DESIGN OF WATER SUPPLY, SANITATION, AND SEWERAGE SYSTEMS FOR A 90-ACRE DAIRY FARM INDUSTRIAL PARK

EWCE 432 - Environmental Engineering Design Sessional

GROUP - 03

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Overview

This report presents the design of the water supply, wastewater conveyance, and building plumbing systems for a 90-acre dairy farm industrial park as part of the Environmental Engineering Design Sessional (EWCE 432).

The industrial park is organized into four functional wings – Industrial, Residential, Administrative, and Commercial, distributed across two physical zones: Zone 1 (Residential, Commercial, and Administrative) and Zone 2 (Industrial). An organogram was developed to establish staffing levels, which form the basis for population estimation and subsequent infrastructure design.

Population and water demand were estimated for the present, 10-year, 20-year, and 30-year design periods. Water demand includes domestic, industrial production, commercial, administrative, and firefighting requirements. Deep tube wells were selected as the primary water source based on borehole grain-size analysis, followed by the design of the gravel pack, well strainer, and pumping system. Overhead reservoirs and pumping schedules were then developed to maintain continuous water supply. Both branched and looped distribution networks were designed hydraulically and evaluated for flow and pressure requirements.

A gravity-flow trunk sewer system was designed based on wastewater generation from the individual subzones. The design includes sewer sizing, manhole placement, self-cleansing velocity checks, and longitudinal profiles. In addition, a reference building plumbing system was designed, including down-feed and up-feed distribution, risers, underground and overhead reservoirs, and booster pumping arrangements in accordance with applicable building codes.

Layout and Organogram

The industrial park is organized into four organizational wings – Industrial, Residential, Administrative, and Commercial, distributed across two physical zones: Zone 1 (Residential, Commercial, and Administrative) and Zone 2 (Industrial). Zone 1 accommodates residential, commercial, and administrative activities requiring greater proximity and accessibility, while Zone 2 accommodates industrial and utility-related facilities with greater operational, environmental, and service requirements.

The organizational structure is represented through the corresponding organogram, which establishes the staffing basis for subsequent population and infrastructure design.

Park governance:

The park is governed by a Board of Directors, chaired by the Chairman of the Board. The Park Managing Director oversees executive operations, supported by the Executive Assistant, Board Secretary, Chief Legal Counsel, and Public Relations Officer. Four operational directors oversee the respective wings and report directly to the Managing Director.

Considerations:

The physical zoning generally follows the organizational wings. However, the STP and Solid Waste Dump, although administratively assigned to the Administrative Wing, are physically located in Zone 2 and are therefore included in the Zone 2 hydraulic demand. Their separation from residential areas is intended to minimize potential odor and nuisance impacts. Their location also provides convenient access to the designated discharge area (river) for treated effluent.

Layout

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Organogram: Main

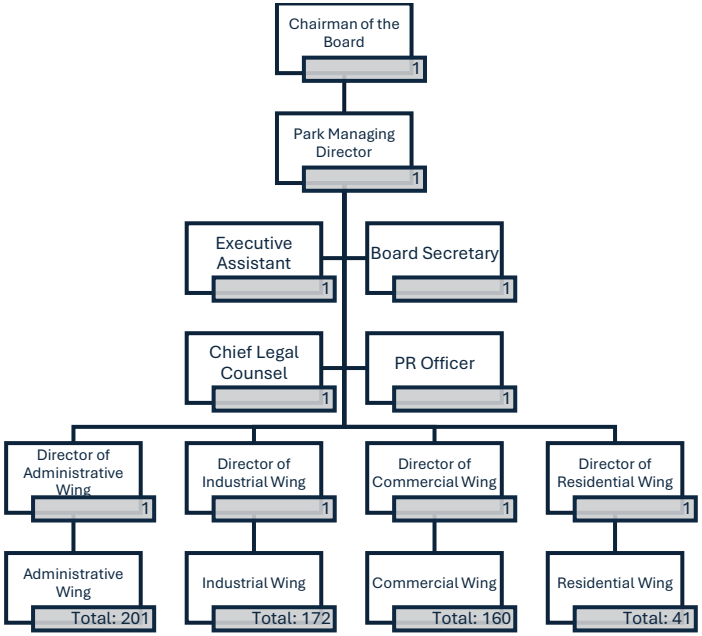


Figure 1 Main organogram of the industrial park

Organogram: Administrative Wing

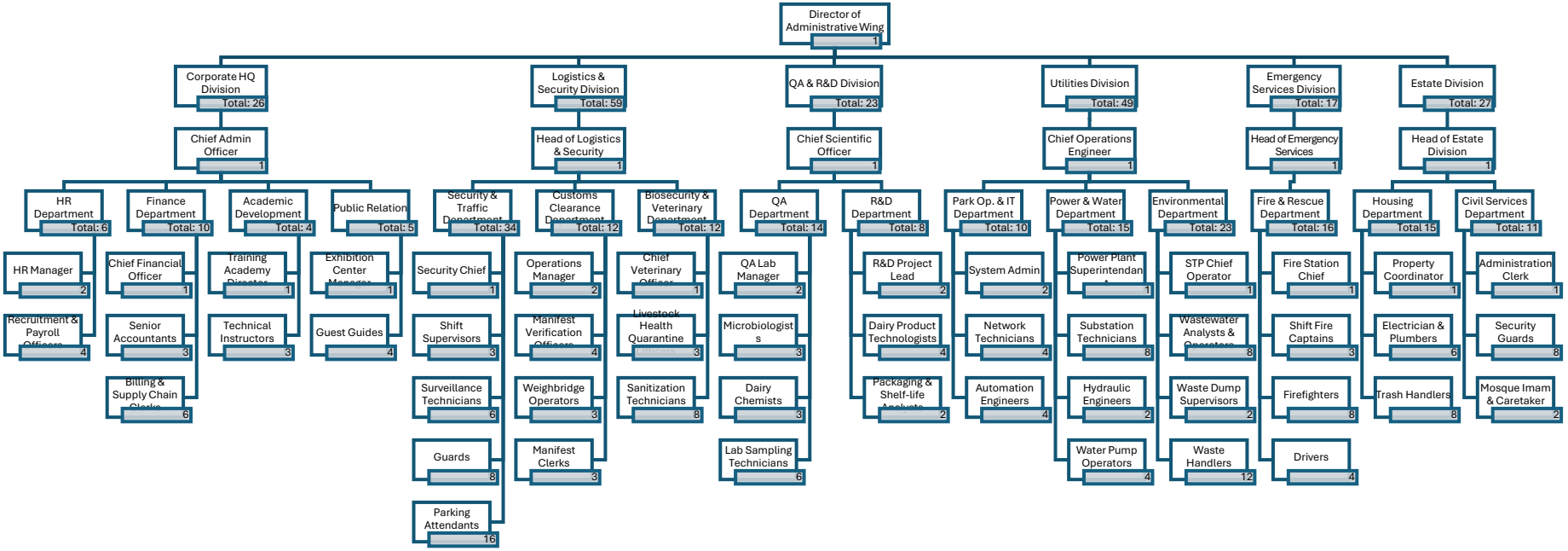


Figure 2 Organogram of the administrative wing

Organogram: Industrial Wing

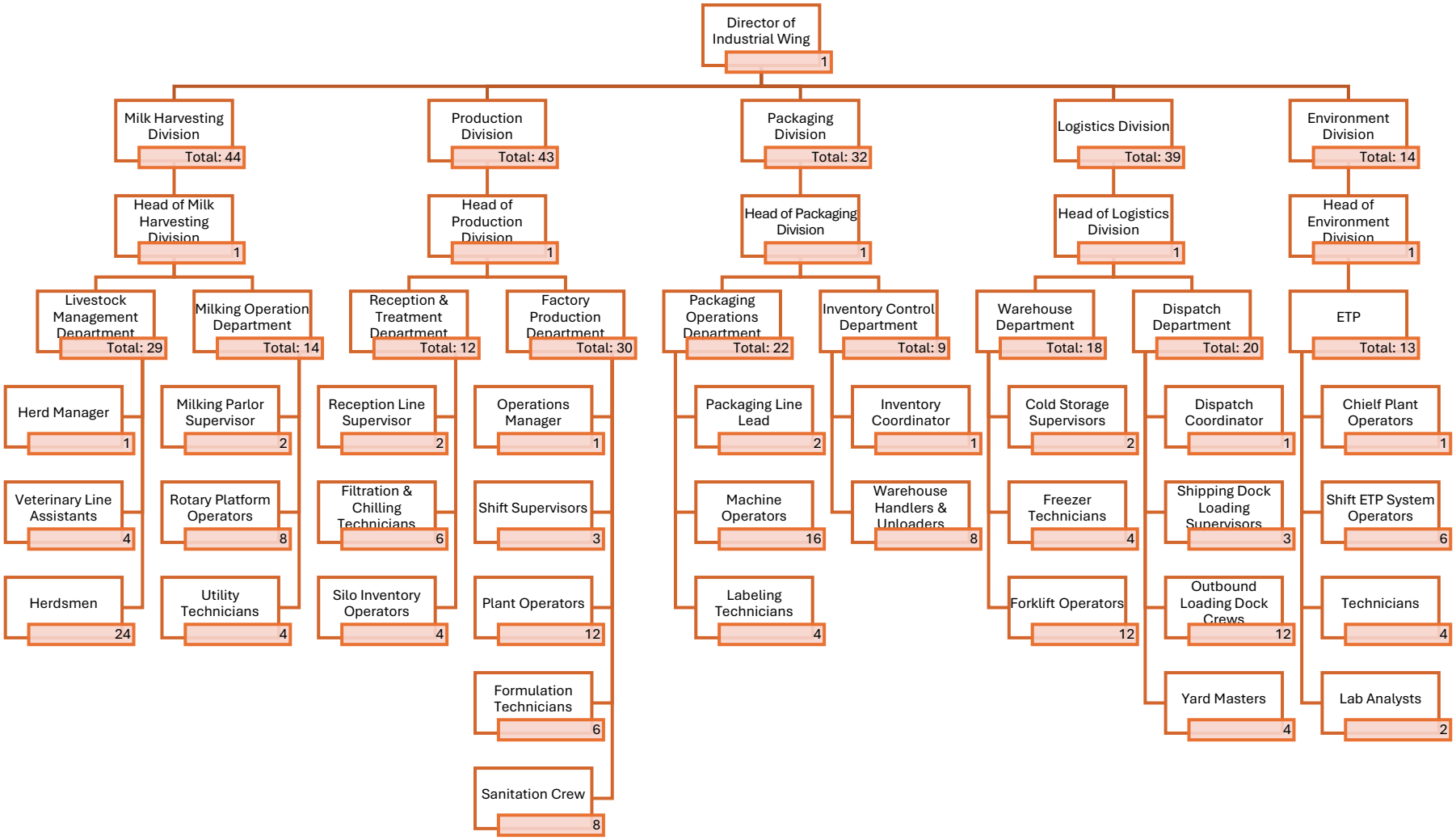


Figure 3 Organogram of the industrial wing

Organogram: Commercial Wing

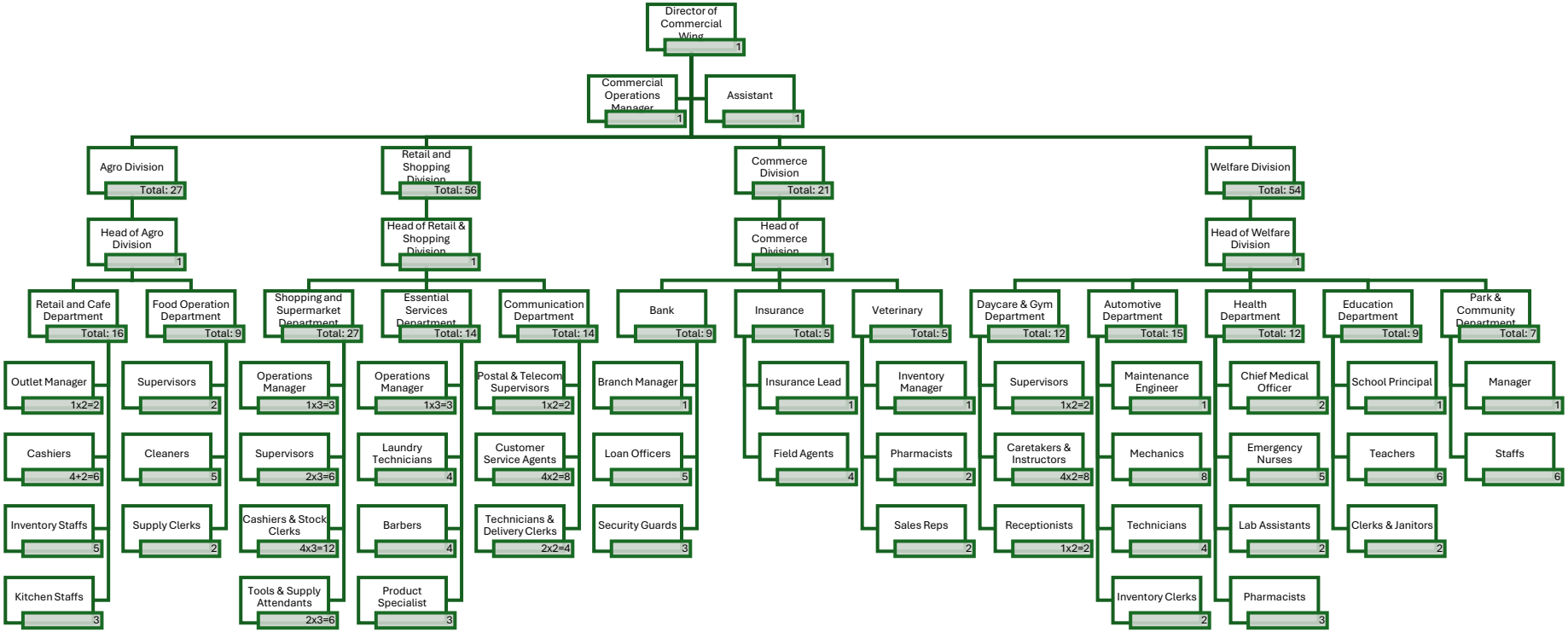


Figure 4 Organogram of the commercial wing

Organogram: Residential Wing

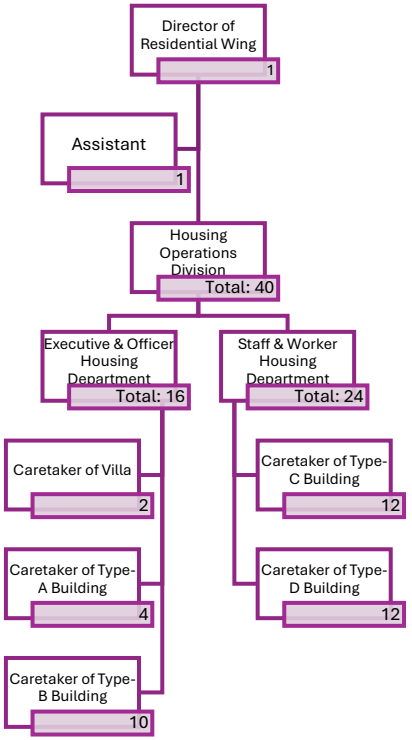


Figure 5 Organogram of the residential wing

Population Prediction

Introduction

This chapter presents the population estimation for a 90-acre dairy farm industrial park. It quantifies both present and future populations and will serve as the baseline for all subsequent engineering designs.

It maps the park's organizational hierarchy directly onto its physical layout. While the organogram outlines personnel down to the department level, this estimation disaggregates those numbers and distributes employees into individual buildings and facilities where they actively execute their shifts.

For the Residential wing, the calculation focuses strictly on the permanent on-site population. This includes:

1. Designated Residents: Occupants permanently residing in designated housing units (Villas and Types A through D).
2. Building Caretakers: Dedicated on-site staff (such as gatekeepers) assigned to each residential building (at least one per building) to manage access control, security, and routine maintenance.

Building Types

Category	Designation	Housing Allocation
Villa	Park Managing Director Director of total four wings Caretaker (two)	Executives Villa
A	Board Secretary Chief Legal Counsel Division Heads Divisional Chief Engineers/Officers Executive Assistant PR Officer Caretaker (one per building)	Type A Quarters
B	Chief Operators Department Leads Department Managers School Principal Superintendents System Administrator Training Academy Director Caretaker (one per building)	Type B Quarters
C	Administration Clerks Assistants Captains Commercial Operations Managers Coordinators Engineers Mosque Imam Officers Senior Accountants Supervisors Teachers Technical Staffs Caretaker (one per building)	Type C Quarters

Category	Designation	Housing Allocation
D	Analysts Assistants Attendants Barbers Caretakers Cashiers Chemists, biologists Clerks Crew Drivers Field Agents Firefighters Guides Handlers Herdsman Janitors Mechanics Nurses Operators Pharmacists Plumbers Product Specialists Receptionists Sales Reps Security Guards Staff Unloaders Yard Masters Caretaker (one per building)	Type D Quarters

Assumptions

Residential Wing:

Category	Family Members	Accommodation Provided (%)	Family Unit (%)	Bachelor Unit (%)	Employee Count	Household Population Growth Rate
Villa	8	100	100	0	7	1.0
A	5	80	80	20	23	1.0
B	5	60	60	40	47	1.2
C	6	60	50	50	150	1.4
D	6	50	40	60	357	1.5

Dorm Population:

Population Growth After 10 Years	Population Growth After 20 Years	Population Growth After 30 Years
30%	35%	40%

Administrative Wing:

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

Commercial Wing:

Population Growth After 10 Years	Population Growth After 20 Years	Population Growth After 30 Years
28%	33%	38%

Industrial Wing:

Population Growth After 10 Years	Population Growth After 20 Years	Population Growth After 30 Years
30%	35%	40%

Sample Calculation

Residential Zone

Type: Villa

- Present employee: 7
- Accommodation provided: 100% of 7 = 7
- Family unit: 100% of 7 = 7
- Bachelor unit: $7 - 7 = 0$
- Assumed family member: 8 people / family
- Total household population: $8 \times 7 = 56$
- Total dorm population: $1 \times 0 = 0$
- Household population growth rate: 1%
- Household population after 10 years: $56 \times \left(1 + \frac{1}{100}\right)^{10} = 62$
- Household population after 20 years: $56 \times \left(1 + \frac{1}{100}\right)^{20} = 69$
- Household population after 30 years: $56 \times \left(1 + \frac{1}{100}\right)^{30} = 76$
- Dorm population after 10 years: 30% growth; $1.30 \times 0 = 0$
- Dorm population after 20 years: 35% growth; $1.35 \times 0 = 0$
- Dorm population after 30 years: 40% growth; $1.40 \times 0 = 0$

Type: A

- Present employee: 23
- Accommodation provided: 100% of 23 = 23
- Family unit: 80% of 23 = 19
- Bachelor unit: $23 - 19 = 4$
- Assumed family member: 5 people / family
- Total household population: $5 \times 19 = 95$
- Total dorm population: $1 \times 4 = 4$
- Household population growth rate: 1%
- Household population after 10 years: $95 \times \left(1 + \frac{1}{100}\right)^{10} = 105$
- Household population after 20 years: $95 \times \left(1 + \frac{1}{100}\right)^{20} = 116$
- Household population after 30 years: $95 \times \left(1 + \frac{1}{100}\right)^{30} = 129$
- Dorm population after 10 years: 30% growth; $1.30 \times 4 = 6$
- Dorm population after 20 years: 35% growth; $1.35 \times 4 = 6$
- Dorm population after 30 years: 40% growth; $1.40 \times 4 = 6$

Type: B

- Present employee: 47
- Accommodation provided: 80% of 47 = 38
- Family unit: 60% of 38 = 23
- Bachelor unit: $38 - 23 = 15$
- Assumed family member: 5 people / family
- Total household population: $5 \times 23 = 115$
- Total dorm population: $1 \times 15 = 15$
- Household population growth rate: 1.2%
- Household population after 10 years: $115 \times \left(1 + \frac{1.2}{100}\right)^{10} = 130$
- Household population after 20 years: $115 \times \left(1 + \frac{1.2}{100}\right)^{20} = 146$
- Household population after 30 years: $115 \times \left(1 + \frac{1.2}{100}\right)^{30} = 165$
- Dorm population after 10 years: 30% growth; $1.30 \times 15 = 20$
- Dorm population after 20 years: 35% growth; $1.35 \times 15 = 21$
- Dorm population after 30 years: 40% growth; $1.40 \times 15 = 21$

Type: C

- Present employee: 150
- Accommodation provided: 60% of 150 = 90
- Family unit: 50% of 90 = 45
- Bachelor unit: $90 - 45 = 45$
- Assumed family member: 6 people / family
- Total household population: $6 \times 45 = 270$
- Total dorm population: $1 \times 45 = 45$
- Household population growth rate: 1.4%
- Household population after 10 years: $270 \times \left(1 + \frac{1.4}{100}\right)^{10} = 311$
- Household population after 20 years: $270 \times \left(1 + \frac{1.4}{100}\right)^{20} = 357$
- Household population after 30 years: $270 \times \left(1 + \frac{1.4}{100}\right)^{30} = 410$
- Dorm population after 10 years: 30% growth; $1.30 \times 45 = 59$
- Dorm population after 20 years: 35% growth; $1.35 \times 45 = 61$
- Dorm population after 30 years: 40% growth; $1.40 \times 45 = 63$

Type: D

- Present employee: 357
- Accommodation provided: 50% of 357 = 179
- Family unit: 40% of 179 = 72
- Bachelor unit: $179 - 72 = 107$
- Assumed family member: 6 people / family
- Total household population: $6 \times 72 = 432$
- Total dorm population: $1 \times 107 = 107$
- Household population growth rate: 1.5%
- Household population after 10 years: $432 \times \left(1 + \frac{1.5}{100}\right)^{10} = 502$
- Household population after 20 years: $432 \times \left(1 + \frac{1.5}{100}\right)^{20} = 582$
- Household population after 30 years: $432 \times \left(1 + \frac{1.5}{100}\right)^{30} = 676$
- Dorm population after 10 years: 30% growth; $1.30 \times 107 = 140$
- Dorm population after 20 years: 35% growth; $1.35 \times 107 = 145$
- Dorm population after 30 years: 40% growth; $1.40 \times 107 = 150$

Administrative Zone

Corporate HQ:

- Present population: 43
- Population after 10 years: 25% growth; $1.25 \times 43 = 54$
- Population after 20 years: 30% growth; $1.30 \times 43 = 56$
- Population after 30 years: 35% growth; $1.35 \times 43 = 59$

Commercial Zone

Retail & Café:

- Present population: 40
- Population after 10 years: 28% growth; $1.28 \times 40 = 52$
- Population after 20 years: 33% growth; $1.33 \times 40 = 54$
- Population after 30 years: 38% growth; $1.40 \times 40 = 56$

Industrial Zone

Truck Staging Yard:

- Present population: 17
- Population after 10 years: 30% growth; $1.30 \times 17 = 23$
- Population after 20 years: 35% growth; $1.35 \times 17 = 23$
- Population after 30 years: 40% growth; $1.40 \times 17 = 24$

Population: Residential Wing

Building / Facility	Corresponding Employees	Accommodation Provided (%)	Residential Employees	Family Count	Bachelor Count	People/Family*	Household Population Growth Rate (%)*	Household Population: Present	Household Population: In 10 Years**	Household Population: In 20 Years	Household Population: In 30 Years	Dorm Population: Present	Dorm Population: In 10 Years***	Dorm Population: In 20 Years***	Dorm Population: In 30 Years***
Villa	7	100	7	7	0	8	1	56	62	69	76	0	0	0	0
A	23	100	23	19	4	5	1	95	105	116	129	4	6	6	6
B	47	80	38	23	15	5	1.2	115	130	146	165	15	20	21	21
C	150	60	90	45	45	6	1.4	270	311	357	410	45	59	61	63
D	357	50	179	72	107	6	1.5	432	502	582	676	107	140	145	150
Total	**584**							**968**	**1110**	**1270**	**1456**	**171**	**225**	**233**	**240**

* Assumed

** $FutureHouseholdPopulation = PresentHouseholdPopulation \times \left(1 + \frac{GrowthRate}{100}\right)^{n}$; where, n is number of years.

*** $FutureDormPopulation = PresentDormPopulation \times \left(1 + \frac{GrowthInNYears}{100}\right)$

Population: Administrative Wing

Facility / Building	Population: Present	Population: In 10 Years**	Population: In 20 Years**	Population: In 30 Years**	Remarks
Security Checkpoint	2	3	3	3	Security & Traffic Wing
Inspection Bay	4	5	6	6	Security & Traffic Wing
CMS	12	15	16	17	Security & Traffic Wing
Logistics & Customs Office	12	15	16	17	Custom Clearance Wing
Veterinary Office	12	15	16	17	Biosecurity & Veterinary Wing
Parking Lot	16	20	21	22	Security & Traffic Wing
Exhibition Center*	150	188	195	203	Public Relation
Corporate HQ	53	67	69	72	Offices of governance body, wing directors, divisional heads, HR and finance department
Park Op. Center	5	7	7	7	Park Op. & IT Department
IT Center	5	7	7	7	Park Op. & IT Department
R&D Facility	8	10	11	11	R&D Department
QA Office	14	18	19	19	QA Department
Fire Station	16	20	21	22	Fire & Rescue Wing
Water Pump Station	6	8	8	9	Power & Water Department
Power Plant	9	12	12	13	Power & Water Department
Training Academy*	40	50	52	54	Academic Development

Facility / Building	Population: Present	Population: In 10 Years**	Population: In 20 Years**	Population: In 30 Years**	Remarks
Central Mosque*	400	500	520	540	Civil Services Department
Residential Estate Office	15	19	20	21	Housing Department
Solid Waste Dump	14	18	19	19	Environmental Department
Sewage Treatment Plant	9	12	12	13	Environmental Department
Total	**802**	**1009**	**1050**	**1092**	

* Assumed accounting for non-permanent personnels.

** $FuturePopulation = PresentPopulation \times \left(1 + \frac{Growth}{100}\right)$; where, $Growth$ is assumed total population increases (in %) over the given years.

Population: Commercial Wing

Facility / Body	Population: Present	Population: In 10 Years**	Population: In 20 Years**	Population: In 30 Years**	Remarks
Retail & Café*	40	52	54	56	Retail & Café Department
Food Court*	50	64	67	69	Food Operation Department
Shopping Complex*	42	54	56	58	Shopping and Supermarket Department
Supermarket*	38	49	51	53	Shopping and Supermarket Department
Hardware Store	4	6	6	6	Essential Services Department
Salon	5	7	7	7	Essential Services Department
Laundry	5	7	7	7	Essential Services Department
Telecom Center	7	9	10	10	Communication Department
Postal Services	7	9	10	10	Communication Department
Bank*	50	64	67	69	Bank
Insurance Corporate Office	5	7	7	7	Insurance
Veterinary Medicine*	15	20	20	21	Veterinary

Facility / Body	Population: Present	Population: In 10 Years**	Population: In 20 Years**	Population: In 30 Years**	Remarks
Daycare Center*	22	29	30	31	Daycare & Gym Department
Gym*	37	48	50	52	Daycare & Gym Department
Autoshop & Truck Servicing Center	15	20	20	21	Automotive Department
Central Park & Sports Field*	120	154	160	166	Park & Community Department
Community Center*	129	166	172	179	Park & Community Department
School*	200	256	266	276	Education Department
Pharmacy	3	4	4	5	Health Department
Health Clinic*	98	126	131	136	Health Department
Total	**892**	**1151**	**1195**	**1239**	

* Assumed accounting for non-permanent personnels.

** $FuturePopulation = PresentPopulation \times \left(1 + \frac{Growth}{100}\right)$; where, $Growth$ is assumed total population increases (in %) over the given years.

Population: Industrial Wing

Facility / Body	Population: Present	Population: In 10 Years*	Population: In 20 Years*	Population: In 30 Years*	Remarks
Cow Barn A	15	20	21	21	Livestock Management Department
Cow Barn B	15	20	21	21	Livestock Management Department
Milking Rotary	10	13	14	14	Milking Operation Department
Milking Center Utilities	4	6	6	6	Milking Operation Department
Chilling & Filtration Block	7	10	10	10	Reception & Treatment Department
Raw Milk Silos	5	7	7	7	Reception & Treatment Department
Processing Core	30	39	41	42	Factory Production Department
Packaging Station	22	29	30	31	Packaging Operations Department
Bottle Inventory	9	12	13	13	Inventory Control Department
Cold Storage Warehouse	18	24	25	26	Warehouse Department
Shipping Docks	4	6	6	6	Dispatch Department
Truck Staging Yard	17	23	23	24	Dispatch Department

Facility / Body	Population: Present	Population: In 10 Years*	Population: In 20 Years*	Population: In 30 Years*	Remarks
Effluent Treatment Plant	13	17	18	19	ETP
Total	**169**	**226**	**235**	**240**	

* $FuturePopulation = PresentPopulation \times \left(1 + \frac{Growth}{100}\right)$; where, $Growth$ is assumed total population increases (in %) over the given years.

Summary of Population Prediction

Wing	Population: Present	Population: In 10 Years	Population: In 20 Years	Population: In 30 Years
Residential	1139	1335	1503	1696
Villa	56	62	69	76
Type A	99	111	122	135
Type B	130	150	167	186
Type C	315	370	418	473
Type D	539	642	727	826
Administrative	802	1009	1050	1092
Commercial	892	1151	1195	1239
Industrial	169	226	235	240
Total	**3002**	**3721**	**3983**	**4267**

Estimate Water Demand

Assumptions

Wing	Peak Factor
Residential Wing	2.5
Administrative Wing	2 to 4
Commercial Wing	2 to 4
Industrial Wing	2.1
Fire Fighting	1

Industrial production:

- Milk production per day: $180{,}000$ L/day
- Milk production by average cow: 25 L/day
- Total cows: $180{,}000/25 = 7{,}200$ Nos.
- Water requirement for a cow: 115 L/day
- Time factor: $24/24 = 1$
- Peak factor: 2.1

Firefighting:

- Diameter of nozzle of hydrant: 3 in
- Velocity: 3 fps
- Flow duration: 30 minutes
- Fire incidents occurrence: once a day
- Active Hydrants at once: 2 Nos.

Methodology

All wings have water demand for personal consumption. However, the industrial wing additionally has water demand for production purposes.

For personal consumption:

1. Current and future population is obtained from "Estimate Population" report.
2. Water requirement per capita is obtained from BNBC 2020 (Appendix A-1, Appendix A-2, Appendix A-3).
3. The following formula is used for estimating water demand:

$$Demand = Population \times LPCD \times TimeFactor$$

4. Peak water demand is obtained by multiplying the previously obtained water demand with peak factor.

For production purposes:

1. Milk production per day is given.
2. Milk production per day for an average cow is assumed.
3. Daily water consumption by an average is assumed.
4. By using data from step 2 and 3, we can get the amount of water required per liter of milk production.
5. Daily water demand is calculated by multiplying that with total milk production per day.
6. Peak water demand is obtained by multiplying the previously obtained water demand with peak factor.

In addition to the above, water demand for firefighting is also estimated.

For firefighting purposes:

1. Firefighting water demand remains constant across time.
2. Fire hydrants' nozzle size, velocity, flow duration, number of incidents per day, and number of fire hydrants are assumed.
3. Flow of water per hydrant is determined by multiplying area with velocity.
4. Water demand for each hydrant is determined by multiplying flow with duration.
5. Total water demand is obtained by multiplying that with number of fire hydrants.

Sample Calculation

Residential Wing

Type: Villa

- Type of occupancy: A1
- Per capita consumption (lpcd): 260
- Time factor: 24/24 = 1
- Peak factor: 2.5
- Present population: 56
- Present water demand: $56 \times 260 \times 1 = 14{,}560\ L$
- Present peak water demand: $14{,}560 \times 2.5 = 36{,}400\ L$
- Population after 10 years: 62
- Water demand after 10 years: $62 \times 260 \times 1 = 16{,}120\ L$
- Peak water demand after 10 years: $16{,}120 \times 2.5 = 40{,}300\ L$
- Population after 20 years: 69
- Water demand after 20 years: $69 \times 260 \times 1 = 17{,}940\ L$
- Peak water demand after 20 years: $17{,}940 \times 2.5 = 44{,}850\ L$
- Population after 30 years: 76
- Water demand after 30 years: $76 \times 260 \times 1 = 19{,}760\ L$
- Peak water demand after 30 years: $19{,}760 \times 2.5 = 49{,}400\ L$

Administrative Wing

Corporate HQ:

- Type of occupancy: E1: Offices
- Per capita consumption (lpcd): 45
- Time factor: 24/8 = 3
- Peak factor: 2.5
- Present population: 53
- Present water demand: $53 \times 45 \times 3 = 7{,}155\ L$
- Present peak water demand: $7{,}155 \times 2.5 = 17{,}888\ L$
- Population after 10 years: 67
- Water demand after 10 years: $67 \times 45 \times 3 = 9{,}045\ L$
- Peak water demand after 10 years: $9{,}045 \times 2.5 = 22{,}613\ L$
- Population after 20 years: 69
- Water demand after 20 years: $69 \times 45 \times 3 = 9{,}315\ L$
- Peak water demand after 20 years: $9{,}315 \times 2.5 = 23{,}288\ L$
- Population after 30 years: 72
- Water demand after 30 years: $72 \times 45 \times 3 = 9{,}720\ L$
- Peak water demand after 30 years: $9{,}720 \times 2.5 = 24{,}300$

Commercial Wing

Food Court:

- Type of occupancy: F1: Small Shops & Market
- Per capita consumption (lpcd): 45
- Time factor: 24/12 = 2
- Peak factor: 3.5
- Present population: 50
- Present water demand: $50 \times 45 \times 2 = 4{,}500\ L$
- Present peak water demand: $4{,}500 \times 3.5 = 15{,}750\ L$
- Population after 10 years: 64
- Water demand after 10 years: $64 \times 45 \times 2 = 5{,}760\ L$
- Peak water demand after 10 years: $5{,}760 \times 3.5 = 20{,}160\ L$
- Population after 20 years: 67
- Water demand after 20 years: $67 \times 45 \times 2 = 6{,}030\ L$
- Peak water demand after 20 years: $6{,}030 \times 3.5 = 21{,}105\ L$
- Population after 30 years: 69
- Water demand after 30 years: $69 \times 45 \times 2 = 6{,}210\ L$
- Peak water demand after 30 years: $6{,}210 \times 2.5 = 21{,}735$

Industrial Wing (Personal)

Processing Core:

- Type of occupancy: G1: Low Hazard Industries
- Per capita consumption (lpcd): 40
- Time factor: 24/16 = 1.5
- Peak factor: 2.1
- Present population: 30
- Present water demand: $30 \times 40 \times 1.5 = 1{,}800\ L$
- Present peak water demand: $1{,}800 \times 2.1 = 3{,}780\ L$
- Population after 10 years: 39
- Water demand after 10 years: $39 \times 40 \times 1.5 = 2{,}340\ L$
- Peak water demand after 10 years: $2{,}340 \times 2.1 = 4{,}914\ L$
- Population after 20 years: 41
- Water demand after 20 years: $41 \times 40 \times 1.5 = 2{,}460\ L$
- Peak water demand after 20 years: $2{,}460 \times 2.1 = 5{,}166\ L$
- Population after 30 years: 42
- Water demand after 30 years: $42 \times 40 \times 1.5 = 2{,}520\ L$
- Peak water demand after 30 years: $2{,}520 \times 2.1 = 5{,}292$

Industrial Wing (Production)

- Milk production per day: 180,000 L/d
- Milk production by an avg cow: 30 L/d
- Water consumption by an avg cow: 115 L/d
- Water required per liter of milk: $\frac{115}{30} \approx 4\ L/L$
- Time factor: 1
- Preset water demand: $4 \times 180{,}000 = 720{,}000\ L/d$
- Present peak water demand: $720{,}000 \times 2.1 = 1{,}512{,}000\ L/d$
- Water demand after 10 years: 25% growth; $1.25 \times 720{,}000 = 900{,}000\ L/d$
- Peak water demand after 10 years: $2.1 \times 900{,}000 = 1{,}890{,}000\ L/d$
- Water demand after 20 years: 30% growth; $1.30 \times 720{,}000 = 936{,}000\ L/d$
- Peak water demand after 20 years: $2.1 \times 936{,}000 = 1{,}965{,}600\ L/d$
- Water demand after 30 years: 35% growth; $1.35 \times 720{,}000 = 972{,}000\ L/d$
- Peak water demand after 30 years: $2.1 \times 972{,}000 = 2{,}041{,}200\ L/d$

Firefighting Demand

- Nozzle diameter: 3 in
- Velocity: 3 fps
- Flow duration: 30 minutes
- Number of hydrants: 2
- Flow through one hydrant: $Q = AV = \frac{\pi \times (3/12)^2}{4} \times 3 = 0.1473\ f^3/s$
- Volume of water per hydrant: $Q \times t = 0.1473 \times 30 \times 60 = 265.14\ ft^3$
- Total volume of water: $265.14 \times 2 = 530.28\ ft^3 = 15{,}016\ L$

Water Demand: Residential Wing

Building	Occupancy Type	Per Capita Consumption (lpcd)	Time Factor	Water Demand: Present (lpd)	Peak Water Demand: Present (lpd)	Water Demand: In 10 Years (lpd)	Peak Water Demand: In 10 Years (lpd)	Water Demand: In 20 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Water Demand: In 30 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Villa	A1	260	1	14,560	36,400	16,120	40,300	17,940	44,850	19,760	49,400
A	A3	200	1	19,800	49,500	22,200	55,500	24,400	61,000	27,000	67,500
B	y1	180	1	23,400	58,500	27,000	67,500	30,060	75,150	33,480	83,700
C	y2	120	1	37,800	94,500	44,400	111,000	50,160	125,400	56,760	141,900
D	z1	80	1	43,120	107,800	51,360	128,400	58,160	145,400	66,080	165,200
Total				**138,680**	**346,700**	**161,080**	**402,700**	**180,720**	**451,800**	**203,080**	**507,700**

Water Demand: Administrative Wing

Facility / Building	Occupancy Type	Per Capita Consumption (lpcd)	Time Factor	Peak Factor	Water Demand: Present (lpd)	Peak Water Demand: Present (lpd)	Water Demand: In 10 Years (lpd)	Peak Water Demand: In 10 Years (lpd)	Water Demand: In 20 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Water Demand: In 30 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Security Checkpoint	E1: Offices	45	1	2	90	180	135	270	135	270	135	270
Inspection Bay	K3: Repair Garage	15	2	2	120	240	150	300	180	360	180	360
CMS	G1: Low Hazard Industries	40	3	2.5	1,440	3,600	1,800	4,500	1,920	4,800	2,040	5,100
Logistics & Customs Office	E1: Offices	45	3	2.5	1,620	4,050	2,025	5,063	2,160	5,400	2,295	5,738
Veterinary Office	E2: Research & Testing Laboratories	70	3	2	2,520	5,040	3,150	6,300	3,360	6,720	3,570	7,140
Parking Lot	K1: Parking Garage	15	1.5	2.5	360	900	450	1,125	473	1,181	495	1,238

