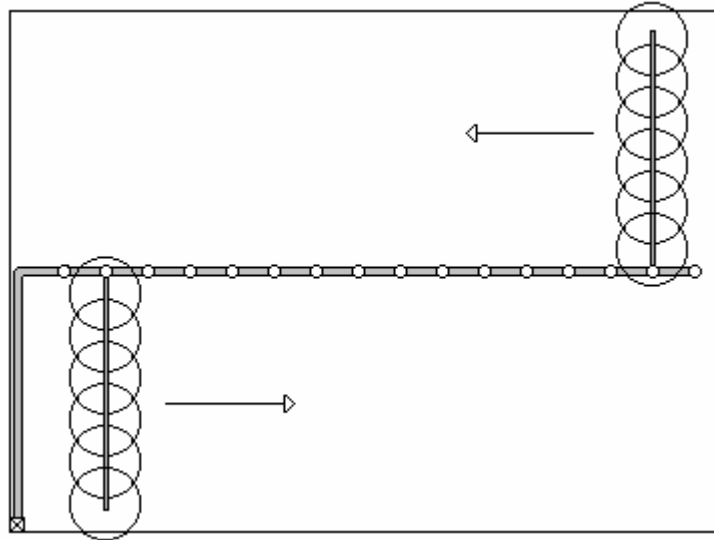


## Lecture 9

### Mainline Pipe Design

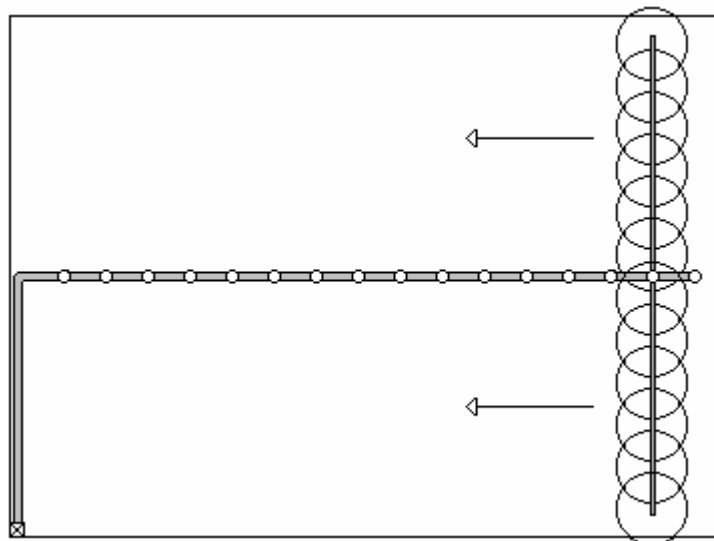
#### I. Split-Line Laterals



Laterals are usually distributed evenly along a mainline because:

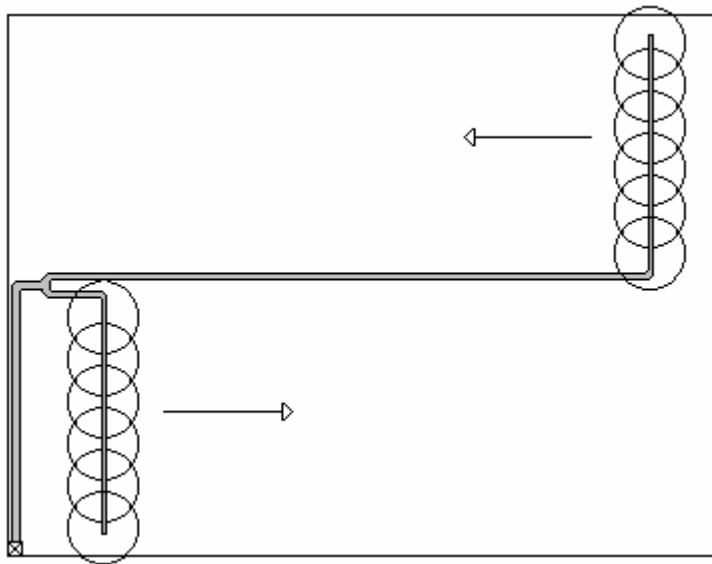
- More equal pump load at different lateral positions
- Reduced mainline cost
- Don't need to "dead-head" back when finished (cross over to other side)
- But, split-line laterals may interfere with cultural operations (wet areas at both ends of field)

