Lecture 21

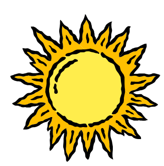
Pipe Specifications & Trickle Lateral Design

I. Plastic Pipe Specifications

- Trickle and sprinkle irrigation systems are commonly built with plastic pipe, of which there are various types and specifications
- It is important to understand how the technical specifications affect design decisions (pipe sizing)
- Standards for the design and operation of pipelines are available from various professional organizations such as ASAE (American Society of Agricultural Engineers) and AWWA (American Water Works Association)
- Some of the material below is taken from ASAE standard S376.1 OCT92
- ASAE standard S435 pertains to the use of PE pipe for microirrigation laterals

- Plastic pipe is now commonly used in irrigation and other pipelines
- Some of the most common types are PVC (polyvinyl chloride), ABS (acrylonitrile-butadiene-styrene), and PE (polyethylene)
- PVC pipes are usually white, while ABS and PE are usually black
- ABS pipes are often used for buried drains and drainage pipes

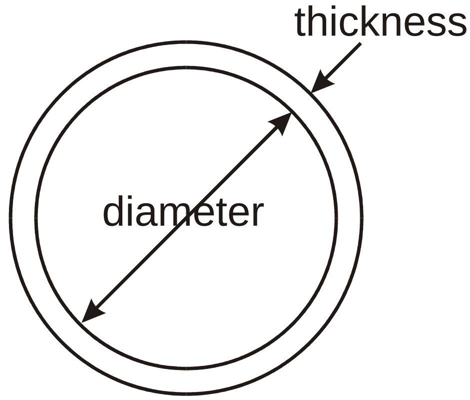
- All of these pipe materials are called “thermoplastic” because the material can be repeatedly softened by increasing the temperature, and hardened by a decrease in temperature
- The pressure rating of plastic pipe (especially PVC) decreases rapidly with increasing temperature of the pipe and or water
- For example, at about 43°C (109°F) the PVC pressure rating drops to one-half of the nominal value at 23°C (73°F), and almost the same amount for PE
- PE pipe temperature can easily reach 43°C on a sunny day



- Unlike most metal pipes, these plastic pipe materials are immune to almost all types of corrosion, whether chemical or electrochemical
- The resistance to corrosion is a significant benefit when chemigation is practiced in a pressurized irrigation system

- The *dimension ratio* (DR) of a plastic pipe is the ratio of average diameter (ID or OD) to wall thickness
- PVC, ABS and some PE are OD-based, while other PE pipe is ID-based

- Plastic pipe is currently manufactured up to a maximum diameter of 54 inches
- There are several *standard dimension ratios* (SDR) for several values, each with its own pressure rating (at 23°C)
- Different types of PVC, ABS and PE compounds exist, some of which are stronger than others
- Some plastic pipe is manufactured with non-standard dimension ratios; in these cases the ratio is called "DR" rather than "SDR"



- Some pipe sizes are correspond to *iron pipe size* (IPS), *plastic irrigation pipe* (PIP), and others
- These are different standards for indirectly specifying pipe dimension ratios and pressure ratings

- The relationship between SDR, hydrostatic design stress (S in psi), and pressure rating (PR in psi) for OD-based pipe is defined by ISO standard 161/1-1978
- The pressure rating (PR), which is the maximum recommended operating pressure, is determined by the following equations:

$$PR = \frac{2S}{SDR - 1} = \frac{2S}{\left(\frac{OD}{t} - 1\right)} \qquad \textit{(OD-based)} \qquad (381)$$

$$PR = \frac{2S}{SDR + 1} = \frac{2S}{\left(\frac{ID}{t} + 1\right)} \qquad \textit{(ID-based)} \qquad (382)$$

where t is the pipe wall thickness

- Values of S can be obtained from published tables, as can values of PR for given SDR and pipe material (plastic compound)
- Values of S vary from 6900 to 13,800 kPa for PVC, and from 3400 to 5500 kPa for PE

