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

Assignment #1 (100 pts)
Due: 15 Sep 04

Given:

Data for a field in Cache Valley, Utah:

Crop=	Sweet corn
Topsoil=	Sandy loam
Topsoil depth (m)=	0.5
Subsoil=	Silt Loam
Subsoil depth (m)=	1.4
Field area (ha)=	25
MAD (%)=	35
Irrigation water salinity, EC_w (dS/m)=	1.02
Application efficiency=	88%
Soil intake rate (mm/hr)=	14
Time to change sets (hrs)=	0.5
Lateral length (m)=	180
Lateral spacing, S_l (m)=	12

Weather data:

1. Go to http://climate.usu.edu/
2. Click on "Utah Climate Center Data (Use Microsoft Explorer)"
3. Look at the instructions for selecting a region
4. Select a region which includes Utah
5. Click on the "Update Station List" button
6. At the upper left you see a list of stations
7. Click on the list and type "L"
8. Scroll down further to "logan usu exp stn"
9. Under "Element," select "Maximum Air Temperature"
10. Check the "Full period of record" box
11. Click on the "Export Data" button at the top
12. Click on the "Update Output" button at the lower left
13. Type "Ctrl-A" to select all, then "Ctrl-C" to copy
14. Paste it into Notepad or Word
15. Clean up the data and import to Excel
16. Go back and select “Minimum Air Temperature" and get that data
17. Go back and select “Total Precipitation" and get that data, too

Note that values with “-99999,M” are missing.

Required:

- Perform calculations to answer all of the questions as shown in the table format on the next page
- Show your steps in logical order, and write down your assumptions (if any) in determining the respective values
- Do you work neatly

Notes:

1. Many years of weather data for Logan, Utah (Experiment Station site), are given on the web site.
2. Determine the mean monthly values (Jan – Dec) of maximum daily air temperature for the entire period of record (about 34 years). To do this in Excel, you may want to use functions like COUNTIF and SUMIF.
3. Plot the mean monthly values of maximum air temperature and determine which month is the warmest; this month will be used below as the peak-use (peak ET) month.
4. Use the precipitation data to calculate the 75% rainfall probability value for the peak-use month to determine the net crop ET requirement during that month. This means you need to calculate the total rainfall (inches) for the peak-use month for the 34 years of record. You can consider that the 75% rainfall value is all "effective" rainfall for that particular month.
5. You may notice some problems with the data sets from the Utah Climate Center web site. Document these problems and describe how you have dealt with them.
6. Assume that there will be only six days of irrigation per week (one day off), even during the peak-use period.
7. Obtain needed soil, root depth, EC and ET information from tables in the text (Chapter 3), or from another source (if so, name that source). Use average values where max-min ranges are given in the tables.
8. Use Eq. 3.1 to calculate the maximum net application depth per irrigation.
9. Use Eq. 3.2 to calculate the maximum irrigation interval, then to calculate the net application depth.
10. Use Eq. 3.3 to calculate the leaching requirement.
11. Use Eqs. 5.3a and 5.3b to determine the gross application depth.
12. Use Eq. 5.4 to calculate system flow capacity.

Table Format for BIE 5110/6110 Assignment #1 (Fall 2004)

Given Values:

Crop: ....
Topsoil depth (m):..
Subsoil depth (m): ....
Location ....
Field area (ha): ....
MAD (%): ....
Irrigation water salinity, EC_w (dS/m):........................
Application efficiency (%): ....
Soil intake rate (mm/hr) ....
Time to change sets (hrs): ....
Lateral length (m) ....
Lateral spacing (m)..

Obtained from Tables and Weather Data:

Average W_a of topsoil (mm/m): ....
Average W_a of subsoil (mm/m): ....
Average root depth, Z (m): ....
Seasonal effective rainfall at 75% prob. (mm): ....
Peak ET (mm/day): ....
Seasonal ET (mm): ....
Salinity of soil extract, EC_e (dS/m): ....

