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

Assignment #4 (100 pts)
Mainline Design
Due: 13 Oct 04

Given:

- A large rectangular field, 1,200 m long and 1,000 m wide
- Periodic-move sprinkler laterals with buried mainline pipe
- Four sprinkler laterals operate, each covering ¼ of the field area
- Two laterals are on one side of the mainline, and two on the other side
- All four laterals move in the same direction when changing sets
- The mainline will run down the middle of the field, 1,200 m long
- The mainline will run uphill at a uniform slope of 0.387%
- System capacity is Q_s = 135 lps
- PVC pipe sizes given in Table 8.5 are the available sizes
- Pressure available at the upstream end of the mainline is 389 kPa
- Required lateral inlet pressure is 275 kPa
- Laterals connect to mainline through hydrant valves
- Hydrant hydraulic loss to from mainline to lateral inlet is 25 kPa

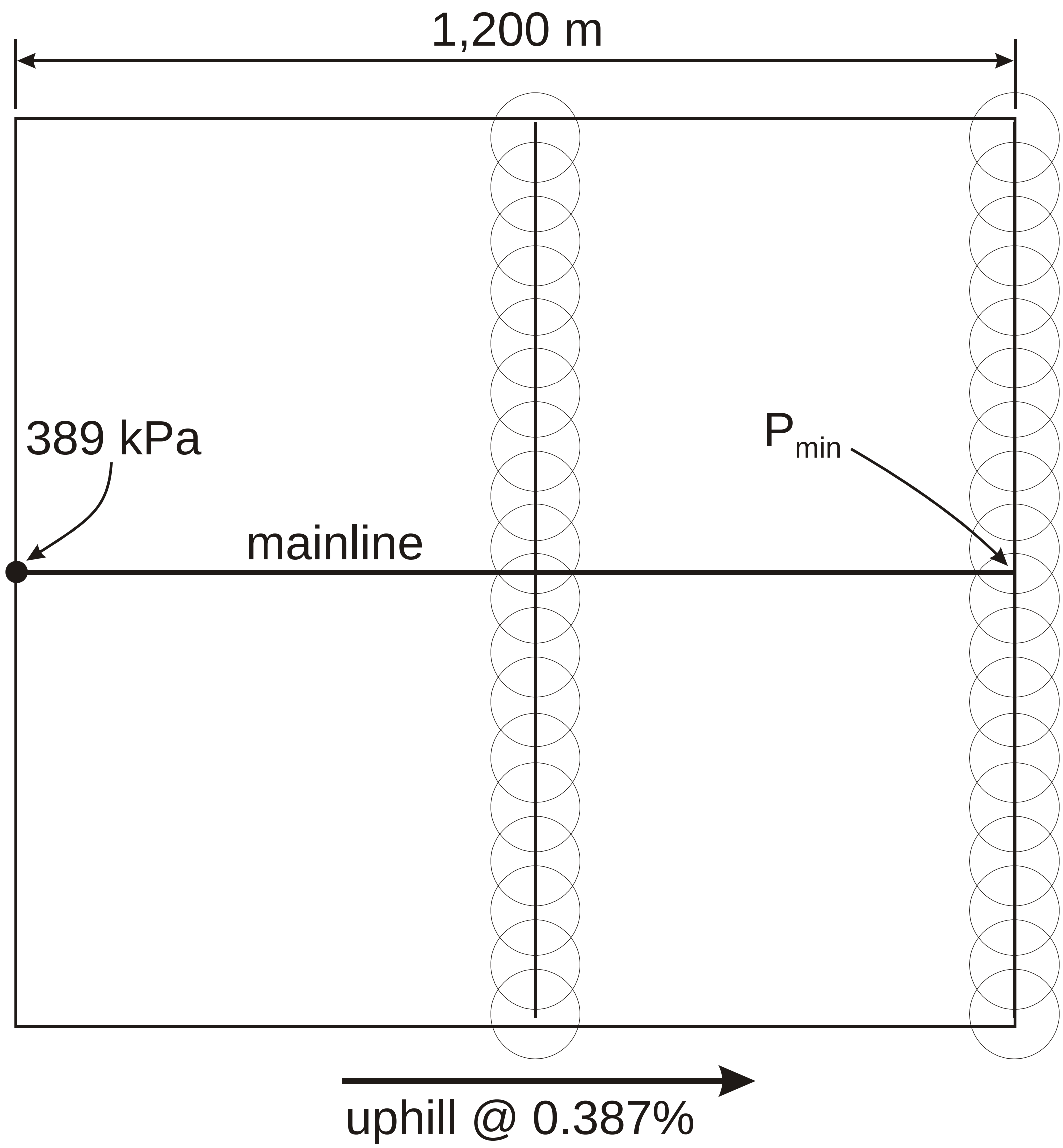
Required:

- Design the mainline to consume all of the available head
- Use the basic procedures from Lecture 9 and Chapter 10
- Consider the critical lateral positions
- Determine mainline pipe diameters and respective lengths of each size
- Check operational velocity limits in the mainline pipe
- Do all calculations in metric units (lengths in m, flow in lps, and diameter in mm)
- Do your work neatly and logically – make it understandable to another engineer
- Include brief comments, as necessary, about design details and decisions

Solution:

(1) Extreme Lateral Position

- Recognize that the extreme lateral position is when two laterals are at the mid-point of the mainline, and the other two at the uphill end of the mainline
- This is because the mainline runs uphill, so pressure must decrease monotonically from upstream to downstream along the mainline pipe
- Also, the critical point is the uphill end of the mainline, because that must be the location of minimum pressure in the mainline
- Thus, for the extreme lateral position, the two laterals at the mid-point will have more than enough pressure if the last two laterals have just the required pressure
- Mainline design, then, should focus on providing P_{min} = 275 + 25 kPa in the pipe
- These facts should be obvious



(2) Allowable Loss due to Friction

- The allowable friction loss is the available pressure at the mainline inlet, minus the elevation change, hydrant loss, and required lateral inlet pressure
- As in the example mainline design in the lecture notes, do not consider minor losses due to flow past closed hydrants along the mainline
- And, as in the example problems in the lecture notes, it may help to look at this problem using a schematic diagram
- First, convert pressures to heads and determine the elevation change along the length of the mainline:

Mainline inlet head: 389 kPa/9.81 = 39.65 m

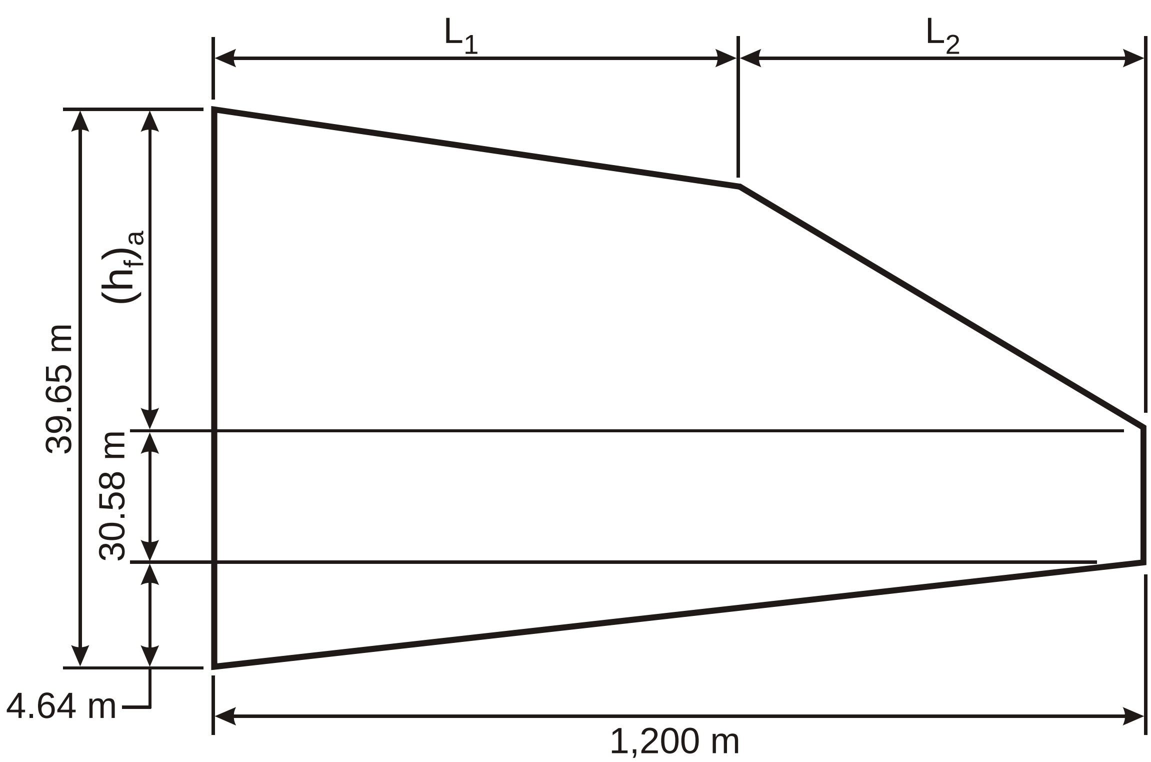
Elevation change:

$$\Delta h_e = 0.00387(1{,}200) = 4.64 \text{ m}$$

Lateral inlet pressure plus hydrant loss:

$$h_l + h_{hydrant} = \frac{275 + 25}{9.81} = 30.58 \text{ m}$$

- Let L_1 be the length of pipe diameter D_1, and L_2 the length for diameter D_2



