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

Assignment #8 (100 pts)
Trickle System Design Calculations
Due: 01 Dec 04

Do you work in an organized, neat way. Write down any assumptions you make.

Given:

- A mature walnut orchard will be drip-irrigated.
- Use a single lateral per row of trees.
- Irrigated area is 44 ha.
- Tree spacing is 6.2 x 6.2 m.
- Peak daily ET is U_d = 4.9 mm/day.
- Seasonal water requirement: U = 541 mm.
- Effective rain, peak-use period: assume zero.
- Residual soil water in the spring: assume zero.
- Use an MAD of 25%.
- Soil water holding capacity is 178 mm/m.
- Water source: deep well with maximum discharge of 125 lps.
- Irrigation water quality: EC_w = 0.61 dS/m.
- Root zone depth is 2.0 m.
- Shaded area is 75%.
- Emitter equation:

$$q = 0.32P^{0.53}$$

for q in lph; and P in kPa.

- Nominal emitter flow rate: q_a = 4 lph.
- Manufacturer coefficient of variation: 0.062.
- Average wetted width at 4 lph: w = 2.33 m.
- Outlets per emitter: one.

Required:

1. Use metric units in your calculations.
2. Select an appropriate emitter spacing, S_e (m).
3. Determine the number of emitters per tree, N_p.
4. Calculate percent wetted area, P_w. Use the equation from Lecture 18 (includes P_d in the denominator). Make sure P_w is between 33% and 67%; if not, increase N_p as necessary.
5. Calculate maximum net depth to apply per irrigation, d_x (mm).
6. Calculate the average peak daily "transpiration" rate, T_d (mm/day).
7. Calculate the maximum irrigation interval, f_x. If $f_x \geq 1$ day, then use f' = 1day.
8. Calculate the net depth per irrigation, d_n (mm).
9. Select a reasonable target EU value (Table 20.3).
10. Determine $(EC_e)_{max}$ (Table 19.2).
11. Determine the transmission ratio, T_r (Table 19.3).
12. Calculate the leaching requirement, LR_t.
13. Calculate the gross depth to apply per irrigation, d (mm).
14. Calculate the gross volume of water per tree per day, G (liter/tree/day).
15. Calculate h_a, corresponding to q_a = 4 lph, in m of water head (not kPa).
16. Calculate the water application time, T_a (hrs).
17. If T_a > 21.6 hrs/day, recalculate q_a such that T_a = 21.6 hrs/day, then calculate h_a corresponding to the new q_a value.
18. Determine the number of stations, N_s.
19. Determine the minimum number of emitters per tree, N_p'.
20. Calculate the system coefficient of variation, ν_s.
21. Calculate the minimum allowable emitter flow rate, q_n (lph).
22. Calculate the allowable subunit pressure head variation, ΔH_s (m).
23. Calculate the system capacity, Q_s (lps). Is this less than or equal to the well capacity of 125 lps?
24. Calculate the total gross seasonal depth to apply, D_g (mm).
25. Calculate the gross seasonal volume of irrigation water, V_s (m^3).
26. Calculate the required number of operating hours per season, O_t (hrs/season). Make sure it is not more than 8,760 hrs!

Required:

I. Emitter spacing

Use the "optimal" spacing: S_e = 0.8w = 0.8(2.33) = 1.86 m

II. Emitters per tree

$$N_p = \frac{S_p}{S_e} = \frac{6.2}{1.86} = 3.33$$

III. Percent wetted area

$$P_w = 100\left(\frac{N_p S_e w}{S_p S_r P_d}\right) = 100\left(\frac{(3.33)(1.86)(2.33)}{(6.2)(6.2)(0.75)}\right) = 50.1\%$$

IV. Maximum net application depth

$$d_x = \frac{MAD}{100}\frac{P_w}{100}W_a Z = (0.25)(0.501)(178)(2.0) = 44.6 \text{ mm}$$

V. Average peak daily transpiration rate

$$T_d = 0.1U_d\sqrt{P_d} = 0.1(4.9)\sqrt{75} = 4.24 \text{ mm/day}$$

VI. Maximum irrigation interval

$$f_x = \frac{d_x}{T_d} = \frac{44.6}{4.24} = 10.5 \text{ days}$$

Then, use f' = 1 day (for design purposes).

VII. Net depth per irrigation

$$d_n = T_d f' = (4.24)(1) = 4.24 \text{ mm/day}$$

VIII. Target EU

Table 20.3: "point-source" water applicators with N_p > 3 gives recommended EU range of 90 to 95%. In this design iteration, choose EU = 92%.

IX. Maximum EC_e

From Table 19.2, for a walnut crop, $(EC_e)_{max}$ = 8 dS/m.

X. Transmission ratio

From Table 19.3, for a “deep-rooted” (Z > 1.5 m) crop and a “medium-textured” (see Wa above) soil: T_r = 1.00.