Facility / Building	Occupancy Type	Per Capita Consumption (lpcd)	Time Factor	Peak Factor	Water Demand: Present (lpd)	Peak Water Demand: Present (lpd)	Water Demand: In 10 Years (lpd)	Peak Water Demand: In 10 Years (lpd)	Water Demand: In 20 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Water Demand: In 30 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Exhibition Center	I4: Small Assembly without Fixed Seats	15	3	3	6,750	20,250	8,460	25,380	8,775	26,325	9,135	27,405
Corporate HQ	E1: Offices	45	3	2.5	7,155	17,888	9,045	22,613	9,315	23,288	9,720	24,300
Park Op. Center	E1: Offices	45	1	2	225	450	315	630	315	630	315	630
IT Center	E3: Essential Services	70	1	1.5	350	525	490	735	490	735	490	735
R&D Facility	E2: Research & Testing Laboratories	70	3	2	1,680	3,360	2,100	4,200	2,310	4,620	2,310	4,620
QA Office	E2: Research & Testing Laboratories	70	1	2	980	1,960	1,260	2,520	1,330	2,660	1,330	2,660
Fire Station	E3: Essential Services	70	1	2	1,120	2,240	1,400	2,800	1,470	2,940	1,540	3,080

Facility / Building	Occupancy Type	Per Capita Consumption (lpcd)	Time Factor	Peak Factor	Water Demand: Present (lpd)	Peak Water Demand: Present (lpd)	Water Demand: In 10 Years (lpd)	Peak Water Demand: In 10 Years (lpd)	Water Demand: In 20 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Water Demand: In 30 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Water Pump Station	L: Utility	10	1	1.5	60	90	80	120	80	120	90	135
Power Plant	G1: Low Hazard Industries	40	1	1.5	360	540	480	720	480	720	520	780
Training Academy	B2: Facilities for Training	100	3	3	12,000	36,000	15,000	45,000	15,600	46,800	16,200	48,600
Central Mosque	I3: Large Assembly without Fixed Seats	15	6	4	36,000	144,000	45,000	180,000	46,800	187,200	48,600	194,400
Residential Estate Office	E1: Offices	45	3	2.5	2,025	5,063	2,565	6,413	2,700	6,750	2,835	7,088
Solid Waste Dump	L: Utility	10	3	2	420	840	540	1,080	570	1,140	570	1,140

Facility / Building	Occupancy Type	Per Capita Consumption (lpcd)	Time Factor	Peak Factor	Water Demand: Present (lpd)	Peak Water Demand: Present (lpd)	Water Demand: In 10 Years (lpd)	Peak Water Demand: In 10 Years (lpd)	Water Demand: In 20 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Water Demand: In 30 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Sewage Treatment Plant	L: Utility	10	1	1.5	90	135	120	180	120	180	130	195
Total					**75,365**	**247,350**	**94,565**	**309,948**	**98,583**	**322,839**	**102,500**	**335,613**

Water Demand: Industrial Wing

Facility / Building	Occupancy Type	Per Capita Consumption (lpcd)	Time Factor	Peak Factor	Water Demand: Present (lpd)	Peak Water Demand: Present (lpd)	Water Demand: In 10 Years (lpd)	Peak Water Demand: In 10 Years (lpd)	Water Demand: In 20 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Water Demand: In 30 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Cow Barn A	G1: Low Hazard Industries	40	1	2.1	600	1,260	800	1,680	840	1,764	840	1,764
Cow Barn B	G1: Low Hazard Industries	40	1	2.1	600	1,260	800	1,680	840	1,764	840	1,764
Milking Rotary	G1: Low Hazard Industries	40	1.33	2.1	532	1,117	692	1,452	745	1,564	745	1,564
Milking Center Utilities	L: Utility	10	1	2.1	40	84	60	126	60	126	60	126
Chilling & Filtration Block	G1: Low Hazard Industries	40	1	2.1	280	588	400	840	400	840	400	840
Raw Milk Silos	H1: Low Fire Risk Storage	10	1	2.1	50	105	70	147	70	147	70	147
Processing Core	G1: Low Hazard Industries	40	1.5	2.1	1,800	3,780	2,340	4,914	2,460	5,166	2,520	5,292

Facility / Building	Occupancy Type	Per Capita Consumption (lpcd)	Time Factor	Peak Factor	Water Demand: Present (lpd)	Peak Water Demand: Present (lpd)	Water Demand: In 10 Years (lpd)	Peak Water Demand: In 10 Years (lpd)	Water Demand: In 20 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Water Demand: In 30 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Packaging Station	G1: Low Hazard Industries	40	1.5	2.1	1,320	2,772	1,740	3,654	1,800	3,780	1,860	3,906
Bottle Inventory	H1: Low Fire Risk Storage	10	2	2.1	180	378	240	504	260	546	260	546
Cold Storage Warehouse	H1: Low Fire Risk Storage	10	1	2.1	180	378	240	504	250	525	260	546
Shipping Docks	H1: Low Fire Risk Storage	10	1.5	2.1	60	126	90	189	90	189	90	189
Truck Staging Yard	K1: Parking Garage	15	1	2.1	255	536	345	725	345	725	360	756
Effluent Treatment Plant	L: Utility	10	1	2.1	130	273	170	357	180	378	190	399
Total					**6,027**	**12,657**	**7,987**	**16,772**	**8,340**	**17,514**	**8,495**	**17,839**

Water Demand: Commercial Wing

Facility / Building	Occupancy Type	Per Capita Consumption (lpcd)	Time Factor	Peak Factor	Water Demand: Present (lpd)	Peak Water Demand: Present (lpd)	Water Demand: In 10 Years (lpd)	Peak Water Demand: In 10 Years (lpd)	Water Demand: In 20 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Water Demand: In 30 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Dairy Retail Outlet & Café	F1: Small Shops & Market	45	2	3	3,600	10,800	4,680	14,040	4,860	14,580	5,040	15,120
Food Court	F1: Small Shops & Market	45	2	3.5	4,500	15,750	5,760	20,160	6,030	21,105	6,210	21,735
Shopping Complex	F2: Large Shops & Market	45	2	2.5	3,780	9,450	4,860	12,150	5,040	12,600	5,220	13,050
Supermarket	F2: Large Shops & Market	45	2	2.5	3,420	8,550	4,410	11,025	4,590	11,475	4,770	11,925
Hardware Store	E3: Essential Services	70	1	2	280	560	420	840	420	840	420	840

Facility / Building	Occupancy Type	Per Capita Consumption (lpcd)	Time Factor	Peak Factor	Water Demand: Present (lpd)	Peak Water Demand: Present (lpd)	Water Demand: In 10 Years (lpd)	Peak Water Demand: In 10 Years (lpd)	Water Demand: In 20 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Water Demand: In 30 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Salon	E3: Essential Services	70	1	2	350	700	490	980	490	980	490	980
Laundry	E3: Essential Services	70	1	2	350	700	490	980	490	980	490	980
Telecom Center	E1: Offices	45	2.4	2.5	756	1,890	972	2,430	1,080	2,700	1,080	2,700
Postal Services	E1: Offices	45	2.4	2.5	756	1,890	972	2,430	1,080	2,700	1,080	2,700
Bank	E1: Offices	45	3	2.5	6,750	16,875	8,640	21,600	9,045	22,613	9,315	23,288
Insurance Corporate Office	E1: Offices	45	3	2	675	1,350	945	1,890	945	1,890	945	1,890
Veterinary Medicine	E2: Research & Testing Laboratories	70	2.4	2	2,520	5,040	3,360	6,720	3,360	6,720	3,528	7,056

Facility / Building	Occupancy Type	Per Capita Consumption (lpcd)	Time Factor	Peak Factor	Water Demand: Present (lpd)	Peak Water Demand: Present (lpd)	Water Demand: In 10 Years (lpd)	Peak Water Demand: In 10 Years (lpd)	Water Demand: In 20 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Water Demand: In 30 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Daycare Center	B3: Pre-School Facilities	50	2.4	3	2,640	7,920	3,480	10,440	3,600	10,800	3,720	11,160
Gym	B3: Pre-School Facilities	50	2.4	3	4,440	13,320	5,760	17,280	6,000	18,000	6,240	18,720
Autoshop & Truck Servicing Center	K3: Repair Garage	15	2.4	2	540	1,080	720	1,440	720	1,440	756	1,512
Central Park & Sports Field	I4: Small Assembly without Fixed Seats	15	2	3	3,600	10,800	4,620	13,860	4,800	14,400	4,980	14,940
Community Center	I4: Small Assembly without Fixed Seats	15	2	3	3,870	11,610	4,980	14,940	5,160	15,480	5,370	16,110

Facility / Building	Occupancy Type	Per Capita Consumption (lpcd)	Time Factor	Peak Factor	Water Demand: Present (lpd)	Peak Water Demand: Present (lpd)	Water Demand: In 10 Years (lpd)	Peak Water Demand: In 10 Years (lpd)	Water Demand: In 20 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Water Demand: In 30 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
School	B1: Educational (Up to Higher Secondary)	70	3.43	3.5	48,020	168,070	61,466	215,130	63,867	223,533	66,268	231,937
Pharmacy	F2: Large Shops & Market	45	2	2.5	270	675	360	900	360	900	450	1,125
Health Clinic	D2: Emergency Medical Facilities	300	1	2.5	29,400	73,500	37,800	94,500	39,300	98,250	40,800	102,000
Total					**120,517**	**360,530**	**155,185**	**463,735**	**161,237**	**481,986**	**167,172**	**499,767**

Summary of Water Demand Prediction

Wing	Water Demand: Present	Peak Water Demand: Present	Water Demand: In 10 Years	Peak Water Demand: In 10 Years	Water Demand: In 20 Years	Peak Water Demand: In 20 Years	Water Demand: In 30 Years	Peak Water Demand: In 30 Years
Residential	138,680	346,700	161,080	402,700	180,720	451,800	203,080	507,700
Administrative	75,365	247,350	94,565	309,948	98,583	322,839	102,500	335,613
Industrial	726,027	1,524,657	907,987	1,906,772	944,340	1,983,114	980,495	2,059,039
Personal	6,027	12,657	7,987	16,772	8,340	17,514	8,495	17,839
Production	720,000	1,512,000	900,000	1,890,000	936,000	1,965,600	972,000	2,041,200
Commercial	120,517	360,530	155,185	463,735	161,237	481,986	167,172	499,767
Firefighting	15,016	15,016	15,016	15,016	15,016	15,016	15,016	15,016
Total	**1,075,605**	**2,494,253**	**1,333,833**	**3,098,171**	**1,399,896**	**3,254,755**	**1,468,263**	**3,417,135**

Development of Water Source

The following steps were followed in developing the water source of our Dairy Farm Industrial Park:

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

Grain Size Analysis

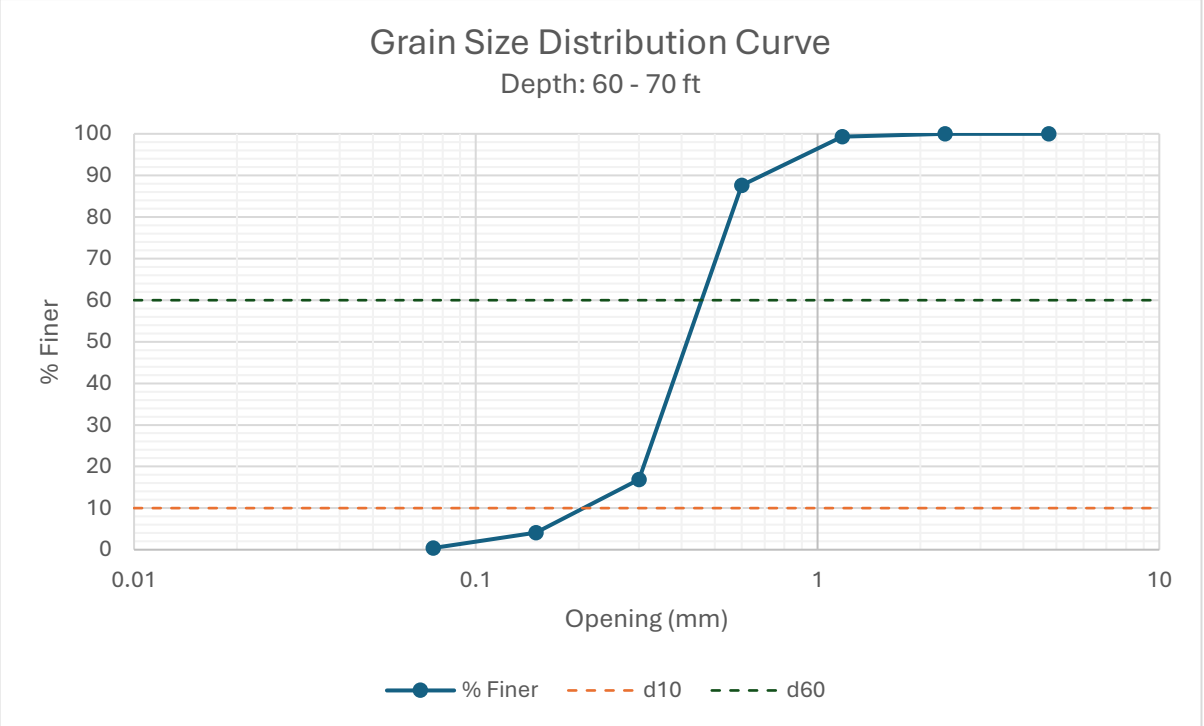
The analyses of grain size distribution were performed on spreadsheet, and their output is attached to this report. The following characteristics were determined:

- Fineness Modulus: (Cumulative % retained on standard sieve sizes) / 100
- D_{10}, D_{30}, D_{60}: Size representing 10%, 30%, and 60% finer particles on particular soil strata. Log-linear interpolation was performed (through the equation $y = m \log x + c$) to produce these values.
- Uniformity coefficient: D_{60}/D_{10}.
- MIT Classification: Percentage of fine, medium, and coarse sand were computed through log-linear interpolation.

Sieve Size Analysis: Depth 60-70 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	521.2	0	0.00	0.00	100.00
16	1.18	489.3	490	0.7	0.70	0.70	99.30
30	0.6	461.3	473	11.7	11.70	12.40	87.60
50	0.3	411.5	482.2	70.7	70.70	83.10	16.90
100	0.15	393.2	406	12.8	12.80	95.90	4.10
200	0.075	385.3	389	3.7	3.70	99.60	0.40
Pan		328.6	329	0.4	0.40	100.00	0.00
Total				**100**			

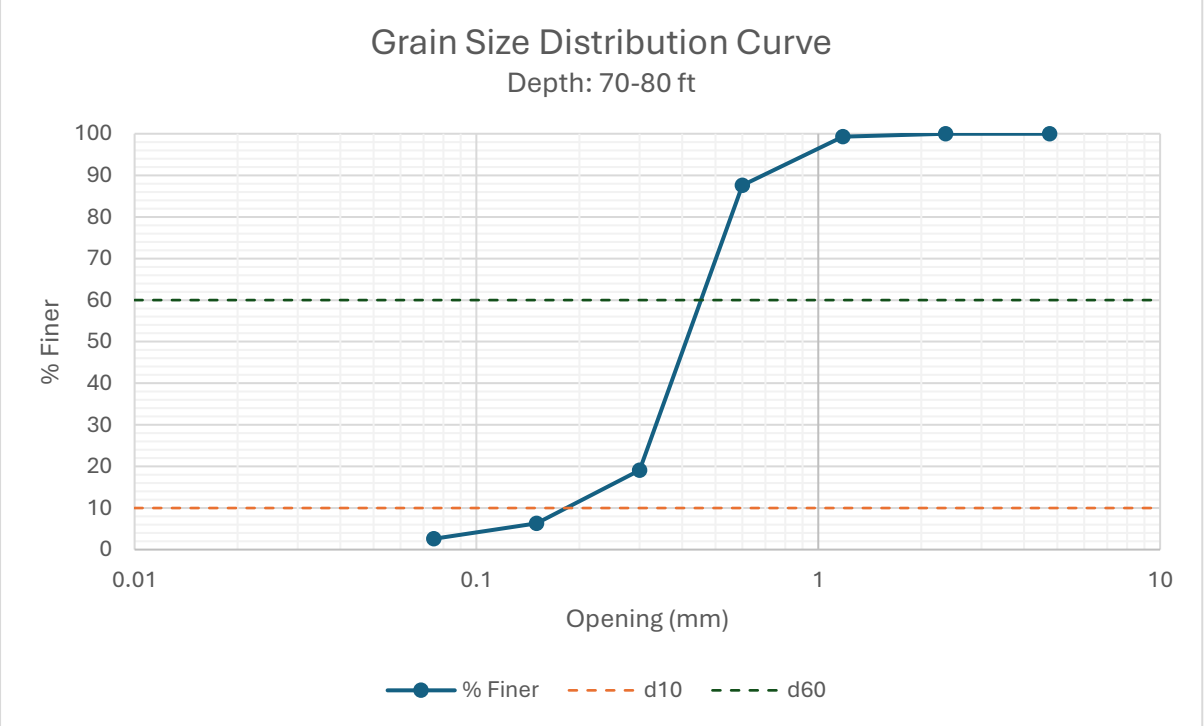
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.21	0.34	0.46	2.22	1.92	12.23	78.19	9.01



Sieve Size Analysis: Depth 70-80 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	521.2	0	0.00	0.00	100.00
16	1.18	489.3	490	0.7	0.70	0.70	99.30
30	0.6	461.3	473	11.7	11.70	12.40	87.60
50	0.3	411.5	480	68.5	68.50	80.90	19.10
100	0.15	393.2	406	12.8	12.80	93.70	6.30
200	0.075	385.3	389	3.7	3.70	97.40	2.60
Pan		328.6	331.2	2.6	2.60	100.00	0.00
Total				**100**			

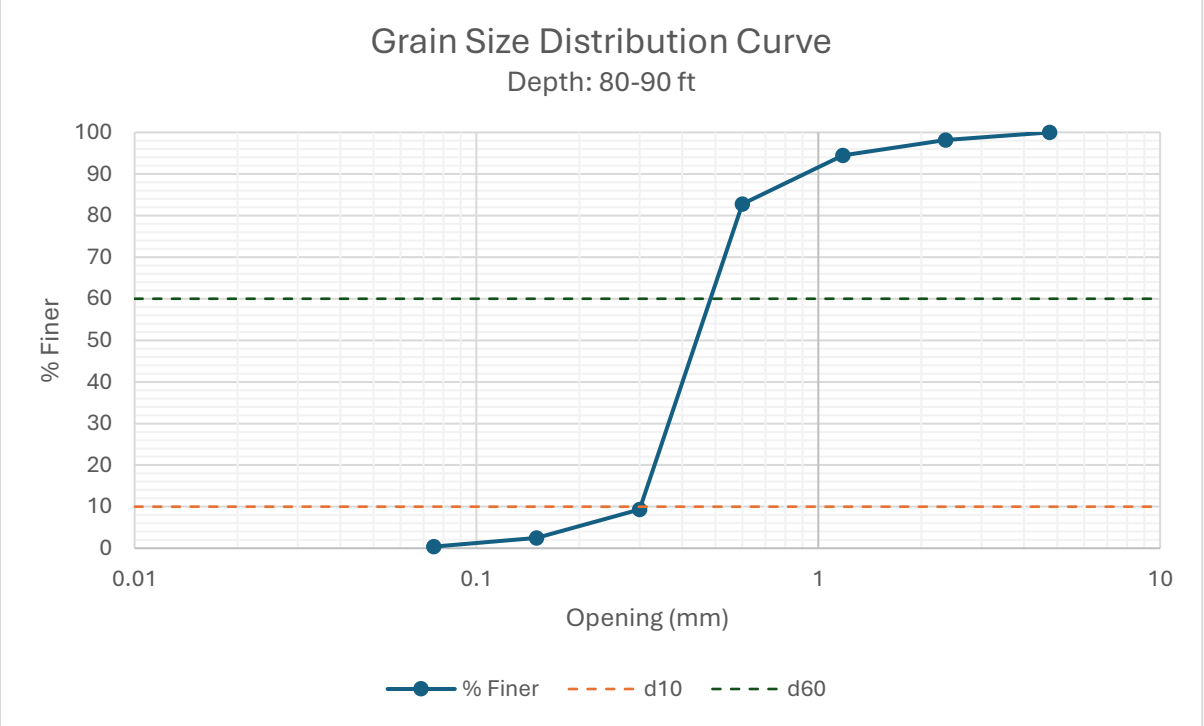
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.18	0.33	0.45	2.48	1.88	12.23	75.99	9.01



Sieve Size Analysis: Depth 80-90 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	523	1.8	1.80	1.80	98.20
16	1.18	489.3	493	3.7	3.70	5.5	94.50
30	0.6	461.3	473	11.7	11.70	17.20	82.80
50	0.3	411.5	485	73.5	73.50	90.70	9.30
100	0.15	393.2	400	6.8	6.80	97.50	2.50
200	0.075	385.3	387.4	2.1	2.10	99.60	0.40
Pan		328.6	329	0.4	0.40	100.00	0.00
Total				**100**			

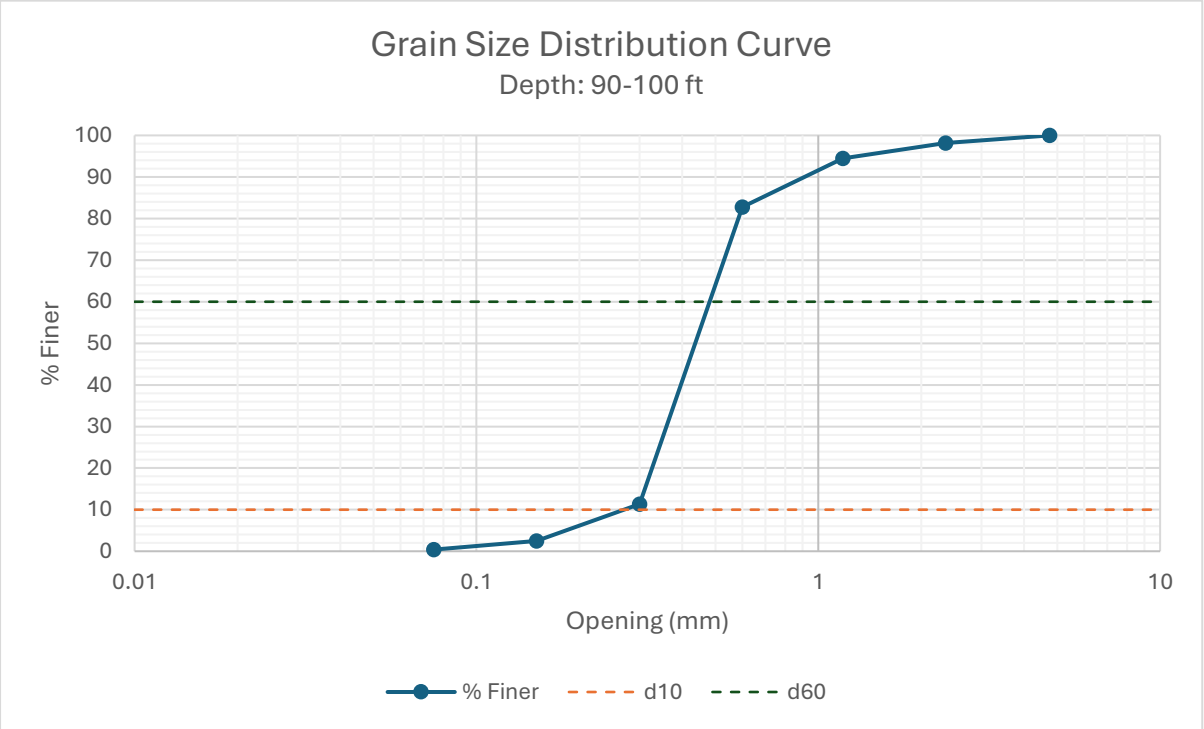
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.30	0.36	0.48	1.60	2.13	14.52	77.48	4.92



Sieve Size Analysis: Depth 90-100 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	523	1.8	1.80	1.80	98.20
16	1.18	489.3	493	3.7	3.70	5.50	94.50
30	0.6	461.3	473	11.7	11.70	17.20	82.80
50	0.3	411.5	483	71.5	71.50	88.70	11.30
100	0.15	393.2	402	8.8	8.80	97.50	2.50
200	0.075	385.3	387.4	2.1	2.10	99.60	0.40
Pan		328.6	329	0.4	0.40	100.00	0.00
Total				**100**			

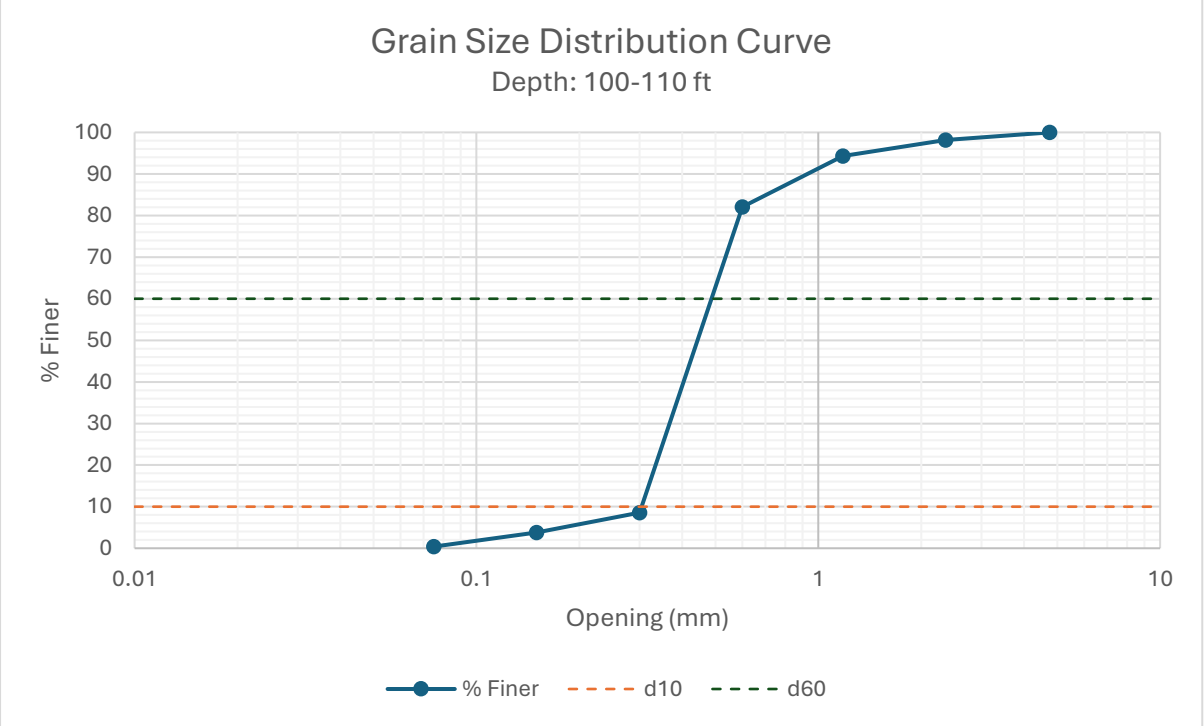
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.27	0.36	0.48	1.78	2.11	14.52	76.65	5.75



Sieve Size Analysis: Depth 100-110 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	523	1.8	1.80	1.80	98.20
16	1.18	489.3	493.2	3.9	3.90	5.70	94.30
30	0.6	461.3	473.5	12.2	12.20	17.90	82.10
50	0.3	411.5	485	73.5	73.50	91.40	8.60
100	0.15	393.2	398	4.8	4.80	96.20	3.80
200	0.075	385.3	388.7	3.4	3.40	99.60	0.40
Pan		328.6	329	0.4	0.40	100.00	0.00
Total				**100**			

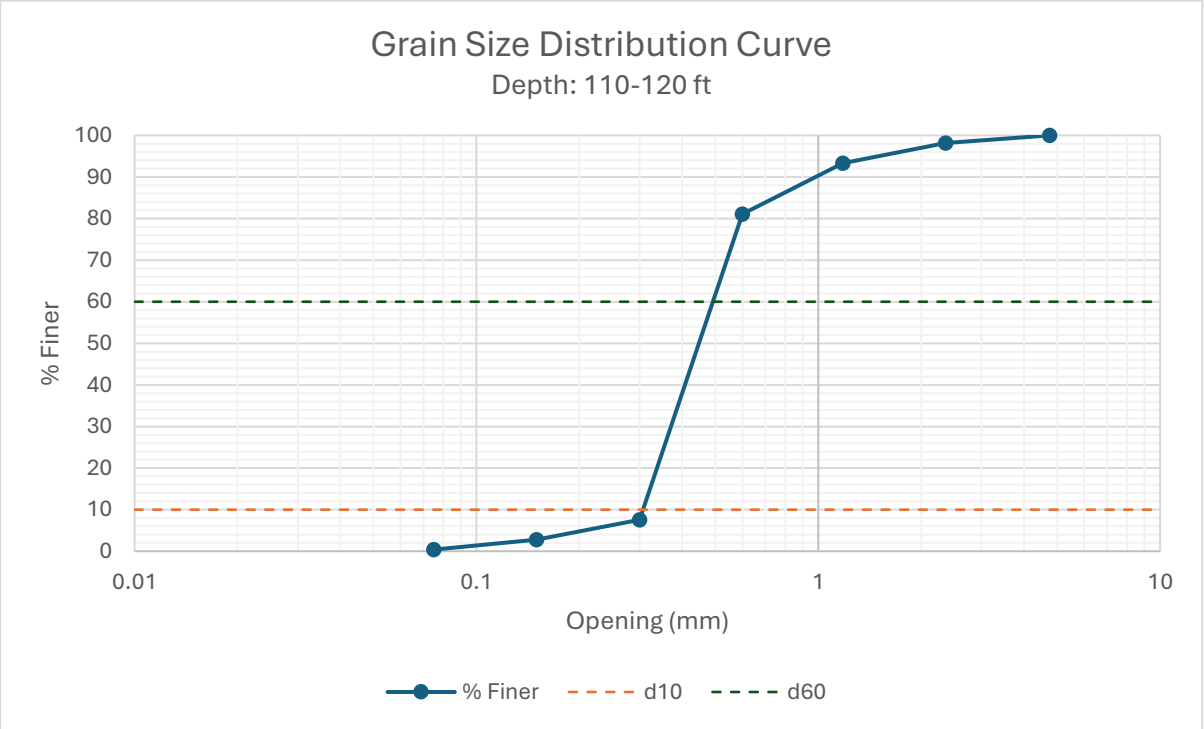
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.30	0.37	0.49	1.60	2.13	15.17	76.31	5.39



Sieve Size Analysis: Depth 110-120 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	523	1.8	1.80	1.80	98.20
16	1.18	489.3	494.2	4.9	4.90	6.70	93.30
30	0.6	461.3	473.5	12.2	12.20	18.90	81.10
50	0.3	411.5	485	73.5	73.50	92.40	7.60
100	0.15	393.2	398	4.8	4.80	97.20	2.80
200	0.075	385.3	387.7	2.4	2.40	99.60	0.40
Pan		328.6	329	0.4	0.40	100.00	0.00
Total				**100**			

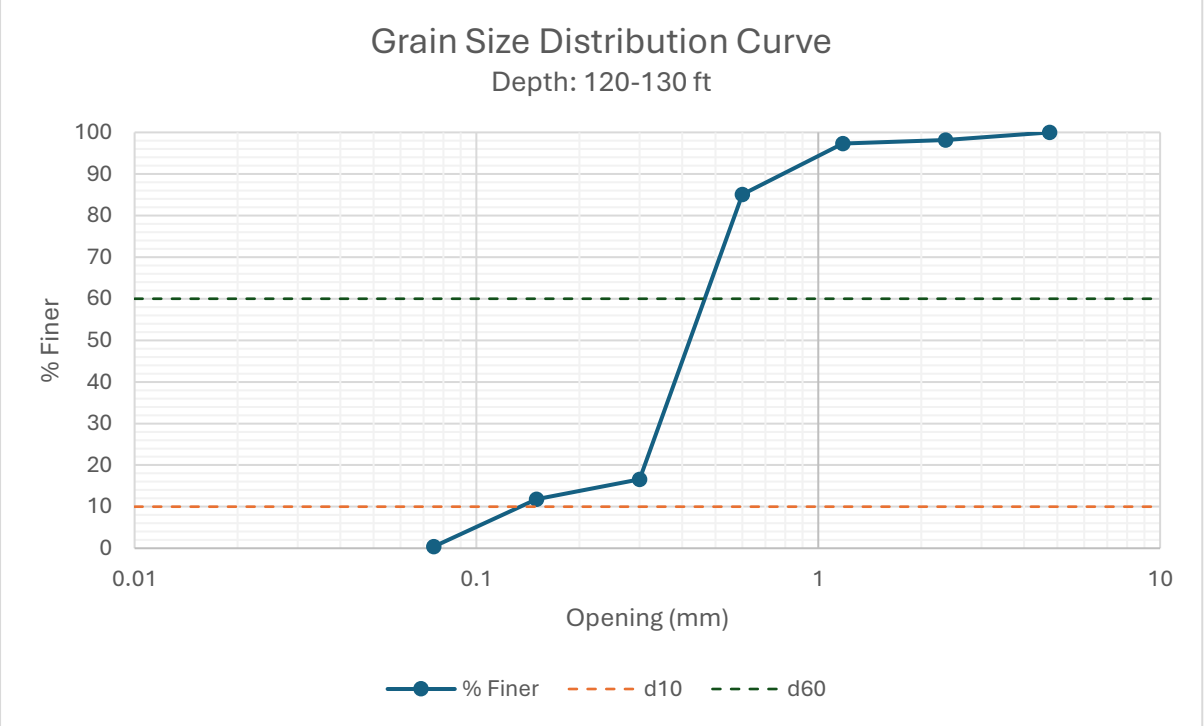
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.31	0.37	0.49	1.60	2.17	15.93	76.31	4.39



Sieve Size Analysis: Depth 120-130 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	523	1.8	1.80	1.80	98.20
16	1.18	489.3	490.2	0.9	0.90	2.70	97.30
30	0.6	461.3	473.5	12.2	12.20	14.90	85.10
50	0.3	411.5	480	68.5	68.50	83.40	16.60
100	0.15	393.2	398	4.8	4.80	88.20	11.80
200	0.075	385.3	396.7	11.4	11.40	99.60	0.40
Pan		328.6	329	0.4	0.40	100.00	0.00
Total				**100**			

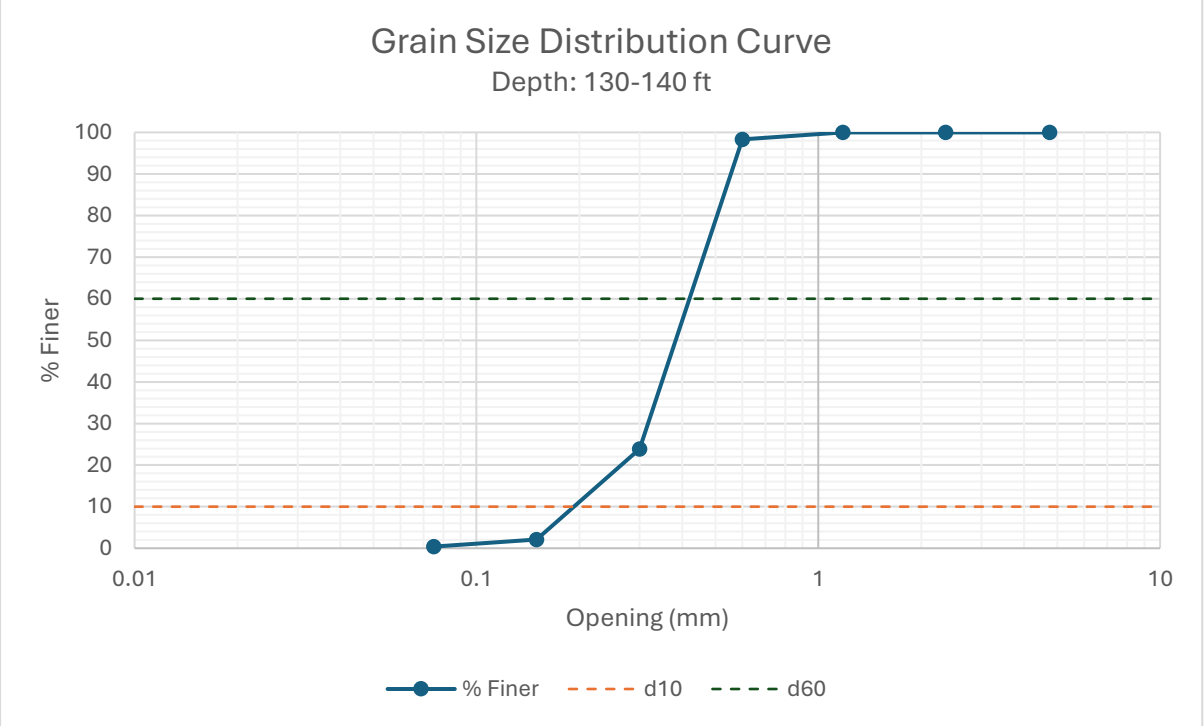
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.13	0.34	0.47	3.46	1.91	12.89	71.31	13.39



Sieve Size Analysis: Depth 130-140 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	521.2	0	0.00	0.00	100.00
16	1.18	489.3	489.3	0	0.00	0.00	100.00
30	0.6	461.3	463	1.7	1.70	1.70	98.30
50	0.3	411.5	485.9	74.4	74.40	76.10	23.90
100	0.15	393.2	415	21.8	21.80	97.90	2.10
200	0.075	385.3	387	1.7	1.70	99.60	0.40
Pan		328.6	329	0.4	0.40	100.00	0.00
Total				**100**			