Consider twin laterals operating in the same direction:



- In the above case, and for only a single lateral on the mainline, the design of the mainline is relatively simple – it is easy to find the most extreme operating position
- However, the friction loss along the mainline is about four times greater than for the split-line configuration
- Note that for the above two configurations the first sprinkler on the laterals would be at  $0.5S_e$  from the inlet, unless the mainline is laid upon a roadway in the field

Twin split-line laterals with dual mainline...



- Same combined mainline length
- No valves on mainline -- elbow at each lateral inlet
- More labor required, but mainline costs less because no valves, and because the mainline is sized for the flow rate of one lateral over the entire mainline length (not half at twice the capacity)
- For different lateral positions, you remove pieces of the mainline from the longer section and put on the shorter section

## II. General Design Considerations

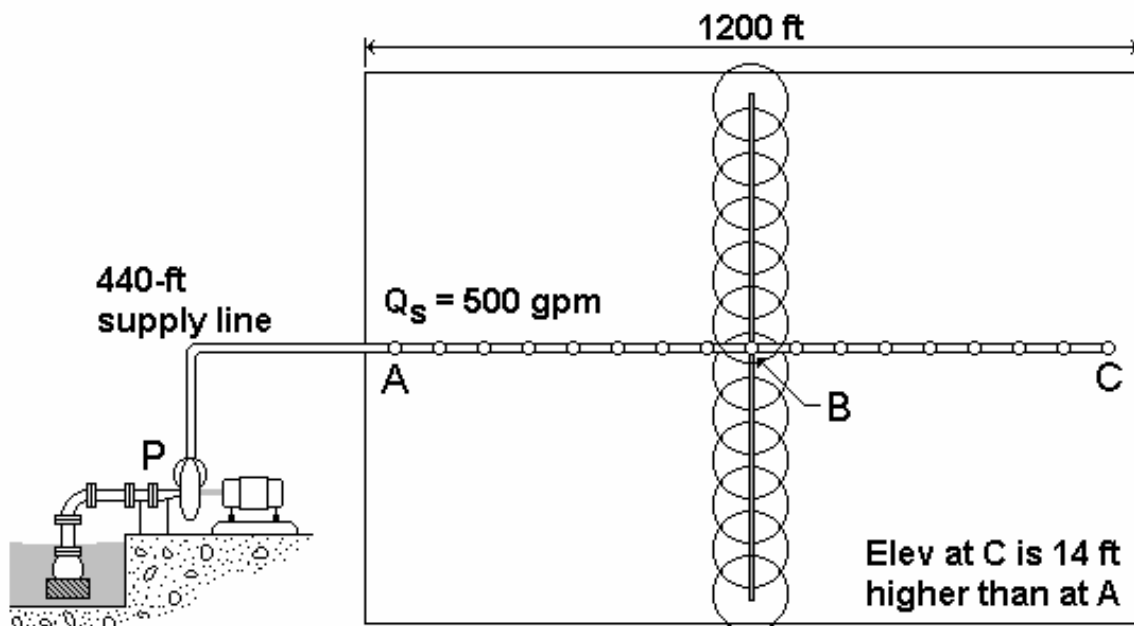
- Look at extreme operating conditions for the mainline by varying lateral positions (this can be more complicated for irregular field shapes and non-uniform field slopes)
- Can use economic pipe selection method, but don't make a big sacrifice in terms of pressure uniformity along the mainline to save pumping costs
- Buried mainlines do not obstruct traffic, nor do they remove any land from production. But, they cannot be moved from field to field

- Buried mainlines tend to last longer, because they are not handled and banged up after installation

