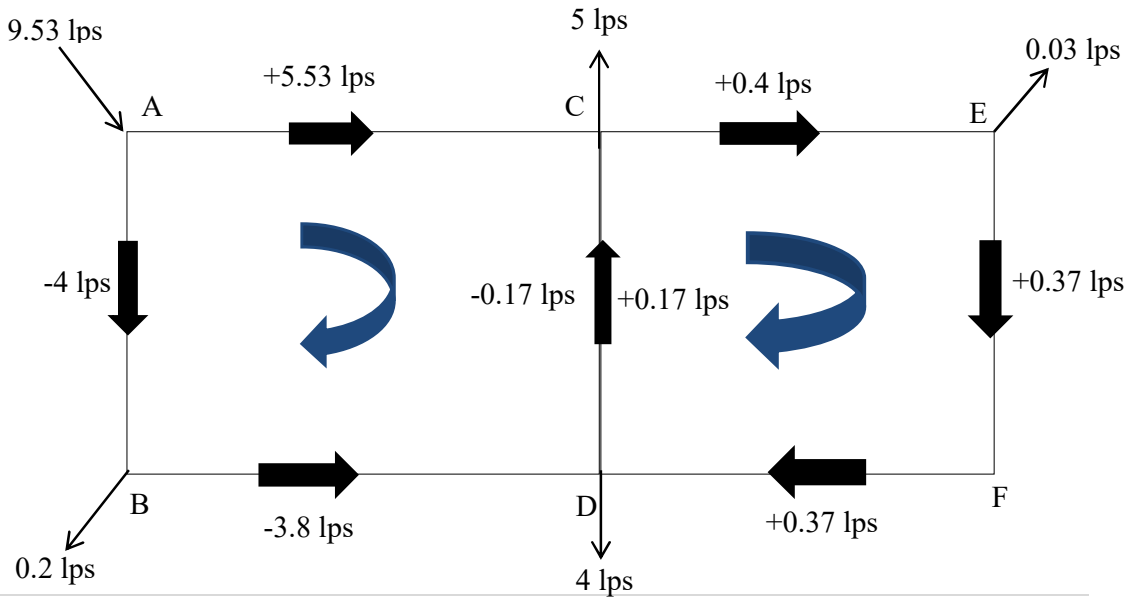
8.4.4 Determination of Final Diameter of Pipe:

- After the flow is corrected for each loop, pipe size is calculated using head loss determination diagram. [**Figure 8 (a)**]
- Pipe diameter and head loss can also be calculated using Nomograph for Hazen-Williams formula for C =100. [**Figure 8 (b)**]
- If roughness coefficient C = 100, the values obtained from the Nomograph can be used directly. But if C is other than 100 then multiply the obtained values from Nomograph by the ratio of 100 to the given value of C.

8.5 SAMPLE CALCULATION FOR LOOP SYSTEM:

8.5.1 Industrial Area Design:

- **TRIAL-1:**



LOOP-1:

Assumed Q:

	AC	=	+5.53 lps	= 0.19514 ft^3/s
	AB	=	-4 lps	= -0.14114 ft^3/s
	CD	=	-0.17 lps	= -0.00599 ft^3/s
	BD	=	-3.8 lps	= -0.13409 ft^3/s

Length of,	AC	=	660 ft
	AB	=	810 ft
	CD	=	810 ft
	BD	=	660 ft
Head loss per 1000 ft,	AC	=	20
	AB	=	-25
	CD	=	-80
	BD	=	-28
Total head loss,	AC	=	13.2 ft
	AB	=	-20.25 ft
	CD	=	-64.8 ft
	BD	=	-18.48 ft

H_o/Q_o for,	AC	=	67.64
	AB	=	143.4642
	CD	=	10802.01
	BD	=	137.8151
Correction, $\Delta 1$		=	$-\Sigma H_o/(x \Sigma H_o/Q_o)$
		=	0.124087 lps

Corrected Q for,	AC	=	5.65 lps
	AB	=	-3.88 lps
	CD	=	-0.01 lps
	BD	=	-3.68 lps

Similar calculations have been done for Loop DCEF & correction Δ2 was determined.

- **TRIAL 2:**

Same procedure was repeated. As the correction Δ value was found to be close to zero it can be said that desired accuracy was attained after Trial - 2.

8.5.2 Calculation for Pipe Diameter:

For AB,

Pipe length	=	810 ft
Ho/1000 ft	=	25 ft
Ho/unit length	=	0.025 ft
Flow rate	=	4.08 lps
Pipe diameter	=	63 mm (C=120)
Correction factor	=	100/120 = 0.833
Pipe diameter	=	52.4979 mm (C=100)
Required diameter	=	2.07 inch
Provided diameter	=	3 inch

INDUSTRIAL AREA DESIGN BY LOOP NETWORK (Trials)

Trial - 1: Inflow = 9.53 lps										
Loop	**Notation**	**Length (ft)**	**Flow Q (lps)**	**Q_o (ft^3/s)**	**H_o per 1000 ft**	**H_o (ft)**	**H_o/Q_o**	**Correction (ft^3/s)**	**Δ (lps)**	**Q_f (lps)**
1	AB	810	-4	-0.1411502	-25	-20.25	143.464188	-0.0014662	-0.04155125	-4.04
	BD	660	-3.8	-0.1340927	-28	-18.48	137.815111	-0.0014662	-0.04155125	-3.84
	CD **(Common Branch)**	810	0.13	0.00458738	80	64.8	14125.7047	-0.0014662	-0.04155125	0.12
								0.00118632	0.033618731	
	AC	660	5.33	0.18808265	20	13.2	70.1819112	-0.0014662	-0.04155125	5.29
	Total					**39.27**	**14477.1659**			
2	CE	360	0.4	0.01411502	75	27	1912.85584	-0.0011863	-0.03361873	0.37
	EF	810	0.37	0.01305639	75	60.75	4652.89259	-0.0011863	-0.03361873	0.34
	FD	360	0.37	0.01305639	75	27	2067.95226	-0.0011863	-0.03361873	0.34
	CD	810	-0.13	-0.0045874	-80	-64.8	14125.7047	-0.0011863	-0.03361873	-0.12
								0.00146624	0.04155125	
	Total					**49.95**	**22759.4054**			

INDUSTRIAL AREA DESIGN BY LOOP NETWORK (Trials - Continued)

Trial - 2: Inflow = 9.53 lps										
Loop	**Notation**	**Length (ft)**	**Flow Q (lps)**	**Q_o (ft^3/s)**	**H_o per 1000 ft**	**H_o (ft)**	**H_o/Q_o**	**Correction (ft^3/s)**	**Δ (lps)**	**Q_f (lps)**
1	AB	810	-4.04	-0.1425617	-25	-20.25	142.043751	-0.0013562	-0.03843247	-4.08
	BD	660	-3.84	-0.1355042	-28	-18.48	136.379537	-0.0013562	-0.03843247	-3.88
	CD	810	0.12	0.00423451	80	64.8	15302.8467	-0.0013562	-0.03843247	0.11
								0.0010938	0.030996674	
	AC	660	5.29	0.18667115	20	13.2	70.7125873	-0.0013562	-0.03843247	5.25
	Total					**39.27**	**15651.9826**			
2	CE	360	0.37	0.01305639	75	27	2067.95226	-0.0010938	-0.03099667	0.34
	EF	810	0.34	0.01199777	75	60.75	5063.44194	-0.0010938	-0.03099667	0.31
	FD	360	0.34	0.01199777	75	27	2250.41864	-0.0010938	-0.03099667	0.31
	CD	810	-0.12	-0.0042345	-80	-64.8	15302.8467	-0.0010938	-0.03099667	-0.11
								0.00135619	0.038432469	
	Total					**49.95**	**24684.6596**			

CALCULATION OF PIPE DIAMETER FOR INDUSTRIAL AREA BY LOOP NETWORK

Pipe	Pipe Length (ft)	Head Loss Per 1000 ft	Head Loss Per Unit Length	Flow Rate, Q (lps)	Pipe Diameter (For C =120) (mm)	Correction Factor	Pipe Diameter (For C=100) (mm)	Required Diameter (inch)	Provided Diameter (inch)
AB	810	25	0.025	4.08	63	0.8333	52.4979	2.066317344	3
BD	660	28	0.028	3.88	62	0.8333	51.6646	2.033518656	3
CD	810	80	0.08	0.11	17	0.8333	14.1661	0.557577696	1.5
AC	660	20	0.02	5.45	80	0.8333	66.664	2.62389504	3
CE	360	75	0.075	0.34	24	0.8333	19.9992	0.787168512	1.5
EF	810	75	0.075	0.31	23	0.8333	19.1659	0.754369824	1.5
FD	360	75	0.075	0.31	23	0.8333	19.1659	0.754369824	1.5

CHAPTER - 9

DESIGN OF SANITARY WASTE WATER SYSTEM: SANITARY SEWER DESIGN

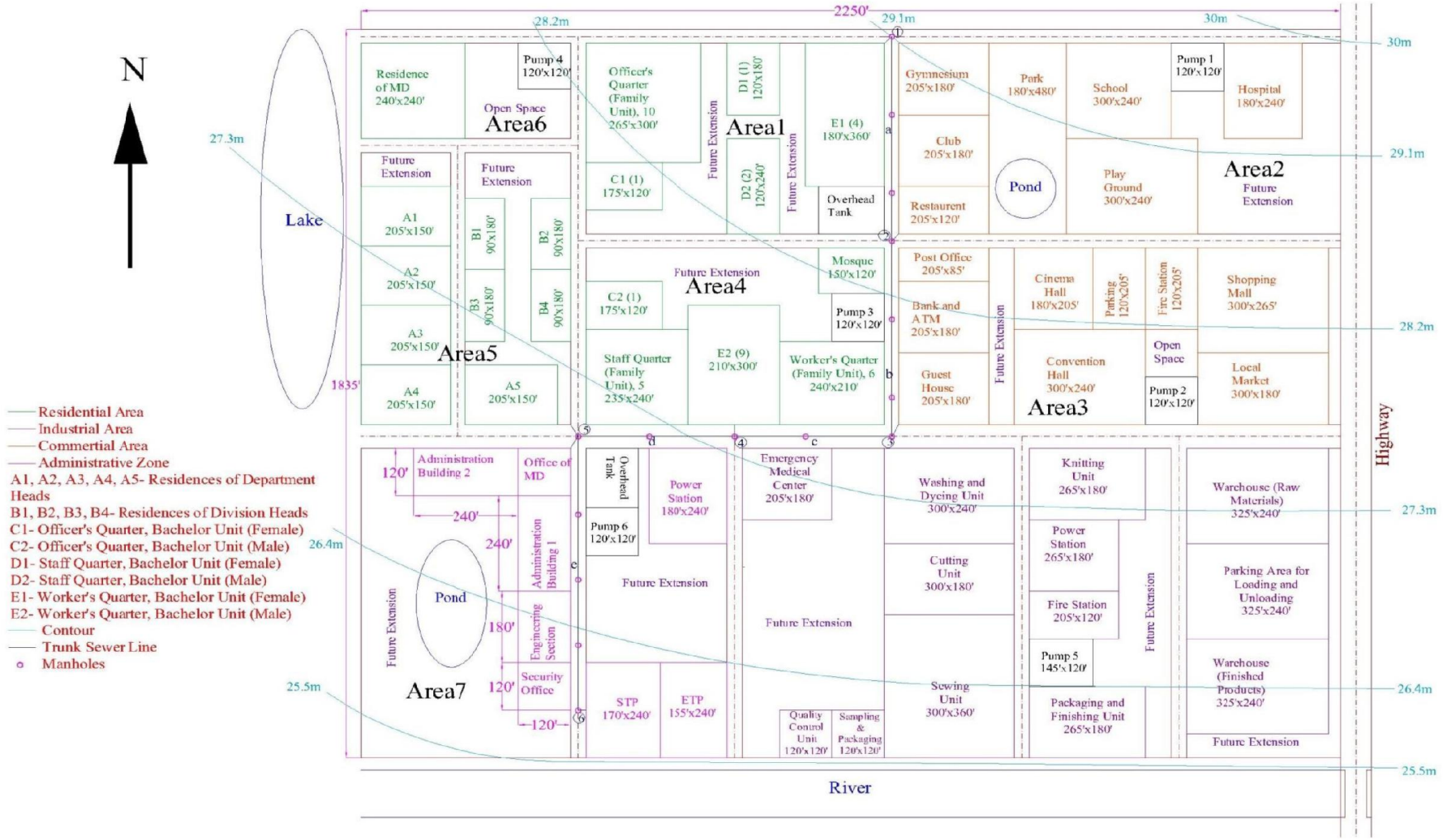


FIGURE 9.1: LAYOUT OF THE TRUNK SEWER LINE OF THE INDUSTRIAL VILLAGE

9.1 INTRODUCTION:

The basic functional elements of a conventional sewerage system include:

- **House connections -** collecting wastewater from houses.
- **Network of sewer systems -** for collection and conveying the wastewater.
- **Treatment plant -** for processing wastewater.
- **Receiving environment (water or land) -** for disposal of the treated wastewater.

9.2 SANITARY SEWER: BASIC DESIGN CONSIDERATIONS:

- Wastewater flow -industrial, commercial & residential
- Hydraulic-design equation
- Sewer pipe materials
- Minimum pipe sizes
- Minimum and maximum velocities
- Slopes and cover
- Evaluation of alternative alignments or designs
- Selection of appropriate sewer appurtenances

9.3 ASSUMPTIONS:

- Only sanitary sewer system is designed & the system is separate sewer system.
- Wastewater is transported by gravity and discharged to STP.
- A percentage of total average water demand in each zone is taken equal to wastewater flows from that zone:

Industrial	90%
Residential	70%
Institutional	70%
Commercial	70%

- Following peak factors are considered in wastewater calculation:

Industrial	2.1
Institutional	4.0
Commercial	1.8
Residential	3.34 **[Figure 9(a)]**

- Since new sewers were laid out, Manning's n = **0.013** is used.
- Minimum pipe size of **6 inch (150 mm)** is used.
- Minimum velocity for self cleansing is taken **2 ft/sec (0.6 m/s)** & maximum velocity for avoiding scouring of pipe is taken **10 ft/sec (3 m/s)**.

9.4 STEPS FOR DESIGN OF TRUNK SEWER:

- From the plan of the Industrial Village the layout of wastewater sewer network is prepared. All the junctions (nodes) of branch sewers/main sewers with the Trunk sewer are identified and marked.
- Each sub area or service area (in hectors) contributing to each junction/node is calculated for determining infiltration rate allowance for each sub area.
- Population/unit used under each sub area is calculated.
- Total water consumption (L/d) for each sub area is calculated.
- Average wastewater flow per day for each type of unit is calculated,
  Average ww flow (per day) = multiplying factor for respective areas * peak factor * time factor * water consumption rate of the unit per day
- PEAK ww flow per day for each unit is calculated,
  Peak ww flow per day = avg. ww flow per day * peak factor
- Infiltration allowance (m^3/ha-d) for each sub area using calculated size of the sub area is found from **Figure 9(b),**
  Infiltration and in flow (I/I) = infiltration allowance (m^3/ha-d) * area (ha)
- Cumulative Peak flow contributing to each node is calculated,
  Total Flow, Q (m/sec) = total peak ww flow towards each node + Infiltration and inflow
- Size of the pipe segment in between two successive nodes is determined using manning formula,
  Pipe Diameter, D (m) = $1.548\ [\ nQ/\ \sqrt{S}]^{0.375}$ ---------- (1)
  The criteria for minimum slope (S) is obtained from **Table 9(a).**
- "Q_{Full}" is calculated using D_{actual} in equation- (1).
- Velocity, V_{full} is calculated using manning's equation,
  $V_{full} = (1/n) * (D/4)^{2/3} * S^{1/2}$
- (Q/Q_{Full}) is calculated. Using **Figure 9(c),** (d/D_{Full}) and (V/V_{Full}) are found out.
- V is determined and checked with V – minimum (self-cleansing velocity) and V – maximum (non-scouring velocity). V is revised if necessary.