- Common terms used in the industry for PVC pipe include *Class 160*, *Class 200*, *Schedule 40*, *Schedule 80* and *Schedule 120* (in increasing strength and decreasing SDR)
- With the "schedule" classification, the higher the schedule, the thicker the walls, for a given nominal pipe diameter

- The maximum allowable operating pressure is approximately equal to:

$$P = \frac{(\text{schedule})SE}{1000} \quad (383)$$

where P is the operating pressure (psi); S is the allowable stress in the pipe material (psi); E is the "joint efficiency"; and "schedule" is the schedule number (e.g. 40, 80, 120, etc.)

- Joint efficiency (or "joint quality factor") for PVC is approximately 1.00, due to the fact that it is seamless

- Class 160 and 200 refer to 160 psi and 200 psi ratings, respectively
- The Schedule 40 and 80 specifications have carried over from classifications used in iron pipes
- Schedule 80 is seldom used in irrigation because its pressure rating is much higher than the maximum pressures found in most irrigation systems
- Schedule 40 is commonly used in irrigation

- Some specifications for the design and protection of pipelines depend on whether the pressure is "low" or "high"
- Low pressure pipelines are generally considered to have operating pressures less than about 80 psi
- The maximum working pressure in a plastic pipe should normally be about 70% of the pipe's pressure rating, unless special care is taken in design and operation such that surges and excessive pressure fluctuations will not occur

- Manufacturers and testing centers provide data on minimum *bursting pressures*
- Depending on the SDR value, the *minimum* burst pressure for plastic pipes should be between about 900 and 1800 kPa (130 and 260 psi), otherwise the pipe does not meet standard specifications
- Below is a glossary of common pipe abbreviations and terms:

Abbreviation	Meaning
ABS	Acrylonitrile-Butadiene-Styrene
DR	Dimension Ratio
ID	Inside Diameter
IPS	Iron Pipe Size
ISO	International Organization for Standardization
OD	Outside Diameter
PE	Polyethylene
PIP	Plastic Irrigation Pipe
PR	Pressure Rating
PVC	Polyvinyl Chloride
SDR	Standard Dimension Ratio

II. Trickle Irrigation Laterals

- Laterals are often above ground, but may be buried
- Drip "tape", single- and dual-chamber laterals are usually buried a few centimeters below the ground surface
- Above-ground laterals may be on the ground surface, or suspended above the surface (e.g. in vineyards)
- Black polyethylene (PE) plastic pipe (or "hose") is usually used for trickle irrigation laterals
- Lateral pipes are typically about 0.5 or 1.0 inches in diameter
- Standard PE sizes are usually ID based and come in *standard dimension ratio* (SDR) values of 15, 11.5, 9, 7 and 5.3
- Nominal PE pipe sizes for laterals are ½-inch, ¾-inch, 1-inch, and 1¼-inch (all *iron pipe size*, or IPS)

- Laterals are usually single-diameter, but can be dual-sized
- Dual-sized lateral hydraulic analysis is essentially the same as previously discussed for dual-sized sprinkler laterals

- To start a new system design, Keller & Bliesner recommend limiting the lateral pressure variation to $0.5\Delta H_s$, where ΔH_s is calculated from Eq. 20.14
- Then, $0.5\Delta H_s$ remains for the manifolds (if manifolds are subunits, or "stations")

- In lateral designs, the pipe diameter is usually chosen (not calculated), and if the pressure variation or loss is "out of range", then a different size can be selected
- There are usually only a few lateral diameters to choose from

III. Trickle Lateral Hydraulics

- Friction loss gradients in plastic lateral pipe can be approximated by combining the Darcy-Weisbach and Blasius equations (Eq. 8.7a):

$$J = 7.83(10)^7 \frac{Q^{1.75}}{D^{4.75}} \qquad (384)$$

for J in m/100 m; Q in lps; and D in mm

- The Blasius equation estimates the D-W "f" factor for smooth pipes
- If you want to calculate relative roughness, use $\varepsilon = 1.5(10)^{-6}$ m