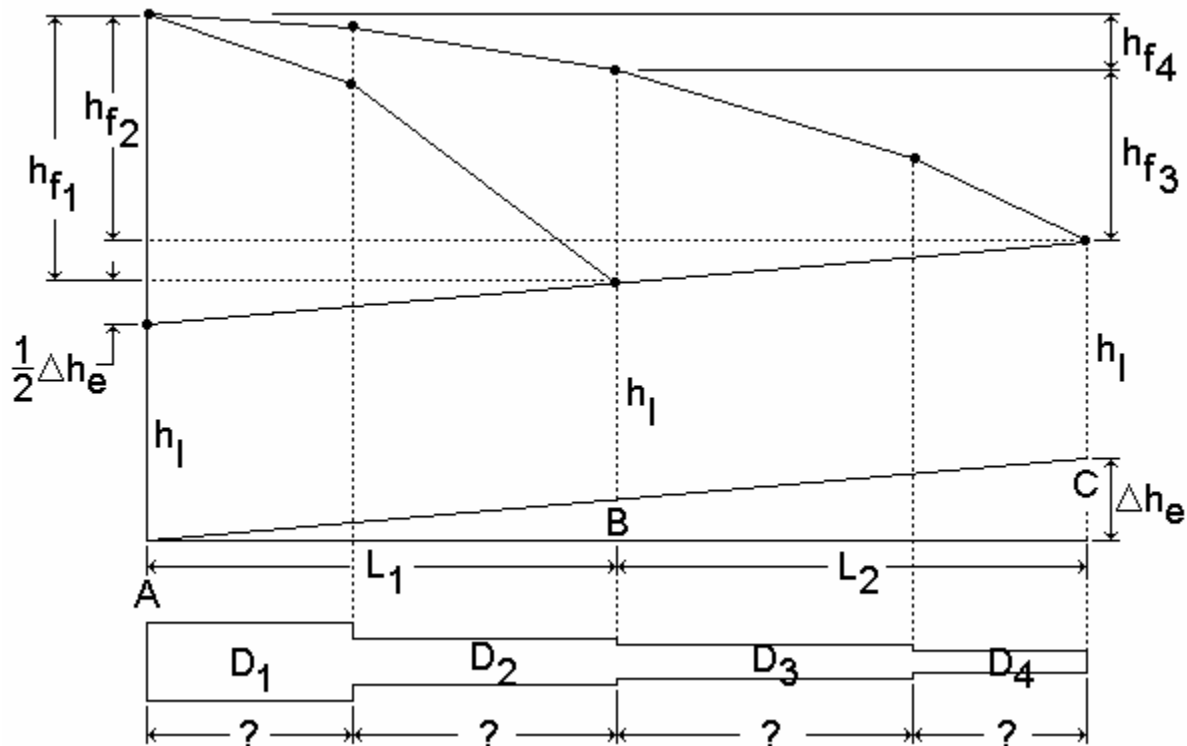
## Uphill Split-Line Mainline Design

### I. Definition of the Example Problem

- See example 10.1 from the textbook, an uphill mainline design for two split-line laterals
- For design, consider the two extreme lateral positions:
  1. Both laterals at position B (mid-point of mainline)
  2. One lateral at position A and the other at position C
- Divide the mainline into two logical lengths, at the mid-point, according to the two extreme lateral positions
- Determine the total allowable head loss due to friction in each of these logical lengths, then find two adjacent pipe sizes for each length
- Determine the lengths of each pipe size so that the total head loss is just equal to the allowable head loss
- This is somewhat analogous to the procedure for designing dual pipe size laterals
- This is the system layout (shown with both laterals at position B):



- Pump provides at least 172 ft of head at P
- Lateral inlet pressure head is given as 125 ft of head (Eq. 9.2)
- Supply line and mainline are to be aluminum, in 30-ft lengths
- The figure below shows the hydraulic schematic for this mainline, with separate friction loss profiles for the two extreme lateral positions
- The mainline is tentatively divided into sizes  $D_1$  and  $D_2$  for the first half ( $L_1$ ), and  $D_3$  and  $D_4$  for the second half ( $L_2$ ). So, there are *potentially* four different pipe sizes in the mainline from A to C.