9.5 STEPS FOR PREPARING LONGITUDINAL PROFILE OF TRUNK SEWER:

- From available contour diagram of the area, ground surface elevation at each node along the trunk sewer trench line is found.
- Sewer pipe invert elevation at each end (upper and lower) for each segment of pipe is found,
  Invert elevation of sewer pipe at upper end = Ground Elevation – 2 m cover – Pipe thickness (50 mm) – Diameter of the pipe

- Sewer pipe Crown elevation at each end is calculated,
  Crown elevation of sewer pipe at upper end = Invert Elevation + Diameter of the pipe
- Longitudinal profile showing details of ground elevation, tentative position of manholes, invert crown etc. for all nodes is drawn.

9.6 SAMPLE CALCULATION:

9.6.1 Determination of Cumulative Flow:

- **FOR LINE – A:**

From Manhole-1 to Manhole-2,

Subarea = A1

Water demand of,

Officer's Quarter (Family Unit) = 95 * 5 * 225 lpcd = 106875 lpd

Officer's Quarter (Bachelor Unit-Female), C1 = 10 * 225 lpcd = 2250 lpd

Staff Quarter (Bachelor Unit-Female), D1 = 10 * 135 lpcd = 1350 lpd

Staff Quarter (Bachelor Unit-Male), D2 = 52 * 135 lpcd = 7020 lpd

Worker's Quarter (Bachelor Unit-Female), E1 = 441 * 70 lpcd = 30870 lpd

Total water supply for this area = (106875 + 2250 + 1350 + 7020 + 30870)

= 148365 lpd

Now, percentage of average water demand for Residential Area = 70%

So, Total waste water flow = 70% of 148365 lpd

= (0.7 * 148365) lpd

= 103856 lpd

= 103856/(1000 * 3600 * 24) m^3/s

= 0.0012 m^3/s

Since the waste water flow is 0.0012 m^3/s which is less than 0.004 m^3/s,

Peak Factor (Only for Residential Area) = 3.34

So, Peak waste water flow = 103856 * 3.34

= 346880 lpd

= 346880/1000

= 346.88 m^3/day

Total area of Subarea A1 = 215700 ft^2

= (215700 * 9.29 * 10^{-6}) hector

= 2.01 hector

Now, from graph,

Infiltration allowance up to 40.5 hector area = 8.75 $m^3/ha.day$

Infiltration of Subarea A1 = (2.01 * 8.75) m^3/day

= 17.59 m^3/day

So, Total Peak Flow = (17.59 + 346.88) m^3/day

= 364.47 m^3/day

Now, **for Line-a,**

Feeder Line = None

In pipe flow = 0

Entering flow = 364.47 m^3/day

So, Cumulative flow = (0 + 364.47) m^3/day

= 364.47 m^3/day

= 364.47/(24 * 3600) m^3/s

= 0.0043 m^3/s

9.6.2 Design of Trunk Sewer:

- **FOR LINE – A:**

From Manhole-1 to Manhole-2,

Cumulative flow = 0.0043 m^3/s

Pipe slope, S = 0.007 (assumed)

[It needs to be in accordance with Table 9(a)]

n = 0.013 (for new concrete/pvc pipe)

Using Manning's equation,

Exact diameter of pipe, D = $1.548 * (nQ/\sqrt{S})^{0.375}$

= $1.548 [(0.013 * 0.0043)/\sqrt{0.007}]^{0.375}$

= 0.09979172 m

= 99.792 mm

Provided pipe diameter, D_{actual} = 150 mm

Full flow, Q_{full} = $(D/1.548)^{(1/0.375)} * (\sqrt{S}/n)$

= $[(150/1000)^{2.67}/1.548^{2.67}] * (\sqrt{0.007}/0.013)$

= 0.015 m^3/s

Now, V_{full} = $(1/n) * (D/4)^{2/3} * S^{1/2}$

= $(1/0.013) * [(150/1000)/4]^{2/3} * 0.007^{1/2}$

= 0.812 m/s

= (0.812 * 3.28) ft/s

= 2.6638 ft/s

So, Q/Q_{full} = 0.0043/0.015

= 0.287

From **Figure 9(c)**,

For, Q/Q_{full} = 0.287

we get,

d/D_{full} = 0.43

V/V_{full} = 0.76

So, V = $0.76 * V_{full}$

= 0.76 * 2.6638

= 2.03 ft/s ; which is greater than 2 ft/s (minimum velocity)

So, The Pipe Diameter is **OK**.

CALCULATION OF WASTE WATER FLOW FOR RESIDENTIAL AND COMMERCIAL AREA

Line	From	To	Subarea	Description	Area (ft^2)	Area (ha)	Total Water Supply (lpd)	Total Waste Water Flow (lpd)	Total Waste Water Flow (m^3/s)	Peak factor	Peak Flow (lpd)	Cumulative Average Flow (lpd)	Cumulative Peak Flow (lpd)
a	1	2	A1	Officer's Quarter (Family Unit)	215700	2.01	148365	103856	0.0012	3.34	346880	103856	346880
				C1									
				D1									
				D2									
				E1									
b	2	3	A2	School	72000	0.67	91350	63945	0.00074	4	255780	330362	895270
				Gymnasium	300000	2.79	232230	162561	0.0019	1.8	292610		
				Club									
				Restaurant									
				Park									
				Playground									
				Hospital									

CALCULATION OF WASTE WATER FLOW FOR RESIDENTIAL AND COMMERCIAL AREA (Continued)

Line	From	To	Subarea	Description	Area (ft^2)	Area (ha)	Total Water Supply (lpd)	Total Waste Water Flow (lpd)	Total Waste Water Flow (m^3/s)	Peak factor	Peak Flow (lpd)	Cumulative Average Flow (lpd)	Cumulative Peak Flow (lpd)
c	3	4	A3	Post Office Bank Guest House Cinema Hall Convention Hall Parking Fire Station Shopping Mall Local Market	397225	3.7	28830	20181	0.00023	1.8	36326	350543	931596
d	4	6	A4	Mosque	18000	0.17	7200	5040	0.000058	1.8	9072	479511	1354588
				Staff Quarter (Family Unit) Worker's Quarter (Family Unit) C2 E2	205200	1.91	177040	123928	0.0014	3.34	413920		

CALCULATION OF WASTE WATER FLOW FOR RESIDENTIAL AND COMMERCIAL AREA (Continued)

Line	From	To	Subarea	Description	Area (ft^2)	Area (ha)	Total Water Supply (lpd)	Total Waste Water Flow (lpd)	Total Waste Water Flow (m^3/s)	Peak factor	Peak Flow (lpd)	Cumulative Average Flow (lpd)	Cumulative Peak Flow (lpd)
e	5	6	A5	Residence of MD	195000	1.82	10000	7000	0.000081	3.34	23380	503014	1418454
				A1									
				A2									
				A3									
				A4									
			A6	A5	95550	0.89	10000	7000	0.000081	3.34	23380		
				B1									
				B2									
				B3									
				B4									
			A7	Administration Building	108000	1.01	13575	9503	0.00011	1.8	17106		
				Office of MD									
				Engineering Section									
				Security Office									

PEAK DAILY FLOWS ENTERING EACH SEGMENT

Line	From	To	Subarea	Description	Area (ft^2)	Area (ha)	Total Area (ha)	Infiltration Allowance (m^3/ha.day)	Infiltration (m^3/day)	Peak Waste Water Flow (m^3/day)	Peak Flow (m^3/day)
a	1	2	A1	Officer's Quarter (Family Unit)	215700	2.01	2.01	8.75	17.59	346.88	364.47
				C1							
				D1							
				D2							
				E1							
b	2	3	A2	School	72000	0.67	3.46	8.75	30.28	548.39	578.67
				Gymnasium	300000	2.79					
				Club							
				Restaurant							
				Park							
				Playground							
				Hospital							

PEAK DAILY FLOWS ENTERING EACH SEGMENT (Continued)

Line	From	To	Subarea	Description	Area (ft^2)	Area (ha)	Total Area (ha)	Infiltration Allowance (m^3/ha.day)	Infiltration (m^3/day)	Peak Waste Water Flow (m^3/day)	Peak Flow (m^3/day)
c	3	4	A3	Post Office Bank Guest House Cinema Hall Convention Hall Parking Fire Station Shopping Mall Local Market	397225	3.7	3.7	8.75	32.38	36.33	68.71
d	4	6	A4	Mosque	18000	0.17	2.18	8.75	19.08	423	442.08
				Staff Quarter (Family Unit) Worker's Quarter (family Unit) C2 E2	205200	1.91					

PEAK DAILY FLOWS ENTERING EACH SEGMENT (Continued)

Line	From	To	Subarea	Description	Area (ft^2)	Area (ha)	Total Area (ha)	Infiltration Allowance (m^3/ha.day)	Infiltration (m^3/day)	Peak Waste Water Flow (m^3/day)	Peak Flow (m^3/day)
e	5	6	A5	Residence of MD	195000	1.82	3.72	8.75	32.55	63.90	96.45
				A1							
				A2							
				A3							
				A4							
			A6	A5	95550	0.89					
				B1							
				B2							
				B3							
				B4							
			A7	Administration Building	108000	1.01					
				Office of MD							
				Engineering Section							
				Security Office							

CUMULATIVE FLOW CALCULATION

Line	Feeder Line	In Pipe Flow (m^3/day)	Entering Flow (m^3/day)	Cumulative Flow (m^3/day)	Cumulative Flow (m^3/s)
a	none	0	364.47	364.47	0.0043
b	a	364.47	578.67	943.14	0.011
c	b	943.14	68.71	1011.85	0.0118
d	c	1011.85	442.08	1453.93	0.0169
e	d	1453.93	96.45	1550.38	0.018

DESIGN OF TRUNK SEWER

Line Number	Cumulative Flow, Q (m^3/s)	Slope, S	Exact Pipe Diameter (m)	Pipe Diameter Provided (mm)	Full Flow, Q_{full} (m^3/s)	V_{full} (m/s)	V_{full} (ft/s)	Q/Q_{full}	V/V_{full}	V (ft/s)	Remarks	d/D_{full}
a	0.0043	0.0055	0.10440766	150	0.014	0.639	2.09592	0.307	0.75	1.58	**NOT OK**	0.45
b	0.011	0.0056	0.14799148	200	0.03	0.781	2.56168	0.367	0.79	2.03	**OK**	0.5
c	0.0118	0.004	0.16183379	200	0.025	0.66	2.1648	0.472	0.84	1.82	**NOT OK**	0.55
d	0.0169	0.0047	0.17965482	200	0.027	0.716	2.34848	0.626	0.91	2.14	**OK**	0.66
e	0.018	0.004	0.18960101	200	0.025	0.66	2.1648	0.72	0.93	2.02	**OK**	0.72

DESIGN OF TRUNK SEWER (Corrected)

Line Number	Cumulative Flow, Q (m^3/s)	Slope, S	Exact Pipe Diameter (m)	Pipe Diameter Provided (mm)	Full Flow, Q_{full} (m^3/s)	V_{full} (m/s)	V_{full} (ft/s)	Q/Q_{full}	V/V_{full}	V (ft/s)	Remarks	d/D_{full}
a	0.0043	0.007	0.09979172	150	0.015	0.812	2.6638	0.287	0.76	2.03	**OK**	0.43
b	0.011	0.0056	0.14799148	200	0.03	0.781	2.56168	0.367	0.79	2.03	**OK**	0.5
c	0.0118	0.005	0.15520246	200	0.028	0.738	2.42064	0.421	0.84	2.04	**OK**	0.55
d	0.0169	0.0047	0.17965482	200	0.027	0.716	2.34848	0.626	0.91	2.14	**OK**	0.66
e	0.018	0.004	0.18960101	200	0.025	0.66	2.1648	0.72	0.93	2.02	**OK**	0.72

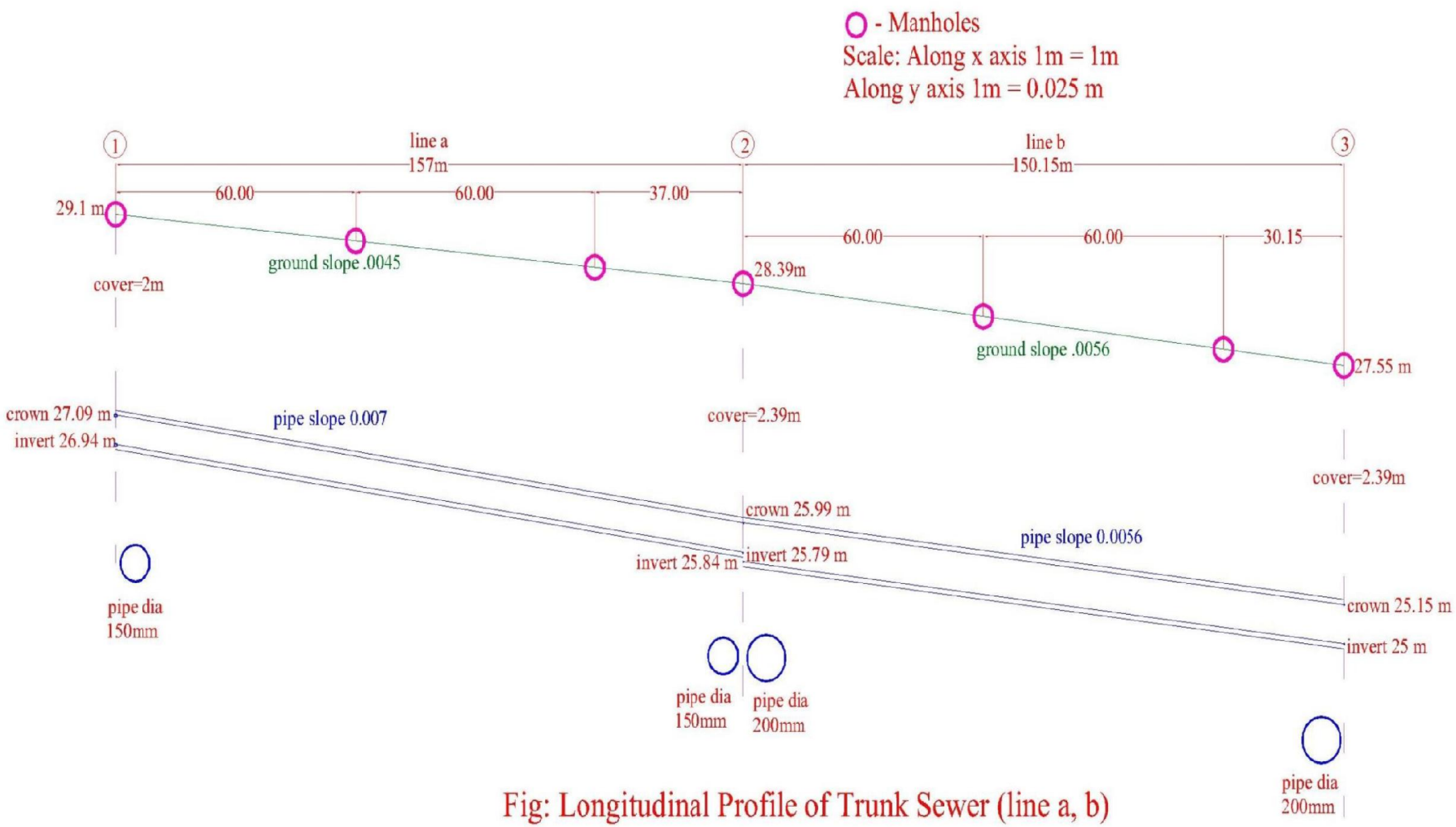


FIGURE 9.2: LONGITUDINAL PROFILE OF THE TRUNK SEWER (LINE – a & b)