- Allowable loss due to friction along the entire length of the mainline pipe:

$$\left(h_f\right)_a = 39.65 - 30.58 - 4.64 = 4.43 \text{ m}$$

<u>(3) Selection of Mainline Pipe Diameters</u>

- Calculate the required mainline pipe inside diameter assuming only one pipe size
- Recognize that at the extreme lateral position, the full system flow rate goes from the beginning of the mainline to the mid-point, where only half the system flow rate continues to the end of the mainline
- Make the allowable friction loss equal to the actual friction loss

$$\left(h_f\right)_a = \frac{J_1\left(L/2\right)}{100} + \frac{J_2\left(L/2\right)}{100}$$

where L = 1,200 m; and $(h_f)_a$ = 4.43 m

$$4.43 = 6\left[\frac{1.217(10)^{12} D^{-4.87}}{C^{1.852}}\right]\left[Q_s^{1.852} + \left(\frac{Q_s}{2}\right)^{1.852}\right]$$

where Q_s = 135 lps; and C = 150 (plastic pipe).

- Solving the above equation, D = 326 mm (12.8 inches).
- This is slightly larger than the 12” pipe (ID = 308.1 mm) in Table 8.5.
- However, the velocity in the 12” pipe at 135 lps would be:

$$V = \frac{4Q}{\pi D^2} = \frac{4(0.135)}{\pi(0.3081)^2} = 1.81 \text{ m/s}$$

which is not too high, but as seen above, the friction loss would be too high

- It might also be noted that 135 lps is more than 2,000 gpm, a flow rate for which an irrigation system would almost always use 12” or 15” nominal pipe size
- Based on the preceding, try 15” pipe (Table 8.6) for the first half of the mainline:

$$\left(h_f\right)_{15"} = 1.217(10)^{10}\left(\frac{Q_s}{C}\right)^{1.852} D^{-4.87}\left(\frac{L}{2}\right)$$

$$\left(h_f\right)_{15"} = 1.217(10)^{10}\left(\frac{135}{150}\right)^{1.852} (369.7)^{-4.87}\left(\frac{1{,}200}{2}\right) = 1.88 \text{ m}$$

- This leaves $(h_f)_a - (h_f)_{15''}$ = 4.43 – 1.88 = 2.55 m allowable head loss in the second half of the mainline
- The allowable friction loss gradient in the second half of the mainline is:

$$J_a = 100\left(\frac{2.55}{600}\right) = 0.425 \text{ m}$$

- At ½ Q_s = 67.5 lps, this is very close to the J value for the 10" pipe in Table 8.5
- Using that 10" pipe,

$$\left(h_f\right)_{10''} = 1.217(10)^{10}\left(\frac{67.5}{150}\right)^{1.852}(259.7)^{-4.87}\left(600\right) = 2.90 \text{ m}$$

which is greater than the allowable loss of 2.55 m, but close

- Using the 15" pipe on the first half of the mainline, and 10" pipe on the second half, the total friction loss would be: $(h_f)_{total}$ = 1.88 + 2.90 = 4.78 m
- Then, the pressure at the last pair of laterals would be:

$$P_{min} = 389 - 25 - 9.81(4.64 + 4.78) = 272 \text{ kPa}$$

which is very close to the required 275 kPa at the lateral inlets

(4) Design Summary

- The design could involve three pipe sizes along the mainline
- But, in this case it works out well to use two sizes: 15" SDR 41 PIP for the first half of the mainline, and 10" SDR 41 IPS for the second half of the mainline
- Thus, there will be 600 m of 15" mainline, and 600 m of 10" mainline
- The pressure will be just about right at the end of the mainline, only 3 kPa below that which is required
- The pressure at other lateral positions will be more than enough

(5) Notes

- Tables 8.5 and 8.6 do not use the same friction loss equation
- Table 8.6 is based on Hazen-Williams with C = 155
- Minor losses past closed hydrants were not considered – if they were, it might be necessary to use a combination of 12" and 10" pipe in the second half of the mainline
- It might also be necessary to use a combination of 12" and 10" pipe in the second half of the mainline if we include a safety factor for uncertainties