

Lecture 24

Hydraulic Design of Mainline & Supply Line

I. Introduction

- Chapter 24 of the textbook contains a good summary and discussion of the design process for trickle irrigation systems
- Keller & Bliesner divide the trickle irrigation design process into three phases:
 1. *Phase 1*: Planning factors, gross application depth, preliminary system capacity, filtration requirements, etc.
 2. *Phase 2*: Hydraulic design of laterals, manifolds, and subunit layout.
 3. *Phase 3*: Hydraulic design of main and supply lines, control head, and pumping plant.

II. Factors Affecting the EU

- Solomon (1985) studied the various factors affecting emission uniformity and ranked them according to importance using model studies and field surveys. This is his ranking:
 1. Plugging of emitters and other system components
 2. Number of emitters per plant, N_p
 3. Emitter coefficient of variation, v
 4. Emitter exponent, x
 5. Emitter discharge variation with temperature
 6. Pressure head variations in subunits
 7. Coefficient of variation on pressure regulators
 8. Friction loss from manifolds to laterals
 9. Number of pipe sizes in manifolds
- In general, plugging (or the lack thereof) has the greatest influence on EU, except in cases where the system design is very poor
- Plugging cannot be prevented by design only -- it is up to the management to continuously maintain the system as necessary
- The above ranking implies that a poorly designed system might perform better (in terms of application uniformity) than a well designed system, provided that the system operation and maintenance is given due attention and effort

III. Mainline, Supply, and Control Head Design

- After designing laterals and manifolds, the mainline, supply line (if necessary), control head, and pump must be designed/selected. This involves calculating the TDH at the pump.
- Maximum system capacity would have already been determined in the preceding design steps, based on the number of subunits, their sizes, emitter discharge and spacing, and number of emitters per plant.
- Subunits should be designed to have nearly the same discharge so that the pump is not wasting energy in lower capacity subunits; but this is not always possible.
- Mainline design is the same as in sprinkle systems, and various pipe selection methods are available (including the economic pipe selection method).
- The control head includes the filters, sand separators, chemical injection equipment, flow rate and or volumetric meters, timers, pressure gauges, and/or other hardware. Most of this equipment is located in the same place in a trickle irrigation system. However, other filters, screens, and gauges may be installed at downstream locations in some cases.
- Sand media and other filters may have a combined head loss of 10-20 psi when “dirty”, and 3-10 psi when clean. However, if too much flow is forced through the filters (i.e. not enough filter capacity) the head loss can be higher, even when clean.
- Flow meters and chemical injection equipment may have 1-5 psi loss, and valves can have up to several psi loss (even when fully open).
- The pressure changes from the control head to the subunits are due to a combination of friction loss and elevation change: if the subunit inlet is at a higher elevation than the control head, both friction and elevation change contribute to a higher required pressure at the control head, otherwise they tend to cancel out (partially or completely).
- Mainline friction losses include minor (local) losses at bends, through valves, and through screens.
- Losses at reductions in pipe diameter (in series) are usually small, unless the reduction is sharp and abrupt. Diameter transitions for PVC are often smooth.
- A “critical” subunit can be defined by calculating the combined friction loss and elevation change to each subunit, and taking the highest value plus the required inlet pressure head to the manifold. The textbook calls this $(H_m + H_{fe})_c$.

- The critical subunit will define the “worst case” for which the pumping unit should be designed. It may then be possible to reduce pipe sizes in other subunits if they will have excess head available.

IV. Trickle System Mainline Design

- Trickle mainlines can be sized using the same approach as is used for sprinkle irrigation systems.
- Manifolds can be considered as stationary sprinkler laterals.
- You can use the EPST approach, where O_t depends (in part) on the number of stations, N_s

Example calculation:

- Size sections A-B, B-C and C-D for a trickle irrigation mainline having three manifolds
- First, decide on the number of stations, N_s

This could be 1, 3 or 6:

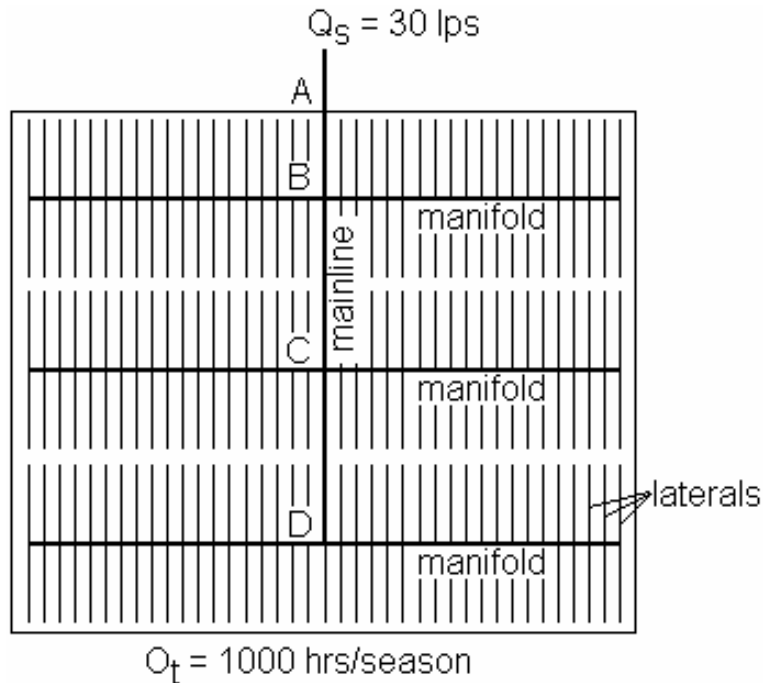
1. All laterals at the same time, or
2. Only laterals on one manifold at a time, or
3. Only laterals on one half of a manifold (on one side of the mainline) at a time

- Set up a table to see the effect of N_s on the flow rates and O_t per station (also see the figure below):

	Number of Stations		
	1	2	3
Q_s (lps)	30	30	30
O_t /station (hrs)	1000	330	165
$O_{t, CD}$	1000	330	330
Q_{CD}	10	30	30
$O_{t, BC}$	1000	660	660
Q_{BC}	20	30	30
$O_{t, AB}$	1000	1000	1000
Q_{AB}	30	30	30

- $O_{t, CD}$, for example, is the number of hours that water is flowing in section CD per season
- This is the O_t that would be used in creating an economic pipe sizing table to determine the pipe size of section CD
- O_t varies with the number of stations and with the location of the mainline segment in the system

- Therefore, the EPST must be developed several times (this is easy in a spreadsheet, as you have seen)



- Notice that the product of Q and O_t is a constant, as this is proportional to the irrigation water requirement, which is the same for each station and location in the field
- Pipe diameters are selected using Q_{AB} , Q_{BC} , and Q_{CD} as the break-even flow rates in the EPST; Q_s remains constant

The TDH is the sum of:

1. static lift
 2. well losses (if applicable)
 3. supply line losses (elevation and friction)
 4. control head pressure losses
 5. losses to the critical subunit plus inlet pressure, $(H_m + H_{fe})_c$
 6. screen and valve losses (if applicable) at subunit inlets
- As in many hydraulic designs for pressurized pipe systems, it is often recommendable to add a “safety factor” to the losses, because losses are not precisely known, and they will probably increase with time
 - A common safety factor is to add 10% to the friction losses for the calculation of TDH

- A separate safety factor can be added, in some cases, to the TDH for compensation for emitter plugging and degradation
- See sample calculations of TDH in Chapter 24

VI. We Live in an Imperfect World

- In many trickle systems, the ground slope changes significantly between subunits, or within subunits
- This complicates the system design and may require more pressure regulation and larger pipe sizes than would otherwise be necessary
- In many locations and countries the available pipes, fittings, emitters, filters, and other hardware are very limited
- Therefore, innovation, resourcefulness, and improvisation may be very important
- If hardware is very limited, it may be best to consider another type of irrigation system
- The system capacity for a micro-irrigation system can have a safety factor added on to account for the possibility of:
 1. slow, partial clogging of emitters and laterals
 2. changes in crop type
 3. inaccurate estimations of peak crop ET
 4. more system “down time” than originally anticipated
 5. various other factors
- It is desirable to minimize the hardware cost of an irrigation system, but the cost of having an insufficient system capacity may be many times higher than the marginal cost of larger pipes, filters and valves
- When in doubt, it may be a good idea to increase the calculated system capacity by 10 or 20%
- See Chapter 25 of the textbook for a thoughtful discussion of factors in selecting a sprinkler or trickle system, or for selecting another type of irrigation system