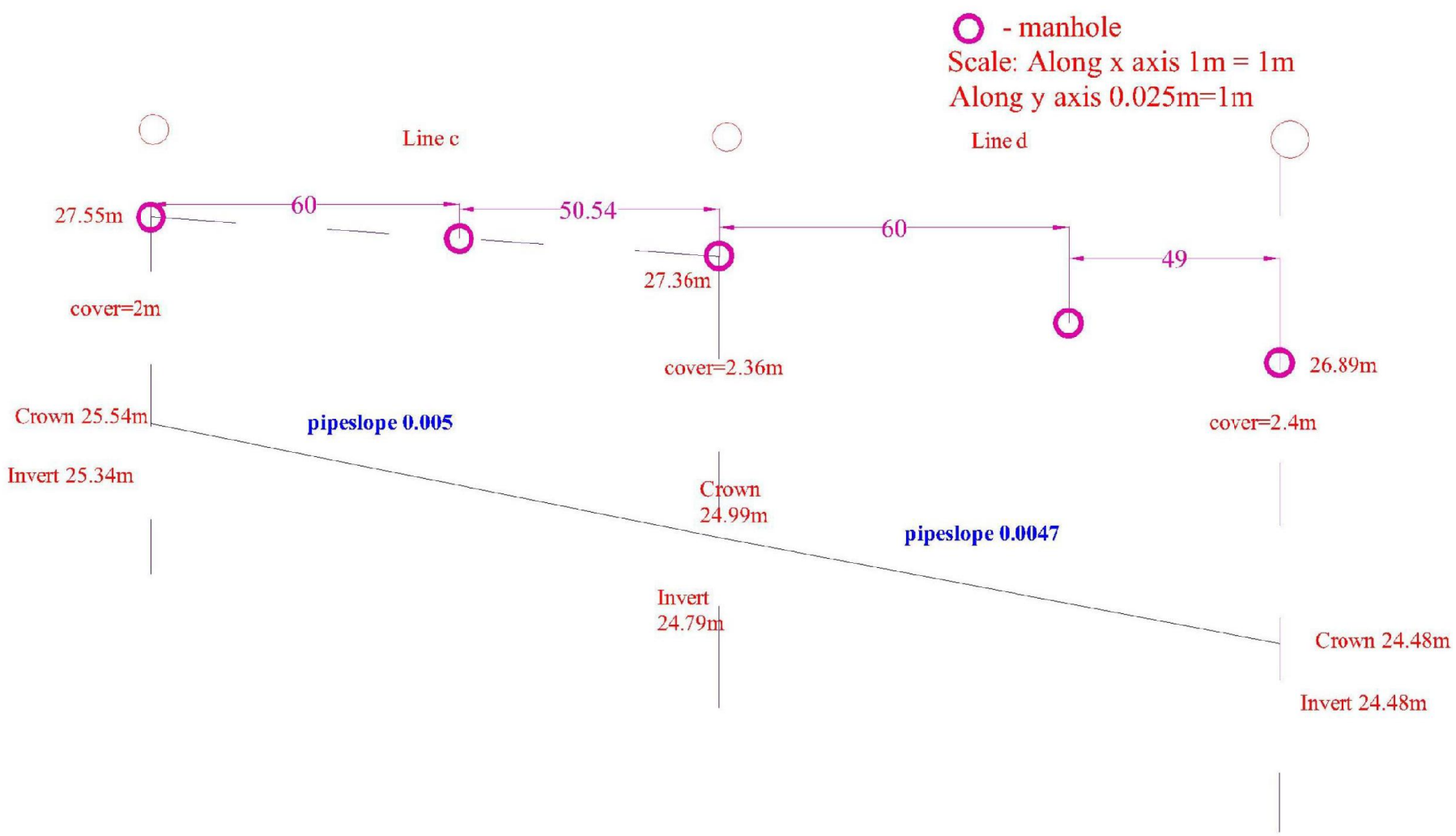


FIGURE 9.3: LONGITUDINAL PROFILE OF THE TRUNK SEWER (LINE – c & d)

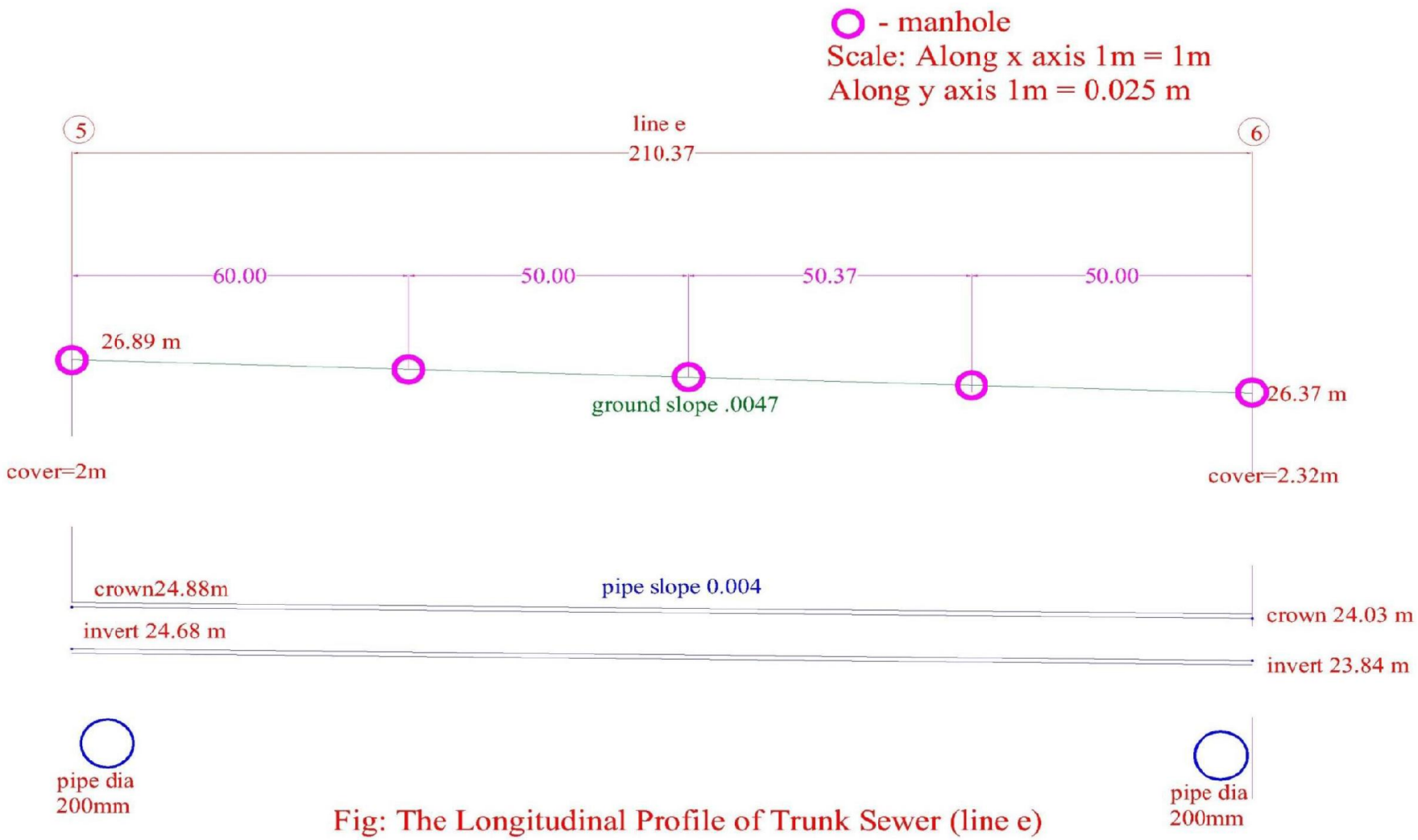


FIGURE 9.4: LONGITUDINAL PROFILE OF THE TRUNK SEWER (LINE – e)

CHAPTER – 10

DESIGN OF PLUMBING SYSTEM OF A 10 STORIED BUILDING

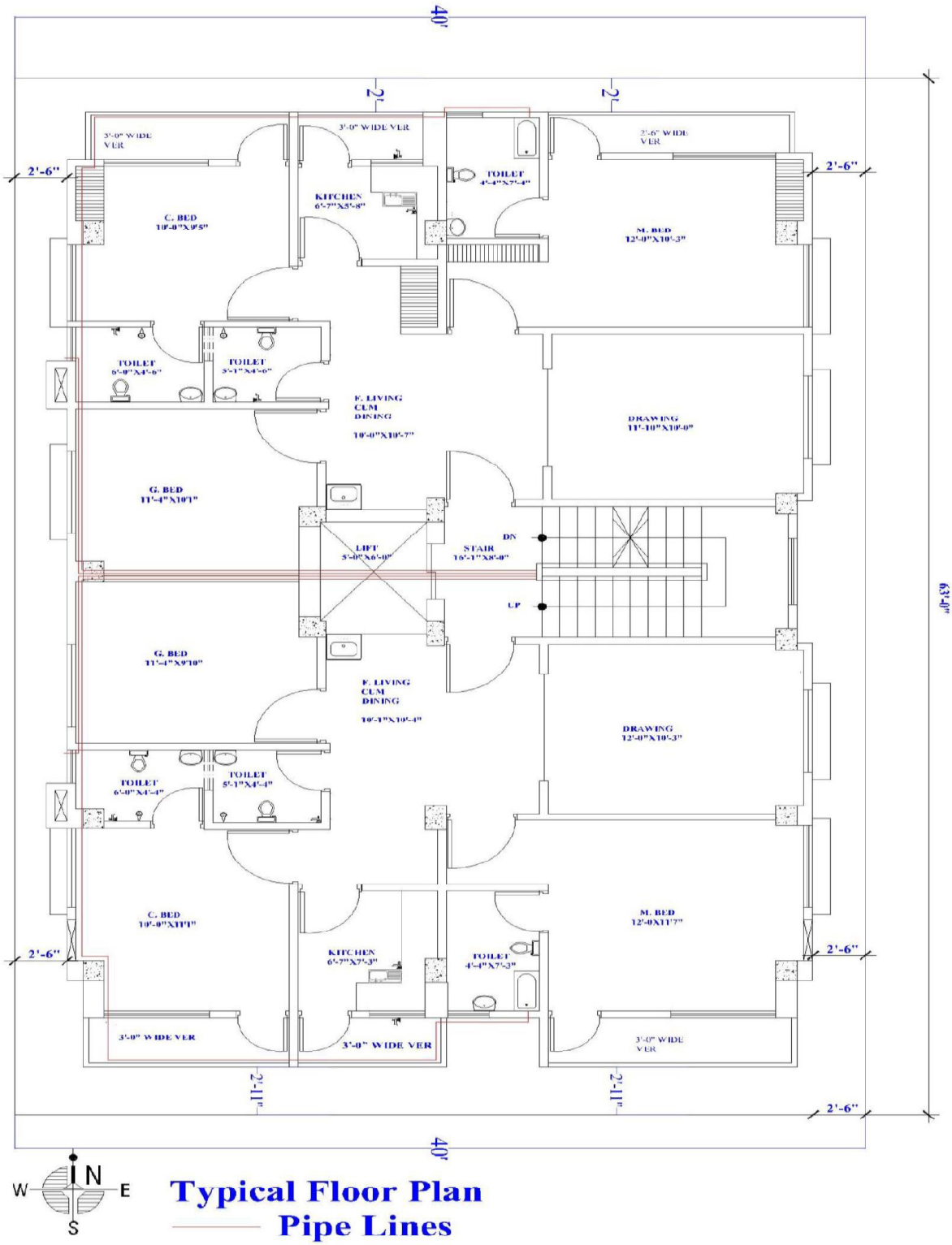


FIGURE 10.1: TYPICAL FLOOR PLAN OF THE 10 STORIED BUILDING SHOWING PLUMBING FIXTURES & WATER SUPPLY MAINS

10.1 INTRODUCTION:

Plumbing includes the practice, materials and fixtures used in the installation, maintenance, extension and alteration of all piping, fixtures, appliances and accessories in connection with sanitary drainage or storm drainage facilities, the venting system and the public or private water supply systems/within or adjacent to any building, structure or conveyance.

Major elements in plumbing systems

- Water supply and distribution pipe: up feed or down feed distribution pipes, underground water reservoir (UGWR), overhead (OH) tank.
- Plumbing fixtures and traps
- Soil, waste and vent pipes
- Building drains and building sewers, including-their respective connections, devices, and appurtenances within the property lines of the premises

10.1.1 Plumbing Fixture:

- The water supply system of a building distributes water to plumbing fixtures at points of use.
- Fixtures include kitchen sinks, water closets, urinals, bathtubs, showers, lavoratories, drinking fountains, laundry trays, and slop sinks.
- Each fixture is served by a soil stack or a waste stack, a vent or vent stack and a trap.

10.1.2 Fixture Unit:

- It is the average discharge, during use, of an arbitrarily selected fixture, such as a lavatory or water closet. Once this value is established, the discharge rates of other types of fixture are stated in terms of the basic fixture.
- A fixture unit is not a flow rate unit but a design factor.

10.2 WATER DISTRIBUTION IN A BUILDING:

Water distribution in a building can be done in many ways

10.2.1 Up Feed Distribution:

- **Simple up feed:** Water fed to fixtures in a building only by the incoming pressure of the supply water.
- **Pumped up feed:** Water fed to the fixture in a building by increasing the pressure of the supply water using additional pumps.

10.2.2 Down Feed Distribution:

Pumps are used to deliver water to a rooftop storage tank of the building. The water in the storage tank feeds fixtures below due to the force of gravity. Commonly one roof top tank is used to distribute water to whole building. For tall building intermediate tank are often used to supply water at different levels.

10.3 DESIGN OF DOWN FEED WATER SUPPLY SYSTEM:

Design components:

1. Sizing of water distribution pipes within the building ‘
2. dimension of UGWR
3. Dimension of OH tank
4. Determination of size of riser
5. Calculation of pump capacity

10.3.1 Sizing of Water Distribution Pipes within the Building:

The design of the consumer’s pipe or the supply pipe to the fixtures is based on:

- The number and kind of fixtures installed
- The fixture unit flow rate
- The probable simultaneous use of these fixtures

10.3.2 Design Steps for Calculation:

- Sketch of the main lines, risers and branches serving different fixtures at different water use points in the building is drawn.
- The number and types of fixture was determined on the basis of the **Table-10(a)** or as per design requirement
- The demand weight of different fixture units has been computed in terms of water supply fixture unit (wsfu) using **Table-10(b) or Table-10(c).**
- As the total down feed zone is supplied by more than one pipe, total peak demand for individual down feed zone has been calculated using the procedure given in the lecture material.
- The peak demand load (or maximum probable flow) in liter per minute may be estimated with the data obtained in step-3 either using
  - **Fig-10(a) (Hunter curve)** or
  - From **Table-10(d)**

10.3.3. Pressure at Fixture:

In a down feed water distribution system (roof tank supply), static pressure due to gravity increases with increasing floor height **4.32 psi** or **0.3 bar per floor of 10 ft**. height at non flow condition. Therefore, water distribution pipe in a building shall be maintained at a pressure so that none of their fittings shall are subject to a water head greater than **35m** (approximately **50 psi**) The distribution system shall be maintained at a pressure not less than those specified in **Table-10(e).**

10.3.4 The Equivalent Length Calculation:

- Determine the length of the main lines, risers and branches from elevation & floor plan.
- The equivalent length of different fittings may be estimated on the basis of the data presented in the **Table-10.2(a), Table-10.2(b) and Table-10.2(c).**
- The total equivalent length is determined from sum of the equivalent lengths of all pipes and fittings.

