BIE 5110/6110
Sprinkle & Trickle Irrigation
Fall Semester, 2004

Assignment #3 (100 pts)
Set Sprinkler Lateral Design

Given:

- Sprinkler spacing, S_e, of 12 m
- Lateral length of 252 m
- Riser height of 1.30 m
- Lateral will run downhill along a ground slope of 0.38%
- Nominal sprinkler discharge of 22 lpm at 2.08 atm pressure
- Nominal aluminum pipes sizes of 2, 3, 4 and 5 inches are available
- Assume a constant value of q_a for each sprinkler along the lateral
- See Table 8.1 in the textbook (Keller & Bliesner) for pipe inside diameters

Required:

- Calculate the required aluminum lateral pipe size
- Round up to the nearest available pipe size
- Calculate the required lateral inlet pressure
- Calculate the location of minimum pressure in the pipe
- Calculate the pressure in the lateral pipe at the downstream end
- Calculate the percent pressure variation in the lateral pipe (%)

Solution:

If Hazen-Williams equation is used, the C value will be 130.
The number of sprinklers on the lateral is:

$$N_n = \frac{L}{S_e} = \frac{252\ \text{m}}{12\ \text{m}} = 21$$

There will be 21 sprinklers per lateral. The multiple-outlet friction loss factor for 21 sprinklers is:

$$F = 0.351 + \frac{1}{2(21)}\left[1 + \frac{4}{13(21)}\right] = 0.38$$

The lateral inflow rate is:

$$Q_l = N_n q_a = \frac{(21)(22\ \text{lpm})}{60\ \text{s/min}} = 7.70\ \text{lps}$$

The elevation change along the length of the lateral is:

$$\Delta h_e = \left(\frac{-0.38}{100}\right)(252\ \text{m}) = -0.958\ \text{m}$$

The nominal sprinkler pressure is ha = 2.08 atm, or,

$$h_a = (2.08\ \text{atm})(10.34\ \text{m/atm}) = 21.5\ \text{m}$$

The allowable friction loss gradient is:

$$J_a = 100\left(\frac{0.20h_a - \Delta h_e}{FL}\right)$$

$$= 100\left(\frac{0.2(21.5\ \text{m}) - (-0.958\ \text{m})}{(0.38)(252\ \text{m})}\right)$$

$$= 5.49\ \text{m/100m}$$

The minimum pipe ID is:

$$D = \left[\frac{16.42(10)^6}{5.49} \left(\frac{7.70 \text{ lps}}{130} \right)^{1.852} \right]^{0.205} = 7.27 \text{ cm}$$

or 7.27 cm/2.54 = 2.86 inches.

From Table 8.1 (page 140) in the textbook, the nominal size of the aluminum lateral pipe is the outside diameter, and the wall thickness is 0.05 inches. The 2" size has ID = 1.9", the 3" size has ID = 2.9", and so forth. From our calculated minimum diameter, we must **round up to the 3" nominal size**. Then, the inside diameter is (2.9 inch)(2.54) = 7.37 cm.

The actual friction loss along the lateral will be:

$$J = 16.42(10)^6 \left(\frac{7.70 \text{ lps}}{130} \right)^{1.852} (7.37 \text{ cm})^{-4.87} = 5.22 \text{ m/100 m}$$

$$h_f = \frac{JFL}{100} = \frac{(5.22)(0.38)(252 \text{ m})}{100} = 5.00 \text{ m}$$

The required lateral inlet pressure is:

$$\begin{aligned} h_l &= h_a + 0.75h_f + 0.5\Delta h_e + h_r \\ &= 21.5 \text{ m} + 0.75(5.00 \text{ m}) + 0.5(-0.958 \text{ m}) + 1.3 \text{ m} \\ &= 26.1 \text{ m} \ (2.52 \text{ atm}) \end{aligned}$$

The minimum pressure in the lateral pipe is located at a distance x from the inlet (q_a is 22 lpm/60 = 0.367 lps; D is 73.7 mm):

$$\begin{aligned} x &= \frac{S_e}{q_a} \left[Q_l - 3(10)^{-7} \left(C(-S)^{0.54} D^{2.63} \right) \right] \\ &= \frac{12}{0.367} \left[7.70 - 3(10)^{-7} \left(130(0.38)^{0.54} (73.7)^{2.63} \right) \right] \\ &= 190 \text{ m} \end{aligned}$$

according to the equations in the lecture notes on pages 64 and 65. This "x" value (distance) is confirmed (approximately) by assuming an inlet pressure head of 26.1 m, a C value of 130, and so forth, calculating the head loss segment-by-segment in a spreadsheet:

Sprinkler Position	Distance (m)	Q (lps)	hf (m)	head (m)
0	0	7.70	0.0000	26.10
1	12	7.33	0.6262	25.52
2	24	6.97	0.5721	24.99
3	36	6.60	0.5203	24.52
4	48	6.23	0.4707	24.09
5	60	5.87	0.4234	23.72
6	72	5.50	0.3785	23.38
7	84	5.13	0.3358	23.09
8	96	4.77	0.2955	22.84
9	108	4.40	0.2576	22.63
10	120	4.03	0.2221	22.45
11	132	3.67	0.1891	22.31
12	144	3.30	0.1585	22.20
13	156	2.93	0.1304	22.11
14	168	2.57	0.1048	22.05
15	180	2.20	0.0819	22.02
16	192	1.83	0.0615	22.00
17	204	1.47	0.0439	22.00
18	216	1.10	0.0290	22.02
19	228	0.73	0.0170	22.05
20	240	0.37	0.0080	22.09
21	252	0.00	0.0022	22.13

whereby the minimum head is found somewhere between 192 and 204 m from the lateral inlet. The difference in the calculations are due to the F-factor for multiple outlets. It is also seen that the maximum pressure head is at the lateral inlet (h_{max} = 26.1 m), which might have been expected because the ground slope is very small.

Thus, the minimum pressure is at a distance of approximately 190 m from the lateral inlet, which is nearest sprinkler number 190/12 ≈ 16.

The pressure in the pipe at the downstream end will be:

$$h_{end} = h_l - h_f - (-\Delta h_e)$$
$$= 26.1 - 5.0 + 0.958 = 22.1\,\text{m}$$

The head loss due to friction from sprinkler 16 to the end of the lateral is estimated as (from Table 8.7, F = 0.46 for 21 – 16 = 5 outlets):

$$J_{x-end} = 16.42(10)^6 \left(\frac{(0.367)(5)\ \text{lps}}{130} \right)^{1.852} (7.37\ \text{cm})^{-4.87} = 0.366\ \text{m/100m}$$

where the pipe length is 5(12 m) = 60 m,

$$\left(h_f\right)_{x-end} = \frac{JFL}{100} = \frac{(0.366)(0.46)(60\ m)}{100} = 0.101\,m$$

The friction loss from the inlet to distance x = 190 m is, then, 5.00 – 0.101 m = 4.90 m. The elevation change from the inlet to 190 m is (-0.0038)(12)(16) = -0.730 m. Finally, the minimum pressure head in the lateral pipe is:

$$h_{min} = 26.1 - 4.90 - (-0.730) = 21.9\ m$$

The pressure (or head) variation is:

$$\Delta P = \frac{h_{max} - h_{min}}{h_a} = \frac{26.1 - 21.9}{21.5} = 0.20$$

which is 20%. This just meets our design criterion.