

Lecture 5

Layout of Laterals for Set Sprinklers

I. Selecting Sprinkler Discharge, Spacing, and Pressure

- In Chapter 6 of the textbook there are several tables that provide guidelines for nozzle sizes for different:
 - Wind conditions
 - Application rates
 - Sprinkler spacings
- For selected values of wind, application rate, and spacing, the tables provide recommended nozzle sizes for single and double-nozzle sprinklers, recommended sprinkler pressure, and approximate uniformity (CU)
- Table values are for standard (non-flexible) nozzles
- Table values are for standard sprinkler and lateral spacings
- More specific information can be obtained from manufacturers' data
- Recall that the maximum application rate is a function of soil texture, soil structure, and topography (Table 5.4)
- For a given spacing and application rate, the sprinkler discharge, q_a , can be determined from Eq. 5.5

$$q_a = \frac{I(S_e S_l)}{3600} = \frac{d_n S_e S_l O_e}{3600 E_{pa} S_{to}} \quad (62)$$

where q_a is in lps; I is in mm/hr; d_n is in mm; S_{to} is the operating time for each set, in hours; and S_l and S_e are in m

- Why is the O_e term included in the above equation? (because E_{pa} includes O_e , as previously defined, and must be cancelled out when considering an individual sprinkler)

II. Number of Operating Sprinklers

- After calculating the system capacity and the design flow rate for sprinklers, the number of sprinklers that will operate at the same time is:

$$N_n = \frac{Q_s}{q_a} \quad (63)$$

where N_n is the minimum number of sprinklers operating, and Q_s and q_a have the same units

- It is recommendable to always operate the same number of sprinklers when the system is running. This practice can help avoid the need for pressure regulation, and can avoid uniformity problems. It can also help avoid wasting energy at the pump.
- For odd-shaped fields, and sometimes for rectangular fields, it is not possible to operate the same number of sprinklers for all sets. In this case, pressure regulation may be necessary, or other steps can be taken (multiple pumps, variable-speed motor, variable application rates).

III. Lateral Design Criteria

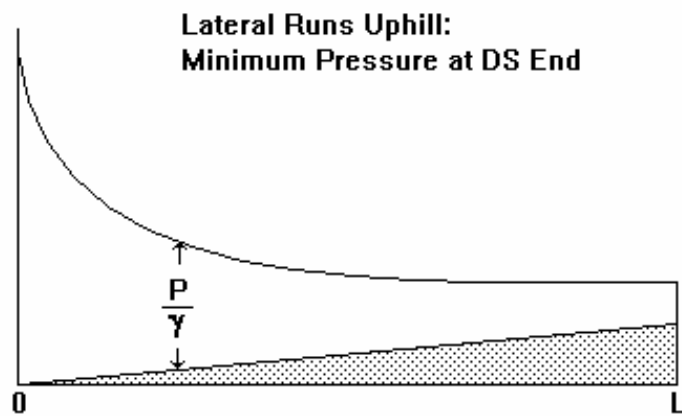
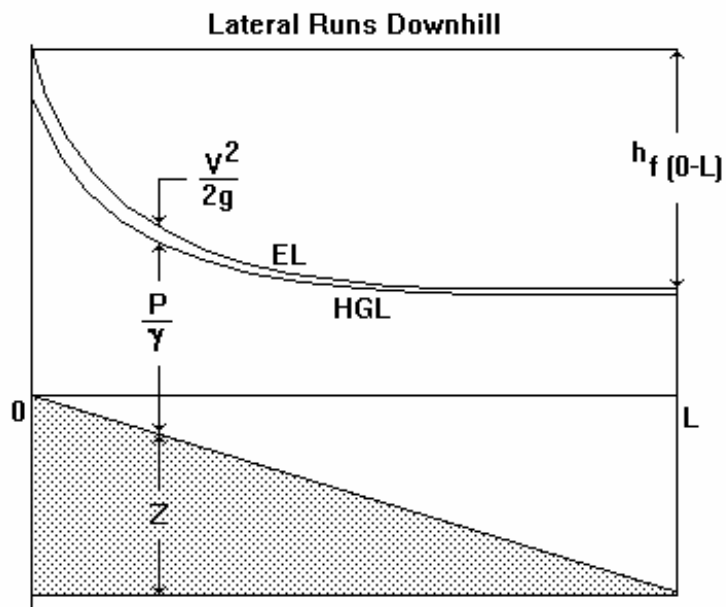
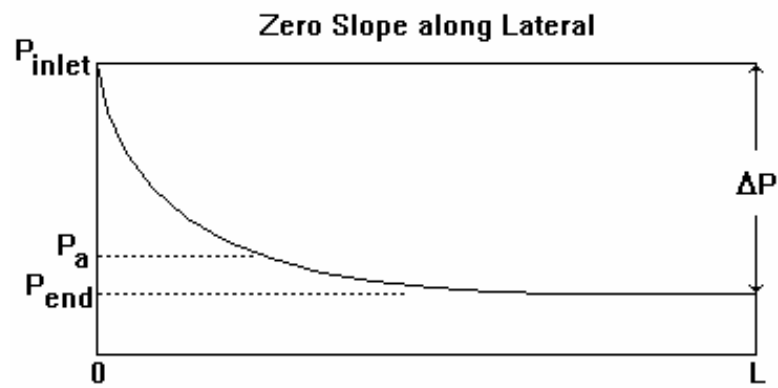
- Lateral pressure varies from inlet to extreme end due to:
 1. friction loss
 2. elevation change
- The fundamental basis upon which sprinkler laterals are designed is:

“pressure head variation in the lateral should not exceed 20% of the average design pressure for the sprinklers”

- This is a design assumption that has been used for many years, and is based on a great deal of experience
- The 20% for pressure variation is not an “exact” value; rather, it is based on judgment and some cost comparisons
- A designer could change this value, but it would affect system performance (uniformity), initial system cost, operating cost, and possibly other factors
- Computer programs could be written to search for an “optimal” percent pressure variation according to initial and operating costs, and according to crop value -- such an “optimal” value would vary from system to system

IV. Sprinkler Lateral Orientation

- It is usually preferable to run laterals on contours (zero slope) so that pressure variation in the lateral pipes is due to friction loss only
- It is advantageous to run laterals downhill, if possible, because the gain in energy due to elevation change will allow longer laterals without violating the 20% rule. But, if the slope is too steep, pressure regulators or flow control nozzles may be desirable.
- If the ground slope is equal to the friction loss gradient, the pressure in the lateral will be constant. However, the friction loss gradient is nonlinear because the flow rate is decreasing with distance along the lateral.



- It is usually not recommendable to run laterals in an uphill direction. In this case:
 1. both friction loss and elevation are working to reduce pressure toward the end of the lateral, and length is more restricted if the 20% rule is still used
 2. However, for small slopes, running laterals uphill may be required to reduce the total length of the mainline pipe
- Note that $V^2/2g$ in the lateral pipe is normally converted into total head as the water flows through the nozzle body. Therefore, the velocity head (and EL) should normally be considered in lateral design. However, since a portion of the velocity head is lost during deceleration of the water at the entrance into risers and as turbulence inside the sprinkler head, and since $V^2/2g$ in a lateral pipe is typically small (< 1 ft of head, or 0.2 psi, or 0.3 m head, or 3 kPa), it is normally neglected during design, and the HGL is used.
- Aside from limits on pressure variation, laterals should be oriented so that they move in the direction of the prevailing winds -- this is because of salinity problems and application uniformity
- Figure 7.1 gives examples of layouts on different topographies

V. Lateral Sizing Limitations

- lateral pipes can be designed with multiple diameters to accommodate desirable pressure distributions, but...
- hand-move laterals should have only one or two different pipe sizes to simplify handling during set changes
- in practice, hand-move systems and wheel lines usually have only one size of lateral pipe
- some wheel lines, greater than 400 m in length, may have 5-inch pipe near the inlet and then 4-inch pipe at the end

Layout of Mainline for Set Sprinklers

I. Mainline Layout and Sizing

- if possible, run the mainline up or down slope so the laterals can be on contours (lateral pressure variation due to friction loss only)
- can also run the mainline along a ridge so the laterals run downhill on both sides (lateral friction loss partially offset by elevation change)
- should consider possible future expansions when sizing the mainline

“Split-Line” Lateral Operation:

- laterals operate on both sides of the mainline
- the mainline can be sized for only half capacity halfway down the mainline if laterals are run in different directions
- sometimes interferes with cultural practices
- it is convenient to have the water supply in the center of one side of the field, but this is seldom a design variable (the well is already there, or the canal is already there)
- may not need pumping if the water supply is at a higher elevation than the field elevation (e.g. 50 psi = 115 ft or 35 m of head) -- when pumping is not required, this changes the mainline layout and pipe sizing strategy
- in some cases it will be justifiable to include one or more booster pumps in the design -- even when the water source is a well (the well pump may not provide enough pressure for any of the lateral settings)
- we will discuss mainline economics in the next few lectures, then we will look at mainline design in more detail later

II. Design Variables to Accommodate Layout

- Number of sprinklers operating
 - Average application rate
 - Gross application depth
 - Average sprinkler discharge
 - Sprinkler spacing
 - Operating hours per day
 - Irrigation frequency
 - Total operating time (fT)
 - System capacity
 - Percent probability of rain during peak-use period
 - MAD
- It may be necessary to adjust the layout if a suitable combination of the above variables cannot be found
 - Can also use flow control nozzles or pressure regulators to accommodate a given layout

III. Sample Calculation

- Consider a periodic-move system with $S_l = 50$ ft, $S_e = 40$ ft, $f = 8$ days, $T = 11.5$ hrs @ 2 sets/day, $d = 2.7$ ", and $q_a = 4.78$ gpm
- The field size is 80 acres ($\frac{1}{2}$ of a "quarter section"), 2,640 ft on one side and 1,320 ft on the other, rectangular
- The laterals will have to be 1,320-ft long