- It may be necessary to increase the J value because of emitter losses *within* the lateral hose (barb, etc.) (see Fig. 20.8)
- Equation 22.1 is:

$$J' = J\left(\frac{S_e + f_e}{S_e}\right) \qquad (385)$$

where f_e is an equivalent length of lateral hose for each emitter, spaced evenly at a distance of S_e

- The f_e pipe length is one way that minor hydraulic losses are calculated in pipes
- From Eq. 8.7a, a dimensionless friction loss equation can be developed (see Fig. 8.2), which is useful in semi-graphical hydraulic design work for trickle irrigation laterals
- This is discussed in detail in the following lectures

- For a given lateral pipe size, lateral length, emitter spacing, and nominal discharge per emitter, the lateral inlet pressure must be determined such that the average lateral pressure is "correct"
- Then, the manifold can be designed to provide this lateral inlet pressure with as little variation (with distance) as possible

- Figure 22.1 shows four different hydraulic cases for single lateral designs
- The design of pairs of laterals is essentially a compound single lateral problem, with the added criterion that the minimum pressure be the same in both laterals

- Not including riser height, the required lateral inlet pressure is (Eq. 22.6):

$$H_l = H_a + k h_f + 0.5 \Delta h_e \qquad (386)$$

where k is 0.75 for single pipe size laterals, or 0.63 for dual pipe size laterals (as in the design of sprinkler laterals); and Δh_e is positive for laterals running uphill

- The minimum pressure in a lateral is given by Eq. 22.7:

$$\begin{aligned} H_n' &= H_l - (h_f + \Delta h_e) - \Delta H_c \\ H_n' &= H_c - \Delta H_c \end{aligned} \tag{387}$$

where H_c is the pressure head at the closed end of the lateral

IV. References (plastic pipe)

http://www.uni-bell.org/lit.cfm
http://www.dpcpipe.com/ag/pipirrig.html
ASAE Standards (1997). American Soc. of Agric. Engineers, St. Joseph, MI.
Handbook of PVC Pipe. (1979). Uni-Bell Plastic Pipe Association, Dallas, TX.

Trickle Manifold Location

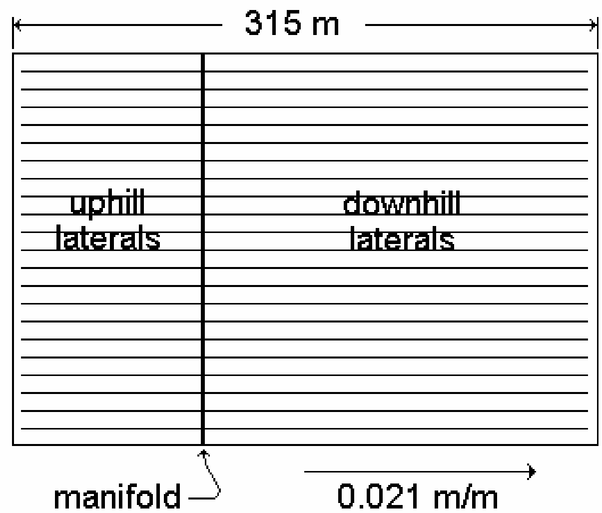
I. Optimal Manifold Location

- If the ground slope along the direction of the laterals is less than 3% or so, it is usually recommendable to run laterals off both sides (uphill and downhill) of each manifold
- If the ground slope along the direction of the laterals is more than 3%, it may be best to run the laterals only in the downhill direction
- The design objective for a pair of laterals is to have equal values of minimum pressure, H_n', in uphill and downhill laterals
- This means that the downhill lateral will always be longer for laterals of equal pipe size on sloping ground
- The manifold should be located in-between rows of plants (trees), not over a row
- For laterals on flat ground, the manifold goes in the center of the field (the *trivial solution*)