10.3.5 Selection of Pipe Size:

- Commercially available standard sizes of pipes are only to be used against the sizes arrived at by actual design.
- The Hazen and William's formula and the charts based on the same may be used without any risk of inaccuracy in view of the fact that the pipes normally to be used for water supply are of smaller sizes.

10.4 ASSUMPTIONS:

- 5 persons / unit of a single floor
- 2 Units per floor

10.5 DETERMINATION OF FIXTURE UNIT:

10.5.1 Design Procedure (Fixture Unit Calculation):

Location	Description	Fixture unit	Number	Per unit total fixture unit per floor
Master Bed	**1.**Water Closet **2.**Bathtub **3.**Wash basin	5 2 1	1 1 1	5 2 1
C-Bed	**1.**Shower **2.**Basin **3.**Water closet **4.**Ablution tap	4 1 5 1	2 2 2 2	8 2 10 2
Kitchen	**1.**Sink **2.**Tap **3.**Lower sink tap	2 1 1	1 1 1	2 1 1
Dining Room	**1.**Wash basin	1	1	1
				Total=35

10.5.2 Sample Calculation:

10 Floors with 2 units

So, Total Fixture Unit = 10*2*35
= 700 F.U

From **Figure 10(a)**, Demand = 10.08 lps
= 159.79 gpm

From **Table 10(d),** Demand = 606 lpm
= 160.11gpm

From **Table 10(g)**, water consumption in moderate apartment with restricted facility
= 135 lpcd
= 35.66 gallon per person per day

Assuming 5 persons per unit = 5*20*135 lpd
= 13500 lpd

10.6 DESIGN OF UNDERGROUND WATER RESERVOIR:

10.6.1 Design Procedure:

For water supply system with inadequate pressure to feed plumbing fixtures or balancing roof tank, the building premises usually have a ground (or underground) tank to store water most commonly below stair case. The water from the ground tank is then boosted up to the roof tank to feed plumbing fixtures.

- Have to calculate total daily demand for the building using **Table 10(g)** (water consumption for domestic purposes in residential building).
- Water is stored in underground water reservoir with extra one day reserve for emergency requirements Therefore total capacity of Under Ground Reservoir (Q) = 2 * Total daily demand of water (m^3)
- UGWR is usually provided below stair case. So the surface area of the tank depends on the area available below stair case. Say, the dimension is e.g., surface area, (A) = 20 ft * 12 ft. Water depth $H_1 = Q/A$
- Using a thumb rule of **10:1**, i.e, a 10 story building will require **10 ft** foundation thus 10 ft depth of U/G reservoir can be provided. Total height = H_1 + Free board (**6 -12 inch**)
- Have to finalize the dimensions of the tank.

10.6.2 Sample Calculation:

Total water volume = 13500 lpd

Total Storage = 13500*2 lpd
= 27000 L
= 952.76 cft

Let, the area of the reservoir be **15 ft*8 ft** (below staircase)

So, Height = 952.76/(15*8)
= 7.9 ft

Adding Free board = 1ft

Total Height = 8.9 ft = 9 ft

Thumb Rule,

For 10 story building maximum height of UGT cab be 10 ft. Here 8.9 ft<10 ft so, **OK**

So, UGWR will be **15 ft*8 ft*9 ft**

10.7 DESIGN OVER HEAD TANK:

10.7.1 Design Procedure:

In addition to daily water consumption, an overhead water reservoir is used to store water in case of emergency such as fire or power cutoff.

- Reasonable pumping schedule is assumed to pump water from UGWR to the overhead tank. e.g., if 1 hr pumping twice daily, tank volume needed V_1 = total daily demand (m^3)/2
- For calculating of water requirement for fire -fighting, use **Table 10(f)** Therefore, V_2 = fire-fighting rate (m3 /min) * 30 min
- Therefore capacity of the tank = $V_1 + V_2$
- Have to calculate appropriate dimensions for the tank.
- In addition to height obtained in step- 4 a freeboard of **10" - 12''** should be provided.

Note: To provide sufficient pressure, the bottom of the tank must be elevated sufficiently above the highest floor water fixtures.

10.7.2 Sample Calculation:

Total daily demand = 13,500 lpd

= 13.5 m^3/d

Tank volume required, V_1 = (13.5/ 2) m^3 [1 hour pumping twice daily]

= 6.75 m^3

Water requirement for fire fighting, V_2

= 1000 lpm * 30 min [**Table 10(f);** building type: light hazard-1]

= 30 m^3

Total tank volume, V = (6.75 + 30) m^3

= 36.75 m^3

= 1296.82 cft

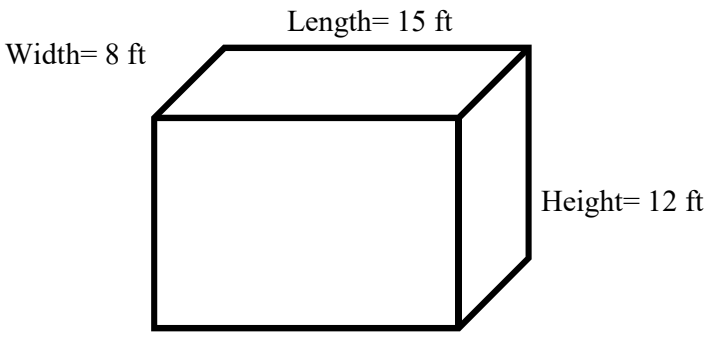
Area = (15 * 8) ft^2

Height = 10.8 ft = 11 ft

Free board = 1 ft

Total height = 12 ft

So, OHT will be **15 ft*8 ft*12 ft**



10.8 DESIGN OF RISER PIPE:

10.8.1 Design Procedure:

Riser pipes are used to convey water from the underground water reservoir to overhead tank and a pump is required so that the water can flow upward through the riser pipe.

- Total amount of water carried by the riser each time of pumping to OH tank (gpd) = total daily demand/ pumping frequency.
- Velocity **8-10 fps** is assumed.
- Using **Figure 10(b)** or **Figure 10(c)**, pipe size (d) and head loss (h_L) (psi/100 ft) are to be determined.

10.8.2 Sample Calculation:

Water is carried at 13500/2 = 6750 lph
= 1783.2 gph
= 29.7 gpm

Assuming velocity of 10 fps

From **Figure 10(b),** Provided Riser pipe diameter = 1.25 inch

Corresponding friction loss is = 17 psi per 100 ft length

10.9 DETERMINATION OF PUMP CAPACITY:

10.9.1 Design Procedure:

- Total length of riser (L) = total building height (10 ft per floor) + 10 ft from UGWR + OH tank inlet height above top roof surface.
- Total Frictional head H_L = (h_L * L)/100 + 8 psi required pressure at the O/H tank + 5 psi minor loss due to bend
- Frictional head in ft h_L = H_L *144 /62.2
- Total Head, H = Static head + Velocity head + Friction head
- Pump capacity = HQ/(3960 E). Assuming E = **60-65%**

10.9.2 Sample Calculation:

Total length of Riser = Total building height + 10 ft from UGWR + OH tank inlet height above rooftop surface

So, L = 100 + 9 + 37
= 146 ft

Total frictional head, H_L = (h_L*L/100) + 8 psi required at OHT + 5 psi minor loss due to bend

So, H_L = (17*146)/100 + 8 + 5
= 37.8 psi

Frictional head in ft = H_L*144/62.4
= 87.3 ft

Velocity Head = $v^2/2g$
= $10^2/2*32$
= 1.6

So, total head, H = Static head + Velocity head + Friction head
= 146 ft + 1.6 ft + 87.3 ft
= 235 ft

Assuming efficiency = 65%

Required Capacity of the pump = HQ/(3960E)
= (235'*29.7)/(3960*0.65)
= 2.71 HP
= 3 HP

So, a pump of 3 HP will be provided.

10.10 DESIGN OF DOWN FEED ZONE PIPES:

Three Down feed zones are selected, 1st supplying water from 10th to 6th floor, 2nd supplying water from 5th to 3rd floor and 3rd supplying water from 2nd to 1st floor.

10.10.1 Sample Calculation for 10th floor:

FU in 10th floor	=	70
Accumulated FU	=	70*5
	=	350
From **Table-10(d)**, Demand flow	=	95 gpm
From Hazen-Williams Nomo graph **[Figure 10(b)]**		
Pipe size	=	2 inch
& friction loss	=	15.2psi/100 ft
Horizontal Pipe length	=	68 ft
Losses for bend & elbows	=	0.023 ft
Friction loss, f	=	(15.2*(68+.023))/100
	=	10.4 psi
	=	71.66 kpa
Height of water column	=	30 ft
	=	9.2 m
Average Available Pressure Loss, F_p	=	9.8*9.2-71.66
	=	18.8 Kpa
	=	3psi
Average Available Pressure Loss per 1000 ft, Fp	=	(38*144*1000)/(30*62.5)
	=	230.4 ft
So, from the Nomo graph, Vertical pipe size	=	2 inch

DETERMINATION OF FRICTION LOSS (From 6th to 10th Floor)

Floor	FU (per floor)	Total FU	Demand, Q (gpm)	Head loss (psi/100')	Horizontal Pipe Size (inch)	Horizontal Pipe length (ft)	Losses for Bend and Elbows (ft)	Friction Loss, f (psi)
10	70	350	95	15.2	2	68	0.023	10.4
9	70	280	81	17.33	2	68	0.023	11.8
8	70	210	66.6	19.5	2	68	0.023	13.3
7	70	140	53	21.67	1.5	68	0.018	14.8
6	70	70	35	23.83	1.5	68	0.018	16.3

PRESSURE CHECK AND DETERMINATION OF VERTICAL PIPE SIZE (From 6th to 10th Floor)

Floor	Friction Loss, f (kpa)	Length of Pipe, H (ft)	Length of Pipe, H (m)	Average Available Pressure Loss, F_p (kpa)	Average Available Pressure Loss, F_p (psi)	Average Available Pressure Loss per 1000', F_p (ft)	Vertical Pipe Size (inch)	Comment
10	71.656	30	9.2	18.6	3	230.4	2	**OK**
9	81.302	40	12.2	38.3	6	345.6	2	**OK**
8	91.637	50	15.3	58.4	9	414.72	2	**OK**
7	101.97	60	18.3	77.4	12	460.8	1.5	**OK**
6	112.31	70	21.4	97.5	15	493.71	1.5	**OK**

DETERMINATION OF FRICTION LOSS (From 3rd to 5th Floor)

Floor	FU (per floor)	Total FU	Demand, Q (gpm)	Head loss (psi/100')	Horizontal Pipe Size (inch)	Horizontal Pipe length (ft)	Losses for Bend and Elbows (ft)	Friction Loss, f (psi)
5	70	210	66.6	19.5	2	68	0.023	13.3
4	70	140	53	21.67	1.5	68	0.018	14.8
3	70	70	35	23.83	1.5	68	0.018	16.3

PRESSURE CHECK AND DETERMINATION OF VERTICAL PIPE SIZE (From 3rd to 5th Floor)

Floor	Friction Loss, f (kpa)	Length of Pipe, H (ft)	Length of Pipe, H (m)	Average Available Pressure Loss, F_p (kpa)	Average Available Pressure Loss, F_p (psi)	Average Available Pressure Loss per 1000', F_p (ft)	Vertical Pipe Size (inch)	Comment
5	91.637	80	24.4	147.5	22	633.6	1.5	**OK**
4	101.972	90	27.5	167.6	25	640	1.5	**OK**
3	112.307	100	30.5	186.6	28	645.12	1.5	**OK**

DETERMINATION OF FRICTION LOSS (From 1st to 2nd Floor)

Floor	FU (per floor)	Total FU	Demand, Q (gpm)	Head loss (psi/100')	Horizontal Pipe Size (inch)	Horizontal Pipe length (ft)	Losses for Bend and Elbows (ft)	Friction Loss, f (psi)
2	70	140	53	21.67	1.5	68	0.018	14.8
1	70	70	35	23.83	1.5	68	0.018	16.3

PRESSURE CHECK AND DETERMINATION OF VERTICAL PIPE SIZE (From 1st to 2nd Floor)

Floor	Friction Loss, f (kpa)	Length of Pipe, H (ft)	Length of Pipe, H (m)	Average Available Pressure Loss, F_p (kpa)	Average Available Pressure Loss, F_p (psi)	Average Available Pressure Loss per 1000', F_p (ft)	Vertical Pipe Size (inch)	Comment
2	101.972	110	33.6	227.4	34	712.15	1.5	**OK**
1	112.307	120	36.6	246.4	36	691.2	1.5	**OK**

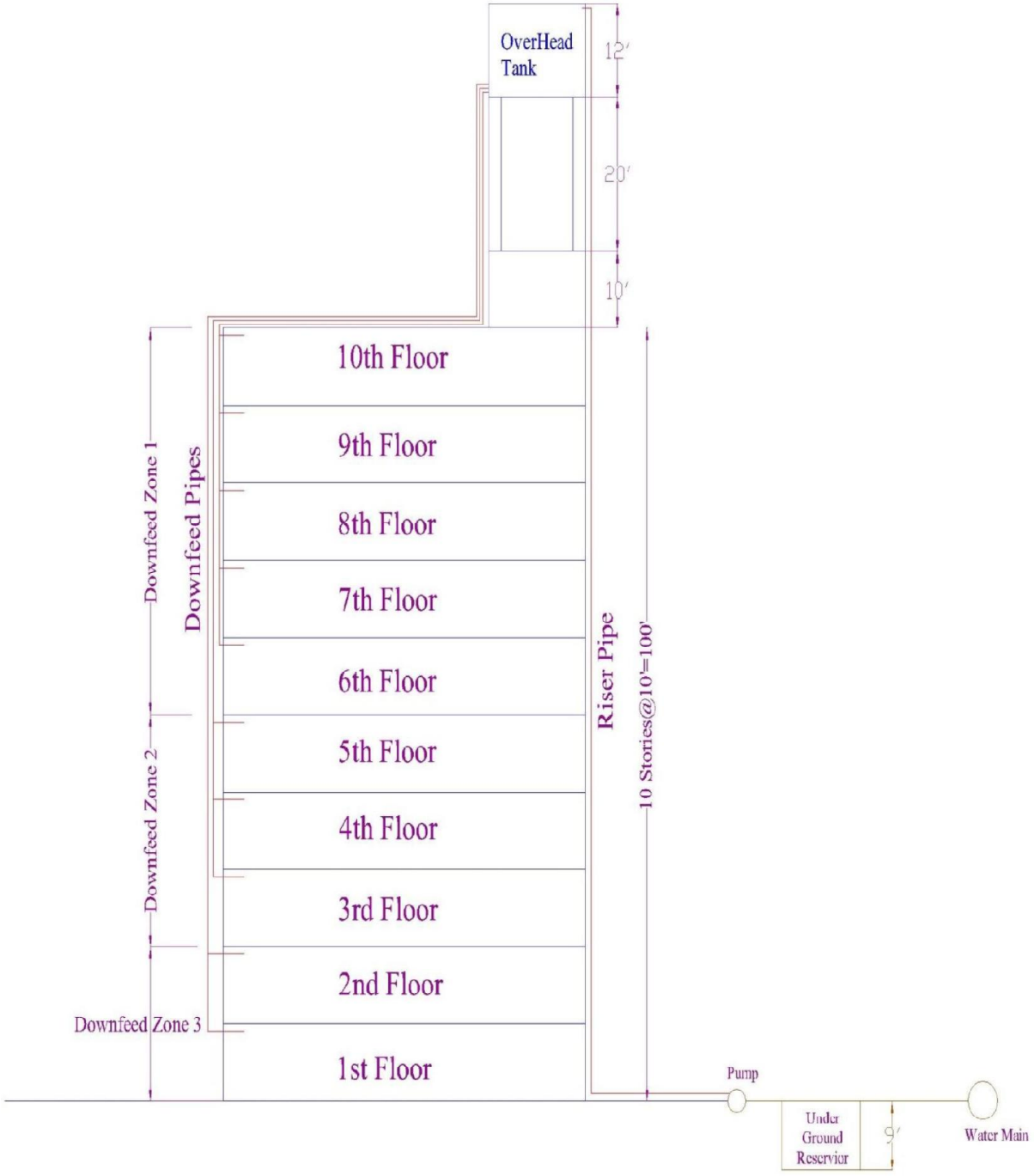


Fig: Elevation of the Building (Showing Water Distribution Network)

FIGURE 10.2: ELEVATION PLAN OF THE 10 STORIED BUILDING

CHAPTER - 11

DESIGN OF WATER SUPPLY AND DRIANAGE NETWORK OF A 10 STORIED BUILDING

11.1 INTRODUCTION:

A drainage system (drainage piping) includes all the piping within public or private premises, which convey sewage, rain water, or other liquid wastes to a legal point disposal, but does not include the mains of a public sewer system or a private or public sewage treatment or disposal plant.