- System capacity:

$$Q_s = \frac{453(80 \text{ ac})(2.7 \text{ inch})}{(8 \text{ days})(2 \text{ sets/day})(11.5 \text{ hrs/set})} = 532 \text{ gpm} \quad (64)$$

- Number of sprinklers operating:

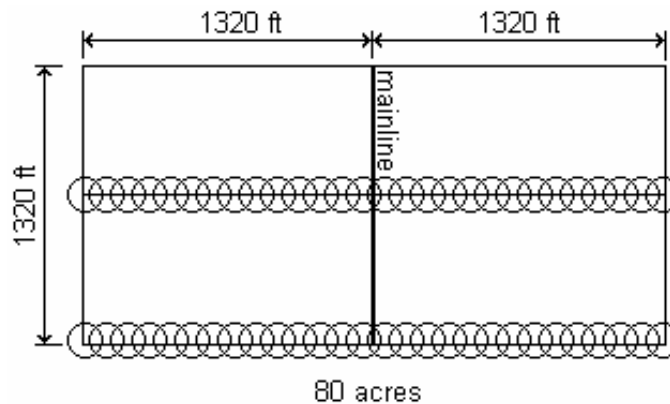
$$N_s = \frac{Q_s}{q_a} = \frac{532}{4.78} = 111 \text{ sprinklers} \quad (65)$$

- Number of laterals,

$$\frac{1320 \text{ ft/lateral}}{40 \text{ ft/sprinkler}} = 33 \text{ sprinklers/lateral} \quad (66)$$

$$\frac{111 \text{ sprinklers}}{33 \text{ sprinklers/lateral}} = 3.36 \text{ laterals} \quad (67)$$

...so, round up to 4 laterals



- Thus, two laterals on each side of the mainline (symmetry)

$$\frac{1320 \text{ ft per lateral pair}}{50 \text{ ft/position}} = 26.4 \quad (68)$$

- Round this up from 26.4 to 27 positions per lateral pair
- This gives $2 \times 27 = 54$ total lateral positions, and $54/4 = 13.5$ sets/lateral
- Use 13 sets for two laterals and 14 sets for the other two laterals
- Then, there will be 14 sets per irrigation, even though the last set will only have two laterals operating

- Adjusted irrigation frequency:

$$f = \frac{14 \text{ sets}}{2 \text{ sets/day}} = 7 \text{ days} \quad (69)$$

- Note that the value of f was for an 8-day interval
- Thus, we need to increase Q_s to complete the irrigation in less time
- Adjusted system capacity:

$$Q_s = (4 \text{ laterals})(33 \text{ sprinklers/lateral})(4.78 \text{ gpm/sprinkler}) \\ = 631 \text{ gpm} \quad (70)$$

- Another way to adjust the system capacity:

$$Q_s = \left(\frac{8 \text{ days}}{7 \text{ days}} \right) (532 \text{ gpm}) = 608 \text{ gpm} \quad (71)$$

- You might say that we are “effectively” finishing in somewhat less than 7 days, because the last set has only two laterals in operation, giving a system capacity of 608 instead of 631
- Consider this calculation: there are $2 \times 13 + 2 \times 14 = 54$ sets, but the last 2 sets have only 2 laterals. So, $(52/54) \times 631 = 608$ gpm, as calculated above.
- Which is correct?
- There are $(52/54) \times (4 \text{ laterals}) = 3.85$ laterals operating *on average* during each irrigation of the field
- However, you cannot always base the system capacity on the average number of laterals operating
- The system capacity should be based on the “worst case”, which is when all four laterals operate simultaneously
- This means that the required capacity is 631 gpm, not 608 gpm
- Note that many farmers will accept some increase in system capital cost to provide more operational flexibility and safety
- In summary, we have essentially lowered f to accommodate the system configuration (layout), but:
 - same gross depth
 - same number of hours per set
 - same sprinkler flow rate
 - same sprinkler spacing
 - increased system capacity

Pipeline Hydraulics

I. Review

- Read Chapter 8 of the textbook to review the hydraulics of pipelines
- For pipe friction loss we will be using the Hazen-Williams and Darcy-Weisbach equations
- Be familiar with the Moody diagram, for use with the Darcy-Weisbach equation
- You can use the Swamee-Jain equation instead of the Moody diagram:

$$f = \frac{0.25}{\left[\log_{10} \left(\frac{\varepsilon}{3.75D} + \frac{5.74}{N_R^{0.9}} \right) \right]^2} \quad (72)$$

which is valid for turbulent flow in the range: $4,000 \leq N_R \leq 1.0(10)^8$. The ratio ε/D is called “relative roughness.” The roughness height, ε , varies widely

- We will also use the Blasius equation (Eq. 8.6) to determine the value of “f,” in some cases, for “smooth pipes”