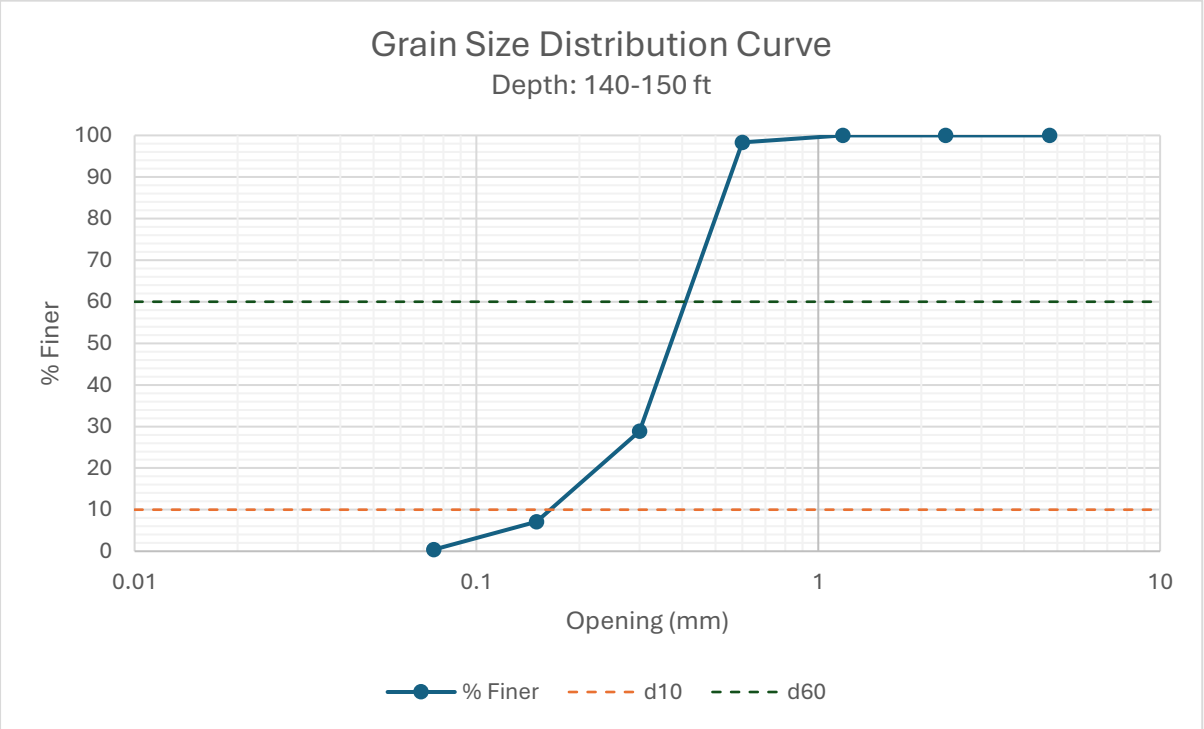
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.19	0.32	0.42	2.18	1.76	1.70	87.15	10.75



Sieve Size Analysis: Depth 140-150 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	521.2	0	0.00	0.00	100.00
16	1.18	489.3	489.3	0	0.00	0.00	100.00
30	0.6	461.3	463	1.7	1.70	1.70	98.30
50	0.3	411.5	480.9	69.4	69.40	71.10	28.90
100	0.15	393.2	415	21.8	21.80	92.90	7.10
200	0.075	385.3	392	6.7	6.70	99.60	0.40
Pan		328.6	329	0.4	0.40	100.00	0.00
Total				**100**			

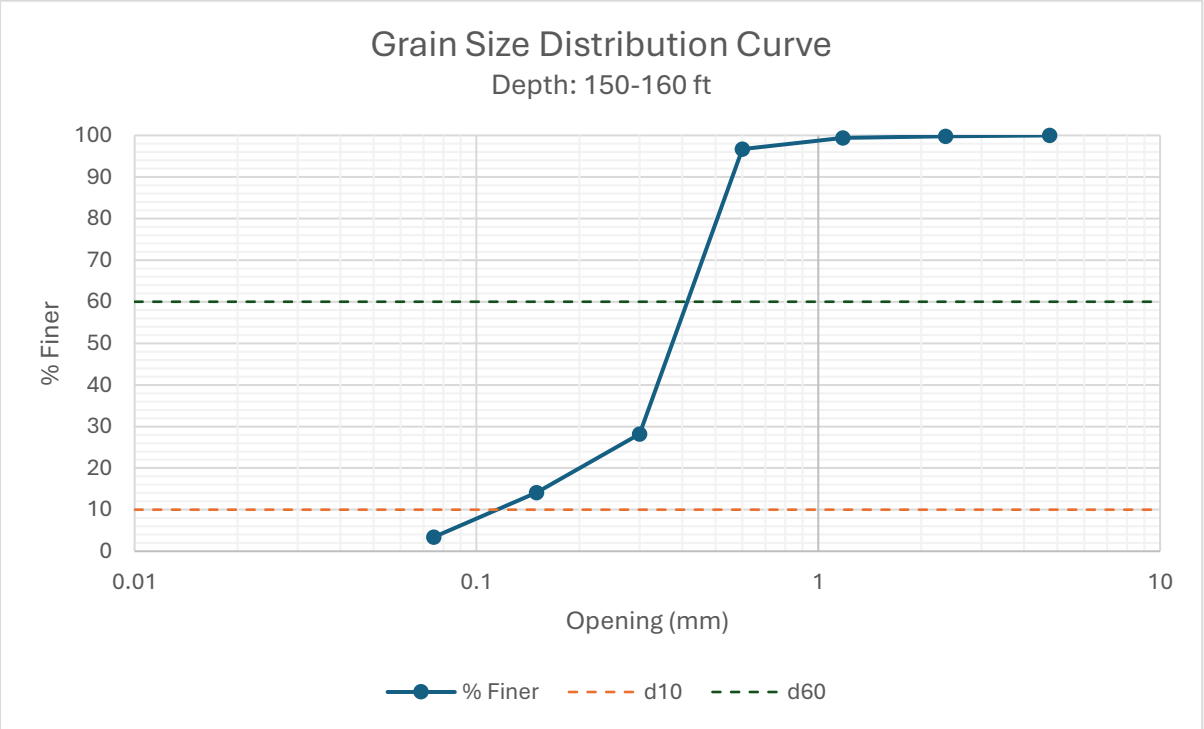
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.16	0.30	0.41	2.49	1.66	1.70	82.15	15.75



Sieve Size Analysis: Depth 150-160 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	521.4	0.2	0.20	0.20	99.80
16	1.18	489.3	489.7	0.4	0.40	0.60	99.40
30	0.6	461.3	464	2.7	2.70	3.30	96.70
50	0.3	411.5	480	68.5	68.50	71.80	28.20
100	0.15	393.2	407.3	14.1	14.10	85.90	14.10
200	0.075	385.3	396	10.7	10.70	96.60	3.40
Pan		328.6	332	3.4	3.40	100.00	0.00
Total				**100**			

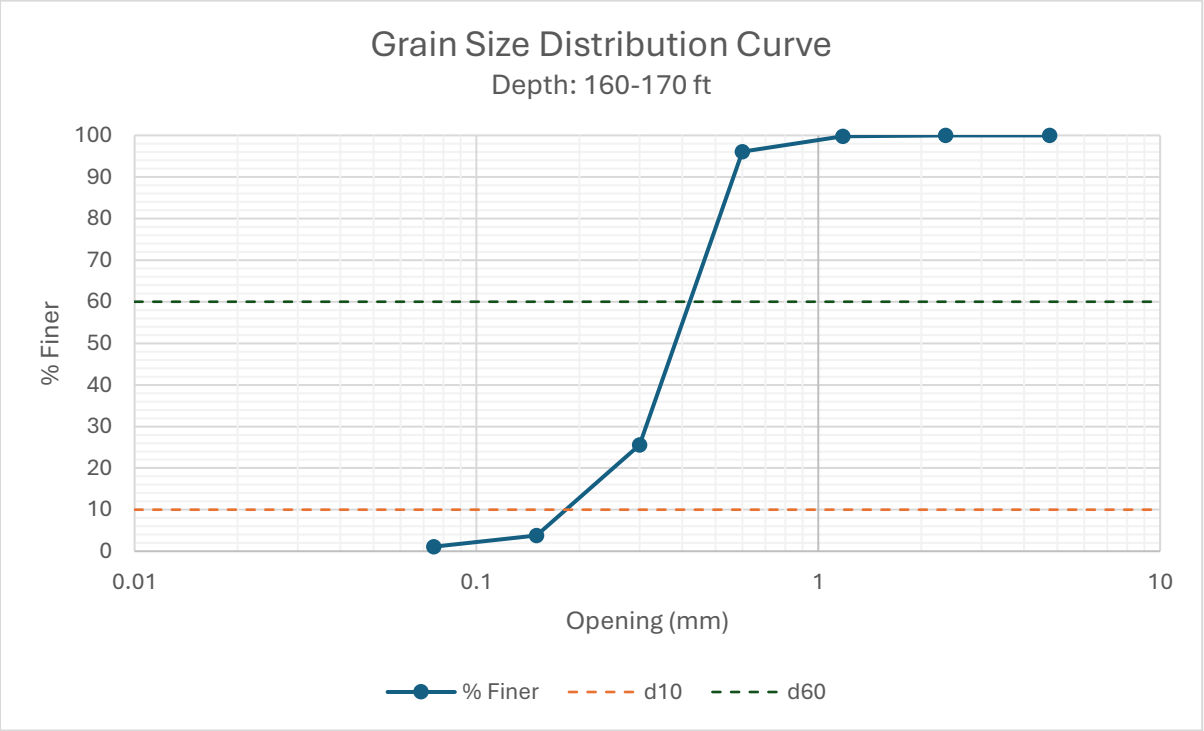
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.12	0.31	0.41	3.60	1.62	3.00	76.75	16.55



Sieve Size Analysis: Depth 160-170 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	521.2	0	0.00	0.00	100.00
16	1.18	489.3	489.5	0.2	0.20	0.20	99.80
30	0.6	461.3	465	3.7	3.70	3.90	96.10
50	0.3	411.5	482	70.5	70.50	74.40	25.60
100	0.15	393.2	415	21.8	21.80	96.20	3.80
200	0.075	385.3	388	2.7	2.70	98.90	1.10
Pan		328.6	329.7	1.1	1.10	100.00	0.00
Total				**100**			

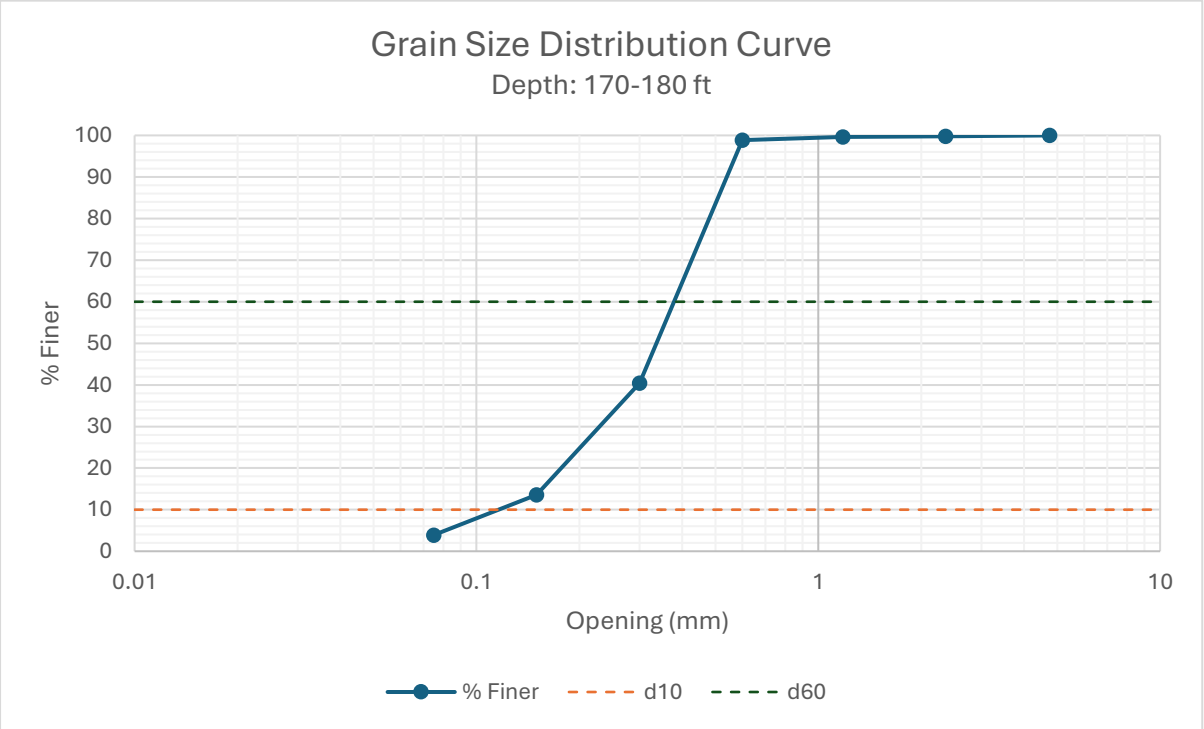
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.18	0.31	0.42	2.30	1.75	3.85	83.25	11.75



Sieve Size Analysis: Depth 170-180 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	521.4	0.2	0.20	0.20	99.80
16	1.18	489.3	489.5	0.2	0.20	0.40	99.60
30	0.6	461.3	462	0.7	0.70	1.10	98.90
50	0.3	411.5	470	58.5	58.50	59.60	40.40
100	0.15	393.2	420	26.8	26.80	86.40	13.60
200	0.075	385.3	395	9.7	9.70	96.10	3.90
Pan		328.6	332.5	3.9	3.90	100.00	0.00
Total				**100**			

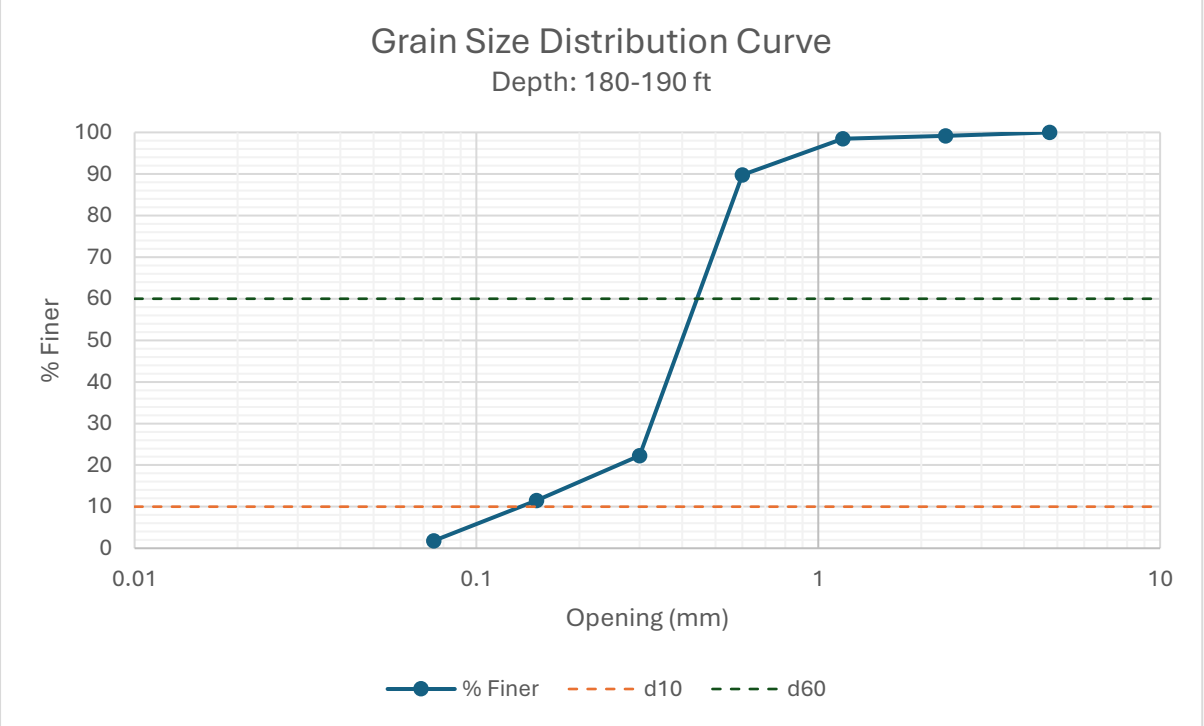
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.12	0.23	0.38	3.26	1.48	0.85	74.18	20.82



Sieve Size Analysis: Depth 180-190 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	522	0.8	0.80	0.80	99.20
16	1.18	489.3	490	0.7	0.70	1.50	98.50
30	0.6	461.3	470	8.7	8.70	10.20	89.80
50	0.3	411.5	479	67.5	67.50	77.70	22.30
100	0.15	393.2	404	10.8	10.80	88.50	11.50
200	0.075	385.3	395	9.7	9.70	98.20	1.80
Pan		328.6	330.4	1.8	1.80	100.00	0.00
Total				**100**			

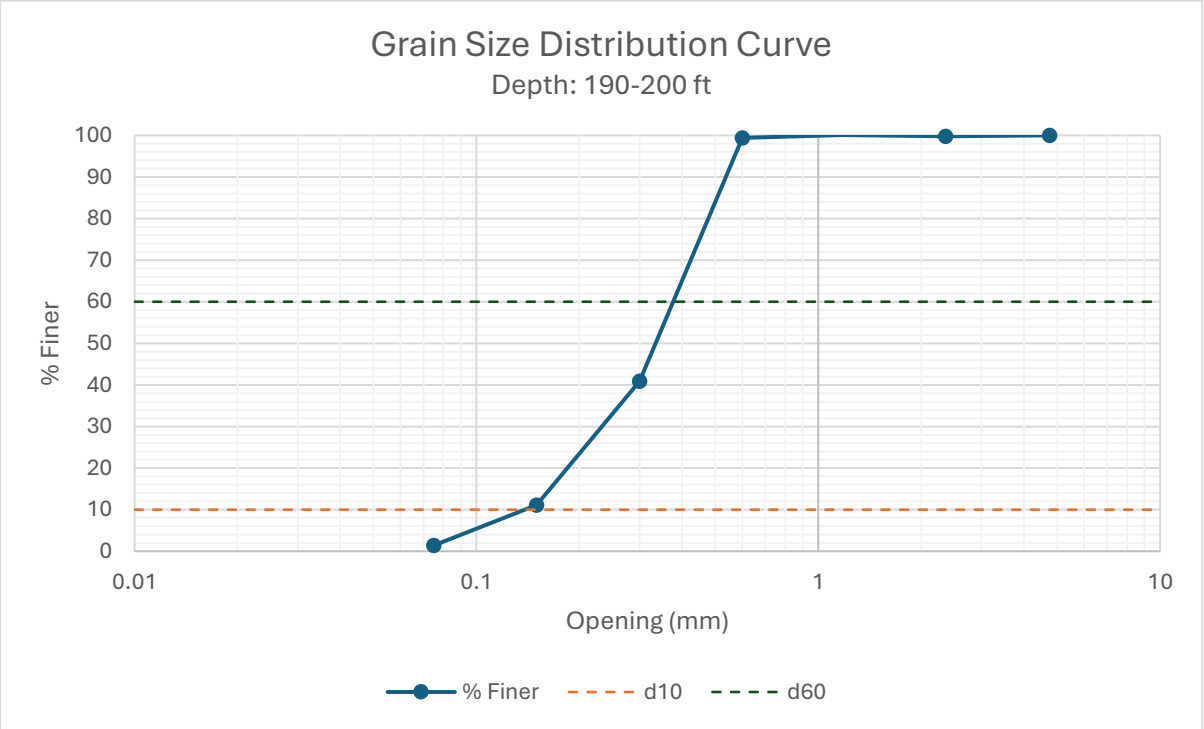
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.13	0.32	0.44	3.28	1.79	9.23	73.82	14.18



Sieve Size Analysis: Depth 190-200 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	521.4	0.2	0.20	0.20	99.80
16	1.18	489.3	489	-0.3	-0.30	-0.10	100.10
30	0.6	461.3	462	0.7	0.70	0.60	99.40
50	0.3	411.5	470	58.5	58.50	59.10	40.90
100	0.15	393.2	423	29.8	29.80	88.90	11.10
200	0.075	385.3	395	9.7	9.70	98.60	1.40
Pan		328.6	330	1.4	1.40	100.00	0.00
Total				**100**			

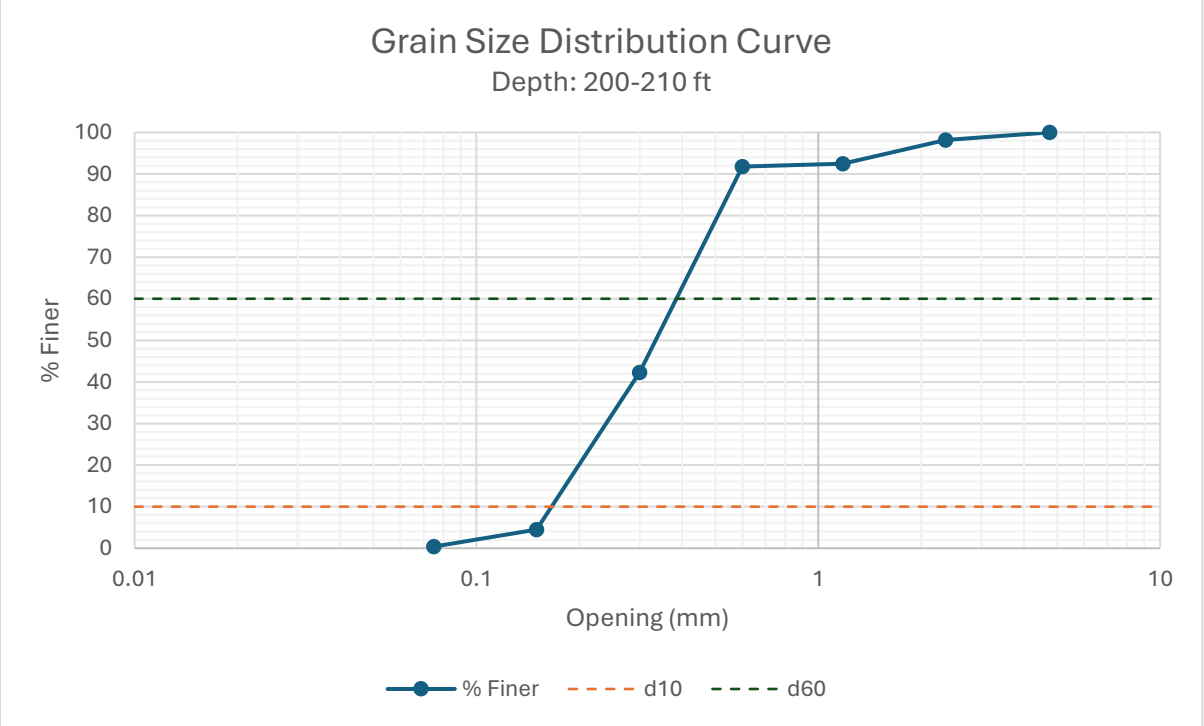
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.14	0.23	0.38	2.71	1.49	0.47	75.93	22.07



Sieve Size Analysis: Depth 200-210 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	523	1.8	1.80	1.80	98.20
16	1.18	489.3	495	5.7	5.70	7.50	92.50
30	0.6	461.3	462	0.7	0.70	8.20	91.80
50	0.3	411.5	461	49.5	49.50	57.70	42.30
100	0.15	393.2	431	37.8	37.80	95.50	4.50
200	0.075	385.3	389.4	4.1	4.10	99.60	0.40
Pan		328.6	329	0.4	0.40	100.00	0.00
Total				**100**			

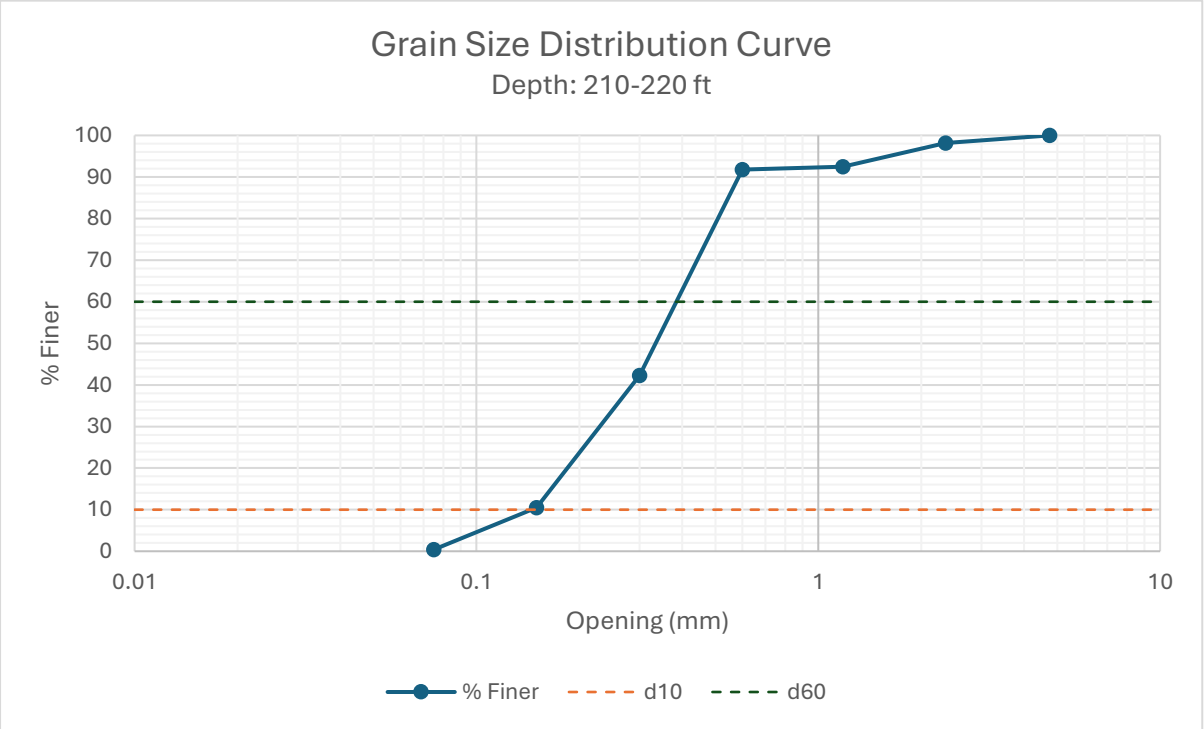
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.17	0.24	0.38	2.32	1.71	5.04	71.61	19.79



Sieve Size Analysis: Depth 210-220 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	523	1.8	1.80	1.80	98.20
16	1.18	489.3	495	5.7	5.70	7.50	92.50
30	0.6	461.3	462	0.7	0.70	8.20	91.80
50	0.3	411.5	461	49.5	49.50	57.70	42.30
100	0.15	393.2	425	31.8	31.80	89.50	10.50
200	0.075	385.3	395.4	10.1	10.10	99.60	0.40
Pan		328.6	329	0.4	0.40	100.00	0.00
Total				**100**			

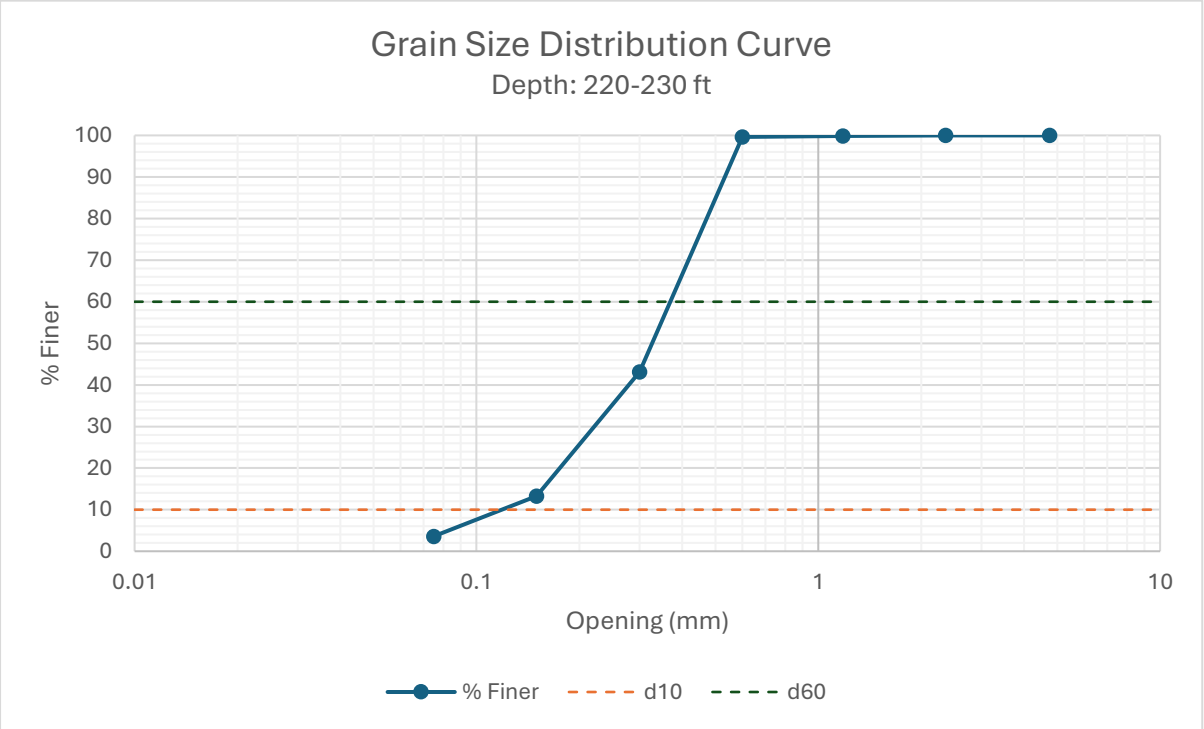
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.14	0.23	0.38	2.65	1.65	5.04	68.10	23.30



Sieve Size Analysis: Depth 220-230 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	521.2	0	0.00	0.00	100.00
16	1.18	489.3	489.4	0.1	0.10	0.10	99.90
30	0.6	461.3	461.6	0.3	0.30	0.40	99.60
50	0.3	411.5	468	56.5	56.50	56.90	43.10
100	0.15	393.2	423	29.8	29.80	86.70	13.30
200	0.075	385.3	395	9.7	9.70	96.40	3.60
Pan		328.6	332.2	3.6	3.60	100.00	0.00
Total				**100**			

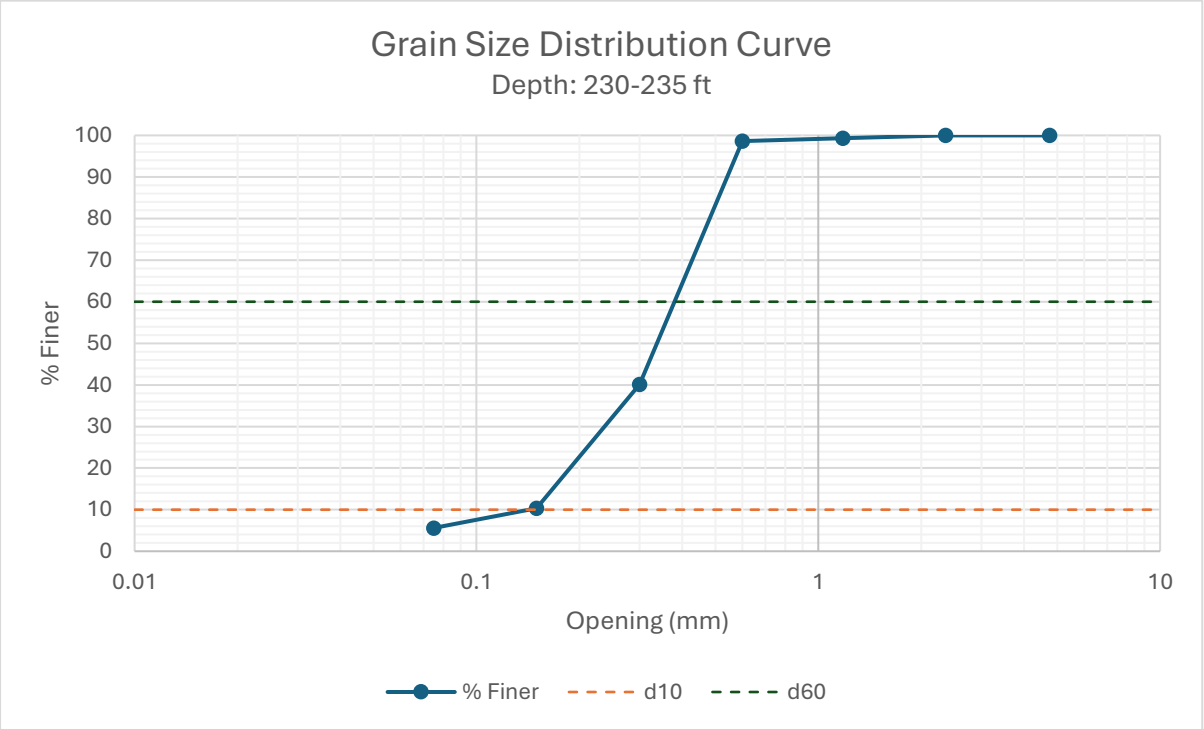
Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.12	0.22	0.37	3.12	1.44	0.38	73.93	22.07



Sieve Size Analysis: Depth 230-235 ft

Sieve No.	Opening (mm)	Can Wt (g)	Sample + Can Wt (g)	Wt of Soil (g)	Soil Retained (%)	Cumulative Retained (%)	% Finer
4	4.75	563.7	563.7	0	0.00	0.00	100.00
8	2.36	521.2	521.2	0	0.00	0.00	100.00
16	1.18	489.3	490	0.7	0.70	0.70	99.30
30	0.6	461.3	462	0.7	0.70	1.40	98.60
50	0.3	411.5	470	58.5	58.50	59.90	40.10
100	0.15	393.2	423	29.8	29.80	89.70	10.30
200	0.075	385.3	390	4.7	4.70	94.40	5.60
Pan		328.6	334.2	5.6	5.60	100.00	0.00
Total				**100**			

Results	D_{10}	D_{30}	D_{60}	C_u	FM	% Coarse	% Medium	% Fine
Value	0.14	0.24	0.38	2.65	1.52	1.23	75.93	17.07



Summary Table for Grain Size Analysis

Depth (ft)	D_{10}	D_{30}	D_{60}	$C_u=D_{60}/D_{10}$	FM	% Coarse	% Medium	% Fine
60-70	0.21	0.34	0.46	2.22	1.92	12.23	78.19	9.01
70-80	0.18	0.33	0.45	2.48	1.88	12.23	75.99	9.01
80-90	0.30	0.36	0.48	1.60	2.13	14.52	77.48	4.92
90-100	0.27	0.36	0.48	1.78	2.11	14.52	76.65	5.75
100-110	0.30	0.37	0.49	1.60	2.13	15.17	76.31	5.39
110-120	0.31	0.37	0.49	1.60	2.17	15.93	76.31	4.39
120-130	0.13	0.34	0.47	3.46	1.91	12.89	71.31	13.39
130-140	0.19	0.32	0.42	2.18	1.76	1.70	87.15	10.75
140-150	0.16	0.30	0.41	2.49	1.66	1.70	82.15	15.75
150-160	0.12	0.31	0.41	3.60	1.62	3.00	76.75	16.55
160-170	0.18	0.31	0.42	2.30	1.75	3.85	83.25	11.75
170-180	0.12	0.23	0.38	3.26	1.48	0.85	74.18	20.82
180-190	0.13	0.32	0.44	3.28	1.79	9.23	73.82	14.18
190-200	0.14	0.23	0.38	2.71	1.49	0.47	75.93	22.07
200-210	0.17	0.24	0.38	2.32	1.71	5.04	71.61	19.79
210-220	0.14	0.23	0.38	2.65	1.65	5.04	68.10	23.30
220-230	0.12	0.22	0.37	3.12	1.44	0.38	73.93	22.07
230-235	0.14	0.24	0.38	2.65	1.52	1.23	75.93	17.07

Determination of Most Productive Aquifer

Factors considered:

Suitable aquifer depth is determined considering layers having the highest hydraulic conductivity. Following techniques are considered:

- Higher percentage of coarse sand ($\geq 5\%$) and medium sand ($\geq 70\%$).
- Greater coefficient of uniformity ($C_u, \geq 1.5$).

Aquifer depth:

Based on the considerations mentioned above, the most productive aquifer depth is determined to be 60'-130' by reviewing the summary table of grain size analysis.

Determination of Strainer Length and Position

Length of casing pipe is the summation of:

1. Static water level at present.
2. Assumed drawdown of 10'-15' while pumping.
3. Average rate of water level declination (per year) times design period.
4. Extra allowance of 10'-15'.

Assumptions:

- Static water level at present: 30 ft
- Drawdown while pumping: 15 ft
- Depletion per year: 2 ft
- Extra allowance: 15 ft
- Design period: 20 years

Length of casing pipe:

$$L_{casing} = 30' + 15' + 2' \times 20 + 15'$$

$$\therefore L_{casing} = 100'$$

Length of strainer:

- Available aquifer thickness: $130' - 100' = 30'$ [$\therefore$ 75% screening]
- Strainer length:

$$L_{strainer} = 30 \times 0.75\ ft$$

$$\Rightarrow L_{strainer} = 23\ ft$$

Design of Gravel Pack Material

Soil strata of depth 60' to 80' and 120' to 130' has d_{10} less than 0.25. Therefore, gravel packs are required.

Procedures

1. Identified the soil strata (governing layer) having the highest percentage of medium sand.
2. A multiplication factor is determined based on the layer's uniformity coefficient:
    a. If $C_u \leq 1.5$, then $M.F = 4$
    b. Else if $C_u \geq 2.5$, then $M.F = 6$
    c. Otherwise, interpolation is used.
3. On a spreadsheet, a nearly parallel curve of the governing layer's gradation curve is produced:
    a. Grain size and percent finer of the governing layer is taken.
    b. On a new column, grain size is multiplied by the $M.F$.
    c. A graph is drawn with governing layer's percent finer vs grain size and percent finer vs new grain size.
4. Through interpolation, percent finer for standard sieve sizes are computed. Then, range of percent retained is produced by adding and subtracting 4 to the calculated percent retained on each sieve.

Identification of governing layer:

The layer having the highest percent of medium sand is at 130'-140'.