- We do not yet know what these pipe diameters will be
- We do not yet know the required lengths of the different diameter pipes
- $hf_1$  is for the case when both laterals are at B
- $hf_2$ ,  $hf_3$ , and  $hf_4$  are for the case when one lateral is at A and the other at C
- $hf_1$  is for 500 gpm over  $L_1$
- $hf_2$  is for 250 gpm over  $L_1 + L_2$
- $hf_3$  is for 250 gpm over  $L_2$
- $hf_4$  is for 250 gpm over  $L_1$

## II. Select the Size of the Supply Line

- We need to select the size of the supply line to know what the head loss is from P to A (pressure at P is given as 172 ft of head)
- Assume no elevation change between P and A
- From continuity,  $Q = A V$ , then for an allowable velocity of 5 ft/s:

$$D = \sqrt{\frac{4Q}{\pi V}} = \sqrt{\frac{4(1.11 \text{ cfs})}{\pi(5 \text{ fps})}} = 0.53 \text{ ft} \quad (186)$$

- This is 6.4 inches. In Table 8.4, the 6-inch pipe has an inside diameter of 5.884 inches. With this size, the velocity at 500 gpm would be 5.9 ft/s, which we will accept (could use 8-inch pipe, but 6-inch is probably OK)
- From Table 8.4, the head loss gradient in the 6-inch supply line at 500 gpm is 2.27 ft/100 ft. Then,

$$(h_f)_{P-A} = (2.27 \text{ ft}/100 \text{ ft}) \left( \frac{440 \text{ ft}}{100} \right) = 10.0 \text{ ft} \quad (187)$$

- This means that the pressure head at A is 172 ft - 10.0 ft = 162 ft

## III. Determine $D_1$ and $D_2$ for both Laterals at B

- We will tolerate  $(h_f)_1$  head loss over section  $L_1$  of the mainline when both laterals are operating at B. This will give the required  $h_l$  at B.
- We can see that  $(h_f)_1$  is defined as:

$$h_{f1} = 162 \text{ ft} - h_l + 0.5 \Delta h_e \quad (188)$$

$$h_{f1} = 162 \text{ ft} - 125 \text{ ft} - 7 \text{ ft} = 30 \text{ ft} \quad (189)$$

- The allowable loss gradient in section  $L_1$  for both laterals operating at B is

$$(J_a)_{L1} = 100 \left( \frac{30 \text{ ft}}{600 \text{ ft}} \right) = 5 \text{ ft per } 100 \text{ ft} \quad (190)$$

- From Table 8.4, this is between the 5- and 6-inch pipe sizes, which have respective loss gradients of 5.54 ft/100 ft and 2.27 ft/100 ft for the 500 gpm flow rate. Therefore, choose  $D_1 = 6$  inch and  $D_2 = 5$  inch.

- Now we must find out how long  $D_1$  should be so that the friction loss is really equal to 30 ft of head...

$$L_{D1}(2.27) + (600 - L_{D1})(5.54) = 100(30 \text{ ft}) \quad (191)$$

- Solving the above,  $L_{D1} = 99.1 \text{ ft}$
- Using 30-ft pipe lengths, we adjust the length to...

$$L_{D1} = 90 \text{ ft of } 6'' \text{ pipe (3 sections)} \quad (192)$$

$$L_{D2} = 510 \text{ ft of } 5'' \text{ pipe (17 sections)} \quad (193)$$

- With the adjusted lengths, we will get 30.3 ft of head loss over section  $L_1$  for 500 gpm (this is close enough to the allowable 30 ft)

#### IV. Determine $D_3$ and $D_4$ for Laterals at A and C

- We will tolerate  $(h_f)_3 + (h_f)_4$  head loss over the whole length of the mainline when one lateral is operating at A and the other at C
- We can calculate  $(h_f)_4$  straight away because we already know the pipe sizes and lengths in section  $L_1$ ...

$$h_{f4} = \frac{(90 \text{ ft})(0.63) + (510 \text{ ft})(1.53)}{100} = 8.37 \text{ ft} \quad (194)$$

where the friction loss gradients for 250 gpm are 0.63 ft/100 ft (6" size) and 1.53 ft/100 ft (5" size). These values were taken from Table 8.4.