11.1.1 Major Elements of Building Drainage System:

- Wastewater drainage pipe
- Soil stack
- Waste stack
- Vent pipes
- Building drains and building sewers, including connections, devices and appurtenances within the property lines of the premises

11.2 TERMINOLOGIES:

Stack: A stack is the vertical main of a system of soil, waste or vent piping.

Stack vent/Soil Vent/Waste Vent: A stack vent is the extension soil or waste stack above the highest horizontal drain connected to the stack.

Waste pipe: A waste pipe is a pipe which conveys only liquid waste free of fecal sludge.

Soil pipe: A soil pipe is any pipe which conveys the discharge of water closets, urinals, or fixtures having similar functions, with or without the discharge from other fixtures, to the building drain or building sewer.

Vent Stack: A vent stack is a vertical vent pipe installed primarily for the purpose of providing circulation of air to and from any part of the drainage system to protect trap seals from siphonage and back pressure.

Trap: A trap is a fitting or device so designed and constructed as to provide, when properly vented, a liquid seal which will prevent the back passage of air without materially affecting the flow of sewage or waste water through it.

Trap seal: The trap seal is the maximum vertical depth of liquid that a trap will

11.3 DESIGN CONSIDERATIONS:

- The waste branch from bath room, wash basin or sink should be of **32 mm** to **50 mm** diameter and should be trapped immediately beneath such wash basins or sink by an efficient siphon trap with adequate means of inspection and cleaning.
- The minimum recommended size of waste stack is **75 mm**.
- The soil and waste stack should be continued upward undiminished in size **0.6 m** above the roof surface when the roof will be used only for weather protection. Where the roof will be used for any purpose other than weather protection, the soil and vent stack should run at least **2 m** above the roof surface to ensure least possible nuisance.
- The soil and waste stack should be firmly attached to the wall with a minimum clearance of **25 mm** from the wall.
- The diameter of a vent stack should not be less than **50 mm**.
- The diameter of a branch vent pipe on a waste pipe should not be less than **25 mm** or two-thirds of the diameter of the branch waste pipe ventilated.
- The branch vent pipe on a soil pipe should be at least **32 mm** in diameter.
- An relief vent should be at least one-half the size of the drain it vents (no less than **1 1/4"**, **32 mm**)
- All vent stacks should extend undiminished in size above the roof or should be reconnected to a vent header or to the stack vent portion of the soil or waste stack, at least **150 mm** above the flood level of the highest fixture connection discharging into the soil or waste stack. The soil pipe conveying any solid or liquid filth to a sewer drain should be circular with a minimum diameter of **100 mm**.

11.4 DESIGN STEPS OF DRAINAGE SYSTEM:

- **'Two pipe drainage system'** has been designed.
- The total load weight (DFU) carried by a soil or waste pipe and the relative load weight for different kinds of fixtures are estimated using **Table-11(a)**. (**Table-11(b)** provides an approximate rating of those fixtures not listed in **Table-11(a)**)
- **Slope:** Flatter gradient may be used if required but the minimum velocity should not be less than **0.6 m/s** and greater than **2.5 m/s**. A minimum self-cleansing velocity of **0.75 m/s** has to be available.
- Using the load factor unit as obtained from the design table, the diameter of horizontal branches or vertical soil or waste stacks is determined from **Table-11(c).**
- The size of vent piping from its development length and the total number of the fixture units connected are determined using **Table-11(d).**
- Maximum development length for horizontal drainage pipes is obtained from **Table-11(e).**

DESIGN OF SOIL, WASTE AND VENT STACK

Horizontal Pipe	Branch Number	Connected Fixtures	Fixture Number	Load Factor	Total DFU	Size (mm)
Soil Waste Pipe	----	Water closet	3	3	**9**	**65**
Waste Pipe	**1**	Bathtub	1	2	**2**	**40**
	2	Tap	2	1	2	
		Kitchen Sink	1	2	2	
		Wash Basin	1	1	1	
		Total FU			**7**	**65**
	3	Shower	1	2	2	
		Wash Basin	2	1	2	
		Tap	1	1	1	
		Total FU			**5**	**50**
	4	Shower	1	2	2	
		Tap	1	1	1	
		Total FU			**3**	**40**
	5	**Total FU**			**15**	**75**

11.5 SAMPLE CALCULATION:

There are 2 units per floor and it is a 10 story building.

11.5.1 For Soil Stack:

Total DFU = 3*3*2*10

= 180

So, Soil Stack Diameter = 100 mm

11.5.2 For Waste Stack:

Total DFU = Bathtub (1) + Tap (4) + Wash Basin (3) + Shower (2) + Kitchen Sink (1)

= (2+4+3+4+2)*2*10

= 300

So, Waste Stack Diameter = 100 mm

11.5.3 For Vent Stack:

Total FU connected = 300 + 180

= 480

Length of vent stack = (10*10 +10) ft

= 110 ft

= 33.53 m

= 35 m

So, Vent Stack Diameter = 75 mm

Diameter of Horizontal Drainage Pipe (mm)	Slope (mm/m)	Maximum Development Length of Vent Pipe (m)
75	20	NL

CHAPTER - 12

REPORT ON SITE VISIT TO THE CETP AT SAVAR

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APPENDIX

MIT Classification	
Silt/Clay	< 0.06 mm
Fine Sand	0.06 – 0.20 mm
Medium Sand	0.20 – 0.60 mm
Course Sand	0.60 – 2.00 mm
Fine Gravel	> 2.00 mm

Table 6(a): MIT Classification of Soil

Aquifer Thickness	Recommended Screening
< 25’	70% Screening
25’ – 50’	75% Screening
> 50’	80% Screening

Table 6(b): Limitation of Strainer Length

Slot size	Assumed Opening (Steel Screening)
40 Slot	20%
30 Slot	15%
20 Slot	10%

Table 6(c): Strainer Opening Area

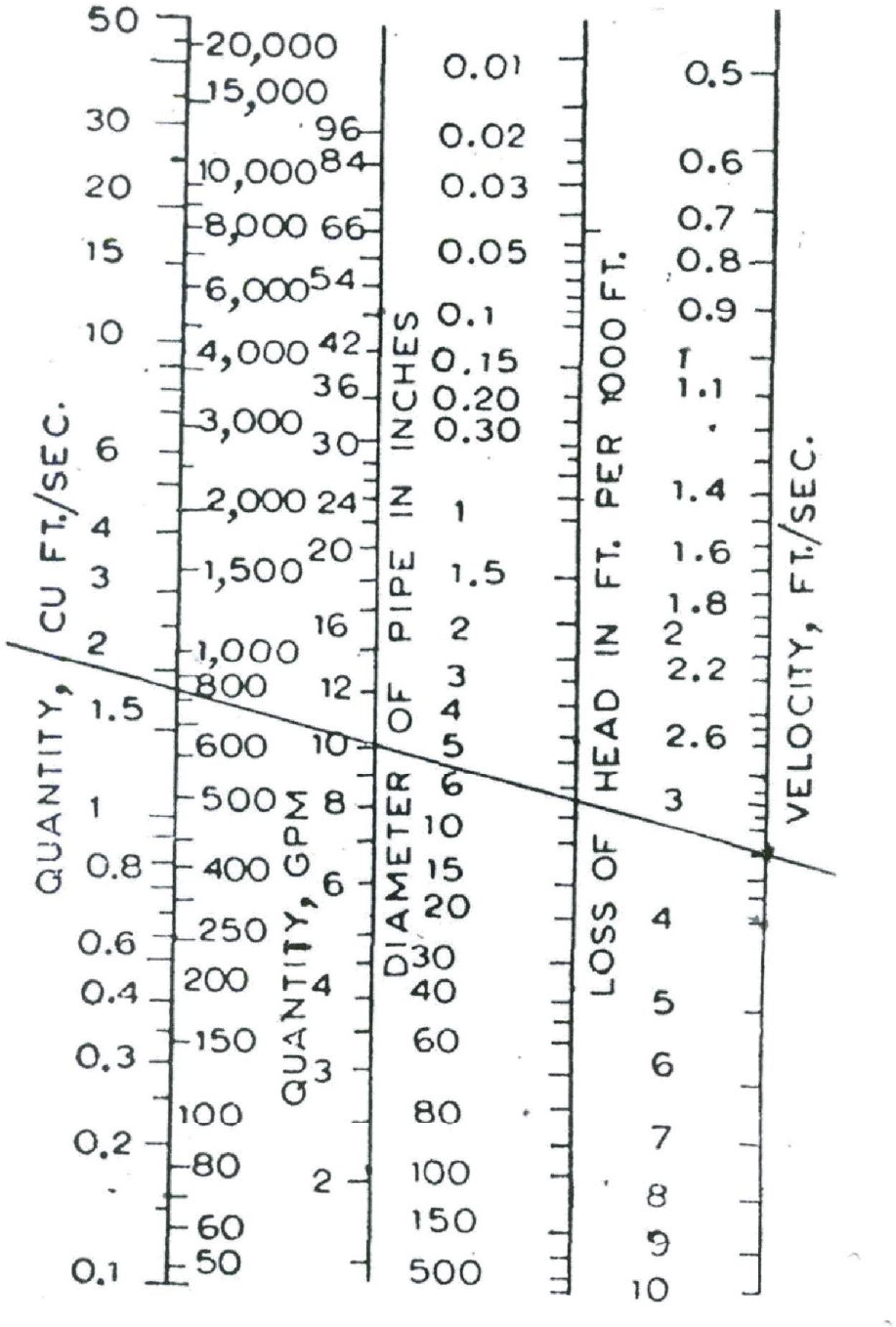


Figure 8(a): Hazen-Williams Nomograph for Roughness Coefficient, C = 100

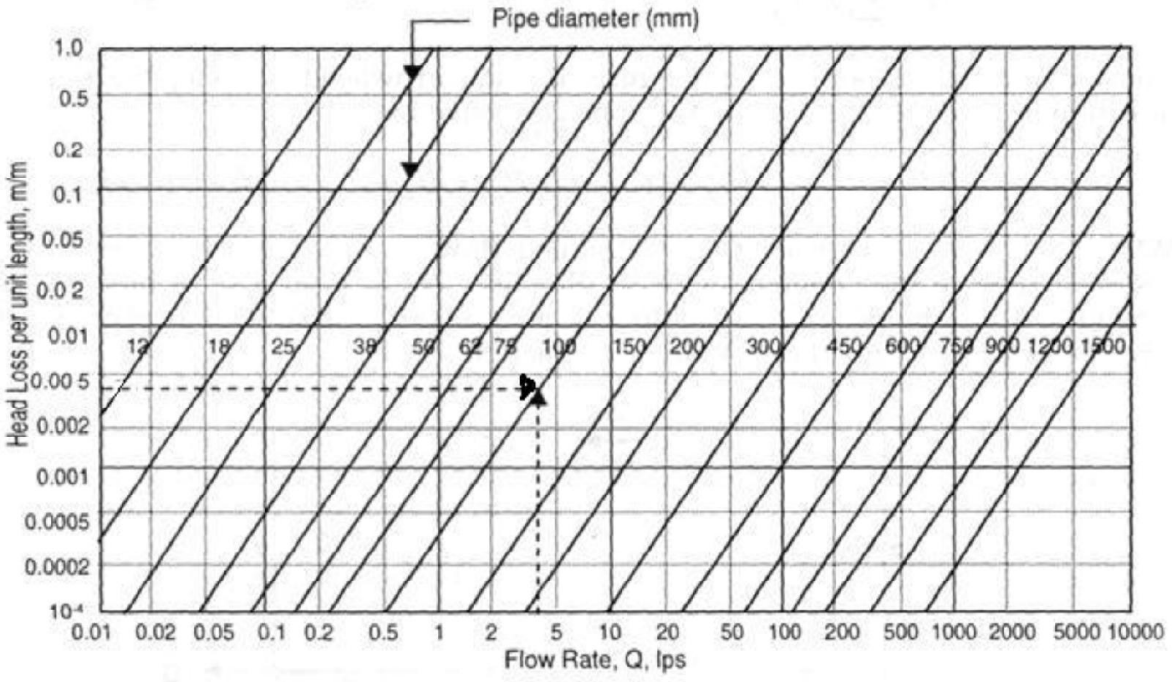


Figure 8(b): Head Loss Determination Diagram (For Roughness Co- Efficient, C = 120)

Size in inch (mm)	Slope m/m	
	n = 0.013	**n = .0.015**
8 (200)	0.0033	0.0044
10 (250)	0.0025	0.0033
12 (300)	0.0019	0.0026
15 (375)	0.0014	0.0019
18 (450)	0.0011	0.0015
21 (525)	0.0009	0.0012
24 (600)	0.0008	0.0010
27 (675)	0.0007	0.0009
30 (750)	0.0006	0.0008
36 (900)	0.0004	0.0006