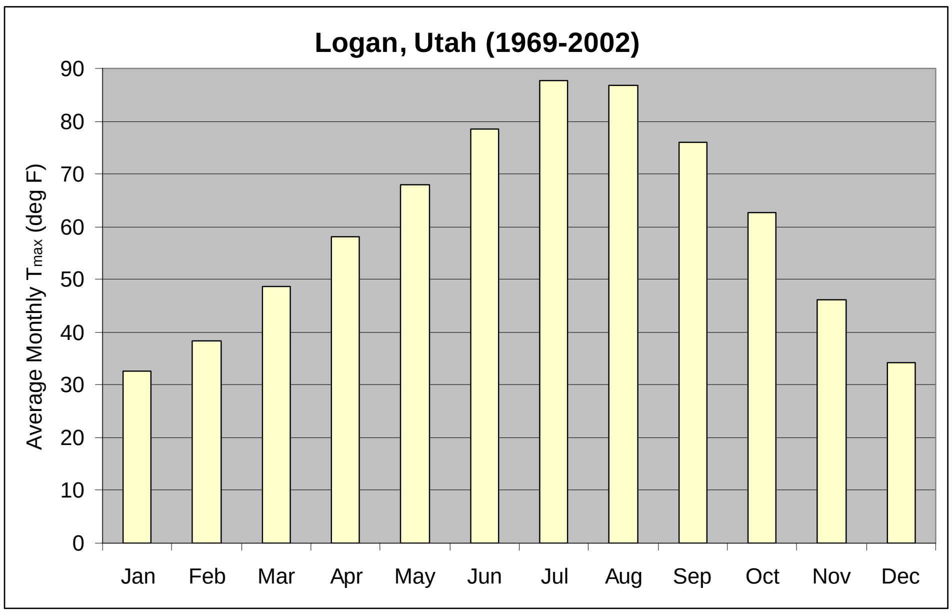
Calculated Values:

Average W_a of root zone (mm/m): ....
Maximum net depth per irrigation (mm): ....
Maximum irrigation interval (days):..........................
Nominal irrigation interval (days): ....
Net depth per irrigation (mm): ....
Days off in each irrigation:..
Operating time per irrigation (days): ....
Leaching requirement: ....
Gross application depth per irrigation (mm): ....
Minimum set operating time (hrs) ....
Nominal set operating time (hrs).............................
Number of sets per day:...
Area per 200-m lateral per irrigation (ha): ....
Number of 200-m laterals required:.........................
Approximate number of irrigations per year: ....
System flow capacity (lps):.......................................

Solution:

To determine the mean monthly values of maximum daily air temperature, the SUMIF function was used in Excel to key on the column with the month names for the 34 years of record. The COUNTIF function was used in the same way, for each month, to determine the number of records in each month. Finally, for each month, the sum of temperature values was divided by the corresponding record count to arrive at an average monthly value:

Month	Count	Sum	Avg Temp
Jan	32	1,041	32.5
Feb	32	1,228	38.4
Mar	33	1,605	48.6
Apr	33	1,914	58.0
May	32	2,173	67.9
Jun	33	2,588	78.4
Jul	33	2,892	87.6
Aug	34	2,954	86.9
Sep	31	2,358	76.1
Oct	32	2,006	62.7
Nov	32	1,480	46.2
Dec	32	1,096	34.3



It is seen that the month of <u>July has the highest maximum monthly temperature</u> for the 34 years of record, and is closely followed by August. This will be the month for which peak ET will occur in Logan, Utah.

To determine the rainfall probability for the month of July, the total daily rainfall values for that month were summed up for each year of record. Following are the tabulated results:

Year	July Rain (inch)	Year	July Rain (inch)
1969	0.34	1986	1.79
1970	0.67	1987	1.65
1971	0.08	1988	0.00
1972	0.21	1989	0.11
1973	0.98	1990	0.31
1974	0.11	1991	0.16
1975	1.46	1992	0.99
1976	0.83	1993	3.21
1977	0.87	1994	0.02
1978	0.11	1995	0.72
1979	0.58	1996	1.44
1980	1.18	1997	2.30
1981	0.49	1998	0.12
1982	1.40	1999	0.57
1983	1.52	2000	0.07
1984	1.59	2001	*missing*
1985	1.50	2002	0.38