- Now we need to know the allowable loss for  $(h_f)_3$ , such that the pressure in the mainline at C will be equal to  $h_1$  (we know that the pressure at A is 162 ft - it is more than enough)...

$$h_{f2} = h_{f1} + 0.5 \Delta h_e = 23.0 \text{ ft} \quad (195)$$

$$h_{f3} = h_{f2} - h_{f4} = 23.0 \text{ ft} - 8.37 \text{ ft} = 14.6 \text{ ft} \quad (196)$$

- The allowable loss gradient in section  $L_2$  for laterals at A and C is

$$(J_a)_{L2} = 100 \left( \frac{14.6 \text{ ft}}{600 \text{ ft}} \right) = 2.43 \text{ ft per } 100 \text{ ft} \quad (197)$$

- From Table 8.1, this is between the 4- and 5-inch pipe sizes, which have respective loss gradients of 4.66 ft/100 ft and 1.53 ft/100 ft for the 250 gpm flow rate. Therefore, choose  $D_3 = 5$  inch and  $D_4 = 4$  inch.
- Now we must find out how long  $D_3$  should be so that the friction loss is really equal to 14.6 ft of head...

$$L_{D3}(1.53) + (600 - L_{D3})(4.66) = 100(14.6 \text{ ft}) \quad (198)$$

- Solving the above,  $L_{D3} = 427$  ft
- Using 30-ft pipe lengths, we adjust the length to...

$$L_{D3} = 420 \text{ ft of } 5" \text{ pipe (14 sections)} \quad (199)$$

$$L_{D4} = 180 \text{ ft of } 4" \text{ pipe (6 sections)} \quad (200)$$

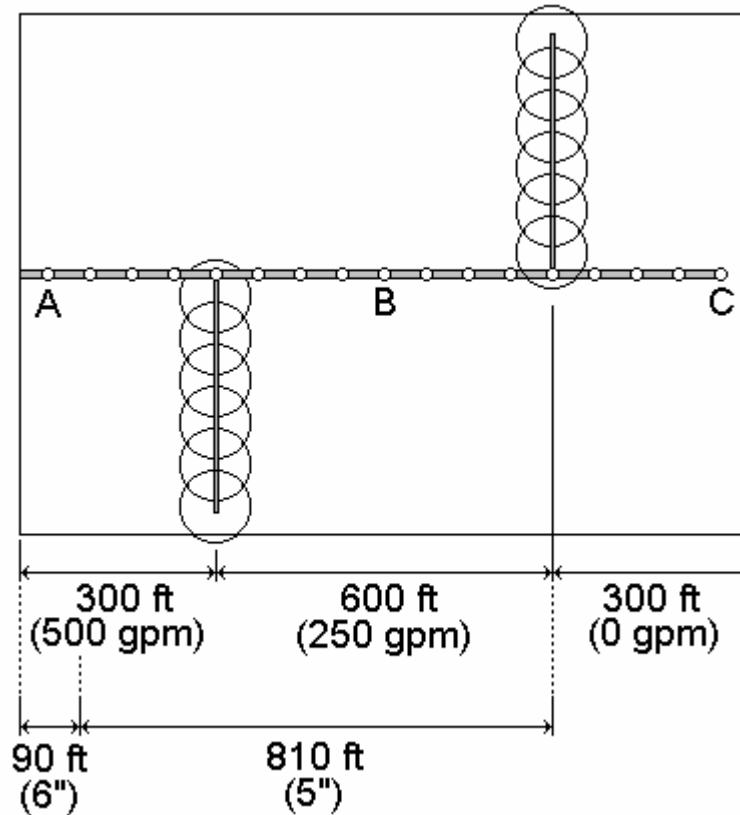
- With the adjusted lengths, we will get 14.8 ft of head loss over section  $L_2$  for 250 gpm (this is close enough to the allowable 14.6 ft)

