Sample Calculation

Zone 2, Trial 1:

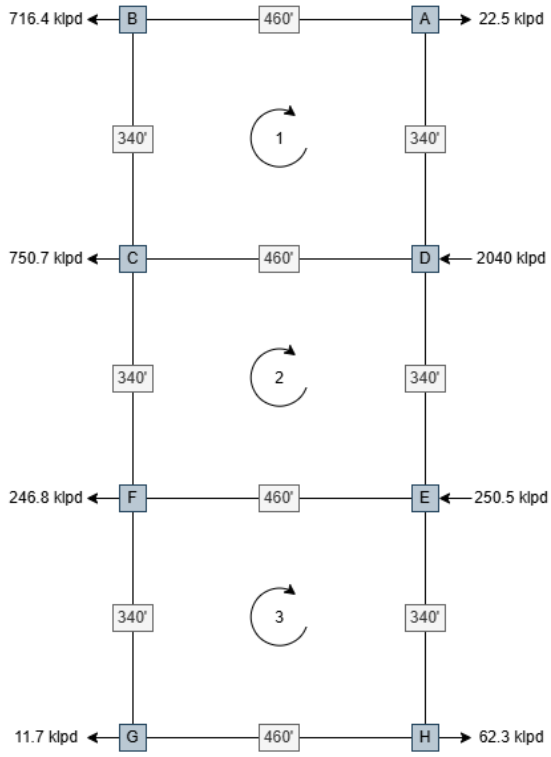


Figure 7 Schematic diagram of Zone 2 loop network

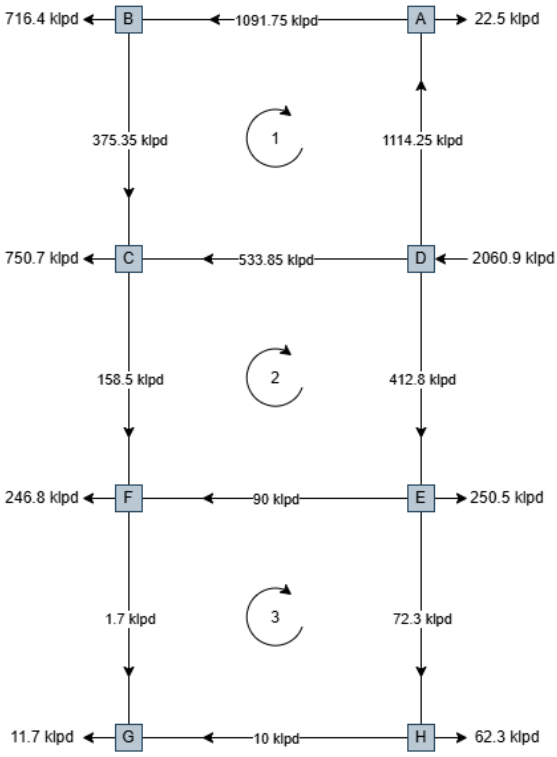


Figure 8 Initially assumed pipe flow of Zone 2

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

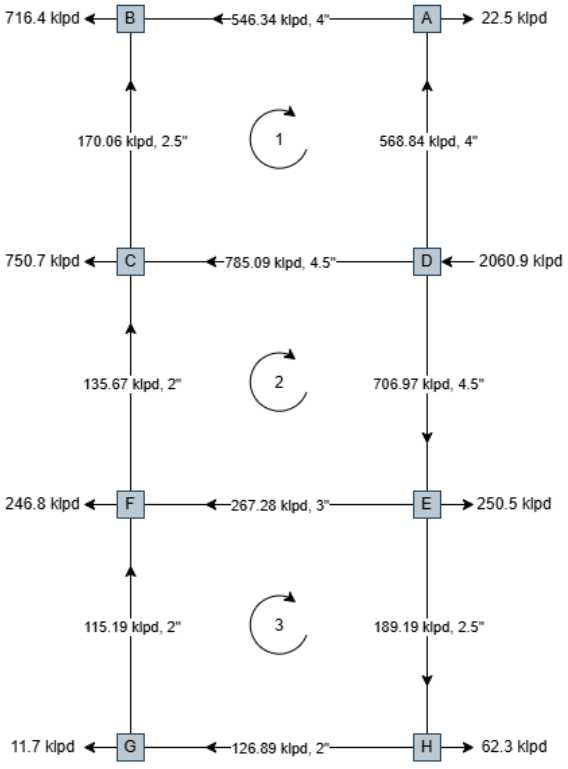