Determination of multiplying factor:

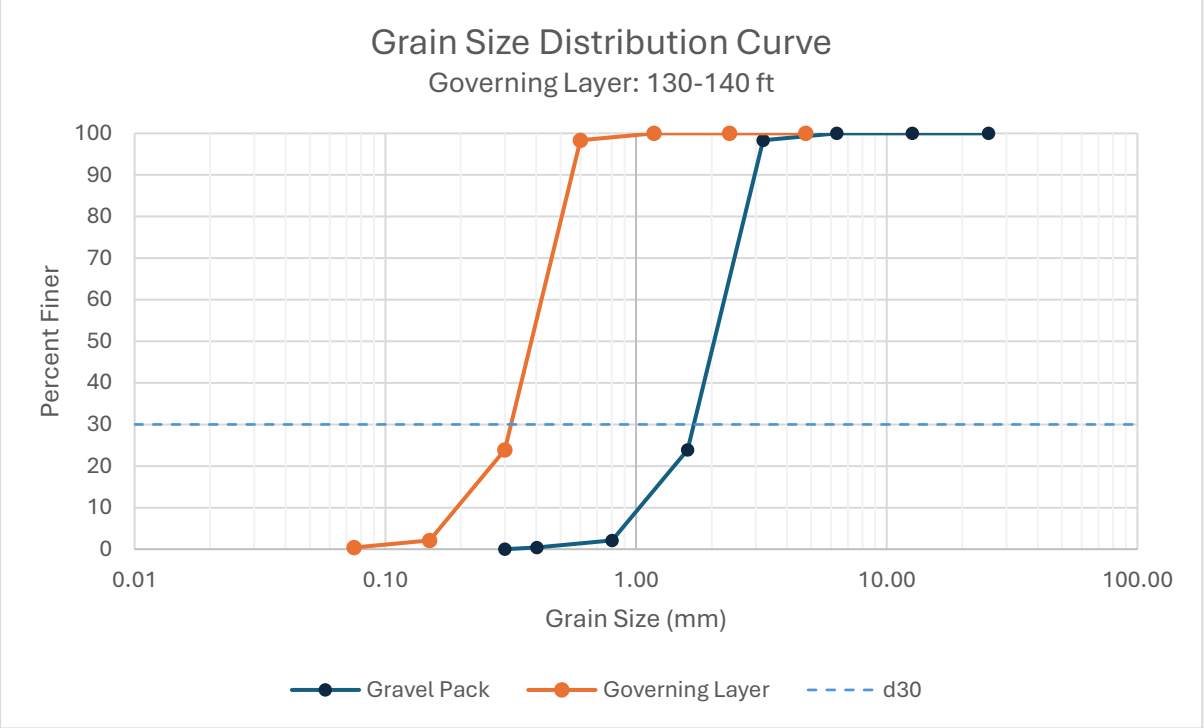
The layer has uniformity coefficient of 2.18. Therefore,

$$M.F. = 4 + \frac{6-4}{2.5-1.5} \times (2.18 - 1.5)$$

$$\therefore M.F. = 5.36$$

Data for parallel curve:

Size (mm)	New Size (mm)	% Finer
4.75	25.44	100.00
2.36	12.64	100.00
1.18	6.32	100.00
0.6	3.21	98.30
0.3	1.61	23.90
0.15	0.80	2.10
0.075	0.40	0.40
PAN	0.30	0.00



Sieve Analysis of the gravel pack material:

Sieve No.	Size (mm)	% Finer	Cumulative Retained (%)	% Retained	Range of % Retained
4	4.75	99.28	0.72	0.72	0 to 5
8	2.36	65.17	34.83	34.11	31 to 39
16	1.18	14.19	85.81	50.98	47 to 55
30	0.6	1.38	98.62	12.81	9 to 17
50	0.3	0.00	100.00	1.38	0 to 6
100	0.15	0.00	100.00	0.00	0 to 4
200	0.075	0.00	100.00	0.00	0 to 4
Total				**100.00**	

Results	**D_{10}**	**D_{60}**	**C_u**
Value	1.03	2.25	2.18 [< 2.5; OK]

Selection of Strainer Size

To ensure that 90% or more of the gravel-pack materials will be retained through strainer opening,

$$Slot = \frac{d_{10}}{25.4} \times 1000$$

$$\Rightarrow Slot = \frac{1.03}{25.4} \times 1000$$

$$\therefore Slot = 40.55$$

Hence, slot number of 40 will be used. Strainer diameter is assumed to be 6".

Yield of Well

Assumptions and previously calculated data:

- Entrance velocity, v: 0.1 fps
- Screen blockage factor, $B.F$: 0.4
- Screen opening: 20% [for 40 slot, steel]
- Length of strainer, $L_{strainer}$: 23 ft
- Diameter of strainer, D: 6"
- Pumping hour per day: 16 hr

Capacity:

- Strainer area, A:

$$0.20 \times \pi D L_{strainer}$$
$$= 0.20 \times \pi \frac{6}{12} \times 23\ ft^2$$
$$= 7.23\ ft^2$$

- Yield of well:

$$Av \times B.F$$
$$= 7.23 \times 0.1 \times 0.4\ ft^3/s$$
$$= 0.29\ ft^3/s$$
$$= 29{,}563\ lph$$
$$= 29{,}563 \times 16\ lpd$$
$$= 473{,}008\ lpd$$

Number of tube-wells required:

- Present water demand: $2{,}494{,}253$ lpd
- Number of tube-well: $\frac{2{,}494{,}253}{473{,}008} = 5.27 = 6$
- Water demand: In 10 years: $3{,}098{,}171$ lpd
- Number of tube-wells $\frac{3{,}098{,}171}{473{,}008} = 6.55 = 7$
- Water demand: In 20 Years $3{,}254{,}755$ lpd
- Number of tube-wells $\frac{3{,}254{,}755}{473{,}008} = 6.88 = 7$
- Water demand: In 30 Years $3{,}417{,}135$ lpd
- Number of tube-wells $\frac{3{,}417{,}135}{473{,}008} = 7.22 = 8$

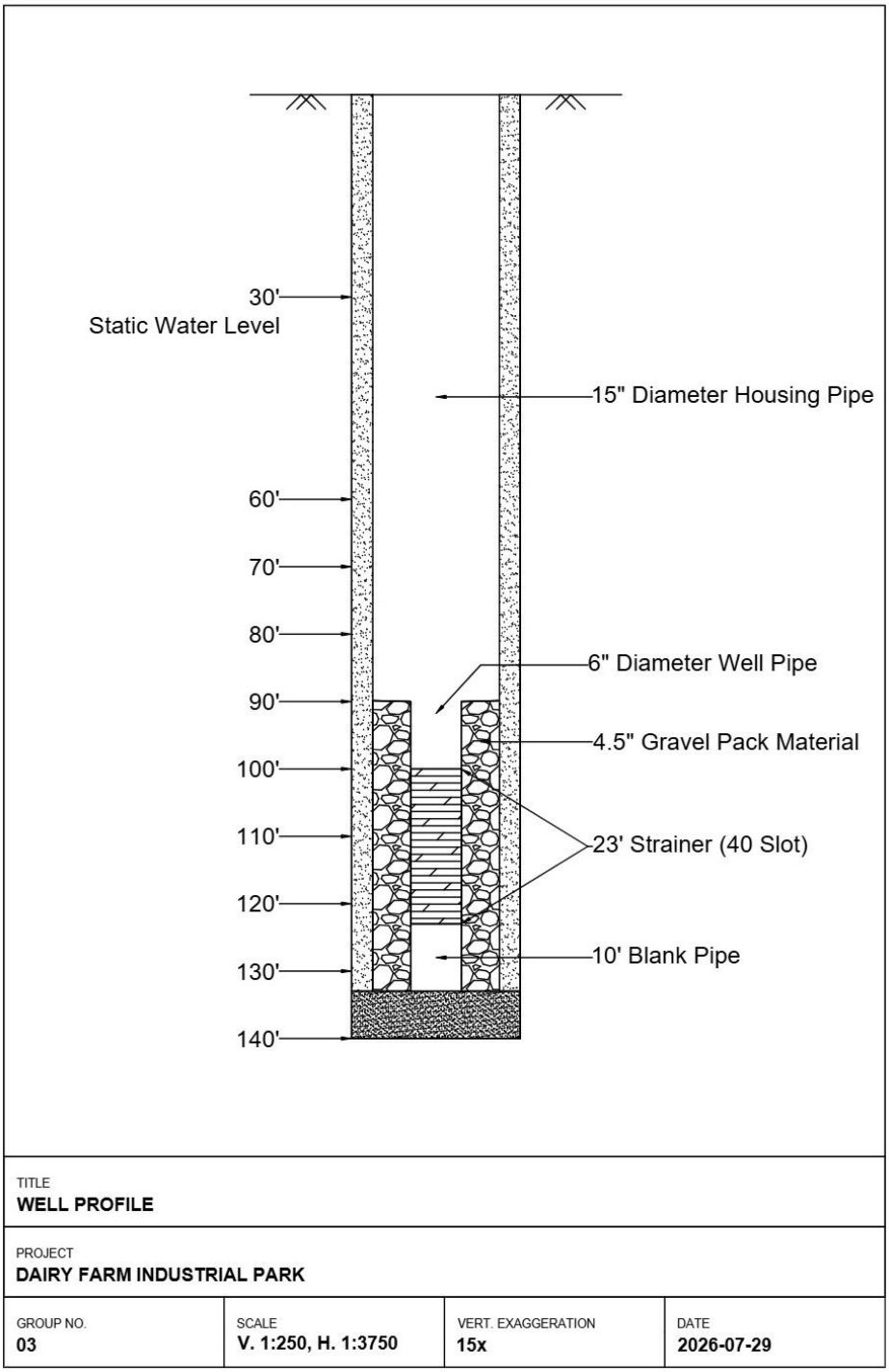


Figure 6 Well profile of the water source

Pump Capacity & Pumping Schedules

Introduction

The water supply system of our dairy park comprises of:

1. Pumps, facilitated by “Water Pump Stations”
2. Storage reservoirs, facilitated by “Overhead Tanks”, and
3. Pipe network to convey the water.

Methodology:

This report is completed in two segments:

1. Determination of Pump Capacity
2. Determination of Pumping Schedules

Pump type:

Pumps can be of different types, including but not limited to:

1. Submersible pump
2. Turbine pump
3. Centrifugal pump

For our dairy park, submersible pump is chosen. It will be installed in the housing pipe (below static water level but above the top of strainer).

Assumptions

- Pump efficiency: 75%
- Velocity for water supply: 3 fps
- Friction loss: 10% of maximum pipe length
- Tallest building: 6 storey = 60 ft
- Overhead tank height: 15 ft

Determination of Pump Capacity

Steps:

1. The dairy park is divided into two major zones:
    a. Zone 1 (Residential, Commercial, Administrative Zone): Comprises of facilities of the respective wings. The left side of the layout.
    b. Zone 2 (Industrial Zone): Comprises *mostly* of facilities of industrial wing. The right side of the layout.
2. Peak water demand for each zone is determined using the report "Estimate Water Demand". For each zone,
    $$WaterDemand = \Sigma(RelevantFacilitiesDemand) + FirefightingDemand$$
3. Total pump required for each zone is determined by dividing total water demand with design pump yields.
4. Capacity of each pump is determined.

Water Demand of Each Zone

Zone / Facilities	Peak Water Demand: Present (lpd)	Peak Water Demand: In 10 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Industrial	1,525,632	1,908,032	1,984,434	2,060,374
Bottle Inventory	378	504	546	546
Chilling & Filtration Block	588	840	840	840
Cold Storage Warehouse	378	504	525	546
Cow Barn A	1,260	1,680	1,764	1,764
Cow Barn B	1,260	1,680	1,764	1,764
Effluent Treatment Plant	273	357	378	399
Industrial (Production)	1,512,000	1,890,000	1,965,600	2,041,200
Milking Center Utilities	84	126	126	126
Milking Rotary	1,117	1,452	1,564	1,564
Packaging Station	2,772	3,654	3,780	3,906
Processing Core	3,780	4,914	5,166	5,292
Raw Milk Silos	105	147	147	147
Sewage Treatment Plant	135	180	180	195
Shipping Docks	126	189	189	189
Solid Waste Dump	840	1,080	1,140	1,140
Truck Staging Yard	536	725	725	756
Residential, Commercial, Administrative	953,605	1,175,122	1,255,304	1,341,745
Bank	16,875	21,600	22,613	23,288
Central Mosque	144,000	180,000	187,200	194,400
CMS	3,600	4,500	4,800	5,100
Corporate HQ	17,888	22,613	23,288	24,300
Exhibition Center	20,250	25,380	26,325	27,405
Fire Station	2,240	2,800	2,940	3,080

Zone / Facilities	Peak Water Demand: Present (lpd)	Peak Water Demand: In 10 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Food Court	15,750	20,160	21,105	21,735
Inspection Bay	240	300	360	360
IT Center	525	735	735	735
Logistics & Customs Office	4,050	5,063	5,400	5,738
Park Op. Center	450	630	630	630
Parking Lot	900	1,125	1,181	1,238
Power Plant	540	720	720	780
QA Office	1,960	2,520	2,660	2,660
R&D Facility	3,360	4,200	4,620	4,620
Residential Estate Office	5,063	6,413	6,750	7,088
Security Checkpoint	180	270	270	270
Training Academy	36,000	45,000	46,800	48,600
Veterinary Office	5,040	6,300	6,720	7,140
Water Pump Station	90	120	120	135
Building Type - Villa	36,400	40,300	44,850	49,400
Building Type - A	49,500	55,500	61,000	67,500
Building Type - B	58,500	67,500	75,150	83,700
Building Type - C	94,500	111,000	125,400	141,900
Building Type - D	107,800	128,400	145,400	165,200
Dairy Retail Outlet & Café	10,800	14,040	14,580	15,120
Shopping Complex	9,450	12,150	12,600	13,050
Supermarket	8,550	11,025	11,475	11,925
Hardware Store	560	840	840	840
Salon	700	980	980	980
Laundry	700	980	980	980
Telecom Center	1,890	2,430	2,700	2,700

Zone / Facilities	Peak Water Demand: Present (lpd)	Peak Water Demand: In 10 Years (lpd)	Peak Water Demand: In 20 Years (lpd)	Peak Water Demand: In 30 Years (lpd)
Postal Services	1,890	2,430	2,700	2,700
Insurance Corporate Office	1,350	1,890	1,890	1,890
Veterinary Medicine	5,040	6,720	6,720	7,056
Daycare Center	7,920	10,440	10,800	11,160
Gym	13,320	17,280	18,000	18,720
Autoshop & Truck Servicing Center	1,080	1,440	1,440	1,512
Central Park & Sports Field	10,800	13,860	14,400	14,940
Community Center	11,610	14,940	15,480	16,110
Primary School	168,070	215,130	223,533	231,937
Pharmacy	675	900	900	1,125
Health Clinic	73,500	94,500	98,250	102,000
Grand Total	**2,479,237**	**3,083,154**	**3,239,738**	**3,402,119**

Number of Pump Requirements

Zone	Peak Water Demand: Present (lpd)	Pump Count: Present	Peak Water Demand: In 10 Years (lpd)	Pump Count: In 10 Years	Peak Water Demand: In 20 Years (lpd)	Pump Count: In 20 Years	Peak Water Demand: In 30 Years (lpd)	Pump Count: In 30 Years
Residential, Commercial, Administrative	968,621	3	1,190,138	3	1,270,320	3	1,356,761	3
Industrial	1,540,648	4	1,923,048	5	1,999,450	5	2,075,390	5
Total	**2,509,269**	**7**	**3,113,186**	**8**	**3,269,770**	**8**	**3,432,151**	**8**

Note: Firefighting demand of 15016 L is considered independently for each zone.

Sample Calculation: Pump Capacity

Pump 1:

- Suction head: 0
- Delivery head: $30 + 60 = 90$ ft
- Velocity head: $\frac{3^2}{2*32.19} = 0.14$ ft
- Maximum horizontal distance: 888 ft
- Maximum pipe length: $888 + 60 + 15 = 963$ ft
- Friction head: $963 \times 0.1 = 96.3$ ft
- Therefore, total head: $0 + 90 + 0.14 + 96.3 = 186.44$ ft
- Yield of well: $29{,}563$ lph $= 130.16$ gpm
- Working horsepower, WHP: $\frac{186.44 \times 130.16}{3960} \approx 7$
- Breaking horsepower, BHP: $\frac{7}{0.75} \approx 10$

Pump Capacity

Pump	Pipe Length (ft)	Friction Head (ft)	Static Head (ft)	Velocity Head (ft)	Total Head (ft)	Yield of Well (gpm)	WHP (HP)	BHP (HP)
Pump 1	963	96.3	90	0.14	186.44	130.16	7	10
Pump 2	240	24	90	0.14	114.14	130.16	4	6
Pump 3	340	34	90	0.14	124.14	130.16	5	7
Pump 4	735	73.5	90	0.14	163.64	130.16	6	8
Pump 5	240	24	90	0.14	114.14	130.16	4	6
Pump 6	1430	143	90	0.14	233.14	130.16	8	11
Pump 7	1110	111	90	0.14	201.14	130.16	7	10
Pump 8	920	92	90	0.14	182.14	130.16	6	8

Determination of Pumping Schedule

Steps:

1. Water demand of each zone was used as aggregated earlier.
2. A 24-hour diurnal demand pattern was established using assigned or average peak factors for the zone and peak operational hours to determine hourly water demands.
3. Pumping chart was prepared:
    a. How many pumps need to be activated was determined as:
    $$\frac{Demand_t + Demand_{t+1} - Storage_t + Storage_{reserve}}{PumpYield}$$
    b. Pump was turned on by accounting for which pump was least used throughout the day to distribute the load evenly across the park.
4. Demand curve was prepared.

Method of supply:

In municipal and industrial water supply design, two primary methods of supply are generally considered:

1. Continuous Supply System
2. Intermittent Supply System

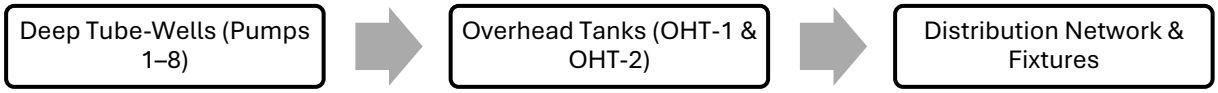
For the proposed 90-acre Dairy Farm Industrial Park, a Continuous Supply System has been selected.

Method of distribution:

The distribution of treated groundwater from production wells to fixtures across the park can be accomplished through two distinct configurations:

1. System with Direct Pumping
2. System with Pumping and Storage (Overhead Tanks)

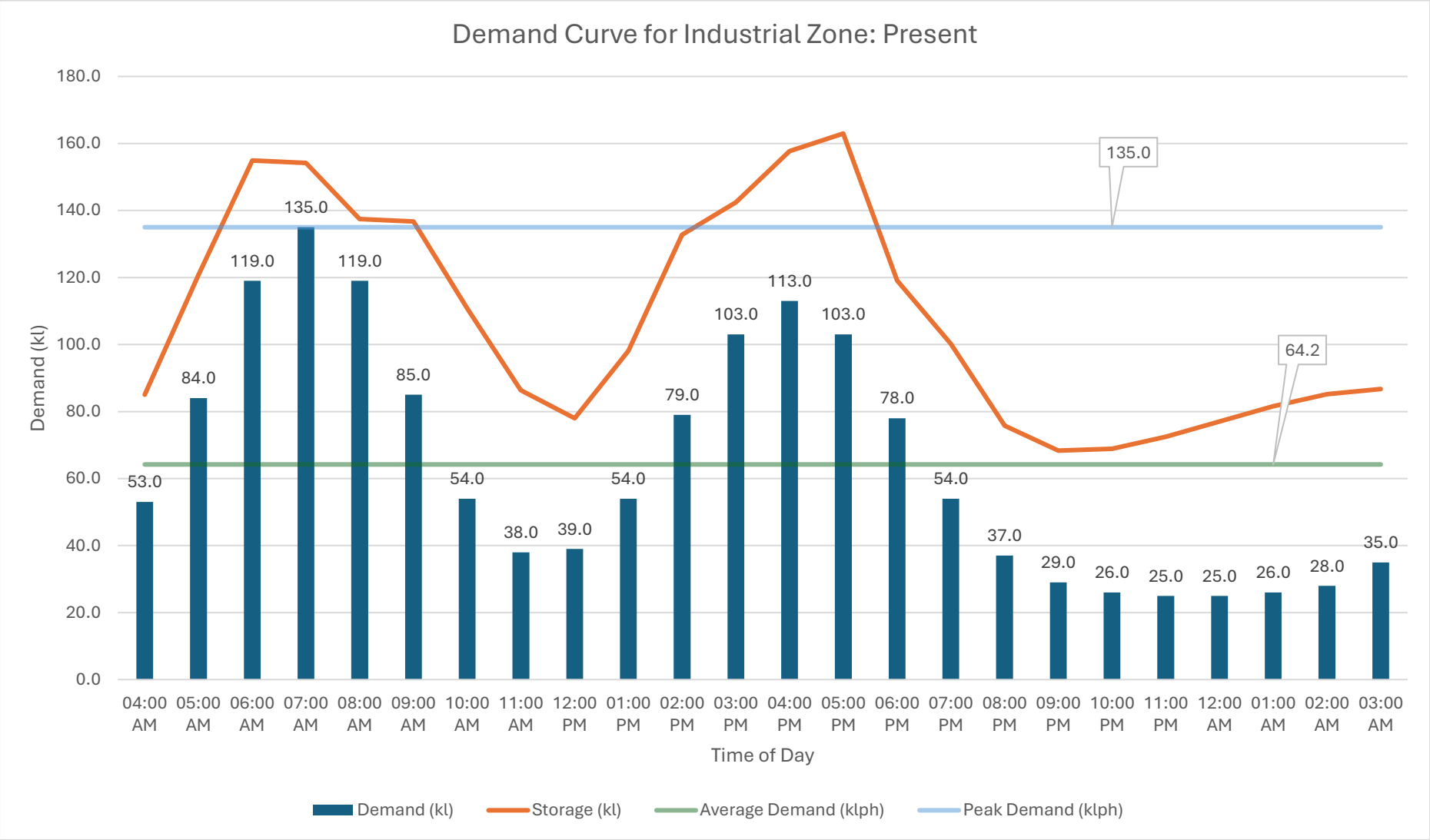
The water distribution network for this park is designed as a System with Pumping and Storage.



Schedule: Zone 2 - Industrial, Present

Start Time	End Time	Demand (kl)	Current Storage (kl)	Required Pump	Supply (kl)	Net Storage (kl)	Pump 4	Pump 5	Pump 6	Pump 7	Pump 8
04:00 AM	05:00 AM	53.0	85.0	3	88.7	120.7	X	X	X		
05:00 AM	06:00 AM	84.0	120.7	4	118.3	154.9	X	X		X	X
06:00 AM	07:00 AM	119.0	154.9	4	118.3	154.2	X		X	X	X
07:00 AM	08:00 AM	135.0	154.2	4	118.3	137.4		X	X	X	X
08:00 AM	09:00 AM	119.0	137.4	4	118.3	136.7	X	X	X	X	
09:00 AM	10:00 AM	85.0	136.7	2	59.1	110.8	X				X
10:00 AM	11:00 AM	54.0	110.8	1	29.6	86.4		X			
11:00 AM	12:00 PM	38.0	86.4	1	29.6	77.9			X		
12:00 PM	01:00 PM	39.0	77.9	2	59.1	98.1				X	X
01:00 PM	02:00 PM	54.0	98.1	3	88.7	132.8	X	X	X		
02:00 PM	03:00 PM	79.0	132.8	3	88.7	142.5	X			X	X
03:00 PM	04:00 PM	103.0	142.5	4	118.3	157.7		X	X	X	X
04:00 PM	05:00 PM	113.0	157.7	4	118.3	163.0	X	X	X	X	
05:00 PM	06:00 PM	103.0	163.0	2	59.1	119.1	X				X
06:00 PM	07:00 PM	78.0	119.1	2	59.1	100.2		X	X		
07:00 PM	08:00 PM	54.0	100.2	1	29.6	75.8				X	
08:00 PM	09:00 PM	37.0	75.8	1	29.6	68.3					X
09:00 PM	10:00 PM	29.0	68.3	1	29.6	68.9	X				
10:00 PM	11:00 PM	26.0	68.9	1	29.6	72.5		X			
11:00 PM	12:00 AM	25.0	72.5	1	29.6	77.0			X		
12:00 AM	01:00 AM	25.0	77.0	1	29.6	81.6				X	
01:00 AM	02:00 AM	26.0	81.6	1	29.6	85.2					X
02:00 AM	03:00 AM	28.0	85.2	1	29.6	86.7	X				
03:00 AM	04:00 AM	35.0	86.7	1	29.6	81.3		X			
Total		**1,541.0**			**1,566.8**		**11**	**11**	**11**	**10**	**10**

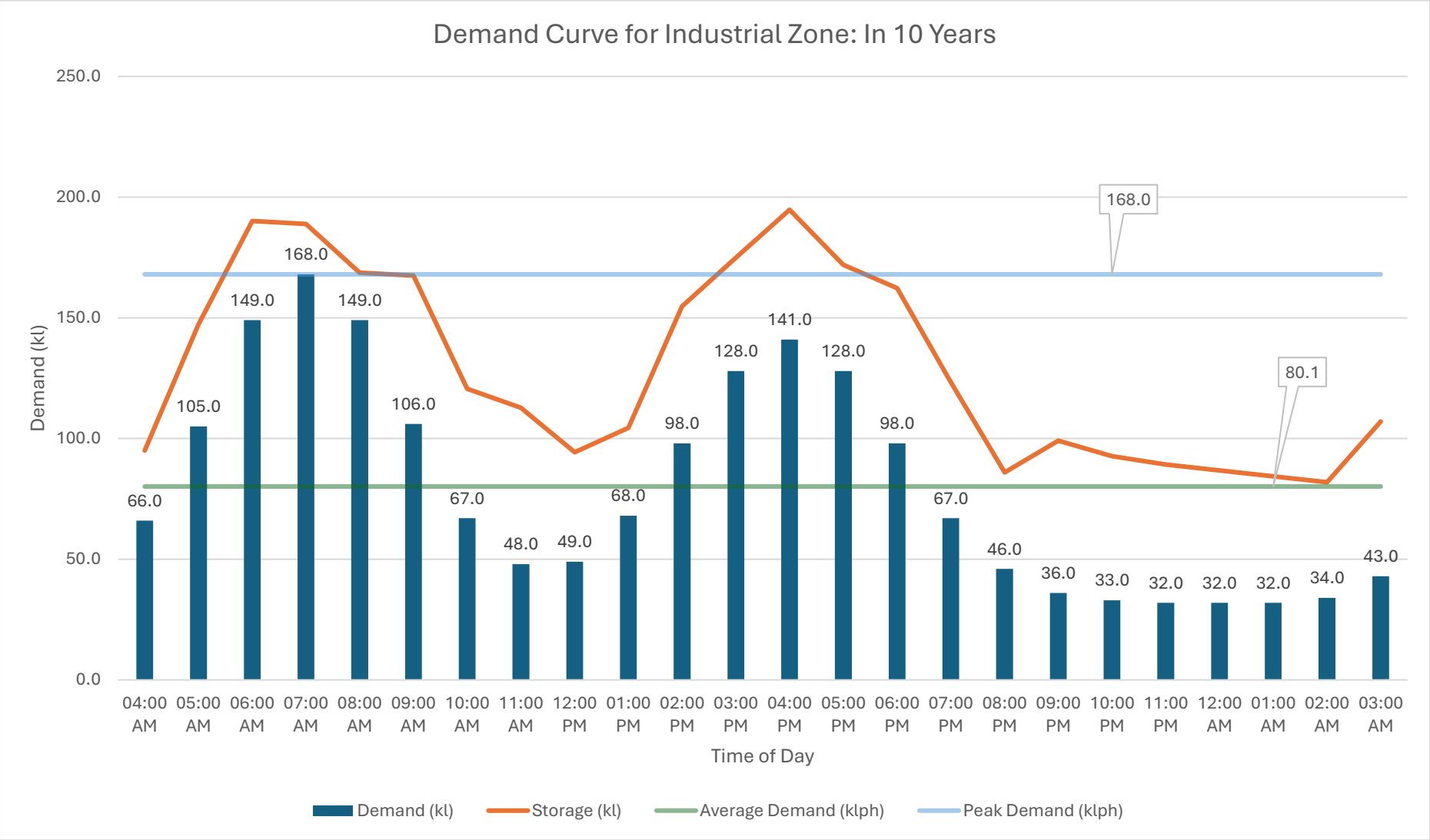
Demand Curve: Zone 2 – Industrial, Present



Schedule: Zone 2 - Industrial, In 10 Years

Start Time	End Time	Demand (kl)	Current Storage (kl)	Required Pump	Supply (kl)	Net Storage (kl)	Pump 4	Pump 5	Pump 6	Pump 7	Pump 8
04:00 AM	05:00 AM	66.0	95.0	4	118.3	147.3	X	X	X	X	
05:00 AM	06:00 AM	105.0	147.3	5	147.8	190.1	X	X	X	X	X
06:00 AM	07:00 AM	149.0	190.1	5	147.8	188.9	X	X	X	X	X
07:00 AM	08:00 AM	168.0	188.9	5	147.8	168.7	X	X	X	X	X
08:00 AM	09:00 AM	149.0	168.7	5	147.8	167.5	X	X	X	X	X
09:00 AM	10:00 AM	106.0	167.5	2	59.1	120.6	X				X
10:00 AM	11:00 AM	67.0	120.6	2	59.1	112.8		X	X		
11:00 AM	12:00 PM	48.0	112.8	1	29.6	94.3				X	
12:00 PM	01:00 PM	49.0	94.3	2	59.1	104.5	X				X
01:00 PM	02:00 PM	68.0	104.5	4	118.3	154.7		X	X	X	X
02:00 PM	03:00 PM	98.0	154.7	4	118.3	175.0	X	X	X	X	
03:00 PM	04:00 PM	128.0	175.0	5	147.8	194.8	X	X	X	X	X
04:00 PM	05:00 PM	141.0	194.8	4	118.3	172.0	X	X	X		X
05:00 PM	06:00 PM	128.0	172.0	4	118.3	162.3	X	X		X	X
06:00 PM	07:00 PM	98.0	162.3	2	59.1	123.4			X	X	
07:00 PM	08:00 PM	67.0	123.4	1	29.6	86.0					X
08:00 PM	09:00 PM	46.0	86.0	2	59.1	99.1	X	X			
09:00 PM	10:00 PM	36.0	99.1	1	29.6	92.7			X		
10:00 PM	11:00 PM	33.0	92.7	1	29.6	89.2				X	
11:00 PM	12:00 AM	32.0	89.2	1	29.6	86.8					X
12:00 AM	01:00 AM	32.0	86.8	1	29.6	84.3	X				
01:00 AM	02:00 AM	32.0	84.3	1	29.6	81.9		X			
02:00 AM	03:00 AM	34.0	81.9	2	59.1	107.0			X	X	
03:00 AM	04:00 AM	43.0	107.0	1	29.6	93.6					X
Total		**1,923.0**			**1,921.6**		**13**	**13**	**13**	**13**	**13**

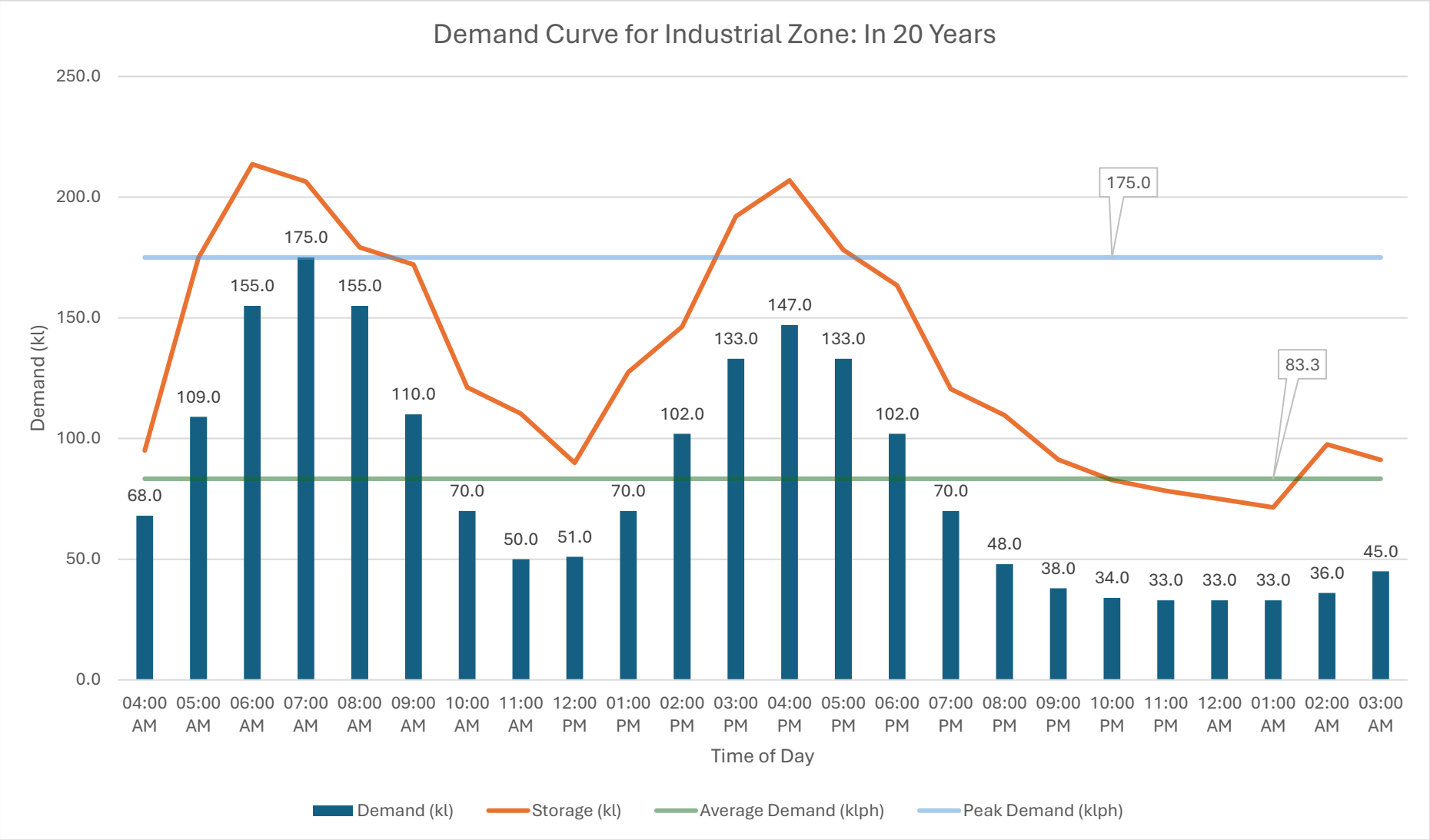
Demand Curve: Zone 2 – Industrial, In 10 Years



Schedule: Zone 2 - Industrial, In 20 Years

Start Time	End Time	Demand (kl)	Current Storage (kl)	Required Pump	Supply (kl)	Net Storage (kl)	Pump 4	Pump 5	Pump 6	Pump 7	Pump 8
04:00 AM	05:00 AM	68.0	95.0	5	147.8	174.8	X	X	X	X	X
05:00 AM	06:00 AM	109.0	174.8	5	147.8	213.6	X	X	X	X	X
06:00 AM	07:00 AM	155.0	213.6	5	147.8	206.4	X	X	X	X	X
07:00 AM	08:00 AM	175.0	206.4	5	147.8	179.3	X	X	X	X	X
08:00 AM	09:00 AM	155.0	179.3	5	147.8	172.1	X	X	X	X	X
09:00 AM	10:00 AM	110.0	172.1	2	59.1	121.2	X	X			
10:00 AM	11:00 AM	70.0	121.2	2	59.1	110.3			X	X	
11:00 AM	12:00 PM	50.0	110.3	1	29.6	89.9					X
12:00 PM	01:00 PM	51.0	89.9	3	88.7	127.6	X	X	X		
01:00 PM	02:00 PM	70.0	127.6	3	88.7	146.3	X			X	X
02:00 PM	03:00 PM	102.0	146.3	5	147.8	192.1	X	X	X	X	X
03:00 PM	04:00 PM	133.0	192.1	5	147.8	206.9	X	X	X	X	X
04:00 PM	05:00 PM	147.0	206.9	4	118.3	178.2		X	X	X	X
05:00 PM	06:00 PM	133.0	178.2	4	118.3	163.4	X	X	X	X	
06:00 PM	07:00 PM	102.0	163.4	2	59.1	120.5	X				X
07:00 PM	08:00 PM	70.0	120.5	2	59.1	109.7		X	X		
08:00 PM	09:00 PM	48.0	109.7	1	29.6	91.2				X	
09:00 PM	10:00 PM	38.0	91.2	1	29.6	82.8					X
10:00 PM	11:00 PM	34.0	82.8	1	29.6	78.3	X				
11:00 PM	12:00 AM	33.0	78.3	1	29.6	74.9		X			
12:00 AM	01:00 AM	33.0	74.9	1	29.6	71.5			X		
01:00 AM	02:00 AM	33.0	71.5	2	59.1	97.6				X	X
02:00 AM	03:00 AM	36.0	97.6	1	29.6	91.2	X				
03:00 AM	04:00 AM	45.0	91.2	2	59.1	105.3		X	X		
Total		**2,000.0**			**2,010.3**		**14**	**14**	**14**	**13**	**13**