Table 9(a): Minimum Pipe Slope for Gravity Sewer

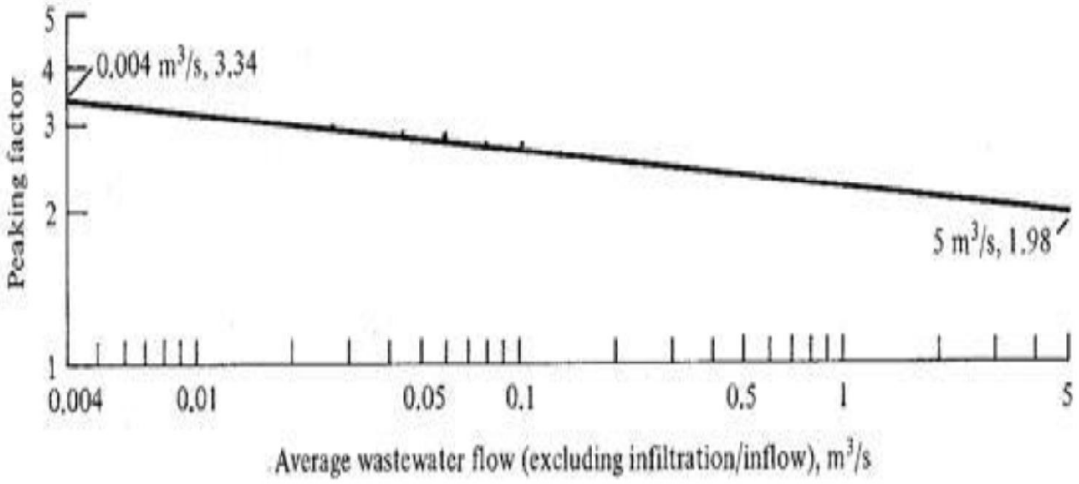


Figure 9(a): Peak Factor for Residential Wastewater Flows

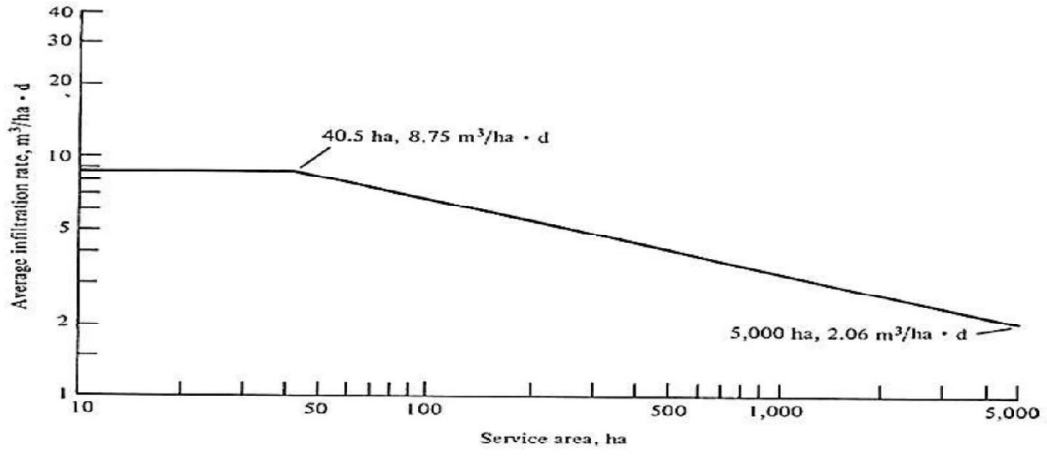


Figure 9(b): Average Infiltration Rate Allowance for New Sewers

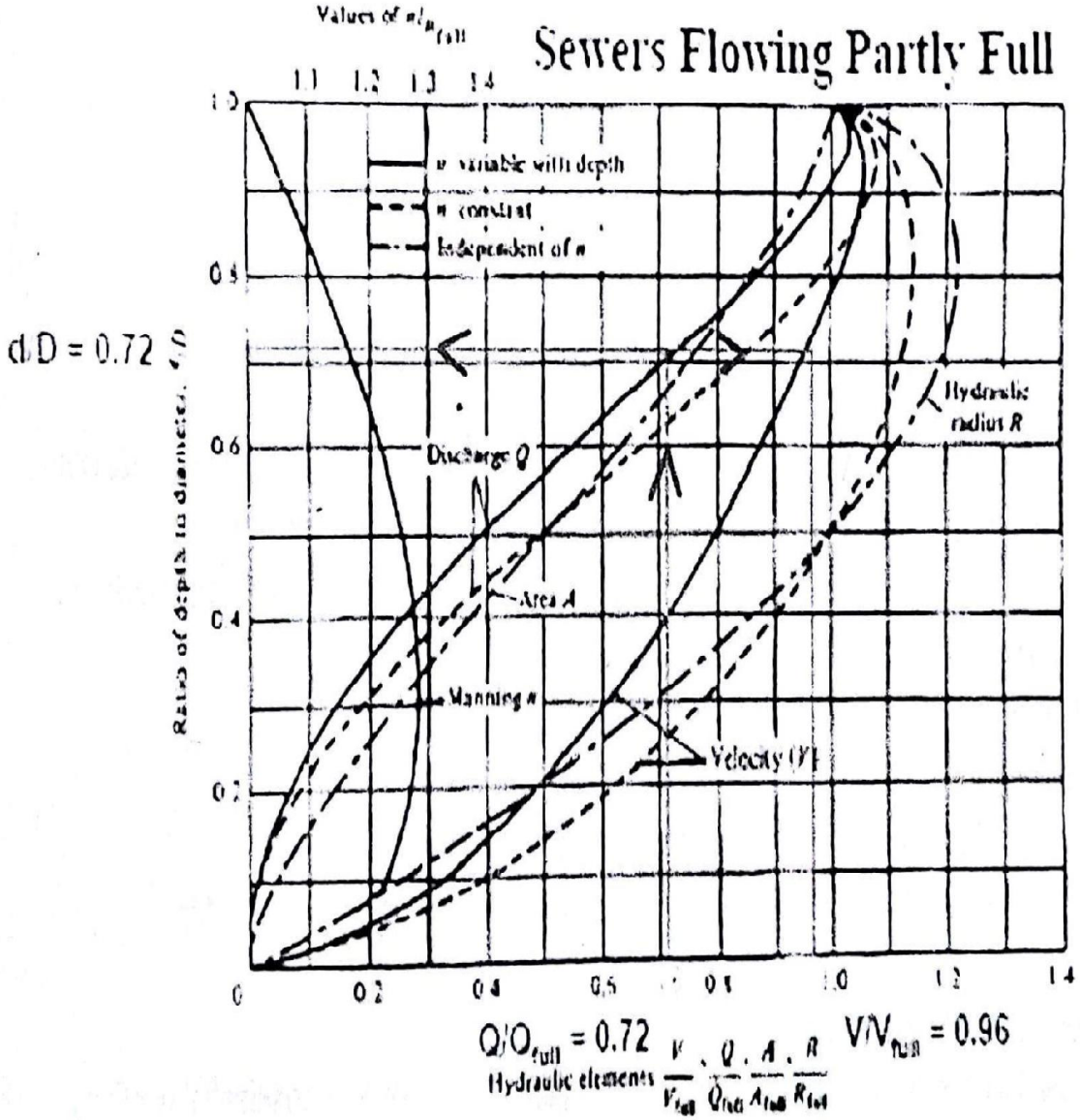


Figure 9(c): Hydraulic Elements for Circular Sewer

Type of Building/ Occupancy	Water Closet*	Urinals**	Wash Basin***	Bathtubs or Shower	Drinking Fountains	Other Fixtures
(A) Residential Buildings:						
A1 Detached Single Family Dwelling A2 Flats or Apartments A4 Minimum Standard housing A3 Mess, Boarding Houses and Hostels	1 per dwelling or apartment	-	1 per dwelling or apartment	1 per dwelling or apartment	-	1 kitchen sink per dwelling
For Residence and Residential Staff	**Males:** 1 for 8 persons **Females:** 1 for 6 persons	**Males:** 1 for 25 persons up to 150 persons. Add 1 fixture for each additional 50 persons	**Males:** 1 for 8 persons **Females:** 1 for 6 persons	**Males:** 1 for 8 persons **Females:** 1 for 6 persons	1 for 75 persons	1 kitchen sink in each kitchen
For Nonresidential Staff	**Males:** 1 for 1-15 persons 2 for 16-35 persons 3 for 36-65 persons 4 for 66-100 persons **Females:** 1 for 1-12 persons 2 for 13-25 persons 3 for 26-40 persons 4 for 41-57 persons 5 for 58-77 persons 6 for 78-100 persons	**Males:** Nil up to 6 persons 1 for 7-20 persons 2 for 21-45 persons 3 for 46-70 persons 4 for 71-100 persons	**Males:** 1 for 1-15 persons 2 for 16-35 persons 3 for 36-65 persons 4 for 66-100 persons **Females:** 1 for 1-12 persons 2 for 13-25 persons 3 for 26-40 persons 4 for 41-57 persons 5 for 58-77 persons 6 for 78-100 persons	-	1 for 100 persons	-
Rooms wherein Outsiders are Received Houses	**Males:** 1 for 100 persons up to 400 persons and add 1 fixture for additional 250 persons **Females:** 2 for 100 persons up to 200 persons and add 1 fixture for additional 100 persons	**Males:** 1 for 50 persons	**Males:** 1 per water closet and 1 per urinal or group of urinals **Females:** 1 per water closet	-	-	-
For Residential Public and Staff	1 for 8 persons omitting the occupant of the room with attached water closet; minimum of 2 if both sex are lodged	-	1 for 10 persons omitting the wash basins installed in the room or suite	1 for 10 persons omitting the occupants of the room with bath in suite	1 for 100 persons	1 kitchen sink in each kitchen
For Public Rooms	**Males:** 1 for 100 persons up to 400 persons and add 1 fixture for additional 250 persons or part thereof **Females:** 2 for 100 persons up to 200 persons and add 1 fixture for additional 100 persons or part thereof	**Males:** 1 for 50 persons	**Males:** 1 per water closet and 1 per urinal or group or urinals **Females:** 1 per water closet	-	1 for 100 persons	-

(Continue to next page)

Type of Building/ Occupancy	Water Closet*	Urinals**	Wash Basin***	Bathtubs or Shower	Drinking Fountains	Other Fixtures
(B) Educational:						
B1 Educational Facilities	**Males:** 1 for 40 persons **Females:** 1 for 25 persons	**Males:** 1 for 20 persons	**Males:** 1 for 60 persons but minimum 2 **Females:** 1 for 40 persons but minimum 2	-	1 for 50 persons	**Service sink:** 1 per floor
B2 Preschool Facilities	1 for 15 children	-	1 for 15 children	-	1 for 50 children	**Service sink:** 1 per floor
(C) Institutional:						
C1 Institution for Care of Children	**Boys:** 1 for boys **Girls:** 1 for girls	Urinals may be provided in boys toilet rooms in lieu of water closets but for not more than ½ of the required number of water closets	**Boys:** 1 for 8 boys **Girls:** 1 for 6 girls	1 for 8 persons (boys or girls)	1 for 50 persons (boys or girls)	**Service sink:** 1 per floor
C2 Custodial Institutions for Physically Capable C3 Custodial Institution for the Incapable	1 unisex facility or 1 for each sex for 1-100 persons 2 unisex facilities or 1 unisex facility and 1 for each sex for 100-200 persons. Over 200 persons one additional unisex facility or 1 for each sex for each additional 100 persons	- -	1 for 200 persons	1 for 10 persons but not less than 1 for use by both sexes	1 for 100 persons	**Service sink:** 1 per floor
C4 Penal and Mental Institutions	1 per call	-	1 per call	1 for 15 persons	1 for 100 persons	Service sink
(D) Health Care Building:						
D1 Normal Medical Facilities (Indoor Patient Ward)	1 for 8 patient (male or female)	-	2 up to 30 patients and add 1 fixture for additional 30 patients	1 for 8 patients	1 for 75 patients	**Service sink:** 1 for each ward Bed Pan **Washing sink:** 1 for each ward **Kitchen sink:** 1 for each kitchen
D2 Emergency Medical Facilities and Outdoor Patient Ward	**Males:** 1 for 100 persons **Females:** 2 for 100 persons	**Males:** 1 for 50 persons	1 for 100 persons	-	1 for persons	**Service sink:** 1 for each ward

(Continue to next page)

Type of Building/ Occupancy	Water Closet*	Urinals**	Wash Basin***	Bathtubs or Shower	Drinking Fountains	Other Fixtures
(E) Assembly Building:						
E1 Large Assembly with Fixed Seats E2 Small Assembly with Fixed Seats E3 Large Assembly without Fixed Seats E4 Small Assembly without Fixed Seats Mosque	1 for 30 persons	-	-	1 for 100 persons	1 for 100 persons	**Water taps with drainage arrangement:** 1 for 10 persons
Junction Stations, Intermediate Stations, Terminal Stations and Bus Terminals	**Males:** Min 2, 4 for 1000 persons and add 1 for additional 1000 persons **Females:** Min 2, 5 for 1000 persons and then add 1 for additional 1000 persons	**Males:** Min 2, 4 for 1000 persons and add 1 for additional 1000 persons	**Males:** Min 2, 4 for 1000 persons and add 1 for additional 1000 persons **Females:** Min 2, 6 for 1000 persons and then add 1 for additional 1000 persons	-	1 for 300 persons	**Service sink:** 1 per floor
Domestic Airport Minimum for 200 persons for 400 persons for 600 persons for 800 persons for 1000 persons	 **Males:** 2 **Females:** 2 **Males:** 4 **Females:** 5 **Males:** 6 **Females:** 8 **Males:** 8 **Females:** 10 **Males:** 9 **Females:** 13 **Males:** 10 **Females:** 13	 **Males:** 1 **Males:** 2 **Males:** 4 **Males:** 5 **Males:** 6 **Males:** 7	 2 4 6 8 9 10	-	1 per 300 persons	**Service sink:** 1 per floor
International Airport for 200 persons for 600 persons for 1000 persons	 **Males:** 6 **Females:** 10 **Males:** 12 **Females:** 20 **Males:** 18 **Females:** 29	 **Males:** 8 **Males:** 22 **Males:** 22	 10 20 25	4 shower stalls in the females or males toilet in the transit and departure lounge and also in the main concourse	1 per 300 persons	**Service sink:** 1 per floor
Cinemas, Concert halls, Theatres (for public use)	**Males:** 1 for 100 persons up to 400 persons. Add 1 for additional 250 persons **Females:** 3 for 100 persons up to 200 persons. Add 2 for additional 100 persons	**Males:** 1 for 25 persons	1 for 200 persons	-	1 for 500 persons	**Service sink:** 1
Cinemas, Concert halls, Theatres (for permanent employee use)	**Males:** 1 for 1-15 persons 2 for 16-35 persons **Females:** 1 for 1-12 persons 2 for 13-25 persons	**Males:** Nil up to 6 persons 1 for 7-20 persons 2 for 21-45 persons	**Males:** 1 for 1-15 persons 2 for 16-35 persons **Females:** 1 for 1-12 persons 2 for 13-25 persons	-	1 for 500 persons	-

(Continue to next page)