Figure 9 Pipe parameters of Zone 2

Zone 1: Residential, Commercial, Administrative

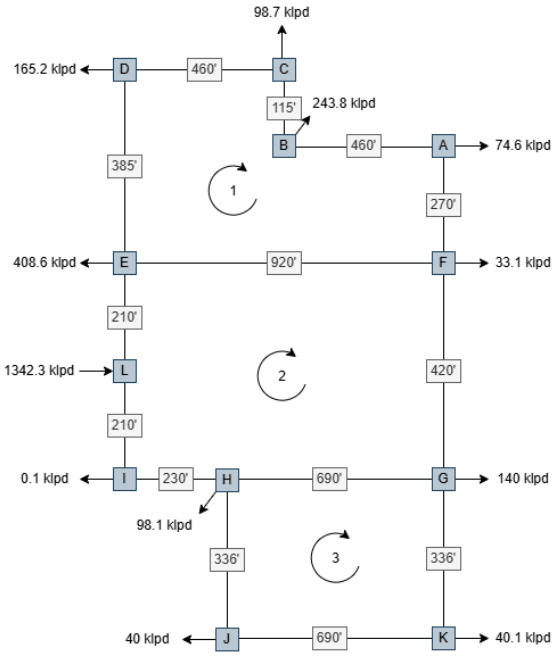


Figure 10 Schematic diagram of Zone 1 loop network

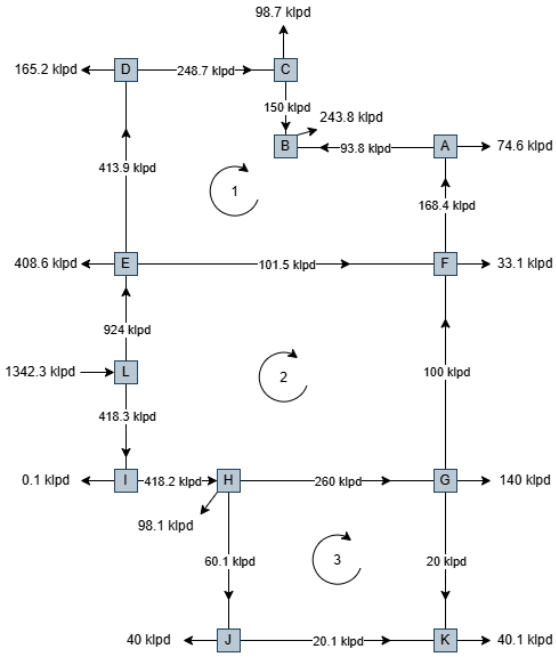


Figure 11 Initially assumed pipe flow of Zone 1

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