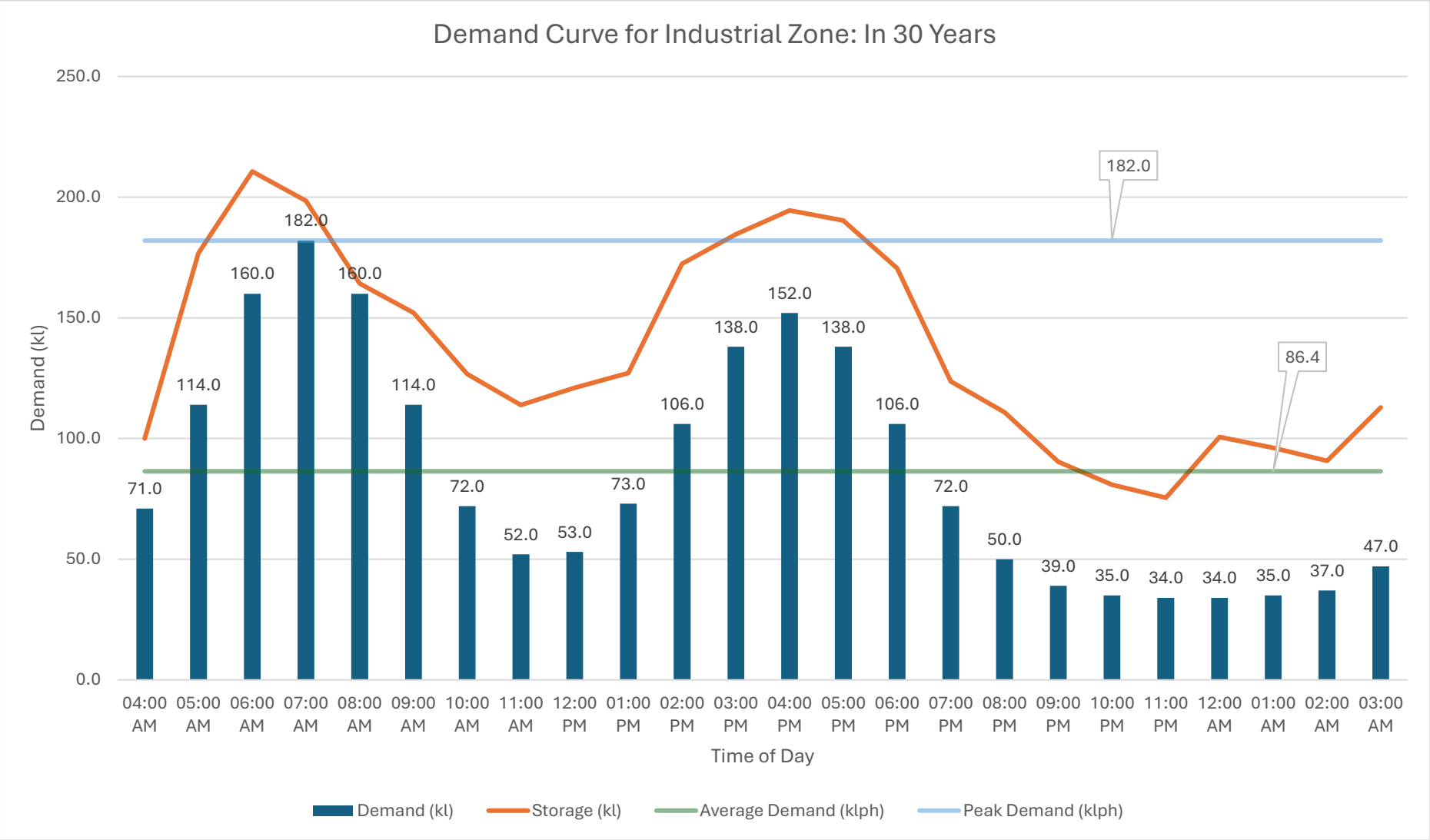
Demand Curve: Zone 2 – Industrial, In 20 Years



Schedule: Zone 2 - Industrial, In 30 Years

Start Time	End Time	Demand (kl)	Current Storage (kl)	Required Pump	Supply (kl)	Net Storage (kl)	Pump 4	Pump 5	Pump 6	Pump 7	Pump 8
04:00 AM	05:00 AM	71.0	100.0	5	147.8	176.8	X	X	X	X	X
05:00 AM	06:00 AM	114.0	176.8	5	147.8	210.6	X	X	X	X	X
06:00 AM	07:00 AM	160.0	210.6	5	147.8	198.4	X	X	X	X	X
07:00 AM	08:00 AM	182.0	198.4	5	147.8	164.3	X	X	X	X	X
08:00 AM	09:00 AM	160.0	164.3	5	147.8	152.1	X	X	X	X	X
09:00 AM	10:00 AM	114.0	152.1	3	88.7	126.8	X	X	X		
10:00 AM	11:00 AM	72.0	126.8	2	59.1	113.9				X	X
11:00 AM	12:00 PM	52.0	113.9	2	59.1	121.0	X	X			
12:00 PM	01:00 PM	53.0	121.0	2	59.1	127.1			X	X	
01:00 PM	02:00 PM	73.0	127.1	4	118.3	172.4	X	X	X		X
02:00 PM	03:00 PM	106.0	172.4	4	118.3	184.6	X	X		X	X
03:00 PM	04:00 PM	138.0	184.6	5	147.8	194.5	X	X	X	X	X
04:00 PM	05:00 PM	152.0	194.5	5	147.8	190.3	X	X	X	X	X
05:00 PM	06:00 PM	138.0	190.3	4	118.3	170.5	X		X	X	X
06:00 PM	07:00 PM	106.0	170.5	2	59.1	123.7		X	X		
07:00 PM	08:00 PM	72.0	123.7	2	59.1	110.8				X	X
08:00 PM	09:00 PM	50.0	110.8	1	29.6	90.3	X				
09:00 PM	10:00 PM	39.0	90.3	1	29.6	80.9		X			
10:00 PM	11:00 PM	35.0	80.9	1	29.6	75.5			X		
11:00 PM	12:00 AM	34.0	75.5	2	59.1	100.6				X	X
12:00 AM	01:00 AM	34.0	100.6	1	29.6	96.2	X				
01:00 AM	02:00 AM	35.0	96.2	1	29.6	90.7		X			
02:00 AM	03:00 AM	37.0	90.7	2	59.1	112.8			X	X	
03:00 AM	04:00 AM	47.0	112.8	1	29.6	95.4					X
Total		**2,074.0**			**2,069.4**		**14**	**14**	**14**	**14**	**14**

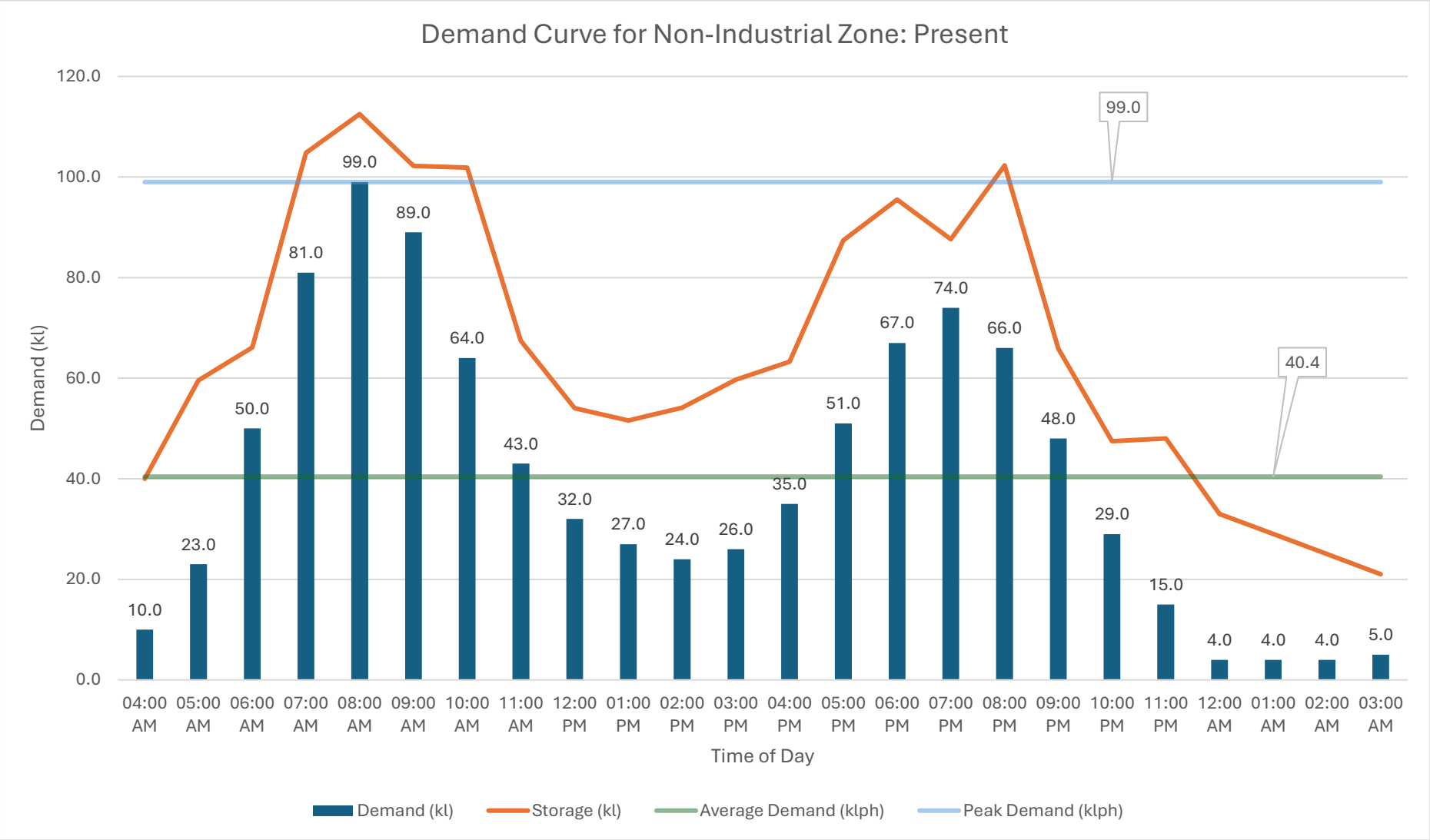
Demand Curve: Zone 2 – Industrial, In 30 Years



Schedule: Zone 1 – Residential, Commercial, Administrative, Present

Start Time	End Time	Demand (kl)	Current Storage (kl)	Required Pump	Supply (kl)	Net Storage (kl)	Pump 1	Pump 2	Pump 3
04:00 AM	05:00 AM	10.0	40.0	1	29.6	59.6	X		
05:00 AM	06:00 AM	23.0	59.6	1	29.6	66.1		X	
06:00 AM	07:00 AM	50.0	66.1	3	88.7	104.8	X	X	X
07:00 AM	08:00 AM	81.0	104.8	3	88.7	112.5	X	X	X
08:00 AM	09:00 AM	99.0	112.5	3	88.7	102.2	X	X	X
09:00 AM	10:00 AM	89.0	102.2	3	88.7	101.9	X	X	X
10:00 AM	11:00 AM	64.0	101.9	1	29.6	67.4			X
11:00 AM	12:00 PM	43.0	67.4	1	29.6	54.0	X		
12:00 PM	01:00 PM	32.0	54.0	1	29.6	51.6		X	
01:00 PM	02:00 PM	27.0	51.6	1	29.6	54.1			X
02:00 PM	03:00 PM	24.0	54.1	1	29.6	59.7	X		
03:00 PM	04:00 PM	26.0	59.7	1	29.6	63.3		X	
04:00 PM	05:00 PM	35.0	63.3	2	59.1	87.4	X		X
05:00 PM	06:00 PM	51.0	87.4	2	59.1	95.5		X	X
06:00 PM	07:00 PM	67.0	95.5	2	59.1	87.6	X	X	
07:00 PM	08:00 PM	74.0	87.6	3	88.7	102.3	X	X	X
08:00 PM	09:00 PM	66.0	102.3	1	29.6	65.9			X
09:00 PM	10:00 PM	48.0	65.9	1	29.6	47.5	X		
10:00 PM	11:00 PM	29.0	47.5	1	29.6	48.0		X	
11:00 PM	12:00 AM	15.0	48.0	0	0.0	33.0			
12:00 AM	01:00 AM	4.0	33.0	0	0.0	29.0			
01:00 AM	02:00 AM	4.0	29.0	0	0.0	25.0			
02:00 AM	03:00 AM	4.0	25.0	0	0.0	21.0			
03:00 AM	04:00 AM	5.0	21.0	1	29.6	45.6			X
Total		**970.0**			**975.6**		**11**	**11**	**11**

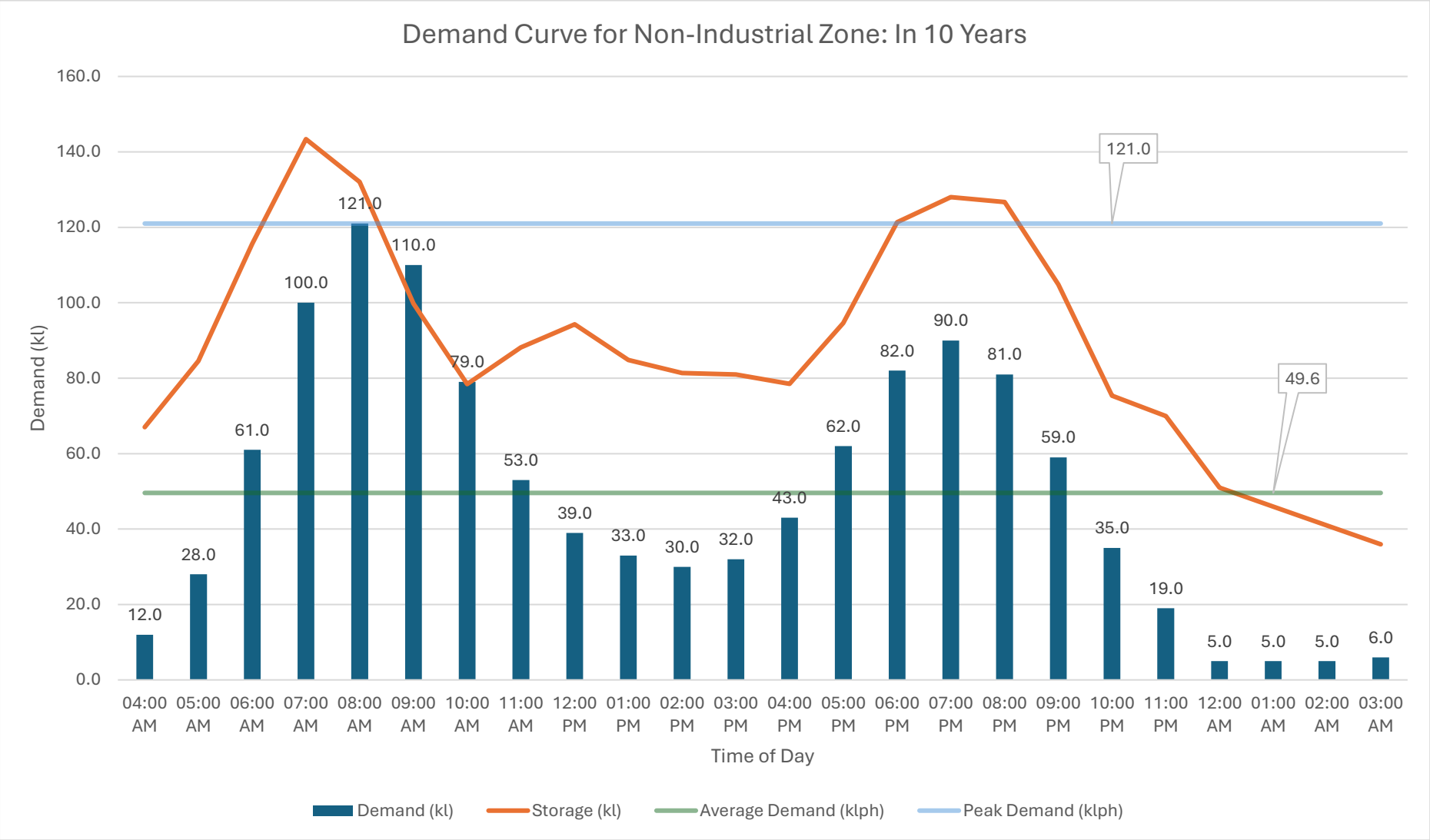
Demand Curve: Residential, Commercial, Administrative, Present



Schedule: Zone 1 – Residential, Commercial, Administrative, In 10 Years

Start Time	End Time	Demand (kl)	Current Storage (kl)	Required Pump	Supply (kl)	Net Storage (kl)	Pump 1	Pump 2	Pump 3
04:00 AM	05:00 AM	12.0	67.0	1	29.6	84.6	X		
05:00 AM	06:00 AM	28.0	84.6	2	59.1	115.7		X	X
06:00 AM	07:00 AM	61.0	115.7	3	88.7	143.4	X	X	X
07:00 AM	08:00 AM	100.0	143.4	3	88.7	132.1	X	X	X
08:00 AM	09:00 AM	121.0	132.1	3	88.7	99.8	X	X	X
09:00 AM	10:00 AM	110.0	99.8	3	88.7	78.4	X	X	X
10:00 AM	11:00 AM	79.0	78.4	3	88.7	88.1	X	X	X
11:00 AM	12:00 PM	53.0	88.1	2	59.1	94.3	X	X	
12:00 PM	01:00 PM	39.0	94.3	1	29.6	84.8			X
01:00 PM	02:00 PM	33.0	84.8	1	29.6	81.4	X		
02:00 PM	03:00 PM	30.0	81.4	1	29.6	80.9		X	
03:00 PM	04:00 PM	32.0	80.9	1	29.6	78.5			X
04:00 PM	05:00 PM	43.0	78.5	2	59.1	94.6	X	X	
05:00 PM	06:00 PM	62.0	94.6	3	88.7	121.3	X	X	X
06:00 PM	07:00 PM	82.0	121.3	3	88.7	128.0	X	X	X
07:00 PM	08:00 PM	90.0	128.0	3	88.7	126.7	X	X	X
08:00 PM	09:00 PM	81.0	126.7	2	59.1	104.8	X		X
09:00 PM	10:00 PM	59.0	104.8	1	29.6	75.4		X	
10:00 PM	11:00 PM	35.0	75.4	1	29.6	70.0			X
11:00 PM	12:00 AM	19.0	70.0	0	0.0	51.0			
12:00 AM	01:00 AM	5.0	51.0	0	0.0	46.0			
01:00 AM	02:00 AM	5.0	46.0	0	0.0	41.0			
02:00 AM	03:00 AM	5.0	41.0	0	0.0	36.0			
03:00 AM	04:00 AM	6.0	36.0	1	29.6	59.5	X		
Total		**1,190.0**			**1,182.5**		**14**	**13**	**13**

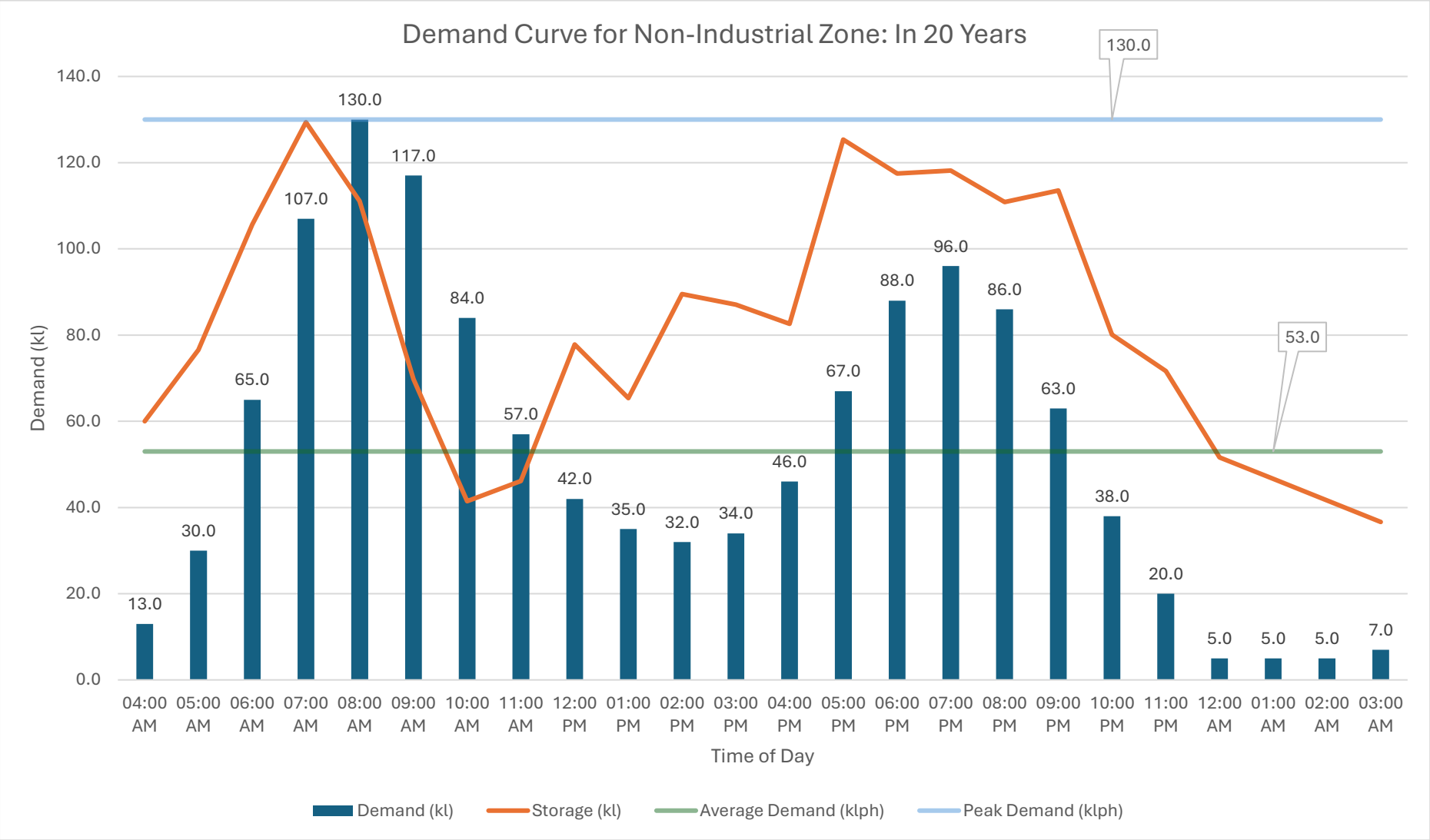
Demand Curve: Residential, Commercial, Administrative, In 10 Years



Schedule: Zone 1 – Residential, Commercial, Administrative, In 20 Years

Start Time	End Time	Demand (kl)	Current Storage (kl)	Required Pump	Supply (kl)	Net Storage (kl)	Pump 1	Pump 2	Pump 3
04:00 AM	05:00 AM	13.0	60.0	1	29.6	76.6	X		
05:00 AM	06:00 AM	30.0	76.6	2	59.1	105.7		X	X
06:00 AM	07:00 AM	65.0	105.7	3	88.7	129.4	X	X	X
07:00 AM	08:00 AM	107.0	129.4	3	88.7	111.1	X	X	X
08:00 AM	09:00 AM	130.0	111.1	3	88.7	69.8	X	X	X
09:00 AM	10:00 AM	117.0	69.8	3	88.7	41.4	X	X	X
10:00 AM	11:00 AM	84.0	41.4	3	88.7	46.1	X	X	X
11:00 AM	12:00 PM	57.0	46.1	3	88.7	77.8	X	X	X
12:00 PM	01:00 PM	42.0	77.8	1	29.6	65.4	X		
01:00 PM	02:00 PM	35.0	65.4	2	59.1	89.5		X	X
02:00 PM	03:00 PM	32.0	89.5	1	29.6	87.1	X		
03:00 PM	04:00 PM	34.0	87.1	1	29.6	82.6		X	
04:00 PM	05:00 PM	46.0	82.6	3	88.7	125.3	X	X	X
05:00 PM	06:00 PM	67.0	125.3	2	59.1	117.5	X		X
06:00 PM	07:00 PM	88.0	117.5	3	88.7	118.1	X	X	X
07:00 PM	08:00 PM	96.0	118.1	3	88.7	110.8	X	X	X
08:00 PM	09:00 PM	86.0	110.8	3	88.7	113.5	X	X	X
09:00 PM	10:00 PM	63.0	113.5	1	29.6	80.1		X	
10:00 PM	11:00 PM	38.0	80.1	1	29.6	71.6			X
11:00 PM	12:00 AM	20.0	71.6	0	0.0	51.6			
12:00 AM	01:00 AM	5.0	51.6	0	0.0	46.6			
01:00 AM	02:00 AM	5.0	46.6	0	0.0	41.6			
02:00 AM	03:00 AM	5.0	41.6	0	0.0	36.6			
03:00 AM	04:00 AM	7.0	36.6	1	29.6	59.2	X		
Total		**1,272.0**			**1,271.2**		**15**	**14**	**14**

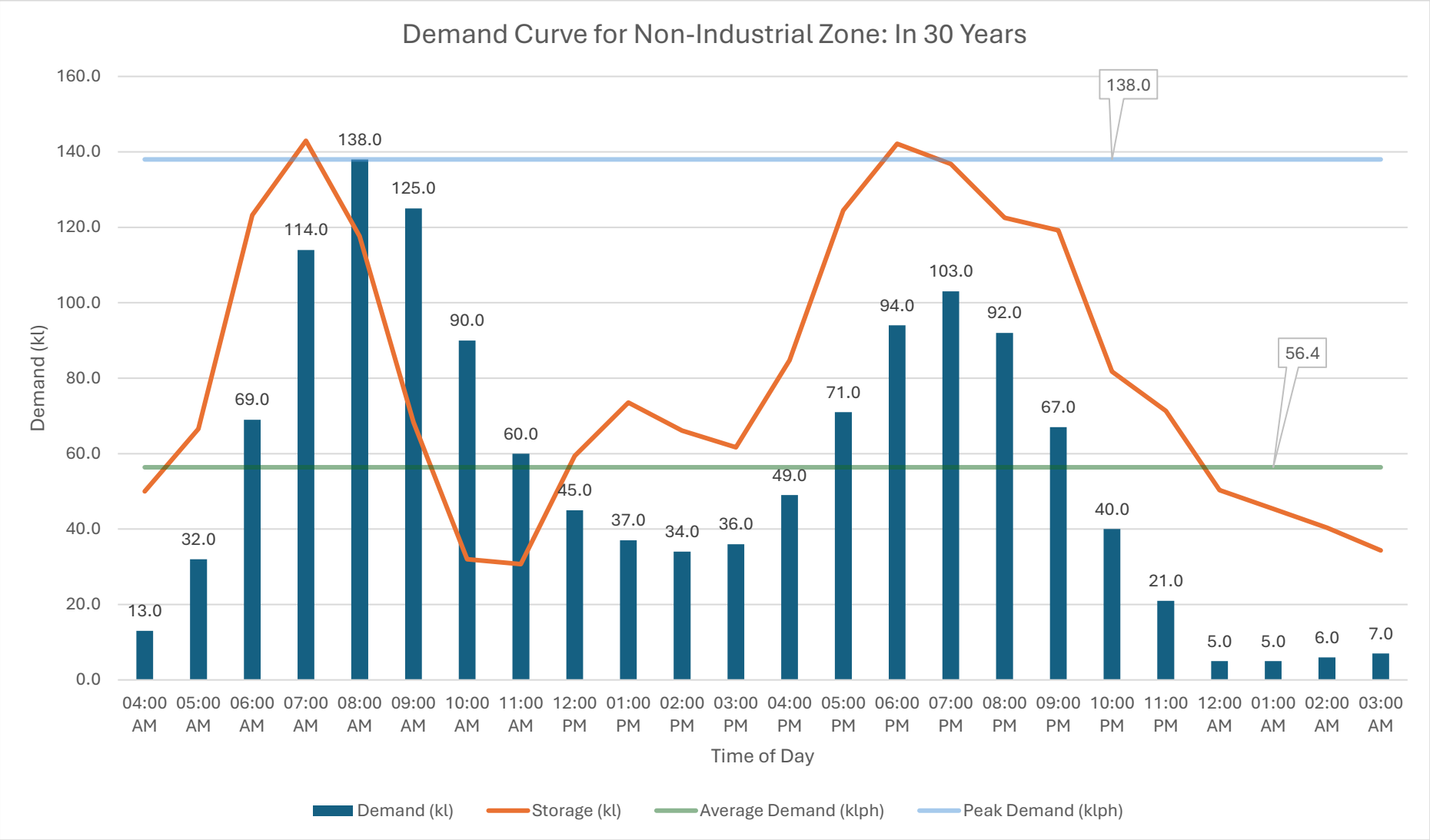
Demand Curve: Residential, Commercial, Administrative, In 20 Years



Schedule: Zone 1 – Residential, Commercial, Administrative, In 30 Years

Start Time	End Time	Demand (kl)	Current Storage (kl)	Required Pump	Supply (kl)	Net Storage (kl)	Pump 1	Pump 2	Pump 3
04:00 AM	05:00 AM	13.0	50.0	1	29.6	66.6	X		
05:00 AM	06:00 AM	32.0	66.6	3	88.7	123.3	X	X	X
06:00 AM	07:00 AM	69.0	123.3	3	88.7	142.9	X	X	X
07:00 AM	08:00 AM	114.0	142.9	3	88.7	117.6	X	X	X
08:00 AM	09:00 AM	138.0	117.6	3	88.7	68.3	X	X	X
09:00 AM	10:00 AM	125.0	68.3	3	88.7	32.0	X	X	X
10:00 AM	11:00 AM	90.0	32.0	3	88.7	30.7	X	X	X
11:00 AM	12:00 PM	60.0	30.7	3	88.7	59.4	X	X	X
12:00 PM	01:00 PM	45.0	59.4	2	59.1	73.5		X	X
01:00 PM	02:00 PM	37.0	73.5	1	29.6	66.1	X		
02:00 PM	03:00 PM	34.0	66.1	1	29.6	61.6		X	
03:00 PM	04:00 PM	36.0	61.6	2	59.1	84.8	X		X
04:00 PM	05:00 PM	49.0	84.8	3	88.7	124.5	X	X	X
05:00 PM	06:00 PM	71.0	124.5	3	88.7	142.1	X	X	X
06:00 PM	07:00 PM	94.0	142.1	3	88.7	136.8	X	X	X
07:00 PM	08:00 PM	103.0	136.8	3	88.7	122.5	X	X	X
08:00 PM	09:00 PM	92.0	122.5	3	88.7	119.2	X	X	X
09:00 PM	10:00 PM	67.0	119.2	1	29.6	81.8		X	
10:00 PM	11:00 PM	40.0	81.8	1	29.6	71.3			X
11:00 PM	12:00 AM	21.0	71.3	0	0.0	50.3			
12:00 AM	01:00 AM	5.0	50.3	0	0.0	45.3			
01:00 AM	02:00 AM	5.0	45.3	0	0.0	40.3			
02:00 AM	03:00 AM	6.0	40.3	0	0.0	34.3			
03:00 AM	04:00 AM	7.0	34.3	1	29.6	56.9	X		
Total		**1,353.0**			**1,359.9**		**16**	**15**	**15**

Demand Curve: Residential, Commercial, Administrative, In 30 Years



Summary of Pumping Schedule

Pump	Pumping Hours: Present	Pumping Hours: In 10 Years	Pumping Hours: In 20 Years	Pumping Hours: In 30 Years
Pump 1	11	14	15	16
Pump 2	11	13	14	15
Pump 3	11	13	14	15
Pump 4	11	13	14	14
Pump 5	11	13	14	14
Pump 6	10	13	14	14
Pump 7	10	13	13	14
Pump 8	10	13	13	14

Branched Water Distribution Network

Introduction

A branched water distribution network of the industrial park for all zones is computed in this report.

Assumptions:

1. Water demand of each facility is taken from previously determined peak water demand for the design period of 30 years.
2. Overhead Tank pressure (head) is considered to be 40 psi.
3. Minimum pressure at distribution end is maintained at least 30 psi and maximum is maintained below 100 psi.
4. Velocity in the pipe is assumed to be 3 fps for initial pipe diameter calculation.
5. Friction factor is assumed to be 0.01.

Methodology:

1. A layout of water distribution pipe is prepared for each zone.
2. Each discharge point or facilities consuming water and intersections are provided with a node number.
3. Peak flows at different facilities are laid out from earlier reports.
   Note: For the industrial zone, production water demand is approximately distributed into relevant facilities.
4. Water demand at each node is determined by summing peak demands at following nodes.
5. An initial pipe diameter is then calculated from the formula:
$$Q = A \times v; A = \frac{\pi d^2}{4}$$
6. Each path of pipe network is isolated and pressure loss at the furthest point from Overhead Tank is computed and checked:
$$\text{Head loss (ft)}, h_f = 4f\frac{L}{D}\frac{v^2}{2g}$$
$$\text{Pressure loss (psi)} = h_f \times \frac{62.4}{144}$$
7. Diameter is reduced/increased on a trial & error basis until adequate pressure is met at all nodes.

Layout of Branched Network

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Sample Calculation

Pipe diameter for Node 20, 21 of Zone 1:

- Water demand at node 21: $7.1 + 24.3 = 31.4$ klpd
- Water demand of d/s nodes: 40.1 klpd
- Cumulative demand: $31.4 + 40.1 = 71.5$ klpd $= 0.0292\ ft^3$/s
- Length: 117.5 ft
- Pipe area: $\frac{Q}{v} = \frac{0.0292}{3} \times 144 = 1.4\ in^2$
- Pipe diameter: $1.4 = \frac{\pi D^2}{4} or, D = 1.34$ in
- Provided pipe diameter: 1.5 in

Pressure check for path P02 of Zone 1:

Pressure loss for node 5, 6,

- Length: 167.5 ft
- Diameter: 1.5 in
- Head loss: $4 \times 0.01 \times \frac{167.5}{1.5/12} \frac{3^2}{2 \times 32.19} = 7.49$ ft
- Pressure loss: $7.49 \times \frac{62.4}{144} = 3.25$ psi

After calculation of pressure loss for other nodes of the same path,

- Total pressure loss:
  $0.52 + 1.20 + 1.83 + 2.13 + 3.25 + 2.04 + 3.25 = 14.21$ psi
- Initial pressure at OHT: 40 psi
- Hence, available pressure: $40 - 14.21 = 25.79$ psi $[< 30$ psi$]$
- Therefore, pipe diameter has to be reconsidered
- After reconsideration, new pressure loss:
  $0.30 + 0.53 + 0.81 + 0.95 + 1.22 + 0.76 + 1.22 = 5.80$ psi
- Available pressure: $40 - 5.80 = 34.2$ psi $[\geq 30$ psi$]$

Zone 1: Residential, Commercial, Administrative

Initial Pipe Diameter

Node	Length (ft)	Peak Demand (klpd)	Peak Demand (ft^3/s)	Pipe Area (in^2)	Required Diameter (in)	Provided Diameter (in)
23, 24	130.0	0.7	0.000286	0.01	0.13	1.5
22, 23	162.5	7	0.002861	0.14	0.42	1.5
21, 22	195.0	40.1	0.016390	0.79	1.00	1.5
20, 21	117.5	71.5	0.029225	1.40	1.34	1.5
25, 26	130.0	2.7	0.001104	0.05	0.26	1.5
20, 25	85.0	3.3	0.001349	0.06	0.29	1.5
17, 20	168.0	74.8	0.030573	1.47	1.37	1.5
18, 19	130.0	4.6	0.001880	0.09	0.34	1.5
17, 18	85.0	53.9	0.022031	1.06	1.16	1.5
11, 17	168.0	128.7	0.052604	2.52	1.79	2
15, 16	134.0	4.6	0.001880	0.09	0.34	1.5
14, 15	138.5	108	0.044143	2.12	1.64	2
13, 14	125.0	109.1	0.044593	2.14	1.65	2
12, 13	85.0	110.9	0.045329	2.18	1.66	2
11, 12	82.6	111.9	0.045737	2.20	1.67	2
10, 11	230.0	243.3	0.099445	4.77	2.47	2.5
2, 10	210.0	243.3	0.099445	4.77	2.47	2.5
7, 8	167.5	13.9	0.005681	0.27	0.59	1.5
6, 7	105.0	24.9	0.010177	0.49	0.79	1.5
5, 6	167.5	47.1	0.019251	0.92	1.08	1.5
4, 5	146.7	92	0.037604	1.80	1.52	2
3, 4	125.8	94.7	0.038707	1.86	1.54	2
2, 3	82.5	126.6	0.051746	2.48	1.78	2
2, 9	82.5	0.1	0.000041	0.00	0.05	1.5
1, 2	62.5	370	0.151232	7.26	3.04	3.5

Node	Length (ft)	Peak Demand (klpd)	Peak Demand (ft^3/s)	Pipe Area (in^2)	Required Diameter (in)	Provided Diameter (in)
60, 61	100.0	16.9	0.006908	0.33	0.65	1.5
59, 60	352.0	33.8	0.013815	0.66	0.92	1.5
58, 59	84.0	42.2	0.017249	0.83	1.03	1.5
57, 58	84.0	50.6	0.020682	0.99	1.12	1.5
56, 57	84.0	59	0.024115	1.16	1.21	1.5
55, 56	84.0	67.4	0.027549	1.32	1.30	1.5
54, 55	62.0	75.8	0.030982	1.49	1.38	1.5
64, 65	70.0	13.8	0.005641	0.27	0.59	1.5
63, 64	70.0	27.6	0.011281	0.54	0.83	1.5
62, 63	70.0	41.4	0.016922	0.81	1.02	1.5
54, 62	70.0	55.2	0.022562	1.08	1.17	1.5
40, 54	165.0	131	0.053544	2.57	1.81	2
48, 49	100.0	16.9	0.006908	0.33	0.65	1.5
47, 48	170.0	40.9	0.016717	0.80	1.01	1.5
46, 47	120.0	284.7	0.116367	5.59	2.67	3
45, 46	177.0	284.7	0.116367	5.59	2.67	3
44, 45	84.0	293.1	0.119800	5.75	2.71	3
43, 44	84.0	301.5	0.123233	5.92	2.74	3
42, 43	84.0	309.9	0.126667	6.08	2.78	3
41, 42	84.0	318.3	0.130100	6.24	2.82	3
40, 41	62.0	341.7	0.139665	6.70	2.92	3
52, 53	70.0	27.6	0.011281	0.54	0.83	1.5
51, 52	70.0	55.2	0.022562	1.08	1.17	1.5
50, 51	70.0	82.8	0.033843	1.62	1.44	1.5
40, 50	55.0	110.4	0.045124	2.17	1.66	2
35, 40	220.0	583.1	0.238333	11.44	3.82	4
38, 39	70.0	23.6	0.009646	0.46	0.77	1.5
37, 38	70.0	47.2	0.019292	0.93	1.09	1.5

Node	Length (ft)	Peak Demand (klpd)	Peak Demand (ft^3/s)	Pipe Area (in^2)	Required Diameter (in)	Provided Diameter (in)
36, 37	70.0	70.8	0.028938	1.39	1.33	1.5
35, 36	55.0	94.4	0.038585	1.85	1.54	2
27, 35	155.0	677.5	0.276918	13.29	4.11	4.5
29, 30	502.5	16.1	0.006581	0.32	0.63	1.5
28, 29	207.2	248	0.101366	4.87	2.49	2.5
27, 28	80.3	248.1	0.101407	4.87	2.49	2.5
33, 34	70.0	11.8	0.004823	0.23	0.54	1.5
32, 33	70.0	23.6	0.009646	0.46	0.77	1.5
31, 32	70.0	35.4	0.014469	0.69	0.94	1.5
27, 31	55.0	47.2	0.019292	0.93	1.09	1.5
1, 27	155.0	972.8	0.397617	19.09	4.93	5