II. Sample Graphical Solution for Manifold Location

- Use the dimensionless friction loss curves (Fig. 8.2) to locate the optimal manifold position in a sloping field
- The laterals run along the 0.021 m/m slope
- The combined uphill + downhill lateral length is 315 m

- The spacing of plants (trees) is S_p = 4.5 m
- The spacing of emitters is S_e = 1.5 m (thus, N_p = 3 for single line)
- The equivalent emitter loss is f_e = 0.12 m
- The nominal emitter discharge is q_a = 3.5 lph at 10 m head (68.9 kPa)
- The lateral pipe ID is 14.7 mm



Solution for Manifold Location:

1. Number of emitters for the pair of laterals is:

$$\frac{315 \text{ m}}{1.5 \text{ m/emitter}} = 210 \text{ emitters} \qquad (388)$$

2. Total nominal discharge for the pair of laterals is:

$$Q_{pair} = \frac{(210 \text{ emitters})(3.5 \text{ lph/emitter})}{(60 \text{ min/hr})} = 12.25 \text{ lpm} \qquad (389)$$

3. From Table 8.2 (page 141), J ≅ 13.3 m/100m. The adjusted J is:

$$J' = J\left(\frac{S_e + f_e}{S_e}\right) = 13.3\left(\frac{1.5 + 0.12}{1.5}\right) = 14.4 \text{ m/100 m} \qquad (390)$$

4. Multiple outlet factor, F = 0.36 for 210 outlets

5. Friction loss for the pair of laterals:

$$(h_f)_{pair} = \frac{J'FL}{100} = \frac{(14.4)(0.36)(315)}{100} = 16.3 \text{ m} \qquad (391)$$

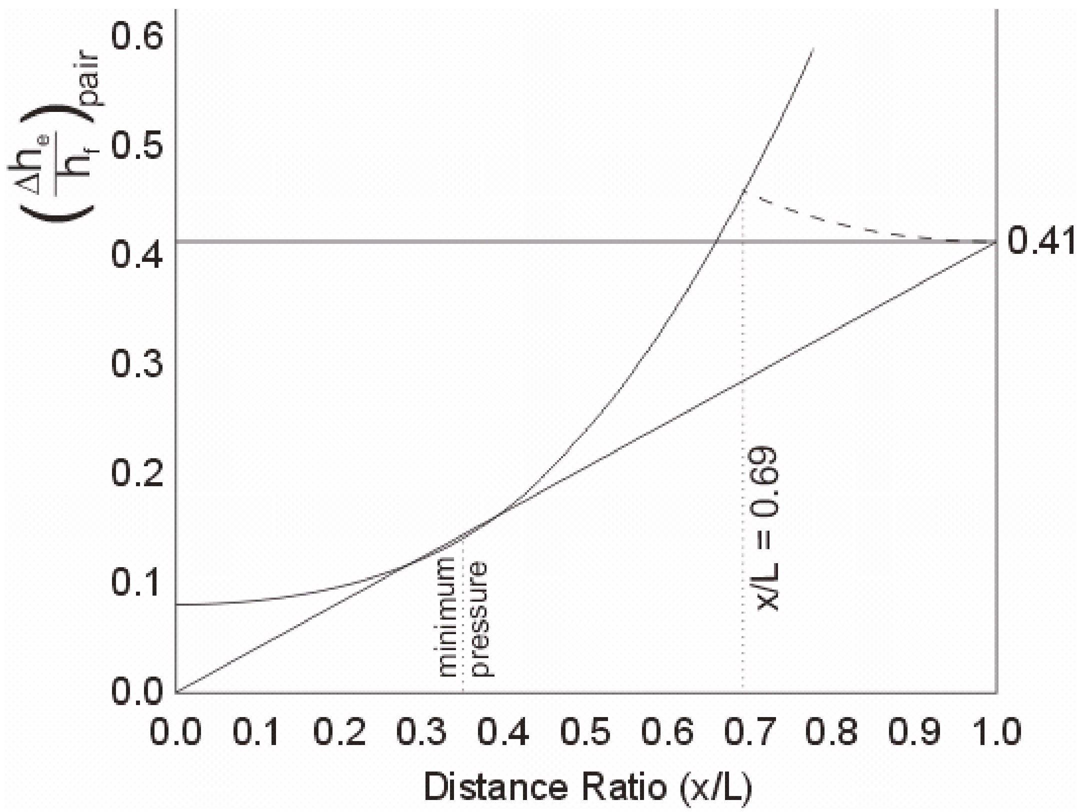
6. Elevation change for the pair of laterals:

$$(\Delta h_e)_{pair} = (315 \text{ m})(0.021) = 6.62 \text{ m} \qquad (392)$$

7. Ratio of elevation change to friction loss for the pair:

$$\left(\frac{\Delta h_e}{h_f}\right)_{pair} = \frac{6.62}{16.3} = 0.41 \quad (393)$$

8. From the nondimensional graphical solution (Fig. 8.2): x/L = 0.69. Then, x = (0.69)(315 m) = 217 m. Look at the figure below:



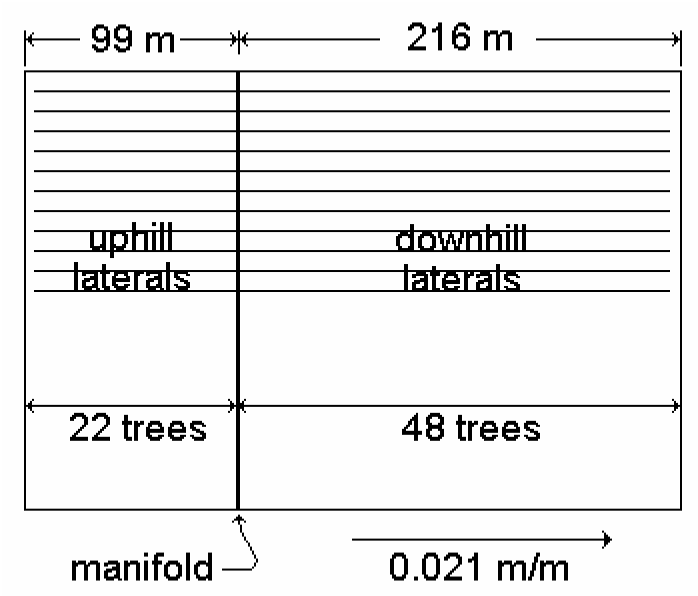
How was this done?

- Looking at the above figure, a straight line was drawn from the origin (0, 0) to (1.0, 0.41), where 0.41 is the ratio calculated above
- The nondimensional curve was overlapped and shifted vertically so that the curve was tangent to the same straight line, then traced onto the graph
- The nondimensional curve was then shifted vertically even more so that the inverse half-curve (dashed) intersected the (1.0, 0.41) point, also tracing it onto the graph
- The intersection of the two traced curve segments gave an abscissa value of about 0.69, which is the distance ratio

9. Finally, adjust x for tree spacing,

$$(217\ \text{m})/(4.5\ \text{m/tree}) = 48.2\ \text{trees}$$

- Therefore, round to 48 trees
- Then, x = (48 trees)(4.5 m/tree) = 216 m
- This way, the manifold lays buried halfway between two rows of trees, not on top of a row



- This manifold position give the same minimum pressure in both the uphill and downhill laterals
- Minimum pressure in the downhill lateral is located approximately (0.35)(315 m) = 110 m from the closed end, or 216 - 110 = 106 m from the manifold.

- This graphical solution could have been obtained numerically
- But the graphical solution is useful because it is *didactic*
- If you like computer programming, you can set up the equations to solve for the lateral hydraulics based on non-uniform emitter discharge (due to pressure variations in the laterals), non-uniform ground slope, etc.

- Note that this procedure could also be used for sprinklers, but it would probably only be feasible for solid-set, fixed systems