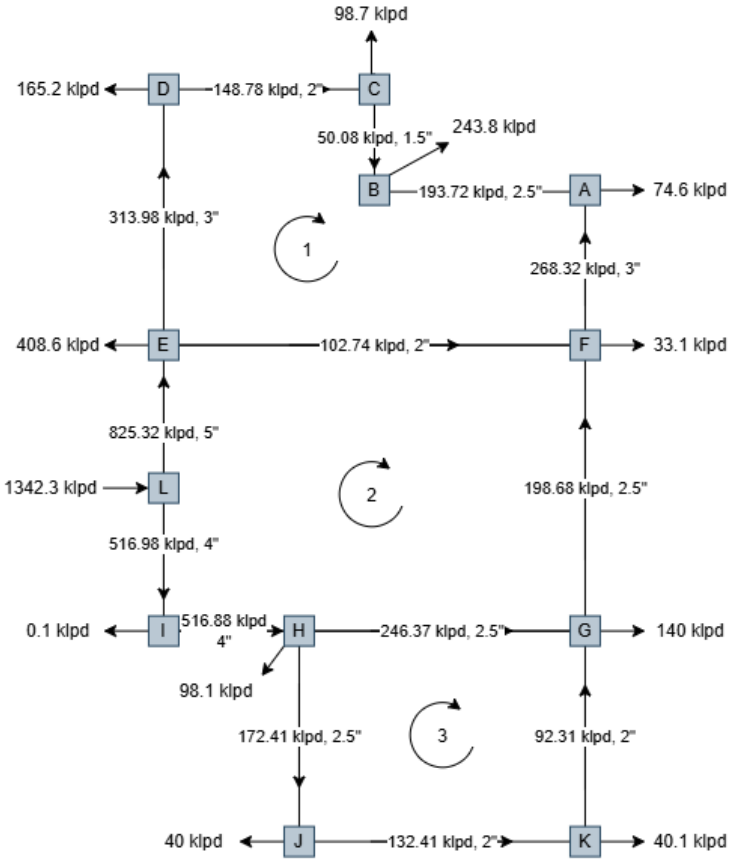


Figure 12 Pipe parameters of Zone 1

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.

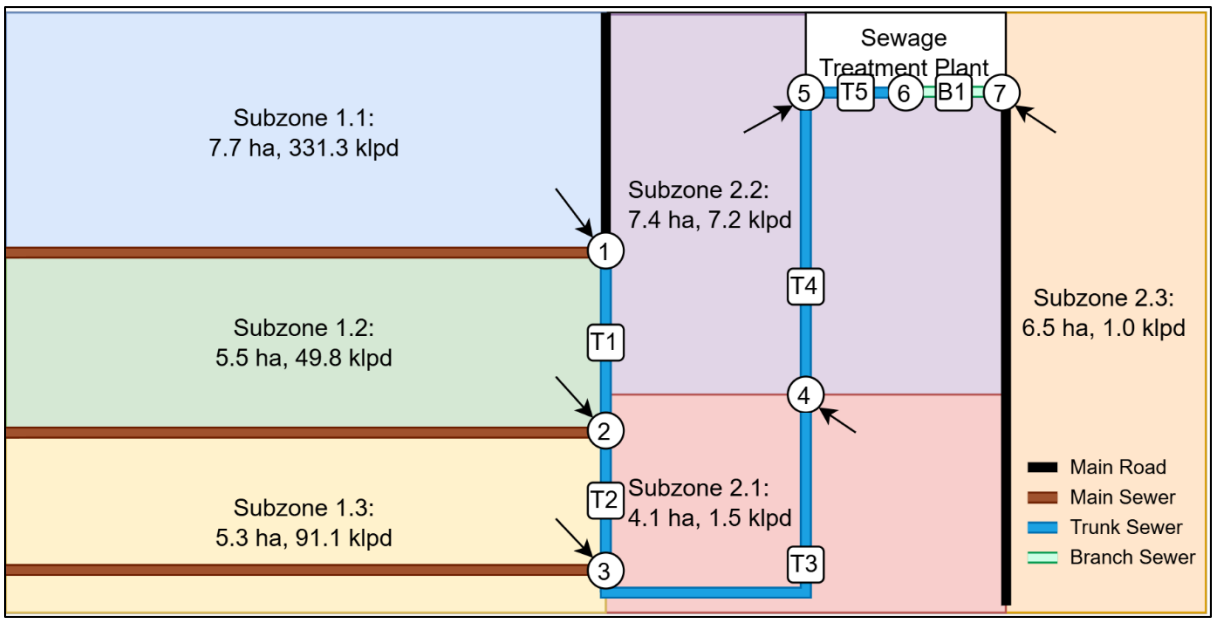


Figure 13 Layout of trunk sewer alignment and tributary subzones

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.