Pressure Check: Trial 1

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
P01	1, 2	62.5	3.5	1.20	0.52	145.0	2.12	37.88	OK
	2, 9	82.5	1.5	3.69	1.60				
P02	1, 2	62.5	3.5	1.20	0.52	857.5	14.21	25.79	NOT OK (Low Pressure)
	2, 3	82.5	2	2.77	1.20				
	3, 4	125.8	2	4.22	1.83				
	4, 5	146.7	2	4.92	2.13				
	5, 6	167.5	1.5	7.49	3.25				
	6, 7	105.0	1.5	4.70	2.04				
	7, 8	167.5	1.5	7.49	3.25				
P03	1, 2	62.5	3.5	1.20	0.52	1067.6	14.50	25.50	NOT OK (Low Pressure)
	2, 10	210.0	2.5	5.64	2.44				
	10, 11	230.0	2.5	6.17	2.68				
	11, 12	82.6	2	2.77	1.20				
	12, 13	85.0	2	2.85	1.24				
	13, 14	125.0	2	4.19	1.82				
	14, 15	138.5	2	4.65	2.01				
	15, 16	134.0	1.5	5.99	2.60				

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
P04	1, 2	62.5	3.5	1.20	0.52	885.5	12.25	27.75	NOT OK (Low Pressure)
	2, 10	210.0	2.5	5.64	2.44				
	10, 11	230.0	2.5	6.17	2.68				
	11, 17	168.0	2	5.64	2.44				
	17, 18	85.0	1.5	3.80	1.65				
	18, 19	130.0	1.5	5.82	2.52				
P05	1, 2	62.5	3.5	1.20	0.52	1443.5	23.06	16.94	NOT OK (Low Pressure)
	2, 10	210.0	2.5	5.64	2.44				
	10, 11	230.0	2.5	6.17	2.68				
	11, 17	168.0	2	5.64	2.44				
	17, 20	168.0	1.5	7.52	3.26				
	20, 21	117.5	1.5	5.26	2.28				
	21, 22	195.0	1.5	8.72	3.78				
	22, 23	162.5	1.5	7.27	3.15				
	23, 24	130.0	1.5	5.82	2.52				
P06	1, 2	62.5	3.5	1.20	0.52	1053.5	15.50	24.50	NOT OK (Low Pressure)
	2, 10	210.0	2.5	5.64	2.44				
	10, 11	230.0	2.5	6.17	2.68				
	11, 17	168.0	2	5.64	2.44				

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
	17, 20	168.0	1.5	7.52	3.26				
	20, 25	85.0	1.5	3.80	1.65				
	25, 26	130.0	1.5	5.82	2.52				
P07	1, 27	155.0	5	2.08	0.90	945.0	13.99	26.01	NOT OK (Low Pressure)
	27, 28	80.3	2.5	2.16	0.93				
	28, 29	207.2	2.5	5.56	2.41				
	29, 30	502.5	1.5	22.48	9.74				
P08	1, 27	155.0	5	2.08	0.90	420.0	6.04	33.96	OK
	27, 31	55.0	1.5	2.46	1.07				
	31, 32	70.0	1.5	3.13	1.36				
	32, 33	70.0	1.5	3.13	1.36				
	33, 34	70.0	1.5	3.13	1.36				
P09	1, 27	155.0	5	2.08	0.90	575.0	6.77	33.23	OK
	27, 35	155.0	4.5	2.31	1.00				
	35, 36	55.0	2	1.85	0.80				
	36, 37	70.0	1.5	3.13	1.36				
	37, 38	70.0	1.5	3.13	1.36				
	38, 39	70.0	1.5	3.13	1.36				
P10	1, 27	155.0	5	2.08	0.90	1495.0	15.47	24.53	

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
	27, 35	155.0	4.5	2.31	1.00				
	35, 40	220.0	4	3.69	1.60				
	40, 41	62.0	3	1.39	0.60				
	41, 42	84.0	3	1.88	0.81				
	42, 43	84.0	3	1.88	0.81				
	43, 44	84.0	3	1.88	0.81				NOT OK (Low Pressure)
	44, 45	84.0	3	1.88	0.81				
	45, 46	177.0	3	3.96	1.72				
	46, 47	120.0	3	2.68	1.16				
	47, 48	170.0	1.5	7.60	3.30				
	48, 49	100.0	1.5	4.47	1.94				
	1, 27	155.0	5	2.08	0.90				
	27, 35	155.0	4.5	2.31	1.00				
	35, 40	220.0	4	3.69	1.60				
P11	40, 50	55.0	2	1.85	0.80	795.0	8.37	31.63	OK
	50, 51	70.0	1.5	3.13	1.36				
	51, 52	70.0	1.5	3.13	1.36				
	52, 53	70.0	1.5	3.13	1.36				
P12	1, 27	155.0	5	2.08	0.90	1545.0	22.38	17.62	

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
	27, 35	155.0	4.5	2.31	1.00				
	35, 40	220.0	4	3.69	1.60				
	40, 54	165.0	2	5.54	2.40				
	54, 55	62.0	1.5	2.77	1.20				
	55, 56	84.0	1.5	3.76	1.63				
	56, 57	84.0	1.5	3.76	1.63				NOT OK (Low Pressure)
	57, 58	84.0	1.5	3.76	1.63				
	58, 59	84.0	1.5	3.76	1.63				
	59, 60	352.0	1.5	15.75	6.82				
	60, 61	100.0	1.5	4.47	1.94				
P13	1, 27	155.0	5	2.08	0.90	975.0	11.33	28.67	
	27, 35	155.0	4.5	2.31	1.00				
	35, 40	220.0	4	3.69	1.60				
	40, 54	165.0	2	5.54	2.40				NOT OK (Low Pressure)
	54, 62	70.0	1.5	3.13	1.36				
	62, 63	70.0	1.5	3.13	1.36				
	63, 64	70.0	1.5	3.13	1.36				

Pressure Check: Trial 2

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
P01	1, 2	62.5	6	0.70	0.30	145.0	0.90	39.10	OK
	2, 9	82.5	4	1.38	0.60				
P02	1, 2	62.5	6	0.70	0.30	857.5	5.80	34.20	OK
	2, 3	82.5	4.5	1.23	0.53				
	3, 4	125.8	4.5	1.88	0.81				
	4, 5	146.7	4.5	2.19	0.95				
	5, 6	167.5	4	2.81	1.22				
	6, 7	105.0	4	1.76	0.76				
	7, 8	167.5	4	2.81	1.22				
P03	1, 2	62.5	6	0.70	0.30	1067.6	6.62	33.38	OK
	2, 10	210.0	5	2.82	1.22				
	10, 11	230.0	5	3.09	1.34				
	11, 12	82.6	4.5	1.23	0.53				
	12, 13	85.0	4.5	1.27	0.55				
	13, 14	125.0	4.5	1.86	0.81				
	14, 15	138.5	4.5	2.07	0.89				
	15, 16	134.0	4	2.25	0.97				

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
P04	1, 2	62.5	6	0.70	0.30	885.5	5.51	34.49	OK
	2, 10	210.0	5	2.82	1.22				
	10, 11	230.0	5	3.09	1.34				
	11, 17	168.0	4.5	2.51	1.09				
	17, 18	85.0	4	1.43	0.62				
	18, 19	130.0	4	2.18	0.95				
P05	1, 2	62.5	6	0.70	0.30	1443.5	9.57	30.43	OK
	2, 10	210.0	5	2.82	1.22				
	10, 11	230.0	5	3.09	1.34				
	11, 17	168.0	4.5	2.51	1.09				
	17, 20	168.0	4	2.82	1.22				
	20, 21	117.5	4	1.97	0.85				
	21, 22	195.0	4	3.27	1.42				
	22, 23	162.5	4	2.73	1.18				
	23, 24	130.0	4	2.18	0.95				
P06	1, 2	62.5	6	0.70	0.30	1053.5	6.73	33.27	OK
	2, 10	210.0	5	2.82	1.22				
	10, 11	230.0	5	3.09	1.34				
	11, 17	168.0	4.5	2.51	1.09				

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
	17, 20	168.0	4	2.82	1.22				
	20, 25	85.0	4	1.43	0.62				
	25, 26	130.0	4	2.18	0.95				
P07	1, 27	155.0	7.5	1.39	0.60	945.0	5.93	34.07	OK
	27, 28	80.3	5	1.08	0.47				
	28, 29	207.2	5	2.78	1.20				
	29, 30	502.5	4	8.43	3.65				
P08	1, 27	155.0	7.5	1.39	0.60	420.0	2.53	37.47	OK
	27, 31	55.0	4	0.92	0.40				
	31, 32	70.0	4	1.17	0.51				
	32, 33	70.0	4	1.17	0.51				
	33, 34	70.0	4	1.17	0.51				
P09	1, 27	155.0	7.5	1.39	0.60	575.0	3.13	36.87	OK
	27, 35	155.0	7	1.49	0.64				
	35, 36	55.0	4.5	0.82	0.36				
	36, 37	70.0	4	1.17	0.51				
	37, 38	70.0	4	1.17	0.51				
	38, 39	70.0	4	1.17	0.51				
P10	1, 27	155.0	7.5	1.39	0.60	1495.0	7.87	32.13	OK

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
	27, 35	155.0	7	1.49	0.64				
	35, 40	220.0	6.5	2.27	0.98				
	40, 41	62.0	5.5	0.76	0.33				
	41, 42	84.0	5.5	1.02	0.44				
	42, 43	84.0	5.5	1.02	0.44				
	43, 44	84.0	5.5	1.02	0.44				
	44, 45	84.0	5.5	1.02	0.44				
	45, 46	177.0	5.5	2.16	0.94				
	46, 47	120.0	5.5	1.46	0.63				
	47, 48	170.0	4	2.85	1.24				
	48, 49	100.0	4	1.68	0.73				
P11	1, 27	155.0	7.5	1.39	0.60	795.0	4.11	35.89	OK
	27, 35	155.0	7	1.49	0.64				
	35, 40	220.0	6.5	2.27	0.98				
	40, 50	55.0	4.5	0.82	0.36				
	50, 51	70.0	4	1.17	0.51				
	51, 52	70.0	4	1.17	0.51				
	52, 53	70.0	4	1.17	0.51				
P12	1, 27	155.0	7.5	1.39	0.60	1545.0	9.47	30.53	OK

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
	27, 35	155.0	7	1.49	0.64				
	35, 40	220.0	6.5	2.27	0.98				
	40, 54	165.0	4.5	2.46	1.07				
	54, 55	62.0	4	1.04	0.45				
	55, 56	84.0	4	1.41	0.61				
	56, 57	84.0	4	1.41	0.61				
	57, 58	84.0	4	1.41	0.61				
	58, 59	84.0	4	1.41	0.61				
	59, 60	352.0	4	5.90	2.56				
	60, 61	100.0	4	1.68	0.73				
P13	1, 27	155.0	7.5	1.39	0.60	975.0	5.33	34.67	OK
	27, 35	155.0	7	1.49	0.64				
	35, 40	220.0	6.5	2.27	0.98				
	40, 54	165.0	4.5	2.46	1.07				
	54, 62	70.0	4	1.17	0.51				
	62, 63	70.0	4	1.17	0.51				
	63, 64	70.0	4	1.17	0.51				
	64, 65	70.0	4	1.17	0.51				

Zone 2: Industrial

Initial Pipe Diameter

Node	Length (ft)	Peak Demand (klpd)	Peak Demand (ft^2/s)	Pipe Area (in^2)	Required Diameter (in)	Provided Diameter (in)
13, 14	230.0	0.1	0.000041	0.0020	0.05	1.5
13, 15	380.0	0.1	0.000041	0.0020	0.05	1.5
12, 13	265.0	0.2	0.000082	0.0039	0.07	1.5
11, 12	150.0	62.3	0.025464	1.2223	1.25	1.5
10, 11	265.0	103.3	0.042222	2.0267	1.61	2
2, 10	170.0	312.7	0.127811	6.1349	2.79	3
8, 9	425.0	11	0.004496	0.2158	0.52	1.5
7, 8	170.0	11.2	0.004578	0.2197	0.53	1.5
6, 7	165.0	11.7	0.004782	0.2295	0.54	1.5
5, 6	150.0	93.6	0.038258	1.8364	1.53	2
4, 5	260.0	258.5	0.105658	5.0716	2.54	3
3, 4	230.0	974.7	0.398394	19.1229	4.93	5
2, 3	230.0	1009.2	0.412495	19.7998	5.02	5.5
1, 2	90.0	1322	0.540347	25.9367	5.75	6
18, 19	190.0	716.2	0.292736	14.0513	4.23	4.5
17, 18	365.0	716.5	0.292858	14.0572	4.23	4.5
17, 20	230.0	0.4	0.000163	0.0078	0.10	1.5
16, 17	85.0	716.9	0.293022	14.0650	4.23	4.5
1, 16	165.0	739	0.302055	14.4986	4.30	4.5

Pressure Check: Trial 1

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
P01	1, 2	90.0	6	1.01	0.44	1720.0	22.42	17.58	NOT OK (Low Pressure)
	2, 3	230.0	5.5	2.81	1.22				
	3, 4	230.0	5	3.09	1.34				
	4, 5	260.0	3	5.82	2.52				
	5, 6	150.0	2	5.03	2.18				
	6, 7	165.0	1.5	7.38	3.20				
	7, 8	170.0	1.5	7.60	3.30				
	8, 9	425.0	1.5	19.01	8.24				
P02	1, 2	90.0	6	1.01	0.44	1170.0	18.44	21.56	NOT OK (Low Pressure)
	2, 10	170.0	3	3.80	1.65				
	10, 11	265.0	2	8.89	3.85				
	11, 12	150.0	1.5	6.71	2.91				
	12, 13	265.0	1.5	11.85	5.14				
	13, 14	230.0	1.5	10.29	4.46				
P03	1, 2	90.0	6	1.01	0.44	1320.0	21.35	18.65	NOT OK (Low Pressure)
	2, 10	170.0	3	3.80	1.65				
	10, 11	265.0	2	8.89	3.85				

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
	11, 12	150.0	1.5	6.71	2.91				
	12, 13	265.0	1.5	11.85	5.14				
	13, 15	380.0	1.5	17.00	7.37				
P04	1, 16	165.0	4.5	2.46	1.07	805.0	5.20	34.80	OK
	16, 17	85.0	4.5	1.27	0.55				
	17, 18	365.0	4.5	5.44	2.36				
	18, 19	190.0	4.5	2.83	1.23				
P05	1, 16	165.0	4.5	2.46	1.07	480.0	6.07	33.93	OK
	16, 17	85.0	4.5	1.27	0.55				
	17, 20	230.0	1.5	10.29	4.46				

Pressure Check: Trial 2

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
P01	1, 2	90.0	8.5	0.71	0.31	1720.0	9.90	30.10	OK
	2, 3	230.0	8	1.93	0.84				
	3, 4	230.0	7.5	2.06	0.89				
	4, 5	260.0	5.5	3.17	1.37				
	5, 6	150.0	4.5	2.24	0.97				
	6, 7	165.0	4	2.77	1.20				
	7, 8	170.0	4	2.85	1.24				
	8, 9	425.0	4	7.13	3.09				
P02	1, 2	90.0	8.5	0.71	0.31	1170.0	7.61	32.39	OK
	2, 10	170.0	5.5	2.07	0.90				
	10, 11	265.0	4.5	3.95	1.71				
	11, 12	150.0	4	2.52	1.09				
	12, 13	265.0	4	4.45	1.93				
	13, 14	230.0	4	3.86	1.67				
P03	1, 2	90.0	8.5	0.71	0.31	1320.0	8.70	31.30	OK
	2, 10	170.0	5.5	2.07	0.90				
	10, 11	265.0	4.5	3.95	1.71				

Path	Node	Length (ft)	Diameter (in)	Head Loss (ft)	Pressure Loss (psi)	Total Length (ft)	Total Pressure Loss (psi)	Available Pressure (psi)	Remarks
	11, 12	150.0	4	2.52	1.09				
	12, 13	265.0	4	4.45	1.93				
	13, 15	380.0	4	6.37	2.76				
P04	1, 16	165.0	4.5	2.46	1.07	805.0	5.20	34.80	OK
	16, 17	85.0	4.5	1.27	0.55				
	17, 18	365.0	4.5	5.44	2.36				
	18, 19	190.0	4.5	2.83	1.23				
P05	1, 16	165.0	4.5	2.46	1.07	480.0	6.07	33.93	OK
	16, 17	85.0	4.5	1.27	0.55				
	17, 20	230.0	1.5	10.29	4.46				

Looped Water Distribution Network

Introduction

Two looped water distribution networks for the two zones of the industrial park are computed in this report using Hardy Cross method.

Assumptions and conditions:

1. Water demand of each facility is taken from previously determined peak water demand for the design period of 30 years.
2. Flow entering a junction is equal to the flow leaving.
3. Algebraic sum of head loss in a closed loop is zero.
4. Value of Hazen-Williams constant k is assumed to be 1.
5. Value of x in Hazen-Williams equation is 1.85.

Methodology:

1. A layout of looped water distribution network is prepared for each zone.
2. Reasonable discharge rate is provided to each junction/intersection points throughout the network. The discharge rate is influenced by surrounding facilities' peak water demand.
   Note: For the industrial zone, production water demand is approximately distributed into relevant facilities
3. Through repeated trials, pipe flow is computed for each path using the Hazen-Williams equation for Hardy Cross method.
   a. For each loop, head loss (H) and H/Q was computed for each pipe.
   $$H = kQ^x$$
   Here,
   - H is head loss (ft).
   - k is a constant assumed to be 1.
   - Q is the assumed/corrected flow for the path.
   - x is 1.85.
   b. While taking into account the direction of flow with respect to adjacent loop, flow correction was computed and applied into initial pipe flow.
   $$Correction = -\frac{\sum H}{x\sum(H/Q)}$$
   c. This procedure is repeated until accuracy of 0.001 is obtained.
4. Pipe diameter (d) is computed assuming velocity (v) is 3 fps.
   $$Q = Av; A = \frac{\pi d^2}{4}$$

Layout of Looped Network

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Sample Calculation

Zone 2, Trial 1:

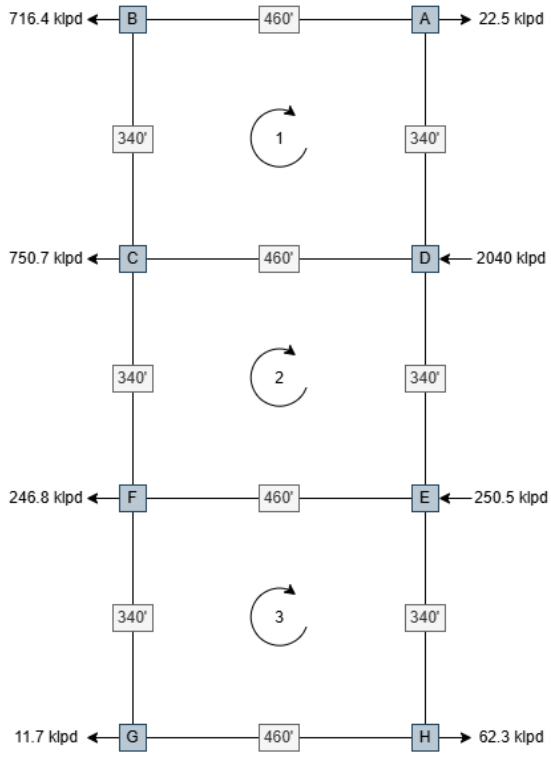


Figure 7 Schematic diagram of Zone 2 loop network

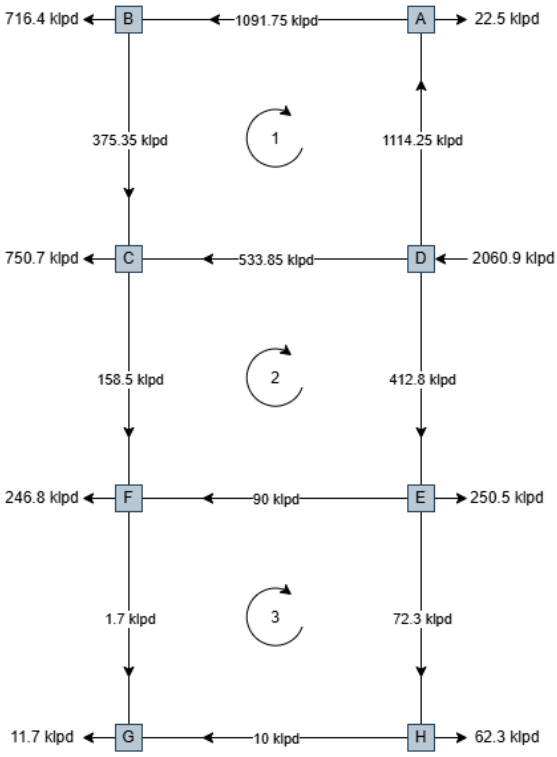


Figure 8 Initially assumed pipe flow of Zone 2

Loop 1:

- Path DA:
  - $Q = \frac{1114.25 \times 1000}{28.317 \times 86400} = 0.4554\ ft^3/s$
  - $H = 1 \times 0.4554^{1.85} = 0.2334$ ft [anticlockwise]
  - $\frac{H}{Q} = \frac{0.2334}{0.4554} = 0.5125$
- Path BA:
  - $Q = \frac{1091.75 \times 1000}{28.317 \times 86400} = 0.4462\ ft^3/s$
  - $H = 1 \times 0.4462^{1.85} = 0.2247$ ft [anticlockwise]
  - $\frac{H}{Q} = \frac{0.2247}{0.4462} = 0.5037$
- Path CB:
  - $Q = \frac{375.35 \times 1000}{28.317 \times 86400} = 0.1534\ ft^3/s$
  - $H = 1 \times 0.1534^{1.85} = 0.0312$ ft [anticlockwise]
  - $\frac{H}{Q} = \frac{0.0312}{0.1534} = 0.2032$

- Path CD (common):
  - $Q = \frac{533.85 \times 1000}{28.317 \times 86400} = 0.2182\ ft^3/\text{s}$
  - $H = 1 \times 0.2182^{1.85} = 0.0598\ \text{ft}$ [clockwise]
  - $\frac{H}{Q} = \frac{0.0598}{0.2182} = 0.2742$
- Correction:
  - $\sum H = -0.2334 - 0.2247 - 0.0312 + 0.0598 = -0.4295\ \text{ft}$
  - $\sum \frac{H}{Q} = 0.5125 + 0.5037 + 0.2032 + 0.2742 = 1.4935$
  - $\Delta = -\frac{-0.4295}{1.85 \times 1.4935} = 0.1554\ \text{ft}^3/s = 380.30\ klpd$

Loop 2:

- Path ED:
  - $Q = \frac{412.80 \times 1000}{28.317 \times 86400} = 0.1687\ ft^3/\text{s}$
  - $H = 1 \times 0.1687^{1.85} = 0.0372\ \text{ft}$ [clockwise]
  - $\frac{H}{Q} = \frac{0.0372}{0.1687} = 0.2203$
- Path CD (common):
  - $Q = \frac{533.85 \times 1000}{28.317 \times 86400} = 0.2182\ ft^3/\text{s}$
  - $H = 1 \times 0.2182^{1.85} = 0.0598\ \text{ft}$ [anticlockwise]
  - $\frac{H}{Q} = \frac{0.0598}{0.2182} = 0.2742$
- Path FC:
  - $Q = \frac{158.50 \times 1000}{28.317 \times 86400} = 0.0648\ ft^3/\text{s}$
  - $H = 1 \times 0.0648^{1.85} = 0.0063\ \text{ft}$ [anticlockwise]
  - $\frac{H}{Q} = \frac{0.0312}{0.0648} = 0.0977$
- Path FE (common):
  - $Q = \frac{90.00 \times 1000}{28.317 \times 86400} = 0.0368\ ft^3/\text{s}$
  - $H = 1 \times 0.0368^{1.85} = 0.0022\ \text{ft}$ [clockwise]
  - $\frac{H}{Q} = \frac{0.0598}{0.0368} = 0.0604$
- Correction:
  - $\sum H = 0.0372 - 0.0598 - 0.0063 + 0.0022 = -0.0268\ \text{ft}$
  - $\sum \frac{H}{Q} = 0.2203 + 0.2742 + 0.0977 + 0.0604 = 0.6526$
  - $\Delta = -\frac{-0.0268}{1.85 \times 0.6526} = 0.0222\ \text{ft}^3/s = 54.22\ klpd$

Loop 3:

- Path HE:
  - $Q = \frac{72.30 \times 1000}{28.317 \times 86400} = 0.0296\ ft^3/\text{s}$
  - $H = 1 \times 0.0296^{1.85} = 0.0015$ ft [clockwise]
  - $\frac{H}{Q} = \frac{0.0015}{0.0296} = 0.0501$
- Path FE (common):
  - $Q = \frac{90.00 \times 1000}{28.317 \times 86400} = 0.0368\ ft^3/\text{s}$
  - $H = 1 \times 0.0368^{1.85} = 0.0022$ ft [anticlockwise]
  - $\frac{H}{Q} = \frac{0.0022}{0.0368} = 0.0604$
- Path GF:
  - $Q = \frac{1.70 \times 1000}{28.317 \times 86400} = 0.0007\ ft^3/\text{s}$
  - $H = 1 \times 0.0007^{1.85} = 1.46E-6$ ft [anticlockwise]
  - $\frac{H}{Q} = \frac{1.46E-6}{0.0007} = 0.0021$
- Path GH:
  - $Q = \frac{10.00 \times 1000}{28.317 \times 86400} = 0.0041\ ft^3/\text{s}$
  - $H = 1 \times 0.0041^{1.85} = 3.83E-5$ ft [clockwise]
  - $\frac{H}{Q} = \frac{3.83E-5}{0.0041} = 0.0093$
- Correction:
  - $\sum H = 0.0015 - 0.0022 - 1.46E-6 + 3.83E-5 = -0.0007$ ft
  - $\sum \frac{H}{Q} = 0.0501 + 0.0604 + 0.0021 + 0.0093 = 0.1219$
  - $\Delta = -\frac{-0.0007}{1.85 \times 0.1219} = 0.0031\ \text{ft}^3/s = 7.63\ klpd$

Corrected flow:

Path	Corrected Flow (klpd)
DA	$1114.25 - 380.30 = 733.95$
BA	$1091.75 - 380.30 = 711.45$
CB	$375.35 - 380.30 = -4.95$
CD	$533.85 + 326.08 = 859.93$
ED	$412.80 + 54.22 = 467.02$
FC	$158.50 - 54.22 = 104.28$
FE	$90.00 + 46.59 = 136.59$
HE	$72.30 + 7.63 = 79.93$
GF	$1.70 - 7.63 = -5.93$
GH	$10.00 + 7.63 = 17.63$

Pipe diameter, Path DA:

- After several trials, corrected flow: 568.84 klpd
- Pipe flow, $Q = \frac{568.84 \times 1000}{28.317 \times 86400} = 0.2325\ ft^3$/s
- Assumed velocity, $v = 3$ ft/s
- Pipe area, $A = \frac{0.2325 \times 144}{3} = 11.16\ in^2$
- Pipe diameter, $d_{req} = \sqrt{\frac{11.16 \times 4}{\pi}} = 3.77$ in
- Provided diameter, $d = 4$ in

Zone 2: Industrial

Pipe Flow Determination

Trial 1:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
DA	-1114.25	-0.4554	-0.2334	0.5125	0.1554	380.30
BA	-1091.75	-0.4462	-0.2247	0.5037		
CB	-375.35	-0.1534	-0.0312	0.2032		
CD	533.85	0.2182	0.0598	0.2742		
Total			**-0.4295**	**1.4935**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
ED	412.80	0.1687	0.0372	0.2203	0.0222	54.22
CD	-533.85	-0.2182	-0.0598	0.2742		
FC	-158.50	-0.0648	-0.0063	0.0977		
FE	90.00	0.0368	0.0022	0.0604		
Total			**-0.0268**	**0.6526**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HE	72.30	0.0296	0.0015	0.0501	0.0031	7.63
FE	-90.00	-0.0368	-0.0022	0.0604		
GF	-1.70	-0.0007	0.0000	0.0021		
GH	10.00	0.0041	0.0000	0.0093		
Total			**-0.0007**	**0.1219**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DA	1114.25	-380.30	733.95
BA	1091.75	-380.30	711.45
CB	375.35	-380.30	-4.95
CD	533.85	326.08	859.93
ED	412.80	54.22	467.02
FC	158.50	-54.22	104.28
FE	90.00	46.59	136.59
HE	72.30	7.63	79.93
GF	1.70	-7.63	-5.93
GH	10.00	7.63	17.63

Trial 2:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
DA	-733.95	-0.3000	-0.1078	0.3594	0.0312	76.42
BA	-711.45	-0.2908	-0.1018	0.3500		
CB	4.95	0.0020	0.0000	0.0051		
CD	859.93	0.3515	0.1445	0.4112		
Total			**-0.0650**	**1.1257**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
ED	467.02	0.1909	0.0467	0.2447	0.0640	156.53
CD	-859.93	-0.3515	-0.1445	0.4112		
FC	-104.28	-0.0426	-0.0029	0.0684		
FE	136.59	0.0558	0.0048	0.0861		
Total			**-0.0959**	**0.8104**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HE	79.93	0.0327	0.0018	0.0546	0.0097	23.70
FE	-136.59	-0.0558	-0.0048	0.0861		
GF	5.93	0.0024	0.0000	0.0060		
GH	17.63	0.0072	0.0001	0.0151		
Total			**-0.0029**	**0.1617**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DA	733.95	-76.42	657.52
BA	711.45	-76.42	635.02
CB	-4.95	-76.42	-81.38
CD	859.93	-80.11	779.83
ED	467.02	156.53	623.55
FC	104.28	-156.53	-52.25
FE	136.59	132.83	269.42
HE	79.93	23.70	103.63
GF	-5.93	-23.70	-29.63
GH	17.63	23.70	41.33

Trial 3:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
DA	-657.52	-0.2688	-0.0880	0.3273	0.0240	58.83
BA	-635.02	-0.2596	-0.0825	0.3178		
CB	81.38	0.0333	0.0018	0.0554		
CD	779.83	0.3187	0.1206	0.3784		
Total			**-0.0480**	**1.0789**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
ED	623.55	0.2549	0.0797	0.3129	0.0142	34.71
CD	-779.83	-0.3187	-0.1206	0.3784		
FC	52.25	0.0214	0.0008	0.0380		
FE	269.42	0.1101	0.0169	0.1533		
Total			**-0.0232**	**0.8826**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HE	103.63	0.0424	0.0029	0.0681	0.0258	63.20
FE	-269.42	-0.1101	-0.0169	0.1533		
GF	29.63	0.0121	0.0003	0.0235		
GH	41.33	0.0169	0.0005	0.0312		
Total			**-0.0132**	**0.2760**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DA	657.52	-58.83	598.69
BA	635.02	-58.83	576.19
CB	-81.38	-58.83	-140.21
CD	779.83	24.11	803.94
ED	623.55	34.71	658.27
FC	-52.25	-34.71	-86.97
FE	269.42	-28.48	240.94
HE	103.63	63.20	166.83
GF	-29.63	-63.20	-92.83
GH	41.33	63.20	104.53

Trial 4:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
DA	-598.69	-0.2447	-0.0740	0.3022	0.0052	12.62
BA	-576.19	-0.2355	-0.0689	0.2926		
CB	140.21	0.0573	0.0050	0.0880		
CD	803.94	0.3286	0.1276	0.3883		
Total			**-0.0102**	**1.0711**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
ED	658.27	0.2691	0.0881	0.3276	0.0140	34.19
CD	-803.94	-0.3286	-0.1276	0.3883		
FC	86.97	0.0355	0.0021	0.0586		
FE	240.94	0.0985	0.0137	0.1394		
Total			**-0.0236**	**0.9140**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HE	166.83	0.0682	0.0070	0.1020	0.0022	5.31
FE	-240.94	-0.0985	-0.0137	0.1394		
GF	92.83	0.0379	0.0024	0.0620		
GH	104.53	0.0427	0.0029	0.0686		
Total			**-0.0015**	**0.3720**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DA	598.69	-12.62	586.07
BA	576.19	-12.62	563.57
CB	-140.21	-12.62	-152.83
CD	803.94	-21.57	782.37
ED	658.27	34.19	692.46
FC	-86.97	-34.19	-121.16
FE	240.94	28.88	269.82
HE	166.83	5.31	172.14
GF	-92.83	-5.31	-98.14
GH	104.53	5.31	109.84

Trial 5:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
DA	-586.07	-0.2395	-0.0711	0.2968	0.0051	12.48
BA	-563.57	-0.2304	-0.0661	0.2871		
CB	152.83	0.0625	0.0059	0.0947		
CD	782.37	0.3198	0.1213	0.3794		
Total			**-0.0100**	**1.0580**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
ED	692.46	0.2830	0.0968	0.3420	0.0021	5.20
CD	-782.37	-0.3198	-0.1213	0.3794		
FC	121.16	0.0495	0.0038	0.0777		
FE	269.82	0.1103	0.0169	0.1535		
Total			**-0.0037**	**0.9527**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HE	172.14	0.0704	0.0074	0.1048	0.0051	12.53
FE	-269.82	-0.1103	-0.0169	0.1535		
GF	98.14	0.0401	0.0026	0.0650		
GH	109.84	0.0449	0.0032	0.0715		
Total			**-0.0037**	**0.3948**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DA	586.07	-12.48	573.59
BA	563.57	-12.48	551.09
CB	-152.83	-12.48	-165.31
CD	782.37	7.28	789.65
ED	692.46	5.20	697.66
FC	-121.16	-5.20	-126.36
FE	269.82	-7.33	262.49
HE	172.14	12.53	184.67
GF	-98.14	-12.53	-110.67
GH	109.84	12.53	122.37

Trial 6:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
DA	-573.59	-0.2344	-0.0683	0.2914	0.0008	1.88
BA	-551.09	-0.2252	-0.0634	0.2817		
CB	165.31	0.0676	0.0068	0.1012		
CD	789.65	0.3228	0.1234	0.3824		
Total			**-0.0015**	**1.0568**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
ED	697.66	0.2852	0.0982	0.3442	0.0028	6.94
CD	-789.65	-0.3228	-0.1234	0.3824		
FC	126.36	0.0516	0.0042	0.0806		
FE	262.49	0.1073	0.0161	0.1500		
Total			**-0.0050**	**0.9571**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HE	184.67	0.0755	0.0084	0.1112	0.0007	1.66
FE	-262.49	-0.1073	-0.0161	0.1500		
GF	110.67	0.0452	0.0033	0.0720		
GH	122.37	0.0500	0.0039	0.0784		
Total			**-0.0005**	**0.4115**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DA	573.59	-1.88	571.71
BA	551.09	-1.88	549.21
CB	-165.31	-1.88	-167.19
CD	789.65	-5.06	784.59
ED	697.66	6.94	704.61
FC	-126.36	-6.94	-133.31
FE	262.49	5.28	267.77
HE	184.67	1.66	186.34
GF	-110.67	-1.66	-112.34
GH	122.37	1.66	124.04

Trial 7:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
DA	-571.71	-0.2337	-0.0679	0.2906	0.0010	2.51
BA	-549.21	-0.2245	-0.0630	0.2809		
CB	167.19	0.0683	0.0070	0.1022		
CD	784.59	0.3207	0.1220	0.3803		
Total			**-0.0020**	**1.0540**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
ED	704.61	0.2880	0.1000	0.3471	0.0004	0.98
CD	-784.59	-0.3207	-0.1220	0.3803		
FC	133.31	0.0545	0.0046	0.0843		
FE	267.77	0.1094	0.0167	0.1525		
Total			**-0.0007**	**0.9643**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HE	186.34	0.0762	0.0085	0.1121	0.0010	2.51
FE	-267.77	-0.1094	-0.0167	0.1525		
GF	112.34	0.0459	0.0033	0.0729		
GH	124.04	0.0507	0.0040	0.0793		
Total			**-0.0008**	**0.4168**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DA	571.71	-2.51	569.19
BA	549.21	-2.51	546.69
CB	-167.19	-2.51	-169.71
CD	784.59	1.53	786.12
ED	704.61	0.98	705.59
FC	-133.31	-0.98	-134.29
FE	267.77	-1.53	266.24
HE	186.34	2.51	188.84
GF	-112.34	-2.51	-114.84
GH	124.04	2.51	126.54

Trial 8:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
DA	-569.19	-0.2326	-0.0674	0.2895	0.0001	0.35
BA	-546.69	-0.2235	-0.0625	0.2798		
CB	169.71	0.0694	0.0072	0.1035		
CD	786.12	0.3213	0.1224	0.3810		
Total			**-0.0003**	**1.0538**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
ED	705.59	0.2884	0.1002	0.3475	0.0006	1.39
CD	-786.12	-0.3213	-0.1224	0.3810		
FC	134.29	0.0549	0.0047	0.0848		
FE	266.24	0.1088	0.0165	0.1518		
Total			**-0.0010**	**0.9651**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HE	188.84	0.0772	0.0087	0.1133	0.0001	0.35
FE	-266.24	-0.1088	-0.0165	0.1518		
GF	114.84	0.0469	0.0035	0.0743		
GH	126.54	0.0517	0.0042	0.0807		
Total			**-0.0001**	**0.4201**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DA	569.19	-0.35	568.84
BA	546.69	-0.35	546.34
CB	-169.71	-0.35	-170.06
CD	786.12	-1.03	785.09
ED	705.59	1.39	706.97
FC	-134.29	-1.39	-135.67
FE	266.24	1.04	267.28
HE	188.84	0.35	189.19
GF	-114.84	-0.35	-115.19
GH	126.54	0.35	126.89

Pipe Diameter Determination

Path	Velocity (fps)	Flow (klpd)	Flow (ft^3/s)	Pipe Area (in^2)	Required Diameter (in)	Provided Diameter (in)
DA	3	568.84	0.2325	11.16	3.77	4
BA	3	546.34	0.2233	10.72	3.69	4
CB	3	170.06	0.0695	3.34	2.06	2.5
CD	3	785.09	0.3209	15.40	4.43	4.5
ED	3	706.97	0.2890	13.87	4.20	4.5
FC	3	135.67	0.0555	2.66	1.84	2
FE	3	267.28	0.1092	5.24	2.58	3
HE	3	189.19	0.0773	3.71	2.17	2.5
GF	3	115.19	0.0471	2.26	1.70	2
GH	3	126.89	0.0519	2.49	1.78	2