Type of Building/ Occupancy	Water Closet*	Urinals**	Wash Basin***	Bathtubs or Shower	Drinking Fountains	Other Fixtures
Art Galleries, Libraries, Museums (for public use)	**Males:** 1 for 200 persons up to 400 persons. Add 1 for additional 250 persons **Females:** 1 for 100 persons up to 200 persons. Add 1 for additional 100 persons	**Males:** 1 for 50 persons	1 for 200 persons up to 200 persons. Add 1 for additional 250 persons	-	1 for 500 persons	**Service sink:** 1
Art Galleries, Libraries, Museums (for permanent employee use)	**Males:** 1 for 1-15 persons 2 for 16-35 persons **Females:** 1 for 1-12 persons 2 for 14-25 persons	**Males:** Nil up to 6 persons 1 for 7-20 persons 2 for 21-45 persons	**Males:** 1 for 1-15 persons 2 for 16-35 persons **Females:** 1 for 1-12 persons 2 for 14-25 persons	-	1 for 100 persons	-
E5 Sports Facilities	**Males:** 1 for 75 persons **Females:** 2 for 50 persons	**Males:** 1 for 75 persons	1 for 60 persons	1 for 50 persons	1 for 300 persons	**Service sink:** 1
(F) Business and Mercantile Building:						
F1 Offices F2 Garages and Petrol Stations F3 Essential Services	**Males:** 1 for 25 persons **Females:** 2 for 15 persons	**Males:** Nil up to 6 persons 1 for 7-20 persons 2 for 21-45 persons 3 for 46-70 persons 4 for 71-100 persons Add @ 3% for 101-200 persons and @ 2.5% for over 200 persons	1 for 25 persons	-	1 for 100 persons	**Service sink:** 1 per floor
F4 Small Shops and Markets F3 Large Shops and Markets	1 for 500 persons	Urinals may be provided in toilet rooms in lieu of water closets but for men but for not more than ½ of the required number of water closets	1 for 750 persons	-	1 for 1000 persons	**Service sink:** 1
(G) Industrial Buildings Factories	**Males:** 1 for 1-15 persons 2 for 16-35 persons 3 for 36-65 persons 4 for 66-100 persons **Females:** 1 for 1-12 persons 2 for 13-25 persons 3 for 26-40 persons 4 for 41-57 persons 5 for 58-77 persons 6 for 78-100 persons	**Males:** Nil up to 6 persons 1 for 7-20 persons 2 for 21-45 persons 3 for 46-70 persons 4 for 71-100 persons Add @ 3% for 101-200 persons and @ 2.5% for over 200 persons	1 for 25 persons	As required by particular trades or occupations	1 for 100 persons	**Service sink:** 1 per floor

(Continue to next page)

Type of Building/ Occupancy	Water Closet*	Urinals**	Wash Basin***	Bathtubs or Shower	Drinking Fountains	Other Fixtures
(H) Storage Buildings	1 for 100 persons	-	1 for 100 persons	Provisions for emergency shower	1 for 1000 persons	Service sink: 1
(J) Hazardous Buildings	1 for 100 persons	-	1 for 100 persons	Provisions for emergency shower	1 for 1000 persons	Service sink: 1

***** Some of the water closets may be of European style. The water closet(s) shall not be oriented in the east -east direction.
****** The urinal(s) shall not be oriented in the east-west direction.
******* Toilet(s) of public use shall have at least one water tap with adequate drainage arrangement for ablution purpose when the number of devotees exceeds twenty.

Table 10(a): Plumbing Fixtures Requirement

Sl No.	Type of Fixture	Fixture Unit (FU) as Load Factors	Minimum size of Fixture Branch (mm)
1	Ablution Tap	1	15
2	Bath tub supply with spout	3	15
3	Shower Stall Domestic	2	15
4	Shower in Group per head	3	15
5	Wash Basin (Domestic Use)	1	15
6	Wash Basin (Public Use)	2	15
7	Wash Basin (Surgical)	2	15
8	Kitchen Sink (Domestic Use)	2	15/20
9	Washing Machine	3	15/20
10	Drinking Fountain	0.5	15

Table 10(b): Fixture Unit for Different Types of Fixtures with Inlet Pipe Diameter

Fixture or Group	Supply Control	wsfu		
		Cold	Hot	Total
Bath group	Flush tank	4.5	3	6
Bath group	Flush valve	6	3	8
Bathtub	Faucet	1.5	1.5	2
Bidet	Faucet	1.5	1.5	2
Combination	Faucet	2	2	3
Kitchen sink	Faucet	1.5	1.5	2
Laundry tray	Faucet	2	2	3
Laundry	Faucet	1.5	1.5	2
Pedestal urinal	Flush valve	10	-	10
Restaurant sink	Faucet	3	3	4
Service sink	Faucet	1.5	1.5	2
Shower head	Mixing valve	3	3	4
Stall or wall urinal	Flush tank	3	-	3
Stall or wall urinal	Flush valve	5	-	5
Water closet	Flush tank	5	-	5
Water closet	Flush valve	10	-	10
*** Fixture with both cold and hot water supplies, the weight for maximum separate demands may be considered 75% of total wsfu.**				

Table 10(c): Water Supply Fixture Unit for Various Plumbing Fixtures

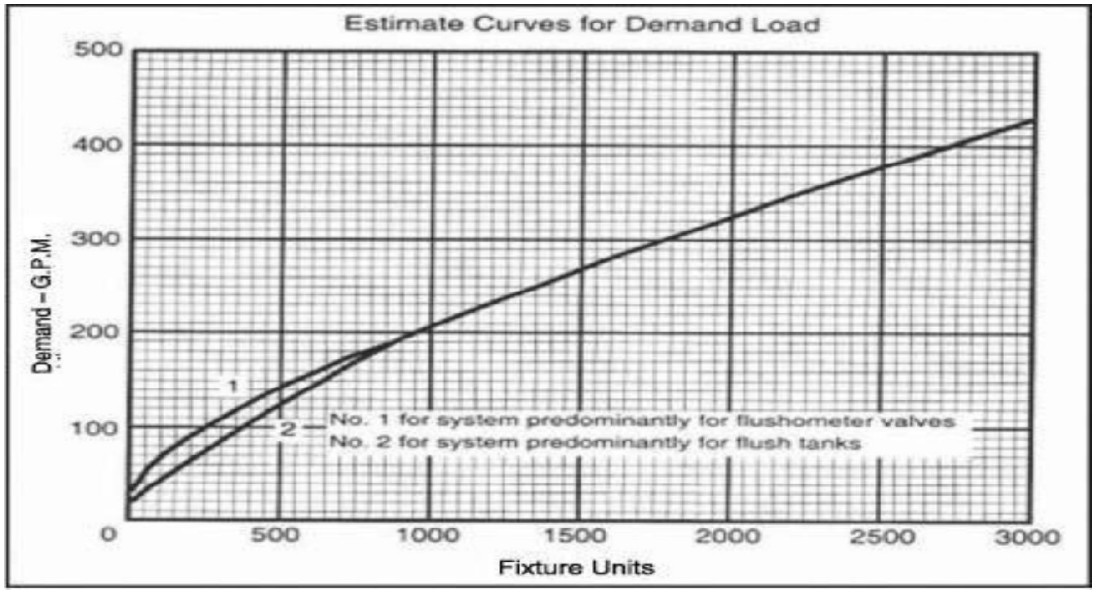


Figure 10(a): Hunter Curve

No. of Fixture Units	System with flush Tanks Demand (Based on Fixture Units)		System with Flush Valves Demand (After Hunter)	
	Unit Rate of Flow[1]	Flow in Litre per Minute	Unit Rate of Flow[1]	Flow in Litre per Minute
(1)	(2)	(3)	(4)	(5)
20	2.0	56.6	4.7	133.1
40	3.3	93.4	6.3	178.4
60	4.3	121.8	7.4	209.5
80	5.1	144.4	8.3	235.0
100	5.7	161.4	9.1	257.7
120	6.4	181.2	9.8	277.5
140	7.1	201.0	10.4	294.5
160	7.6	215.2	11.0	311.5
180	8.2	232.2	11.6	328.5
200	8.6	243.5	12.3	348.3
220	9.2	260.5	12.7	359.6
240	9.6	271.8	13.1	370.9
300	11.4	322.8	14.7	416.2
400	14.0	396.4	17.0	418.4
500	16.7	472.9	19.0	538.0
600	19.4	549.3	21.1	597.5
700	21.4	606.0	23.0	651.3
800	24.1	682.4	24.5	693.7
900	26.1	739.0	26.1	739.0
1000	28.1	795.7	28.1	795.7

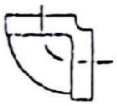
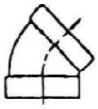
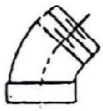
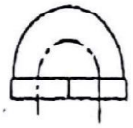
[1] Unit rate of flow = Effective fixture units.

Table 10(d): Probable Simultaneous Demand

Fixture	Supply Control	Minimum Size of Supply Pipe (mm)	Required Flow Pressure (kpa)	Required Flow Rate (lpm)
Bathroom group	Flush tank	--	55	--
Bathroom group	Flushometer valve	--	55	--
Bathtub	Faucet	13	55	15.1
Clothes washer		13	55	--
Combination fixture	Faucet	13	55	--
Dishwashing machine		13	55	10.4
Drinking fountain	Faucet	13	55	2.8
Kitchen sink	Faucet	13	55	9.5
Laundry tray	Faucet	13	55	15.1
Wash basin	Faucet	19	55	--
Pedestal urinal	Flush tank	13	55	56.8
Pedestal urinal	Flushometer valve	19	100	56.8
Restaurant sink	Faucet	19	55	--
Service sink	Faucet	13	55	11.4
Shower head	Mixing valve	13	55	11.4
Water closet	Flush tank	19	55	11.4
Water closet	Flushometer tank	19	55	6.1
Water closet	Flushometer valve	25	100	132
For fixture not listed here but maximum supply size requirement		13	55	--
		19	55	--
		25	100	--
Note: 1 psi = 6.895 kpa (1 kpa = 0.145 psi), 1 gallon = 3.785 litre.				

Table 10(e): Water Supply System Design Requirements

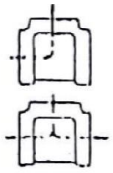
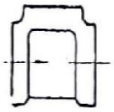
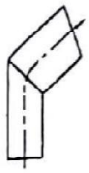
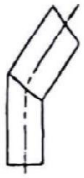
Screwed, Welded, Flanged, Flared and Brazed Connections

Nominal Pipe OR TUBE SIZE (mm)	SMOOTH BEND ELBOWS					
	90° Std*	90° Long Rad.**	90° Street*	45° Std*	45° Street*	180° Std*
						
10	0.43	0.27	0.70	0.21	0.34	0.70
13	0.49	0.31	0.76	0.24	0.40	0.76
19	0.61	0.43	0.98	0.27	0.49	0.98
25	0.79	0.52	1.25	0.40	0.64	1.25
32	1.01	0.70	1.71	0.52	0.92	1.71
38	1.22	0.79	1.92	0.64	1.04	1.92
50	1.53	1.01	2.50	0.79	1.37	2.50
63	1.83	1.25	3.05	0.98	1.59	3.05
75	2.29	1.53	3.66	1.22	1.95	3.66
88	2.75	1.80	4.58	1.43	2.23	4.58
100	3.05	2.04	5.19	1.59	2.59	5.19
125	3.97	2.50	6.41	1.98	3.36	6.41
150	4.88	3.05	7.63	2.41	3.97	7.63
200	6.10	3.97	-	3.05	-	10.07
250	7.63	4.88	-	3.97	-	12.81
300	9.15	5.80	-	4.88	-	15.25
350	10.37	7.02	-	5.49	-	16.78
400	11.59	7.93	-	6.10	-	18.91
450	12.81	8.85	-	7.02	-	21.35
500	15.25	10.07	-	7.93	-	24.71
600	18.30	12.20	-	9.15	-	28.67

** = R/D approximately equal to 1, ** = R/D approximately equal to 1.5*

Table 10.2(a): Fitting Losses in Equivalent Meter of Pipe

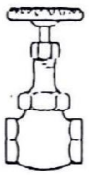
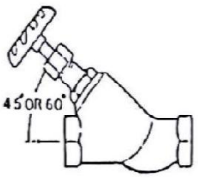
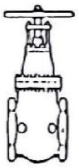
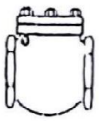
Screwed, Welded, Flanged, Flared and Brazed Connections

Nominal Pipe OR TUBE SIZE (mm)	SMOOTH BEND TEES				METRE ELBOWS			
	Flow-Thru	Straight-Thru Flow			90° Ell	60° Ell	45° Ell	30° Ell
								
10	0.82	0.27	0.37	0.43	0.82	0.34	0.18	0.09
13	0.92	0.31	0.43	0.49	0.92	0.40	0.21	0.12
19	1.22	0.43	0.58	0.61	1.22	0.49	0.27	0.15
25	1.53	0.52	0.70	0.79	1.53	0.64	0.31	0.21
32	2.14	0.70	0.95	1.01	2.14	0.92	0.46	0.27
38	2.44	0.79	1.13	1.22	2.44	1.04	0.55	0.34
50	3.05	1.01	1.43	1.53	3.05	1.37	0.70	0.40
63	3.66	1.25	1.71	1.83	3.66	1.59	0.85	0.52
75	4.58	1.53	2.14	2.29	4.58	1.95	0.98	0.61
88	5.49	1.80	2.44	2.75	5.49	2.23	1.22	0.73
100	6.41	2.04	2.75	3.05	6.41	2.59	1.37	0.82
125	7.63	2.50	3.66	3.97	7.63	3.36	1.83	0.98
150	9.15	3.05	4.27	4.88	9.15	3.97	2.14	1.22
200	12.20	3.97	5.49	6.10	12.20	5.19	2.75	1.56
250	15.25	4.88	7.02	7.63	15.25	6.41	3.66	2.20
300	18.30	5.80	7.93	9.15	18.30	7.63	3.97	2.44
350	20.74	7.02	9.15	10.37	20.74	8.85	4.58	2.75
400	23.79	7.93	10.68	11.59	23.79	9.46	5.19	3.05
450	25.93	8.85	12.20	12.81	25.93	11.29	5.80	3.36
500	30.50	10.07	13.42	15.25	30.50	12.51	6.71	3.97
600	35.08	12.20	15.25	18.30	35.08	14.95	7.63	4.88

** = R/D approximately equal to 1, ** = R/D approximately equal to 1.5*

Table 10.2(b): Fitting Losses in Equivalent Meter of Pipe

Screwed, Welded, Flanged, Flared and Brazed Connections

Nominal Pipe OR TUBE SIZE (mm)	GLOBE	60° – Y	45° – Y	ANGLE*	GATE	SWING CHECK**	LIFT CHECK
							
10							
13	5.49	2.75	2.14	2.14	0.21	1.83	
19	6.71	3.36	2.75	2.75	0.27	2.44	Globe &
25	8.85	4.58	3.66	3.66	0.31	3.05	Lift
32	11.59	6.10	4.58	4.58	0.46	4.27	Vertical
38	13.12	7.32	5.49	5.49	0.55	4.88	Lift
50	16.78	9.15	7.32	7.32	0.70	6.10	Same as
63	21.05	10.68	8.85	8.85	0.85	7.63	Globe
75	25.62	13.12	10.68	10.68	0.98	9.15	Valve**
88	30.50	15.25	12.51	12.51	1.22	10.68	
100	36.60	17.69	14.34	14.34	1.37	12.20	
125	42.70	21.66	17.69	17.69	1.83	15.25	
150	51.85	26.84	21.35	21.35	2.14	18.30	
200	67.10	35.08	25.93	25.93	2.75	24.40	
250	85.40	44.23	32.03	32.03	3.66	30.50	Angle
300	97.60	50.33	39.65	39.65	3.97	36.60	Lift
350	109.8	56.43	41.18	41.18	4.58	41.18	Same as
400	125.05	64.05	54.90	54.90	5.19	45.75	Angle
450	140.3	73.20	61.00	61.00	5.80	50.33	Valve
500	158.6	83.88	71.68	71.68	6.71	61/00	
600	186.05	97.60	80.83	80.83	7.63	73.20	

* = *These loses do not apply to valves with needle point type seat,*
* * = *Losses also apply to the in-line, ball type check valve.*

Table 10.2(c): Fitting Losses in Equivalent Meter of Pipe

Building Type	Sprinkler System (l/min.)*	Standpipe and hose System (l/min.)*	Duration** (minute, min.)
Light hazard – I	1000	1000	30
Light hazard – II	1900	1900	50
Ordinary hazard – I	2650	1900	75
Ordinary hazard – II	3200	1900	75
Ordinary hazard - III	4800	1900	75

NOTES:

Values will be for one riser serving floor area of **1000 m^2**.