#### V. Check this Mainline Design for an Intermediate Position

- Just to be sure, suppose that one lateral is operating halfway between A and B, and the other halfway between B and C
- The allowable friction loss from point A to the furthest lateral is  $(h_f)_2 + \frac{1}{4}\Delta h_e$ , or 23.0 ft + 3.5 ft = 26.5 ft. The actual friction loss would be:

$$h_f = 0.01[(2.27)(90) + (5.54)(210) + (1.53)(600)] = 22.9 \text{ ft} \quad (201)$$

- OK, the head in the mainline at the furthest lateral is more than enough
- See the figure below for a graphical interpretation of the two laterals in intermediate positions



## VI. Comments About the Mainline Design

- Both  $D_2$  and  $D_3$  are the same size in this example
- If we were lucky, both  $D_1$  and  $D_2$  (or  $D_3$  and  $D_4$ ) could be the same size, but that means the friction loss gradient would have to be just right
- The lateral inlet pressure will be just right when both laterals operate at B
- The lateral inlet pressure will be just right for a lateral operating at C
- The lateral inlet pressure will always be too high for a lateral operating between A and B (the inlet pressure to the mainline, at A, is always 162 ft)
- We designed  $D_1$  and  $D_2$  for the condition when both laterals are at B. This is a more demanding condition for  $L_1$  than when one lateral is at A and the other at C (in this case, only half the system flow rate is in  $L_1$ ). So, we don't need to "check"  $D_1$  and  $D_2$  again for the case when the laterals are at A and C.
- We didn't consider the hydrant loss from the mainline into the sprinkler lateral, but this could be added to the requirements (say, *effective*  $h_l$ )
- This design could be also done using the economic pipe selection method (or another pipe selection method. It would be a good idea to check to see if the

172 ft at the pump (point A) could be reduced by using larger supply and mainline pipes, thus reducing the annual energy costs. However, if the 172 ft were due to gravity supply, the design would still be all right.

- However, the velocity in the 5-inch pipe at 500 gpm is too high, at 8.5 fps (always check velocity limits when sizing pipes!)

## VII. Both Laterals Operating at Point C

- How would the mainline design change if it were not split line operation, and both laterals were operating at location C?
- In this case, intuition and past experience tells us location C is the critical lateral position – if you don't agree, then you should test other lateral positions to convince yourself
- We will tolerate  $(h_f)_2$  head loss over the entire 1,200-ft length of the mainline when both laterals are operating at C. This will give the required  $h_l$  at C.
- We can see that  $(h_f)_2$  is defined as:

$$h_{f2} = 162 \text{ ft} - h_l + \Delta h_e \quad (202)$$

$$h_{f2} = 162 \text{ ft} - 125 \text{ ft} - 14 \text{ ft} = 23 \text{ ft} \quad (203)$$

- The allowable loss gradient over the length of the mainline for both laterals operating at C is

$$J_a = 100 \left( \frac{23 \text{ ft}}{1,200 \text{ ft}} \right) = 1.92 \text{ ft per 100 ft} \quad (204)$$

- From Table 8.4, this is between the 6- and 8-inch pipe sizes, which have respective loss gradients of 2.27 ft/100 ft and 0.56 ft/100 ft for the 500 gpm flow rate
- Determine the respective pipe lengths so that the friction loss is really equal to 23 ft of head...

$$L_{8"} (0.56) + (1,200 - L_{8"}) (2.27) = 100(23 \text{ ft}) \quad (205)$$

- Solving the above,  $L_{8"} = 248 \text{ ft}$
- Using 30-ft pipe lengths, we adjust the length to...

$$L_{8"} = 270 \text{ ft of } 8" \text{ pipe (9 sections)} \quad (206)$$

$$L_{6"} = 930 \text{ ft of } 6" \text{ pipe (31 sections)} \quad (207)$$