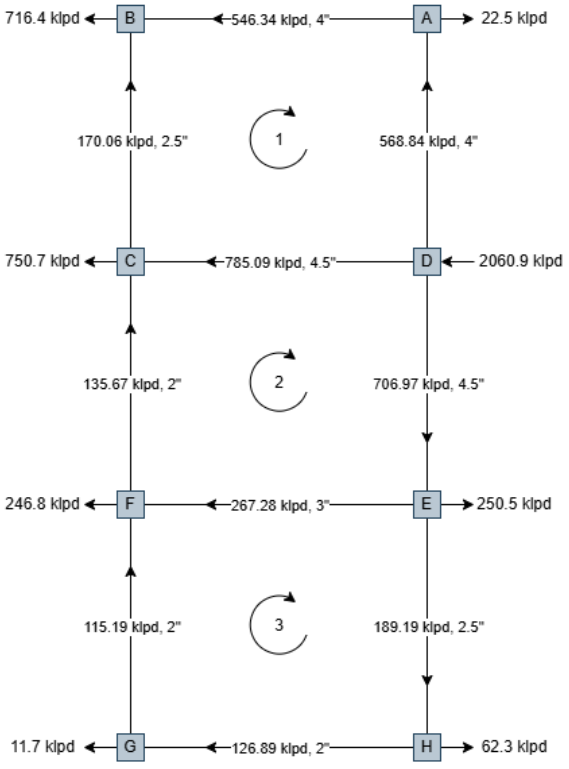


Figure 9 Pipe parameters of Zone 2

Zone 1: Residential, Commercial, Administrative

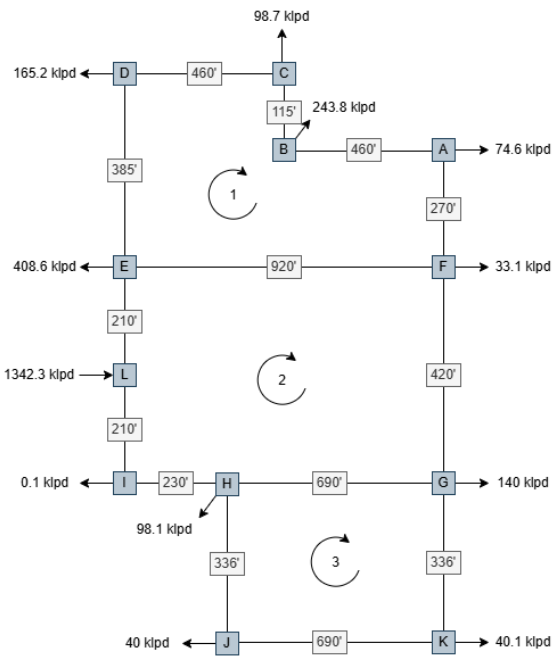


Figure 10 Schematic diagram of Zone 1 loop network

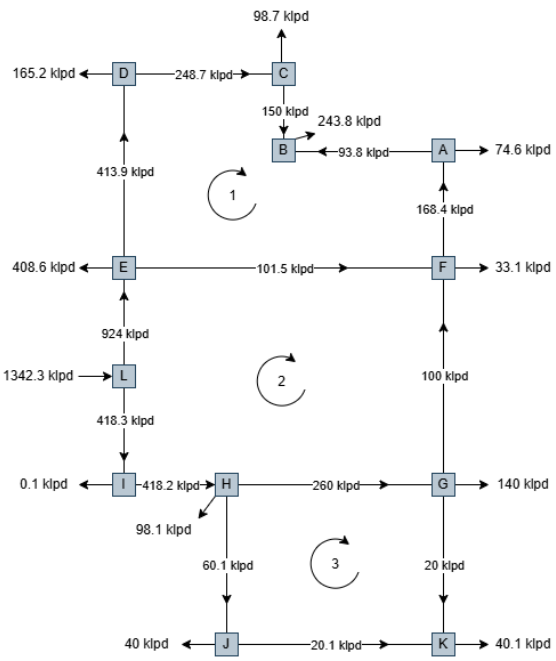


Figure 11 Initially assumed pipe flow of Zone 1

Pipe Flow Determination

Trial 1:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
BA	-93.80	-0.0383	-0.0024	0.0625	-0.0356	-87.05
BC	150.00	0.0613	0.0057	0.0932		
DC	248.70	0.1017	0.0146	0.1432		
ED	413.90	0.1692	0.0374	0.2208		
EF	-101.50	-0.0415	-0.0028	0.0669		
FA	-168.40	-0.0688	-0.0071	0.1028		
Total			**0.0454**	**0.6895**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
EF	101.50	0.0415	0.0028	0.0669	-0.0340	-83.09
LE	924.00	0.3777	0.1651	0.4371		
IL	-418.30	-0.1710	-0.0381	0.2228		
IH	-418.20	-0.1709	-0.0381	0.2228		
HG	-260.00	-0.1063	-0.0158	0.1487		
GF	-100.00	-0.0409	-0.0027	0.0660		
Total			**0.0732**	**1.1643**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HG	260.00	0.1063	0.0158	0.1487	-0.0354	-86.61
JH	-60.10	-0.0246	-0.0011	0.0428		
JK	-20.10	-0.0082	-0.0001	0.0169		
KG	20.00	0.0082	0.0001	0.0168		
Total			**0.0148**	**0.2253**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DC	248.70	-87.05	161.65
BC	150.00	-87.05	62.95
BA	93.80	87.05	180.85
FA	168.40	87.05	255.45
ED	413.90	-87.05	326.85
EF	101.50	3.96	105.46
IH	418.20	83.09	501.29
HG	260.00	-3.53	256.47
IL	418.30	83.09	501.39
LE	924.00	-83.09	840.91
GF	100.00	83.09	183.09
JK	20.10	86.61	106.71
JH	60.10	86.61	146.71
KG	20.00	-86.61	-66.61

Trial 2:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
BA	-180.85	-0.0739	-0.0081	0.1093	-0.0046	-11.19
BC	62.95	0.0257	0.0011	0.0446		
DC	161.65	0.0661	0.0066	0.0993		
ED	326.85	0.1336	0.0241	0.1807		
EF	-105.46	-0.0431	-0.0030	0.0691		
FA	-255.45	-0.1044	-0.0153	0.1465		
Total			**0.0055**	**0.6494**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
EF	105.46	0.0431	0.0030	0.0691	-0.0049	-12.11
LE	840.91	0.3437	0.1387	0.4034		
IL	-501.39	-0.2049	-0.0533	0.2599		
IH	-501.29	-0.2049	-0.0533	0.2599		
HG	-256.47	-0.1048	-0.0154	0.1470		
GF	-183.09	-0.0748	-0.0083	0.1104		
Total			**0.0114**	**1.2498**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HG	256.47	0.1048	0.0154	0.1470	-0.0085	-20.91
JH	-146.71	-0.0600	-0.0055	0.0915		
JK	-106.71	-0.0436	-0.0030	0.0698		
KG	-66.61	-0.0272	-0.0013	0.0467		
Total			**0.0056**	**0.3550**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DC	161.65	-11.19	150.46
BC	62.95	-11.19	51.76
BA	180.85	11.19	192.04
FA	255.45	11.19	266.64
ED	326.85	-11.19	315.66
EF	105.46	-0.92	104.54
IH	501.29	12.11	513.40
HG	256.47	-8.80	247.67
IL	501.39	12.11	513.50
LE	840.91	-12.11	828.80
GF	183.09	12.11	195.20
JK	106.71	20.91	127.62
JH	146.71	20.91	167.62
KG	-66.61	-20.91	-87.52

Trial 3:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
BA	-192.04	-0.0785	-0.0090	0.1150	-0.0006	-1.36
BC	51.76	0.0212	0.0008	0.0377		
DC	150.46	0.0615	0.0057	0.0934		
ED	315.66	0.1290	0.0226	0.1754		
EF	-104.54	-0.0427	-0.0029	0.0686		
FA	-266.64	-0.1090	-0.0166	0.1520		
Total			**0.0007**	**0.6421**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
EF	104.54	0.0427	0.0029	0.0686	-0.0012	-2.99
LE	828.80	0.3388	0.1350	0.3985		
IL	-513.50	-0.2099	-0.0557	0.2653		
IH	-513.40	-0.2098	-0.0557	0.2652		
HG	-247.67	-0.1012	-0.0144	0.1427		
GF	-195.20	-0.0798	-0.0093	0.1166		
Total			**0.0028**	**1.2569**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HG	247.67	0.1012	0.0144	0.1427	-0.0015	-3.72
JH	-167.62	-0.0685	-0.0070	0.1024		
JK	-127.62	-0.0522	-0.0042	0.0812		
KG	-87.52	-0.0358	-0.0021	0.0590		
Total			**0.0011**	**0.3854**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DC	150.46	-1.36	149.10
BC	51.76	-1.36	50.40
BA	192.04	1.36	193.40
FA	266.64	1.36	268.00
ED	315.66	-1.36	314.30
EF	104.54	-1.63	102.91
IH	513.40	2.99	516.38
HG	247.67	-0.74	246.94
IL	513.50	2.99	516.48
LE	828.80	-2.99	825.82
GF	195.20	2.99	198.18
JK	127.62	3.72	131.35
JH	167.62	3.72	171.35
KG	-87.52	-3.72	-91.25

Trial 4:

Loop 1:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
BA	-193.40	-0.0790	-0.0091	0.1157	-0.0001	-0.32
BC	50.40	0.0206	0.0008	0.0369		
DC	149.10	0.0609	0.0057	0.0927		
ED	314.30	0.1285	0.0225	0.1748		
EF	-102.91	-0.0421	-0.0028	0.0677		
FA	-268.00	-0.1095	-0.0167	0.1526		
Total			**0.0002**	**0.6403**		

Loop 2:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
EF	102.91	0.0421	0.0028	0.0677	-0.0002	-0.49
LE	825.82	0.3375	0.1341	0.3973		
IL	-516.48	-0.2111	-0.0563	0.2666		
IH	-516.38	-0.2111	-0.0563	0.2665		
HG	-246.94	-0.1009	-0.0144	0.1424		
GF	-198.18	-0.0810	-0.0096	0.1181		
Total			**0.0005**	**1.2585**		

Loop 3:

Path	Q (klpd)	Q (ft^3/s)	H (ft)	H/Q	Correction (ft^3/s)	Correction (klpd)
HG	246.94	0.1009	0.0144	0.1424	-0.0004	-1.06
JH	-171.35	-0.0700	-0.0073	0.1044		
JK	-131.35	-0.0537	-0.0045	0.0832		
KG	-91.25	-0.0373	-0.0023	0.0611		
Total			**0.0003**	**0.3911**		

Corrected flow:

Path	Flow (klpd)	Correction (klpd)	Corrected Flow (klpd)
DC	149.10	-0.32	148.78
BC	50.40	-0.32	50.08
BA	193.40	0.32	193.72
FA	268.00	0.32	268.32
ED	314.30	-0.32	313.98
EF	102.91	-0.17	102.74
IH	516.38	0.49	516.88
HG	246.94	-0.57	246.37
IL	516.48	0.49	516.98
LE	825.82	-0.49	825.32
GF	198.18	0.49	198.68
JK	131.35	1.06	132.41
JH	171.35	1.06	172.41
KG	-91.25	-1.06	-92.31

Pipe Diameter Determination

Path	Velocity (fps)	Flow (klpd)	Flow (ft^3/s)	Pipe Area (in^2)	Required Diameter (in)	Provided Diameter (in)
DC	3	148.78	0.0608	2.92	1.93	2
BC	3	50.08	0.0205	0.98	1.12	1.5
BA	3	193.72	0.0792	3.80	2.20	2.5
FA	3	268.32	0.1097	5.26	2.59	3
ED	3	313.98	0.1283	6.16	2.80	3
EF	3	102.74	0.0420	2.02	1.60	2
IH	3	516.88	0.2113	10.14	3.59	4
HG	3	246.37	0.1007	4.83	2.48	2.5
IL	3	516.98	0.2113	10.14	3.59	4
LE	3	825.32	0.3373	16.19	4.54	5
GF	3	198.68	0.0812	3.90	2.23	2.5
JK	3	132.41	0.0541	2.60	1.82	2
JH	3	172.41	0.0705	3.38	2.08	2.5
KG	3	92.31	0.0377	1.81	1.52	2

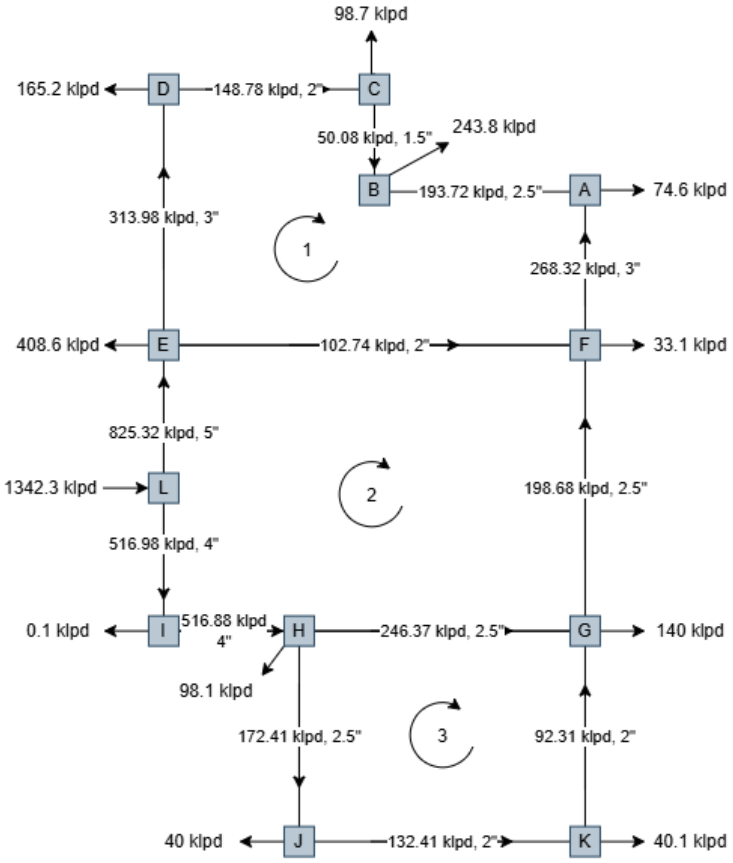


Figure 12 Pipe parameters of Zone 1

Wastewater Conveyance System (Trunk Sewer)

Introduction

The following report designs the trunk sewer network of the wastewater conveyance system for the dairy farm industrial park.

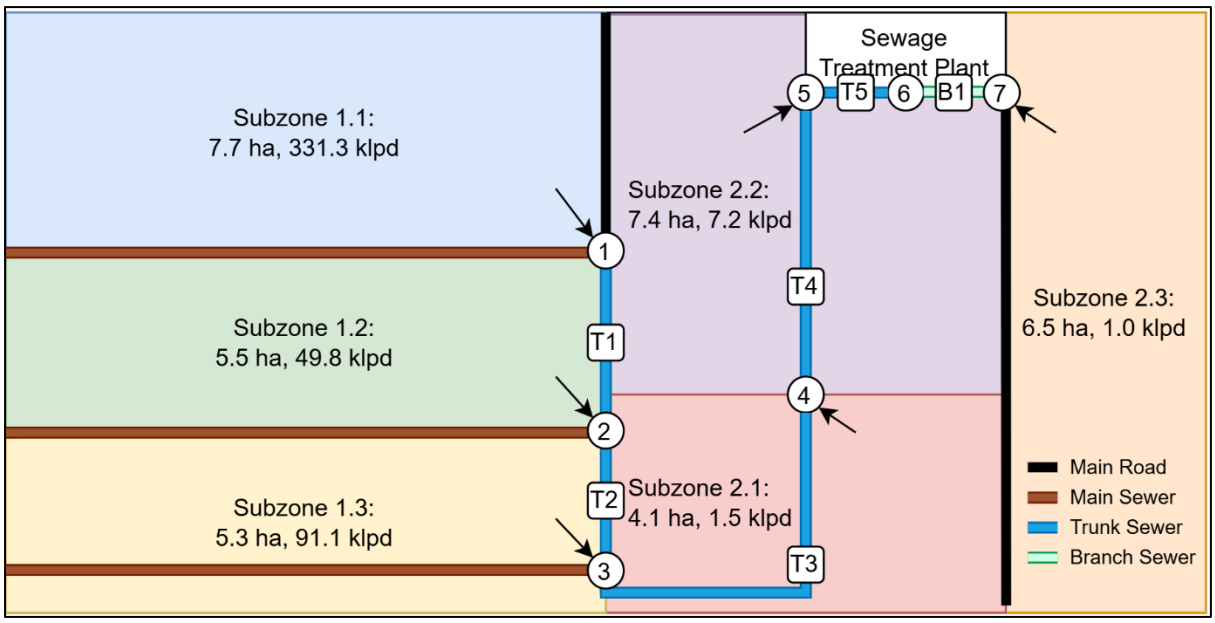


Figure 13 Layout of trunk sewer alignment and tributary subzones

Considerations:

- Four categories of direct wastewater sources considered are: residential, commercial, industrial, and institutional. Additionally, sufficient infiltration inflow is also considered.
- Wastewater and infiltration from residential subzone (subzone 1.1) enter the trunk sewer at the upper end of pipe T1 via main sewers.
- Similarly, wastewater and infiltration from subzone 1.2, 1.3, 2.1, and 2.2 enters the trunk sewer at the upper end of pipe T2, T3, T4, and T5 respectively.
- Wastewater and infiltration from subzone 2.3 are very low and thus this volume is conveyed via a branch sewer directly into the STP entrance node. This branch pipe is omitted from design as we are only interested in trunk sewer design here.

Assumptions:

- Average wastewater generated based on source category and water supply:

Category	Percent Wastewater
Industrial	90.0%
Institutional	80.0%
Commercial	80.0%
Residential	80.0%

- Peak factors considered:

Category	Peak Factor
Industrial	2.1
Institutional	4
Commercial	1.8

*Note: Peak factors for residential zone are determined from peak factor graph (*Appendix B-1 Wastewater flow peaking factor curve*). Equation of the curve:* $PF = 2.228 \times Q^{-0.07333}$ with an upper and lower limit of 3.34 and 1.98.

- Manning's $n = 0.013$.
- Minimum velocity, $v_{min} = 2$ ft/s or $v_{min} = 0.6$ m/s
- Maximum velocity, $v_{max} = 10$ ft/s or $v_{max} = 3$ m/s

Methodology:

Determination of pipe flow:

1. Trunk sewer network is prepared on the industrial park layout.
2. Nodes are determined based on where main sewer or branch sewer joins the trunk sewer.
3. Each of the two zones is further subdivided into multiple subzones where each subzone contributes to the trunk sewer via a node (wastewater/infiltration inflow is conveyed via either main sewer or branch sewer).
4. All facilities in a particular subzone are categorized as either "Residential", "Industrial", "Institutional", or "Commercial".
5. Total water supply, followed by average wastewater flow, peak factor, and peak flow is determined for each category under each subzone. Peak factor is obtained from above mentioned graph or using its curve equation.

$$AverageWastewaterFlow = AverageWaterSupply \times PercentWastewater$$

$$PeakFlow = PeakFactor \times AverageWastewaterFlow$$

6. Total peak wastewater flow is the summation of all peak flows within the subzone.

$$TotalPeakWastewaterFlow = \sum WW_{peak}$$

7. Infiltration allowance per unit area (ha) is determined from the infiltration rate allowance graph (Appendix B-2 Sewer infiltration rate allowances) or using its curve equation of $II = 26.593 \times A^{-0.300}$ with maximum value of 8.75.
8. Infiltration inflow for a particular subzone is the multiplication of earlier determined infiltration allowance and subzone area in hectares.
$$InfiltrationInflow = InfiltrationAllowance \times Area$$
9. Cumulative wastewater flow is determined as the flow carried by each segment of the trunk sewer.
For a particular pipe, cumulative flow is the summation of flow from feeder pipe, connecting subzone's wastewater inflow and infiltration inflow.

Determination of pipe size:

1. Flow (Q) through each pipe is considered as determined by earlier steps.
2. Initial slope (S) is assumed for each pipe to be the minimum slope required (0.0033) for minimum pipe diameter (200 mm) for gravity flow (Appendix B-3 Minimum slopes for gravity sewers).
3. Pipe diameter (D_{calc}) is calculated from the equation:
$$Q = \frac{1}{n}\frac{\pi D^2}{4} \times \left(\frac{D}{4}\right)^{2/3} \sqrt{S} \qquad (1)$$
4. Calculated diameter is rounded to the next available pipe size from the minimum pipe slopes table (Appendix B-3 Minimum slopes for gravity sewers).
5. Corresponding slope is obtained from the same table and check against the initially assumed slope. Steps 3 and 4 are repeated with the new slope until both slopes are same.
6. Discharge at full depth (Q_{full}) is determined by using equation (1).
7. Flow velocity at full depth is determined as:
$$V = \frac{1}{n}\left(\frac{D}{4}\right)^{2/3} \sqrt{S}$$
8. The term Q/Q_{full} is determined and correspondingly, V/V_{full} and d/D is determined using the hydraulic elements for sewers flowing partly full graph (Appendix B-4 Hydraulic elements diagram for circular sewers).
9. Partly full flow velocity V is determined by multiplying V/V_{full} with previously determined V_{full}.
10. Determined V is checked against V_{min} and V_{max}.

Trunk sewer longitudinal profile:

1. Length of each pipe (in meters) is determined from layout.
2. Total elevation fall across the pipe length is determined as:
$$Fall = Slope \times Length$$

3. Invert drop is determined as the difference between the diameter of previous pipe and current pipe.
4. Ground elevation at the two ends of the pipe (designated by *upper* and *lower*) is determined from available contour lines of the village.
5. Initial sewer invert elevation (upper end) is determined ensuring a cover of 2 m:
$$Elv = GroundElv - Cover - PipeThickness - PipeDiameter$$
6. Subsequent invert elevation is determined by subtracting fall in sewer from upper invert elevation.
7. Cover above pipe is calculated as:
$$Cover = GroundElv - InvertElv + PipeDiameter + PipeThickness$$

Manhole placement:

1. Since all pipes are of diameter 48" or smaller, manhole is provided at:
    a. Change in direction
    b. Change in slope
    c. Change in size
    d. And at intervals not greater than 350 ft
2. Manholes at nodal positions are named as MH-*N* where *N* is the node number.
3. Intermediate manholes are named as MH-*NA* where *N* remain the node number but *A* is the alphabetic index of the node within the pipe.

Layout of Sewer Network

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Sample Calculation

Pipe T1:

Determination of wastewater flow:

Category	Facilities	Water Supply (klpd)
Residential	Building Type – Villa	19.8
	Building Type – A	27
	Building Type – B	33.5
	Building Type – C	56.8
	Building Type – D	66.1
Industrial	N/A	0
Institutional	Central Mosque	48.6
	School	66.3
Commercial	Community Center	5.4
	Residential Estate Office	2.8
	Water Pump Station	0.1
	Central Park & Sports Field	5

Total water supply on:

- Residential facilities: $19.8 + 27 + 33.5 + 56.8 + 66.1 = 203.2$ klpd
- Industrial facilities: 0 klpd
- Institutional facilities: $48.6 + 66.3 = 114.9$ klpd
- Commercial facilities: $5.4 + 2.8 + 0.1 + 5 = 13.3$ klpd

Wastewater flows from:

- Residential facilities: $203.2 \times 0.8 = 162.56\ klpd$
  $= 162.56/86400$ cumec
  $= 0.001881$ cumec
- Industrial facilities: $0 \times 0.9 = 0$ klpd $= 0$ cumec
- Institutional facilities: $114.9 \times 0.8 = 91.92$ klpd $= 0.001064$ cumec
- Commercial facilities: $13.3 \times 0.8 = 10.64$ klpd $= 0.000123$ cumec

Peak factor for residential flow: $2.228 \times 0.001881^{-0.07333} \leq 3.34$
$= 3.53 \leq 3.34 = 3.34$

Peak flows:

- Residential facilities: $162.56 \times 3.34 = 542.95$ klpd
- Industrial facilities: $0 \times 2.1 = 0$ klpd
- Institutional facilities: $91.92 \times 4 = 367.68$ klpd
- Commercial facilities: $10.64 \times 1.8 = 19.15$ klpd

Total peak wastewater flow: $542.95 + 0 + 367.68 + 19.15 = 929.78$ klpd

Determination of infiltration flow:

- Subzone: 1.1
- Area: 7.7 ha
- Infiltration allowance: $26.593 \times 7.7^{-0.300} \leq 8.75$
  $= 14.42 \leq 8.75 = 8.75$
- Infiltration flow: $8.75 \times 7.7 = 67.38$ klpd

Determination of cumulative flows:

- Feeder flow: 0 klpd [first node]
- Entering wastewater flow: 929.78 klpd
- Entering infiltration flow: 67.38 klpd
- Total entering flow: $929.78 + 67.38 = 997.16$ klpd
- Cumulative flow: $997.16 + 0 = 997.16\ klpd = 0.0115\ cumec$

Determination of pipe diameter:

- Flow: 0.0115 cumec
- Assumed slope, S: 0.0033
- Calculated diameter: $0.0115 = \frac{1}{0.013}\frac{\pi D_{calc}^2}{4}\left(\frac{D_{calc}}{4}\right)^{2/3}\sqrt{0.0033}$
  $\Longrightarrow D_{calc} = 0.166$ m
- Actual diameter: 0.200 m
- Corrected slope: 0.0033
- Discharge, Q_{full}: $\frac{1}{0.013}\frac{\pi \times 0.2^2}{4}\left(\frac{0.2}{4}\right)^{2/3}\sqrt{0.0033} = 0.0189$ cumec
- Velocity, V_{full}: $\frac{1}{0.013}\left(\frac{0.2}{4}\right)^{2/3}\sqrt{0.0033} = 0.5997$ m/s
- Q/Q_{full}: $0.0115/0.0189 = 0.6122$
- V/V_{full}: 1.06
- d/D: 0.57
- Velocity, v: $1.06 \times 0.5997 = 0.64$ m/s [$0.64 \geq 0.60 \therefore$ OK]

Pipe profile:

- Length: 128.0 m
- Slope: 0.0033
- Diameter: 200 mm
- Fall in sewer: $128.0 \times 0.0033 = 0.422$ m
- Invert drop: 0 mm [no feeder pipe to compare]
- Ground elevation (upper): 28 m
- Ground elevation (lower): 28.3 m [direction towards ground elevation]
- Invert elevation (upper): $28 - 2 - 0.05 - 0.2 = 25.75$ m
- Invert elevation (lower): $25.75 - 0.422 = 25.33$ m
- Cover (upper): $28 - (25.75 + 0.2 + 0.05) = 2.00$ m
- Cover (lower): $28.3 - (25.33 + 0.2 + 0.05) = 2.72$ m

Determination of Wastewater Flow

Pipe	From	To	Category	Facilities	Water Supply (klpd)	Wastewater Flow (klpd)	Wastewater Flow (m^3/s)	Peak Factor	Peak Flow (klpd)	Total Peak Flow (klpd)
T1	1	2	Residential	Building Type - A Building Type - Villa Building Type - B Building Type - C Building Type - D	203.20	162.56	0.001881	3.34	542.95	929.78
			Institutional	Central Mosque School	114.90	91.92	0.001064	4.00	367.68	
			Commercial	Community Center Residential Estate Office Water Pump Station Central Park & Sports Field	13.30	10.64	0.000123	1.80	19.15	

Pipe	From	To	Category	Facilities	Water Supply (klpd)	Wastewater Flow (klpd)	Wastewater Flow (m^3/s)	Peak Factor	Peak Flow (klpd)	Total Peak Flow (klpd)
T2	2	3	Commercial	Insurance Corporate Office Dairy Retail Outlet & Café Shopping Complex Autoshop & Truck Servicing Center Daycare Center Hardware Store Veterinary Medicine Pharmacy Salon Laundry Bank Telecom Center Postal Services Gym Water Pump Station Food Court Supermarket	49.80	39.84	0.000461	1.80	71.71	71.71
T3	3	4	Institutional	Exhibition Center Training Academy	25.30	20.24	0.000234	4.00	80.96	176.00

Pipe	From	To	Category	Facilities	Water Supply (klpd)	Wastewater Flow (klpd)	Wastewater Flow (m^3/s)	Peak Factor	Peak Flow (klpd)	Total Peak Flow (klpd)
			Commercial	Security Checkpoint Inspection Bay CMS Logistics & Customs Office Veterinary Office Parking Lot Corporate HQ IT Center Park Op. Center R&D Facility QA Office Fire Station Health Clinic Water Pump Station Power Plant	66.00	52.80	0.000611	1.80	95.04	
T4	4	5	Industrial	Truck Staging Yard Shipping Docks Cold Storage Warehouse Chilling & Filtration Block Milking Center Utilities Water Pump Station Raw Milk Silos	1.50	1.35	0.000016	2.10	2.84	2.98

Pipe	From	To	Category	Facilities	Water Supply (klpd)	Wastewater Flow (klpd)	Wastewater Flow (m^3/s)	Peak Factor	Peak Flow (klpd)	Total Peak Flow (klpd)
			Commercial	Water Pump Station	0.10	0.08	0.000001	1.80	0.14	
T5	5	6	Industrial	Milking Rotary Processing Core Cow Barn B Packaging Station Bottle Inventory Cow Barn A	7.00	6.30	0.000073	2.10	13.23	13.37
			Commercial	Water Pump Station	0.10	0.08	0.000001	1.80	0.14	
B1	7	6	Industrial	Effluent Treatment Plant	0.20	0.18	0.000002	2.10	0.38	1.67
			Commercial	Water Pump Station Water Pump Station Solid Waste Dump Sewage Treatment Plant	0.90	0.72	0.000008	1.80	1.30	

Determination of Infiltration Flow

Pipe	From	To	Subzone	Area (ha)	Infiltration Allowance (m^3/ha-d)	Infiltration (m^3/d)
T1	1	2	1.1	7.7	8.75	67.375
T2	2	3	1.2	5.5	8.75	48.125
T3	3	4	1.3	5.3	8.75	46.375
T4	4	5	2.1	1.5	8.75	13.125
T5	5	6	2.2	7.4	8.75	64.75
B1	7	6	2.3	6.5	8.75	56.875

Determination of Cumulative Flow

Pipe	Feeder	Feeder Flow (klpd)	Entering Wastewater Flow (klpd)	Entering Infiltration Flow (klpd)	Total Entering Flow (klpd)	Cumulative Flow (klpd)	Cumulative Flow (cumec)
T1	None	0.00	929.78	67.38	997.16	997.16	0.0115
T2	T1	997.16	71.71	48.13	119.84	1116.99	0.0129
T3	T2	1116.99	176.00	46.38	222.38	1339.37	0.0155
T4	T3	1339.37	2.98	13.13	16.10	1355.47	0.0157
T5	T4	1355.47	13.37	64.75	78.12	1433.60	0.0166
B1	None	0.00	1.67	56.88	58.55	58.55	0.0007

Note: Cumulative wastewater flow from the adjacent East subzone of the STP is very low as calculated above. Thus, installation of dedicated trunk sewer is not deemed practical (to ensure self-cleansing velocity). Instead, a branch sewer (*B1*) conveys the wastewater directly into STP's entrance node.

Determination of Pipe Diameter

Pipe	Flow (cumec)	Assumed S	D_{calc} (m)	D_{actual} (m)	Corrected S	Q_{full} (cumec)	V_{full} (m/s)	Q/Q_{full}	V/V_{full}	d/D	V_{actual} (m/s)	Status
T1	0.0115	0.0033	0.166	0.200	0.0033	0.0189	0.5997	0.6122	1.0600	0.5700	0.64	OK
T2	0.0129	0.0033	0.174	0.200	0.0033	0.0189	0.5997	0.6858	1.0800	0.6100	0.65	OK
T3	0.0155	0.0033	0.186	0.200	0.0033	0.0189	0.5997	0.8223	1.1200	0.7000	0.67	OK
T4	0.0157	0.0033	0.187	0.200	0.0033	0.0189	0.5997	0.8322	1.1300	0.7100	0.68	OK
T5	0.0166	0.0033	0.191	0.200	0.0033	0.0189	0.5997	0.8802	1.1350	0.7400	0.68	OK

Trunk Sewer Profile

Pipe	Length (ft)	Length (m)	Slope (m/m)	Diamter (mm)	Fall in Sewer (m)	Invert Drop (m)	Ground Elevation: Upper (m)	Ground Elevation: Lower (m)	Sewer Invert Elevation: Upper (m)	Sewer Invert Elevation: Lower (m)	Cover Above Pipe: Upper (m)	Cover Above Pipe: Lower (m)
T1	420	128.0	0.0033	200	0.422	0	28	28.3	25.75	25.33	2.00	2.72
T2	336	102.4	0.0033	200	0.338	0	28.3	28.5	25.33	24.99	2.72	3.26
T3	1034	315.2	0.0033	200	1.040	0	28.5	27.5	24.99	23.95	3.26	3.30
T4	680	207.3	0.0033	200	0.684	0	27.5	26.9	23.95	23.27	3.30	3.38
T5	230	70.1	0.0033	200	0.231	0	26.9	26.4	23.27	23.03	3.38	3.12

Manhole Placement

Manhole ID	Location	Distance from Upper End of Pipe (m)	Diameter (m)
MH-1	1	0.0	1.5
MH-1A	1–2	64.0	1.5
MH-2	2	64.0	1.5
MH-3	3	102.4	1.5
MH-3A	3–4	19.5	1.5
MH-3B	3–4	70.1	1.5
MH-3C	3–4	70.1	1.5
MH-3D	3–4	77.7	1.5
MH-4	4	77.7	1.5
MH-4A	4–5	103.6	1.5
MH-5	5	103.6	1.5
MH-6	6	70.1	1.5

Longitudinal Profile of Trunk Sewer

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Building Plumbing System

Introduction

The following report designs the water supply system for a typical residential building on the industrial park. For reference, floor plan of an existing 6-storey building in Bangladesh is used.

Design components:

1. Size of water distribution pipes.
2. Dimension of underground water reservoir.
3. Dimension of overhead water reservoir.
4. Pump capacity.

Considerations:

- Water pressure is 30 psi at public main as was ensured by water distribution network design previously.
- Maximum pressure allowed at any fixture is 50 psi.
- Service pipe length is 70 ft.
- Following the design requirements table (Appendix C-5 Water supply system design requirements (Source: BNBC 2020)), the minimum pressure required for water closets (flush tank), shower heads, lavatories, or kitchen sinks are 55 kPa or 8 psi.
- Fixture units (FU) for:
    - Water closet (flush tank): 5 FU
    - Shower head: 4 FU
    - Lavatory: 2 FU
    - Kitchen sink (private): 2 FU

Assumption:

- Pressure drop for branch is 1 psi.
- Distance between overhead tank and roof is 24 ft.
- Occupancy per unit of a typical floor is 5 people.
- Units per typical floor are 2.

Reference Building

The reference building used for design has the following characteristics:

- 6-storey building. Each storey is 3.048 m or 10 ft.
- Typical floors have 6 bathrooms (with integrated showers), 2 dining rooms, and 2 kitchens. These correspond to 6 water closets, 6 shower heads, $6 + 2 = 8$ lavatories, and 2 kitchen sinks.
- Ground floor and roof is assumed to have 1 water closet, 1 lavatory, and 1 kitchen sink each.
- Every water closet uses flush tank system.