****These durations shall be for a building up to the height of **51 m**. For greater height of **51- 102 m** and above **102 m**, the duration will be **1.25** times and **1.5** times of the specified values respectively.

Light hazard – I **:** Occupancy groups, A1, A2, A4

Light hazard – II **:** Occupancy groups, A3, A6, A7, A8, B, C, D, E2, E4, E7, F1 & F2

Ordinary hazard – I **:** Occupancy groups, E1, E3, E5, F3, F4, F5, F6, F7, G1 & G4

Ordinary hazard- II **:** Occupancy groups, G2 & H1

Ordinary hazard- III **:** Occupancy groups, G3 & H2

Extra hazard **:** Occupancy group, J - pressure and flow requirement for this group shall be determined by Fire Department but shall not be less than required value for **Ordinary hazard-III**.

Table 10(f): Fire Protection Flow Requirements

Cat	Socio-economic group, Type of Building & Other Facilities	Water Consumption	
A	**Big Cities/ City Corporation Area/ Big District Towns (Population > 0.5 million)**	**Full Facility (lpcd)**	**Restricted Facility (lpcd)**
a	**High income group:**		
a1	Single Family Dwelling with Garden & Car washing	260	200
a2	Big Multi-Family Apartment/ Flat (> 2500 sft)	200	150
b	**Middle income group:**		
b1	Officer's Qrt./ Colony & moderate Apartment (< 2000 sft)	180	135
b2	Small building/ Staff Qrt. & small Apartment (< 1500 sft)	---	120
c	**Low income group:**		
c1	Junior staff Qrt./ flat (< 1000 sft) & temporary shade	---	80
c2	Stand post connection in the fringe area	---	65
c3	Common yard (stand post) connection in the fringe area	---	50
c4	Slum dwellers collection from road side public stand post	---	40

Table 10(g): Water Consumption for Domestic Purposes (Cities/Big District Towns) [Residential Buildings]

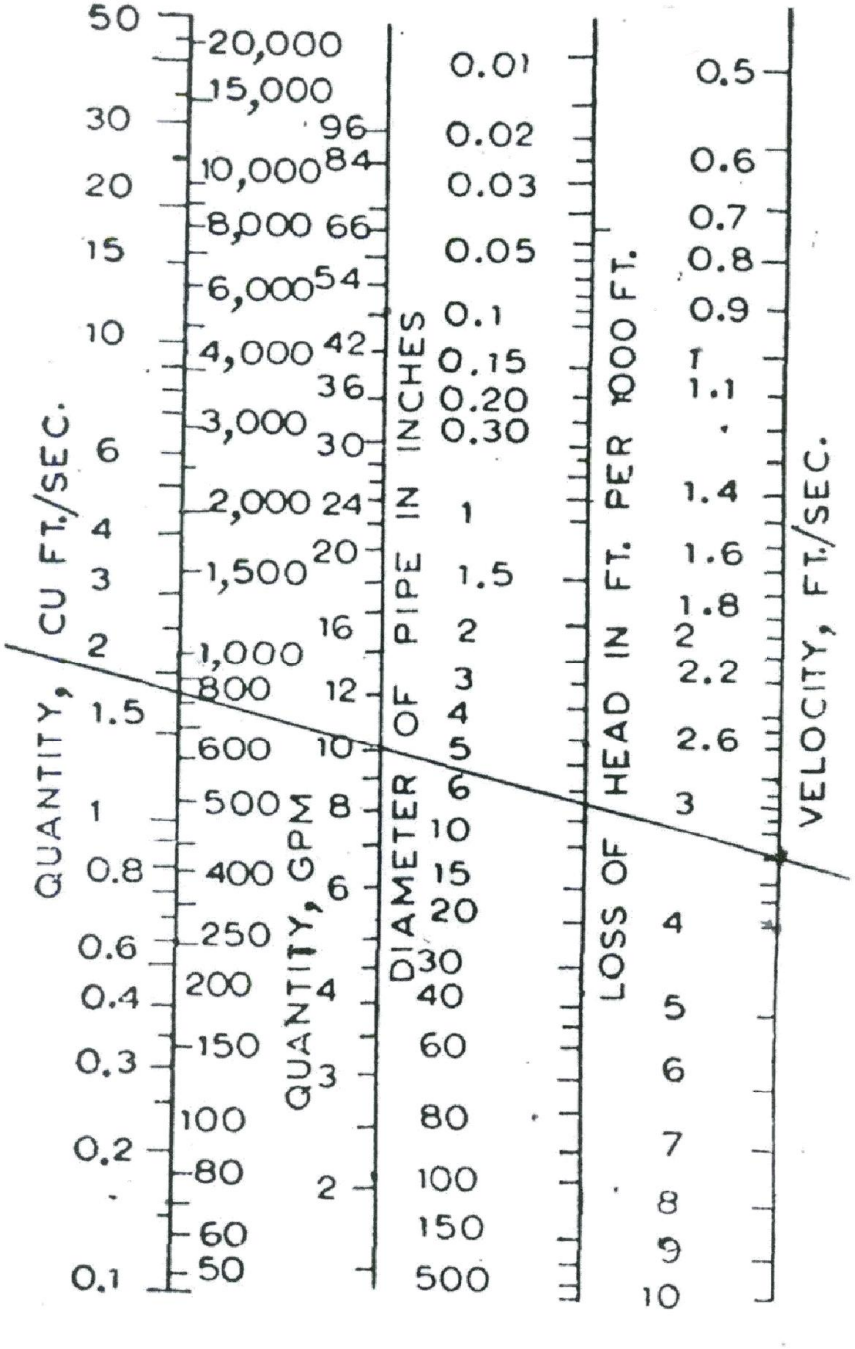


Figure 10(b): Hazen Williams Nomograph for Roughness Coefficient, C=100

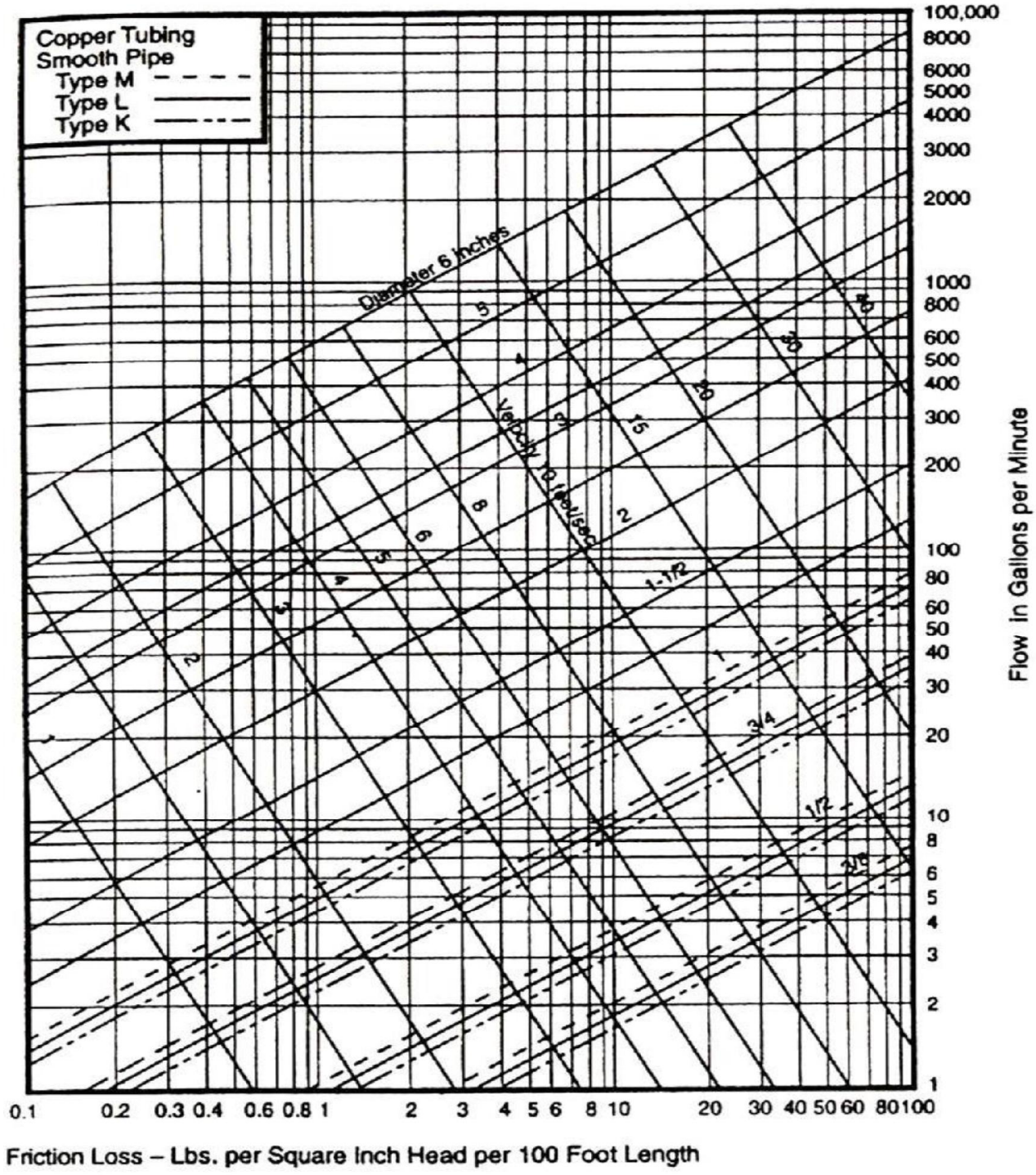

Copper Tubing
Smooth Pipe
Type M
Type L
Type K
Diameter 6 inches
5
4
Velocity 10 feet/sec
3
2
1-1/2
1
3/4
1/2
100,000
8000
6000
5000
4000
3000
2000
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
0.1
0.2
0.3
0.4
0.6
0.8
1
2
3
4
5
6
8
10
20
30
40
50
60
80
100
Flow in Gallons per Minute
Friction Loss – Lbs. per Square Inch Head per 100 Foot Length

Figure 10(c)

Type of Fixture	Fixture Unit Value as Load Factors
One bathroom group consisting of water closet, wash basin and bathtub or shower stall:	
a) Flush Tank water closet	3
b) Flush-valve water closet	6
Bathtub*	2
Bidet	2
Combination sink and tray (drain board)	2
Drinking fountain	0.5
Floor traps**	1
Kitchen sink, domestic	2
Wash basin, ordinary***	1
Wash basin, surgeon's	2
Shower stall, domestic	2
Shower (group) per head	3
Urinal, wall hung	4
Urinal, stall	4
Water closet, tank operated	3
Water closet, valve operated	6
*** A shower head over a bathtub does not increase the fixture unit value.** **** Size of floor trap shall be determined by the area of surface water to be drained.** ***** Wash basin with 32 mm and 40 mm trap have the same load value.**	

Table 11(a): Fixture Units for Different Sanitary Appliances or Groups

Fixture Drain on Trap Size	Fixture Unit Value
30 mm or Smaller	1
40 mm	2
50 mm	3
65 mm	4
75 mm	5
100 mm	6

Table 11(b): Fixture Unit Value for Fixtures Based on Fixture Drain or Trap Size

Diameter of Pipe (mm)	Maximum Number of Fixture Units that can be connected			
	Any Horizontal Fixture Branch[a]	One Stack of 3 Stories in Height or 3 Intervals	More than 3 Stories in Height	
			Total for stack	Total at One story Branch Interval
30	1	2	2	1
40	3	4	8	2
50	6	10	24	6
65	12	20	42	9
75	20	30	60	16
100	160	240	500	90
125	360	540	1100	200
150	620	960	1900	350
200	1400	2200	3600	600
250	2500	3800	5600	1000
300	3900	6000	8400	1500
375	7000	b	b	b

[a] Does not include branches of the building sewer.

[b] Sizing load based on design criteria.

Table 11(c): Maximum Number of Fixture Units that can be connected to Branches or Stacks

Diameter of Soil or Waste Stack (mm)	Total Fixture Unit (FU) Connected to fixture	Maximum Development Length of Vent (m)* for Diameter (mm) of Vent Pipes										
		30	40	50	65	75	100	125	150	200	250	300
30	2	9										
40	8	15	45.5									
40	10	9	30.5									
50	12	9	22.5	61								
50	20	8	15	45.5								
65	42		9	30.5	91.5							
75	10		12	45.5	109.5	317						
75	21			33.5	82	247						
75	53			28.5	70	207						
75	102			26	64	189						
100	43		5	10.5	26	76	298.5					
100	140		9.5	8	19.5	61	228.5					
100	320		8	7	16.5	52	195					
100	540		7.5	6.5	15	45.5	176.5					
125	190				8.5	25	97.5	301.5				
125	490				6.5	19	76	231.5				
125	940				5.5	16	64	204				
125	1400				4.5	15	58	180				
150	500					10	39.5	122	305			
150	1100					6.5	30.5	94.5	237.5			
150	2000					6	25.5	79	210			
150	2900						23.5	73	183			
200	1800						9.5	29	73	286.5		
200	3400						7	22	58	219.5		
200	5600						6	19	48.5	186		
200	7600						5.5	17	42.5	170.5		
250	4000							9.5	23.5	94.5	292.5	
250	7200							7	18	73	225.5	
250	11000							6	15.5	61	192	
250	15000							5.5	14	55	173.5	
300	7300								9.5	36.5	116	286.5
300	13000								7	28.5	91.5	219.5
300	20000								6	24	76	186
300	26000								5.5	22	70	152.5
375	15000									12	39.5	94.5
375	25000									9.5	29	73
375	38000									8	24.5	61
375	50000									7	22.5	55

*** The development length shall be measured from the vent connection to the open air.**

Table 11(d): Size and Length of Vent Stacks and Stack Vents

Diameter of Horizontal Drainage Branch (mm)	Slope of Horizontal Drainage Branch (mm/m)	Maximum Development Length of Vent (m) for Diameter (mm) of Vent Pipe									
		30	**40**	**50**	**65**	**75**	**100**	**125**	**150**	**200**	**250**
30	20	NL*									
	40	NL									
40	20	NL	NL								
	40	NL	NL								
50	10	NL	NL	NL							
	20	85	NL	NL							
	40	45	115	NL							
65	10	54	137	NL							
	20	29	73	NL	NL						
	40	15	39	NL	NL						
75	10	-	58	NL	NL	NL					
	20		29.5	128	NL	NL					
	40		15	67	NL	NL					
100	10		-	58	NL	NL	NL				
	20			30	94	NL	NL				
	40			14.5	48.5	125	NL				
125	10				58	149	NL	NL			
	20				29.5	76	NL	NL			
	40				14	39.5	NL	NL			
150	10					58	NL	NL	NL		
	20					29.5	76	NL	NL		
	40					14	39.5	NL	NL		
200	10						58	NL	NL	NL	
	20						27.5	94.5	NL	NL	
	40						11.5	45.5	125	NL	NL
250	10							58	152	NL	NL
	20							26	73	NL	NL
	40							9.5	33.5	NL	NL
300	10								54.4	NL	NL
	20								24	128	NL
	40								8	61	NL

*** NL means no limit; Actual value in excess of 150 m.**

Table 11(e): Minimum Diameter and Maximum Length of Individual, Branch and Circuit Vents for Horizontal Drainage Branches