XI. Leaching requirement

$$LR_t = \frac{EC_w}{2\left(EC_e\right)_{max}} = \frac{0.61}{2(8)} = 0.038$$

XII. Gross application depth

For $LR_t < 0.1$, the following equation is applied:

$$d = 100\left(\frac{d_n T_r}{EU}\right) = 100\left(\frac{(4.24)(1.00)}{92\%}\right) = 4.61\ \text{mm/day}$$

XIII. Gross volume of water per tree

$$G = \frac{d}{f'} S_p S_r = \frac{4.61}{1}(6.2)(6.2) = 177\ \text{liter/day/tree}$$

XIV. Nominal emitter pressure head

Apply the given emitter equation, and use 9.81 kPa/m:

$$h_a = \left(\frac{1}{9.81}\right)\left(\frac{4}{0.32}\right)^{1/0.53} = 12.0\ \text{m}$$

XV. Water application time per irrigation

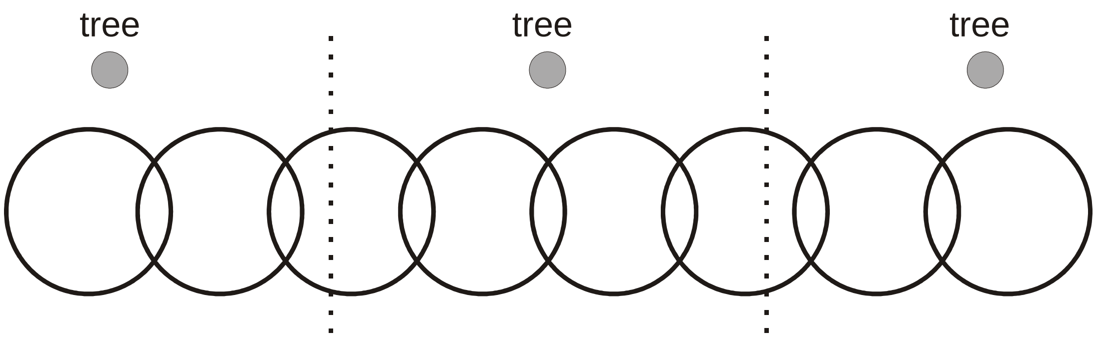
$$T_a = \frac{G}{N_p q_a} = \frac{177}{(3.33)(4)} = 13.3\ \text{hrs/day}$$

XVI. Number of stations

Two stations would require 2(13.3) = 26.6 hrs/day. Thus, there can be only one station (N_s = 1) in this design.

XVII. Minimum number of emitters per tree

See the figure below, showing a tree spacing of 6.2 m, and emitter spacing of 1.86 m, and a wetted width of 2.33 m:



It is seen that, on average, four emitters contribute some irrigation water to each tree. Alternatively,

$$N'_p = \text{trunc}\left(\frac{5\text{ m/tree}}{1.86\text{ m/emitter}} + 2\right) = 4$$

where “trunc” means to truncate (round down) to the nearest whole number.

XVIII. System coefficient of variation

$$\nu_s = \frac{\nu}{\sqrt{N'_p}} = \frac{0.062}{\sqrt{4}} = 0.031$$

XIX. Minimum allowable emitter flow

$$q_n = \frac{q_a EU}{100\left(1 - 1.27\nu_s\right)} = \frac{(4)(92)}{100\left(1 - 1.27(0.031)\right)} = 3.83\text{ lph}$$

which corresponds to a head of:

$$h_n = \left(\frac{1}{9.81}\right)\left(\frac{3.83}{0.32}\right)^{1/0.53} = 11.0\text{ m}$$

XX. Allowable subunit head variation

$$\Delta H_s = 2.5\left(h_a - h_n\right) = 2.5\left(12.0 - 11.0\right) = 2.5 \text{ m}$$

XXI. System capacity

$$Q_s = 2.78\frac{A N_p q_a}{N_s S_p S_r} = 2.78\frac{(44)(3.33)(4)}{(1)(6.2)(6.2)} = 42.4 \text{ lps}$$

which is less than the well capacity of 125 lps. Thus, the well has sufficient flow rate to accommodate this design.

XXII. Gross season water application depth

Assume a T_R value of 1.00 (Table 19.4). Then, E_s = EU = 92%. Effective rain and residual soil moisture are given to be zero. Thus,

$$D_n = U\left(0.1\sqrt{P_d}\right) = 541\left(0.1\sqrt{75}\right) = 469 \text{ mm}$$

Then, gross seasonal depth is:

$$D_g = \frac{100 D_n}{E_s\left(1 - LR_t\right)} = \frac{100(469)}{92(1 - 0.038)} = 530 \text{ mm}$$

XXIII. Gross season application volume

$$V_s = \frac{D_g A}{1000} = \frac{(530)(44)}{1000} = 23.3 \text{ ha-m}$$

XXIV. Operating hours per season

$$O_t = 2778\frac{V_s}{Q_s} = 2778\left(\frac{23.3}{42.4}\right) \approx 1{,}530 \text{ hrs/season}$$