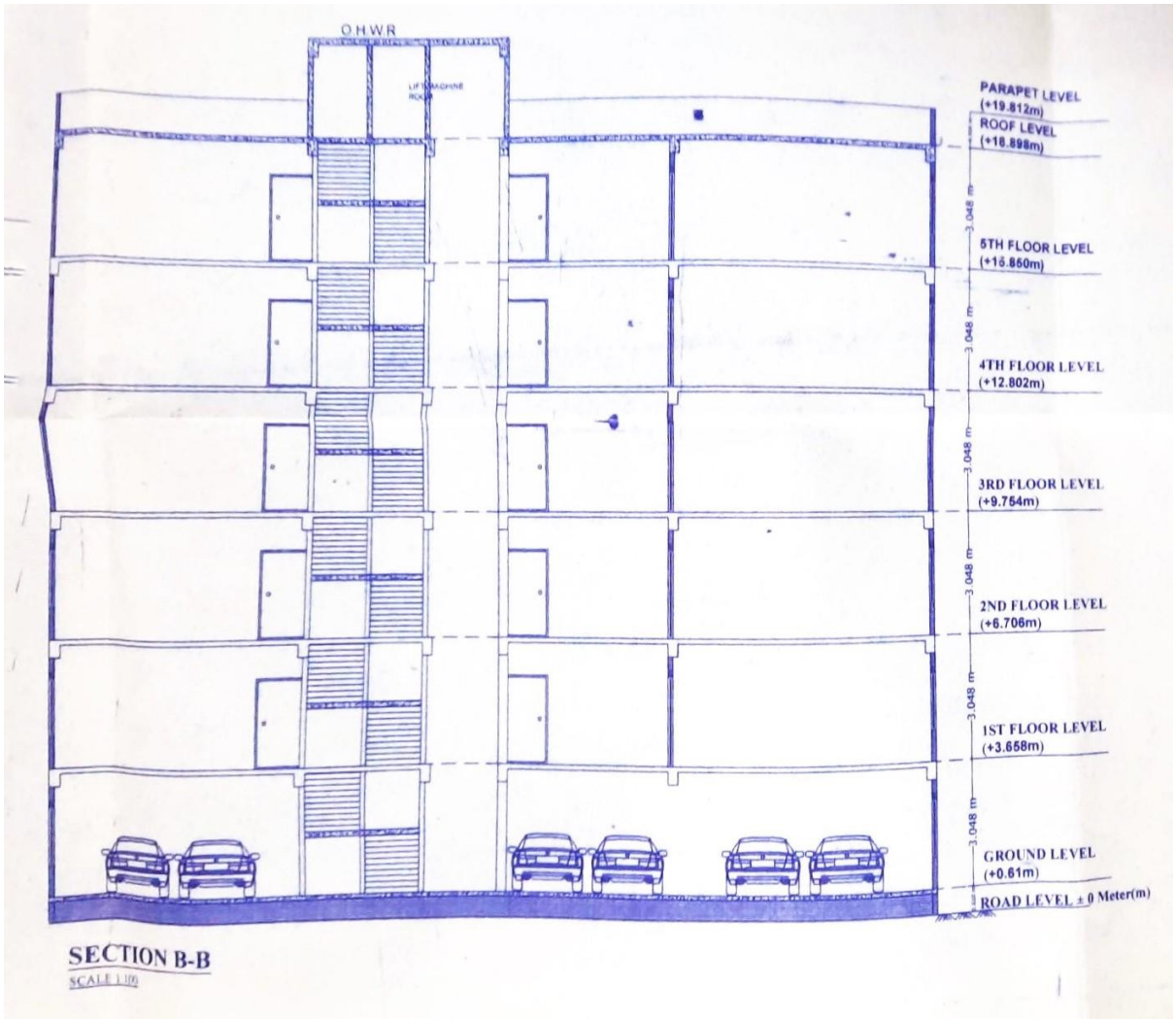


Figure 14 Section view displaying individual floors

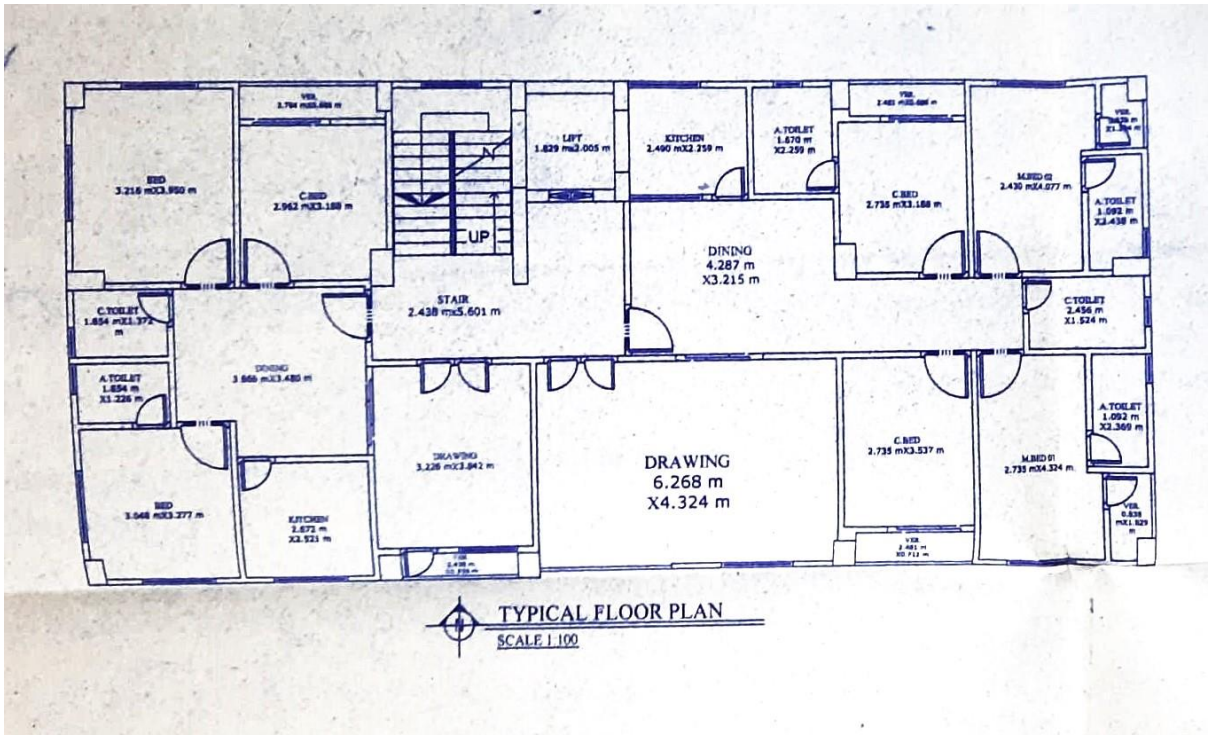


Figure 15 Plan of a typical floor (1st to 5th floor)

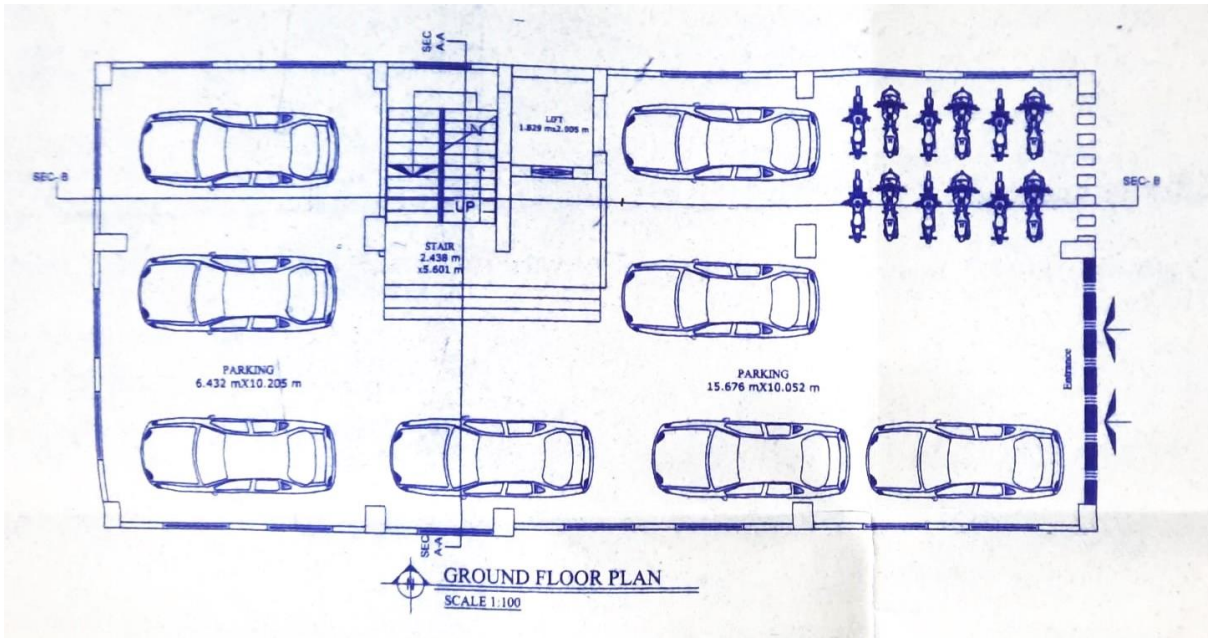


Figure 16 Plan of ground floor

Determination of Zoning

Fixture units:

- Typical floors:
  - 6 water closets: $6 \times 5 = 30$ FU
  - 6 shower heads: $6 \times 4 = 24$ FU
  - 8 lavatories: $8 \times 2 = 16$ FU
  - 2 kitchen sinks: $2 \times 2 = 4$ FU
  - Total: $30 + 24 + 16 + 4 = 74$ FU
- Ground floor and roof:
  - 1 water closet: $1 \times 5 = 5$ FU
  - 1 lavatory: $1 \times 2 = 2$ FU
  - 1 kitchen sink: $1 \times 2 = 2$ FU
  - Total: $5 + 2 + 2 = 9$ FU
- Total FU:
  - 1st to 5th floor level: $5 \times 74 = 370$ FU
  - Ground level + roof: $2 \times 9 = 18$ FU
  - Total: $370 + 18 = 388$ FU

Maximum demand:

For 388 FU, based on demand curve for systems predominantly using flash tanks (Appendix C-1 Estimate curves for demand load based on fixture units), the probable peak demand is determined to be 100 GPM.

Service pipe size:

For iron pipe, based on the pipe friction loss chart (Appendix C-2 Friction loss per 100-ft length of pipe), drop of pressure is:

1. For diameter 3": 1.8 psi/100'
2. For diameter 4": 0.45 psi/100'

The 4" pipe with pressure drop of 0.45 psi/100' will be used tentatively.

From the water meter pressure loss graph (Appendix C-3 Pressure losses in water meter), for 4" pipe, pressure drop is 1 psi.

Upfeed zone:

$$30 = 1 + 1.5(70 + h)(0.45/100) + 0.434h + 8 + 1$$

$$\text{or, } h = 44.3 \text{ ft}$$

Thus, upfeed system would allow water supply to maximum 4 storey, or 3 floors when accounted for underground depth.

Downfeed zone:

$$50/0.434 - 24 = 91 \text{ ft}$$

Thus, downfeed system would allow water supply to maximum 9 storey.

For this design, downfeed system will be used to supply water across all floors as a combined upfeed + downfeed system is unnecessary here.

Design of Downfeed Zone

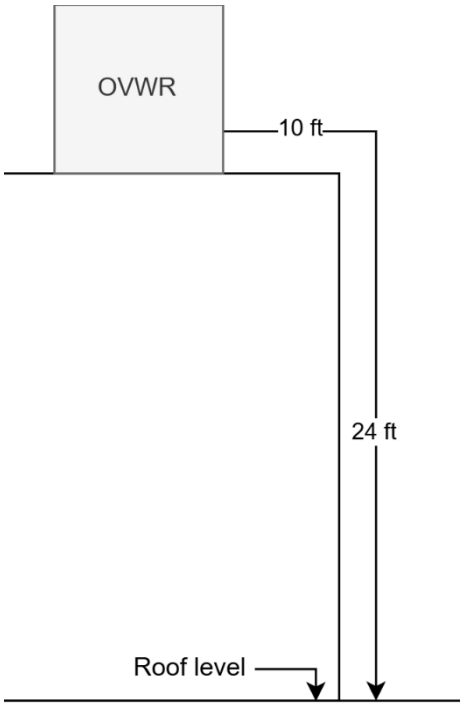
Tank to top fixture:

Pressure available for overcoming friction:

$$p = 24 \times 0.434 - 8 - 1 = 1.42 \text{ psi}$$

Permissible drop per 100 ft:

$$\frac{1.42 \times 100}{1.5(24 + 10)} = 2.78 \text{ psi/100'}$$



5th floor to ground floor:

Pressure available for overcoming friction:

$$p = 9 + 10 \times 0.434 - 8 - 1 = 4.34 \text{ psi}$$

Permissible drop per 100 ft:

$$\frac{4.34 \times 100}{1.5 \times 10} = 28.93 \text{ psi/100'}$$

Pipe sizes:

Floor	FU	Accumulated FU	Demand (gpm)	Pipe Length (ft)	Pressure Drop (psi/100')	Pipe Size (in)
Roof	9	388	100	34	2.78	3.0
5th	74	379	95	10	28.93	2.0
4th	74	305	85	10	28.93	2.0
3rd	74	231	70	10	28.93	1.5
2nd	74	157	55	10	28.93	1.5
1st	74	83	38	10	28.93	1.5
Ground	9	9	20	10	28.93	1.5

Overhead Tank

Daily water demand:

- Total occupancy: $5 \times 2 \times 5 = 50$ person
- Per person daily demand: 120 lpcd [Category y_2: < 1500 sft]
- Total domestic demand: $120 \times 50 = 6{,}000$ lpd $= 6\ m^3$
- Tank volume for regular demand: $6/2 = 3\ m^3$ [2×30 mins pumping]
- Demand for firefighting: 1000 lpm $\times 30$ mins $= 30\ m^3$
  See Appendix C-4 Fire protection flow requirements (Source: BNBC 2020)
- Total tank volume: $3 + 30 = 33\ m^3$
- From building section view, the position of overhead tank is above stair.
  Maximum size of OHWR: $(1.8 + 2.4)$ m $\times$ 5.6 m $= 4.2$ m $\times$ 5.6 m
  Actual size: $10' \times 15' = 3.048$ m $\times$ 4.572 m
- Depth of OHWR: $33/(3.048 \times 4.572) = 2.368$ m
- Freeboard: 1 ft $= 0.305$ m
- Total depth of OHWR: $2.368 + 0.305 = 2.673\ m = 8.770\ ft \approx 9\ ft$
- Therefore, dimension: $10' \times 15' \times 9'$

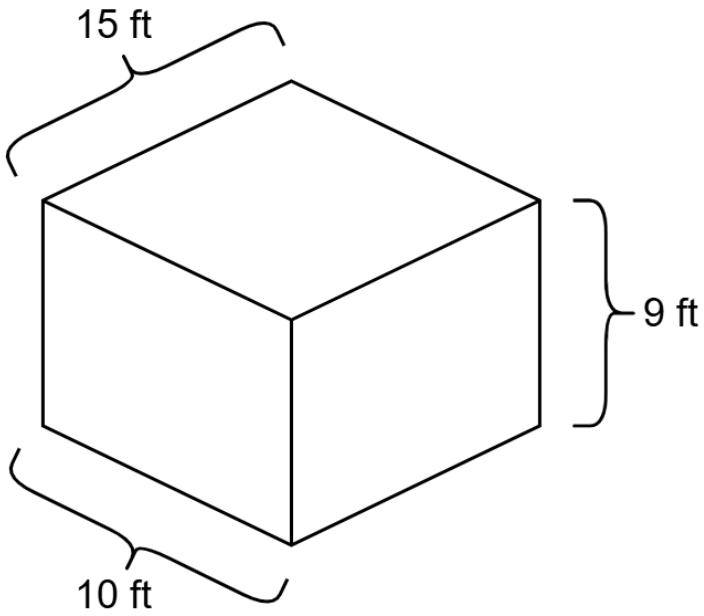


Figure 17 Schematic diagram of OHWR

Underground Water Reservoir

- Daily domestic demand: $6\ m^3$
- Firefighting demand: $30\ m^3$
- Total volume: $6 \times 2 + 30 = 42\ m^3$
- Maximum size of UGWR: $7.37\ \text{m} \times 4.5\ \text{m}$
  Actual size: $20' \times 12' = 6.096\ \text{m} \times 3.658\ \text{m}$
- Depth of UGWR: $42/(6.096 \times 3.658) = 1.883\ \text{m}$
- Freeboard: $0.305\ \text{m}$
- Total depth of UGWR: $1.883 + 0.305 = 2.188\ \text{m} = 7.17\ \text{ft} \approx 8\ \text{ft}$
- Therefore, dimension: $20' \times 12' \times 8'$

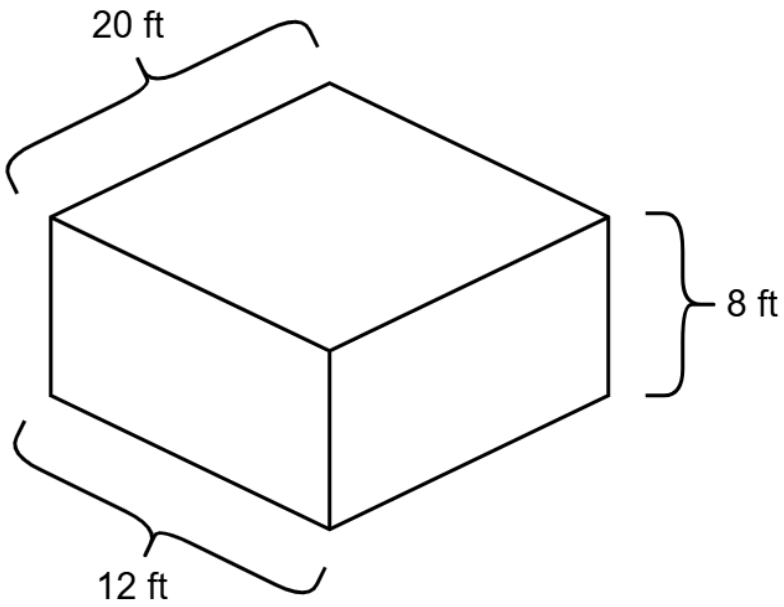


Figure 18 Schematic diagram of UGWR

Pump Capacity

- Water carried per pump: $6{,}000/2 = 3{,}000$ liter/30mins $= 26.42$ gpm
- Assumed velocity: 8 fps
- Corresponding friction loss: 16 psi/100'
- Riser length:
  - L_{static}: $D_{UGWR} + H_{building} + H_{roof-OHWR}$
    $= 8' + 60' + 24' = 92'$
  - $L_{horizontal}$: $L_{UGWR-stair} + L_{raiser-OHWR}$
    $= 24.6' + 10' = 34.6'$
  - L_{total}: $92 + 34.6 = 126.6'$
- Total frictional head, H_L: $L\frac{h_L}{100} + requirements\ at\ OHWR + minor\ loss$
  $= 126.6 \times \frac{16}{100} + 8 + 5 = 33.3$ psi
- Friction head: $33.3 \times \frac{144}{62.4}$ ft
  $= 76.8$ ft
- Velocity head: $\frac{v^2}{2g} = \frac{8^2}{2 \times 32.2} = 0.99$ ft
- Total head, H: $static\ head\ +\ velocity\ head\ +\ friction\ head$
  $= 92 + 0.99 + 76.8 = 169.79$ ft
- Assumed efficiency, E: 65%
- Required capacity of pump: $\frac{HQ}{3960E}$
  $= \frac{169.79 \times 26.42}{3960 \times 0.65}$
  $= 1.74$ HP
  ≈ 2 HP

Appendices

Appendix A Water Demand Design Aids

Table 8.5.1(a): Water Consumption for Domestic Purposes in Residential Buildings (Cities/Big District Towns)

Category	Socio-economic group, Type of Building, Source and Other Facilities	Water Consumption	
		Full Facility (*lpcd*)	Restricted Facility (*lpcd*)
A	**Metropolitan Cities/City Corporation Area/District Towns**		
x	High income group:		
A1	Single family dwelling (with garden and car washing)	260	200
A3	Big multi-family apartment/flat (> 2500 sft)	200	150
y	Middle income group:		
y_1	Officer's qtr./Colony and moderate apartment (< 2000 sft)	180	135
y_2	Small building/staff qtr. and small apartment (< 1500 sft)	---	120
z	Low income group:		
z_1	Junior staff qtr./flat (< 1000 sft) and temporary shade	---	80
z_2	Stand post connection in the fringe area	---	65
z_3	Common yard (stand post) connection in the fringe area	---	50
z_4	Slum dwellers collection from road side public stand post	---	40

Appendix A-1 Residential water consumption (metropolitan & district towns)

Table 8.5.1(d): Domestic Water Requirements for Various other Occupancies and Facility Groups

Class of Occupancy	Occupancy Groups	For Full[a] Facilities (*lpcd*)	For Restricted Facilities (*lpcd*)
A: Residential	A4: Mess, Boarding Houses, Dormitories and Hostels	135	70
	A5: Hotels and Lodging Houses (per bed)	300	135
B: Educational Facilities	B1: Educational Facilities up to Higher Secondary Levels	70	45
	B2: Facilities for Training and above Higher Secondary Education	100	70
	B3: Pre-School Facilities	50	35
C: Institutional	C1: Institution for Care of Children	180	100
	C2: Custodian Institution for Physically Capable Adults	180	100
	C3: Custodian Institution for the Incapable Adults	120	70
	C4: Penal and Mental Institutions for Children	100	60
	C5: Penal and Mental Institutions for Adults	120	70
D: Healthcare Facilities	D1: Normal Medical Facilities (Small Hospitals)	340	225
	Big Hospitals (Over 100 beds)	450	250
	D2: Emergency Medical Facilities	300	135
	Nurses & Medical Quarters	250	135
E: Business	E1: Offices	45	30
	E2: Research and Testing Laboratories	70	45
	E3: Essential Services	70	45
F: Mercantile	F1: Small Shops and Market	45	30
	F2: Large Shops and Market	45	30
	F3: Refueling Station	70	45
G: Industrial Buildings	G1: Low Hazard Industries	40	25
	G2: Moderate Hazards Industries	40	25

Appendix A-2 Non-residential water demand rates (part 1 – educational, institutional & commercial)

Class of Occupancy	Occupancy Groups	For Full[a] Facilities (*lpcd*)	For Restricted Facilities (*lpcd*)
H: Storage Buildings	H1: Low Fire Risk Storage	10	6
	H2: Moderate Fire Risk Storage	10	6
I: Assembly	I1: Large Assembly with Fixed Seats (per seat)	90	45
	I2: Small Assembly with Fixed Seats (per seat)	90	45
	I3: Large Assembly without Fixed Seats[b]	15	10
	I4: Small Assembly without Fixed Seats	15	10
	I5: Sports Facilities	15	10
J: Hazardous Building	J1: Explosion Hazard Building	15	10
	J2: Chemical Hazard Building	15	10
	J3: Biological Hazard Building	10	6
	J4: Radiation Hazard Building	10	6
K: Garage[c]	K1: Parking Garage	15	10
	K2: Private Garage	15	10
	K3: Repair Garage	15	10
L: Utility	L: Utility	10	6
M: Miscellaneous	M1: Special Structures	--[d]	--[d]
	M2: Fences, Tanks and Towers	---	3

Notes:

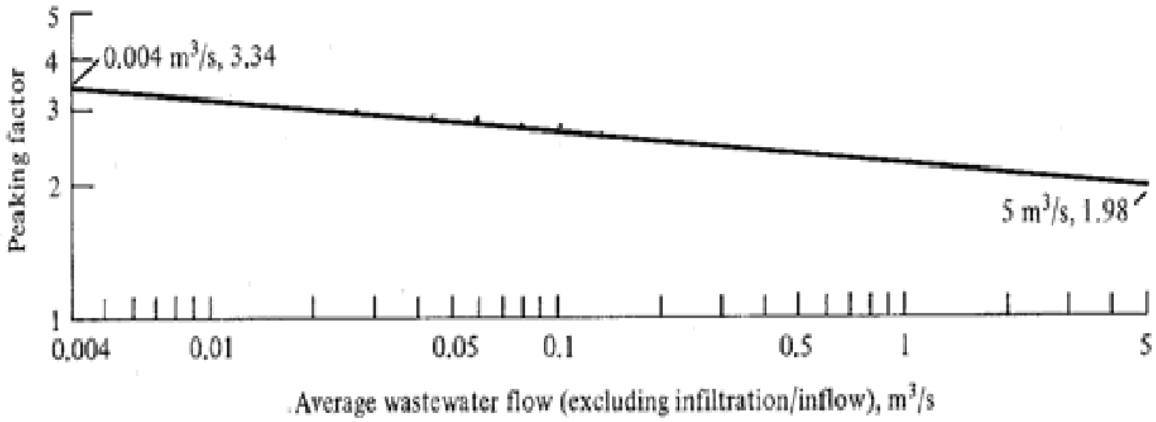
[a] For full facility in occupancy classifications A, B, C and D, the water requirement value includes 25% hot water.

[b] In the case of mosques, the water requirements given above shall be adequate for ablution and other uses of one devotee per prayer. The appropriate LPCD value may be calculated on this basis.

[c] Water requirement for occupancy K is shown as a provision for unknown visitors only.

[d] Water requirement for occupancy M1 shall be assessed considering its nature of use and the similarity in purpose with any of the occupancies mentioned above.

Appendix B Sewer Design Aids



Appendix B-1 Wastewater flow peaking factor curve

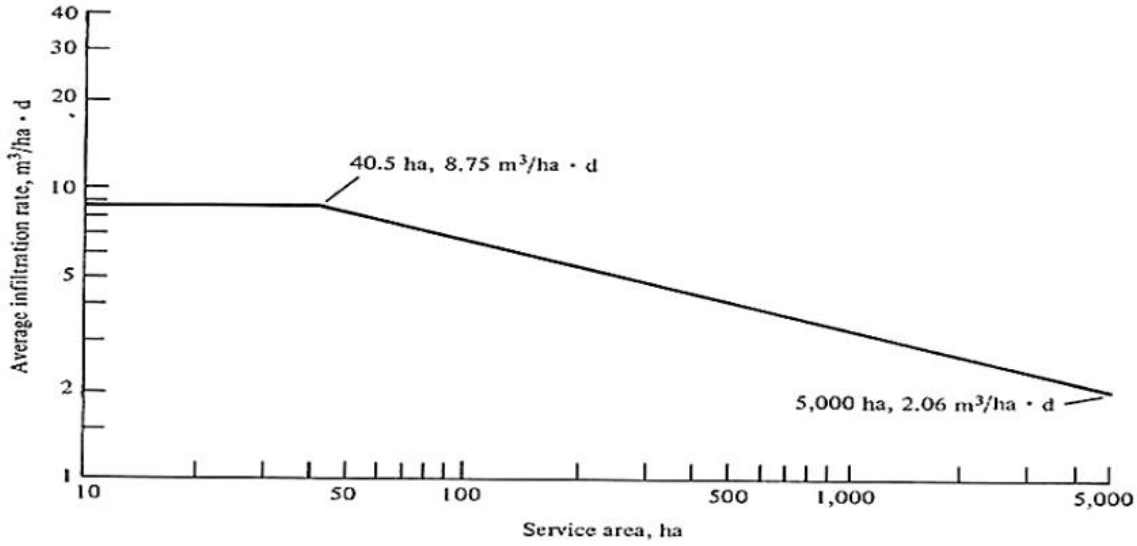


Figure 5 : Average infiltration rate allowance for new sewers. Note: ha × 2.4711 = acre; m³/ha·d × 106.9 = gal/acre·d.

Appendix B-2 Sewer infiltration rate allowances

Table-3: Gravity Sewer Minimum Pipe Slopes

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

Appendix B-3 Minimum slopes for gravity sewers

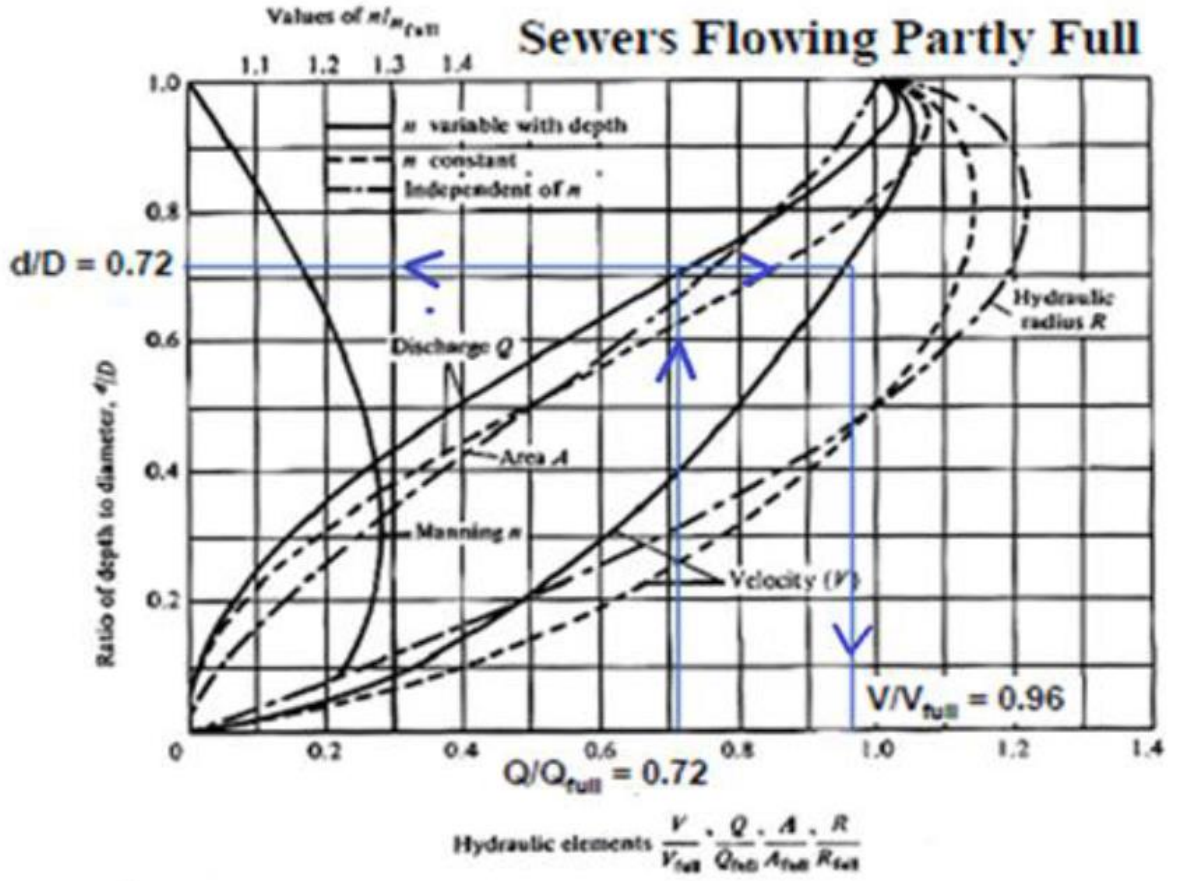
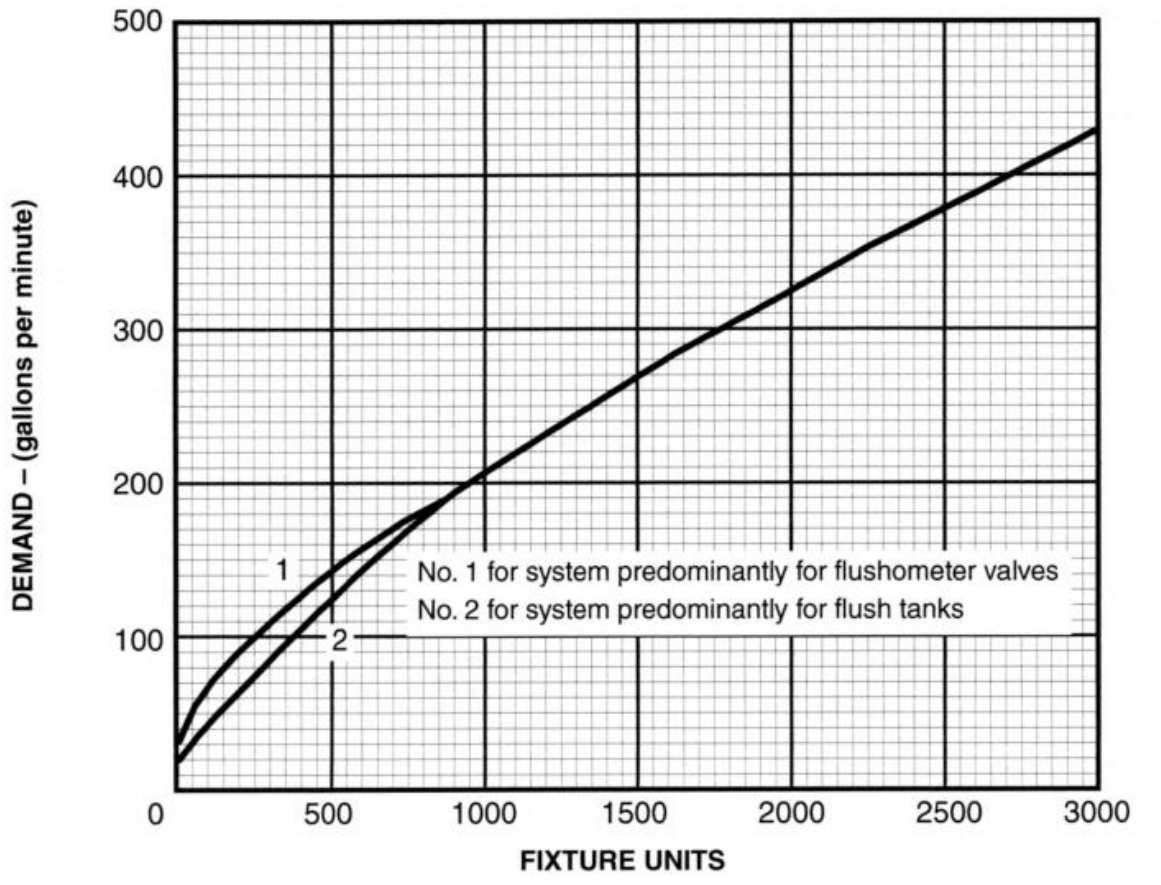


Figure 8: Hydraulic elements for circular sewers [10].

Appendix B-4 Hydraulic elements diagram for circular sewers

Appendix C Plumbing Design Aids



Appendix C-1 Estimate curves for demand load based on fixture units

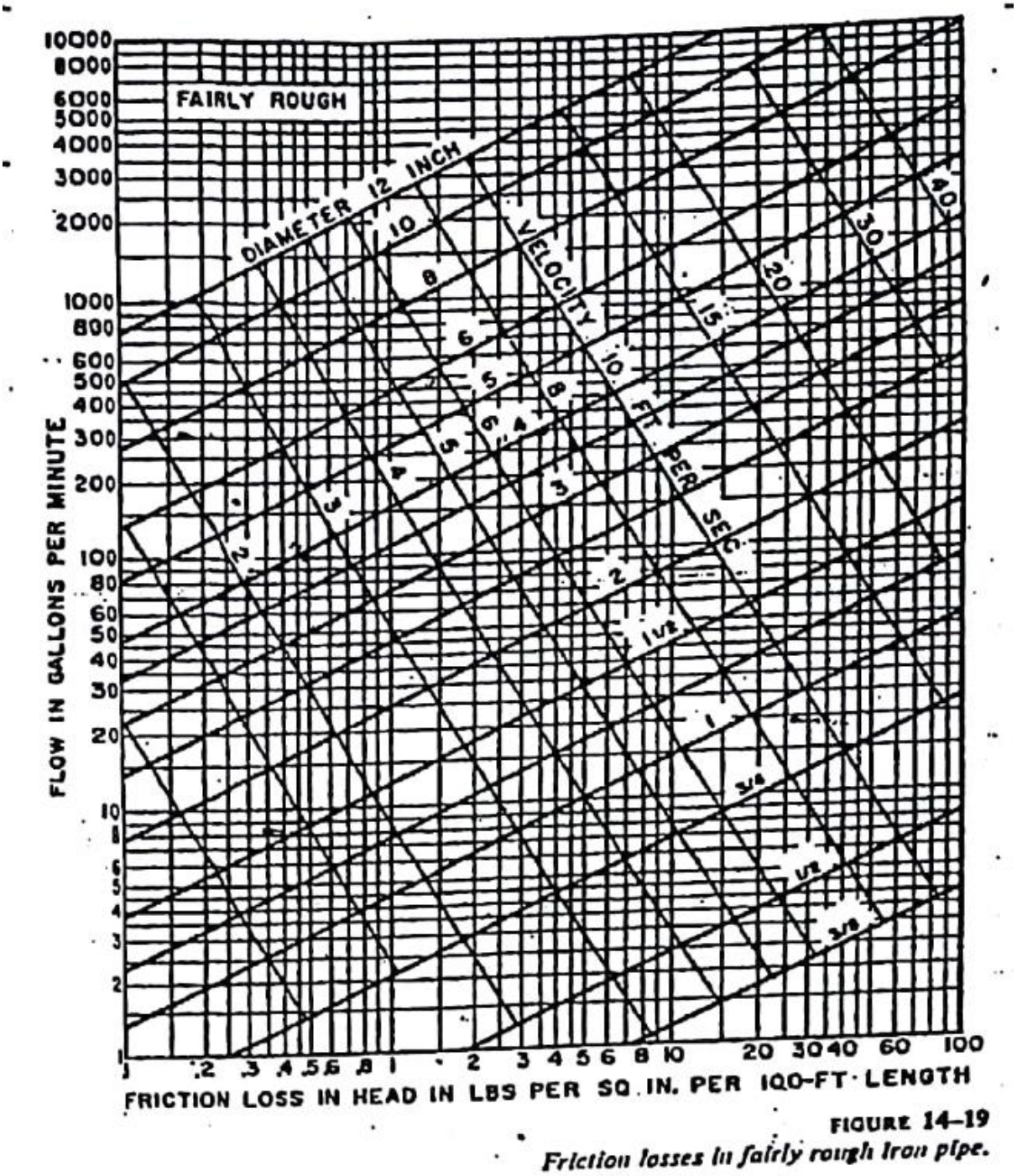
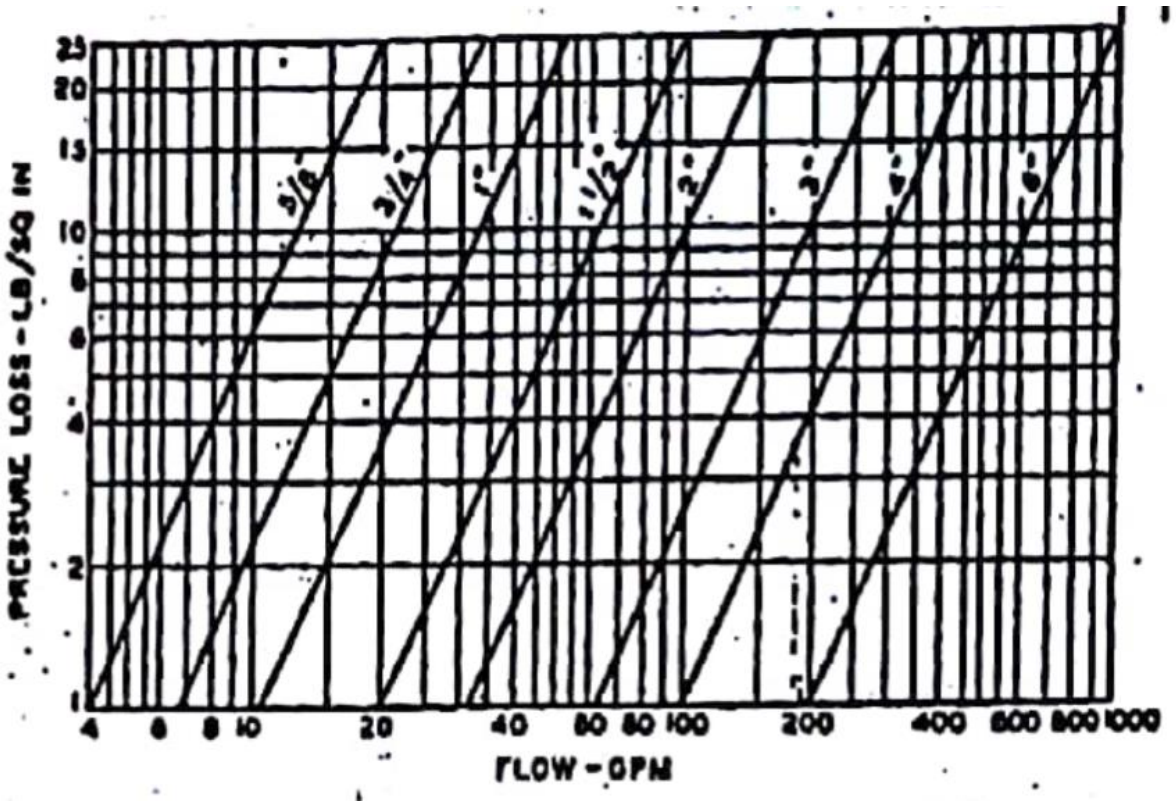


FIGURE 14–19

Friction losses in fairly rough iron pipe.

Appendix C-2 Friction loss per 100-ft length of pipe



Appendix C-3 Pressure losses in water meter

Table 4.4.1: Fire Protection Flow Requirements*

Building Type**	Sprinkler System (litre/min.)	Standpipe and Hose System (litre/min.)	Duration in Minutes for Building Heights		
			Up to 51 m	51 m to 102 m	Above 102 m
Light hazard- I	1000	1000	30	38	45
Light hazard- II	1900	1900	50	62	75
Ordinary hazard- I	2650	1900	75	95	112
Ordinary hazard-II	3200	1900	75	95	112
Ordinary hazard-III	4800	1900	75	95	112

Appendix C-4 Fire protection flow requirements (Source: BNBC 2020)

Table 8.5.6: Water Supply System Design Requirements

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		13	55	--
supply size requirement		19	55	--
		25	100	--

5.10.4.2 For 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 35 m (345 kPa ≈ 50 psi).

Appendix C-5 Water supply system design requirements (Source: BNBC 2020)