Rain (inch)			Relative		
From	To	Frequency	Frequency	Up	Down
0.00	0.25	10	0.303	1.000	0.303
0.26	0.50	4	0.121	0.697	0.424
0.51	0.75	4	0.121	0.576	0.545
0.76	1.00	4	0.121	0.455	0.667
1.01	1.25	1	0.030	0.333	0.697
1.26	1.50	4	0.121	0.303	0.818
1.51	1.75	3	0.091	0.182	0.909
1.76	2.00	1	0.030	0.091	0.939
2.01	2.25	0	0.000	0.061	0.939
2.26	2.50	1	0.030	0.061	0.970
2.51	2.75	0	0.000	0.030	0.970
2.76	3.00	0	0.000	0.030	0.970
3.01	3.25	1	0.030	0.030	1.000
	Totals:	**33**	**1.000**		

As seen in the table above, based on the 34 years of record, there is a 69.7% probability that the total July rainfall in Logan, Utah, will be 0.26 inches or more (column "Up"). There are really not enough data points to determine the 75% level of confidence, so use 0.26 inches of rain in July (the peak ET month) with an approximately 70% level of exceedance. This is equivalent to 6.6 mm.

Given Values:

Crop: .... Sweet corn
Topsoil depth (m):.. 0.5 m
Subsoil depth (m): .... 1.4 m
Location .... Logan, Utah
Field area (ha): .... 25 ha
MAD (%): 35%
Irrigation water salinity, EC_w (dS/m):........................ 1.02 dS/m
Application efficiency (%): 88%
Soil intake rate (mm/hr) .... 14 mm/hr
Time to change sets (hrs): .... 0.5 hrs
Lateral length (m) .... 180 m
Lateral spacing (m).. 12 m

Obtained from Tables and Weather Data:

Average W_a of topsoil (mm/m):............................... 125 mm/m (Table 3.1, average for sandy loam)
Average W_a of subsoil (mm/m): .... 167 mm/m (Table 3.1, average for silt loam)
Average root depth, Z (m):....................................... 0.5 m (Table 3.2, average for sweet corn)
Seasonal effective rainfall at 70% prob. (mm): .... 6.6 mm (for month of July only, not season)
Peak ET (mm/day): .... 6.4 mm/day (Table 3.3, corn in “moderate” climate)
Seasonal ET (mm): .... 559 mm (Table 3.3, corn in “moderate” climate)
Salinity of soil extract, EC_e (dS/m):.......................... 2.5 dS/m (Table 3.5, sweet corn)

Calculated Values:

Note: most of the following is specifically for the peak-use period and does not dictate what the irrigation scheduling might be throughout the growing season. These are calculations leading to system design.

Average W_a of root zone (mm/m):

The topsoil depth is given as 0.5 m, and we have 0.5 m for the average effective root depth of sweet corn, so the subsoil W_a is not considered herein.

Use W_a = 125 mm/m

Maximum net depth per irrigation (mm):

$$d_x = \frac{MAD}{100} W_a Z = \left(\frac{35}{100}\right)(125)(0.5) = 21.9 \text{ mm}$$

Maximum irrigation interval (days):

For July, we have determined that there is a 70% probability of a monthly total of 0.26 inches (6.6 mm), or more, of rain. This comes to an average of 6.6/31 = 0.21 mm/day, which is very little rain. This fact, together with the realization that the rain might not fall during the peak-use period, may lead us to conclude the safer choice is to assume zero effective rainfall during the peak-use period.

$$f_x = \frac{d_x}{U_d} = \frac{21.9 \text{ mm}}{6.4 \text{ mm/day}} = 3.42 \text{ days}$$

Nominal irrigation interval (days):

$$f' = \text{trunc}(f_x) = 3 \text{ days}$$

Net depth per irrigation (mm):

$$d_n = f'U_d = (3 \text{ days})(6.4 \text{ mm/day}) = 19.2 \text{ mm}$$

Days off & operating time per irrigation:

The specification in this case is for one day off per week, but with f' = 3 days, we can assume that the one day off will not fall within the three-day interval during the peak-use period, which might involve only two or three irrigations. Thus, let f = f' = 3 days.

Leaching requirement:

$$LR = \frac{EC_w}{5EC_e - EC_w} = \frac{1.02}{5(2.5) - 1.02} = 0.075$$

LR < 0.1; therefore, use Eq. 5.3a...

Gross application depth per irrigation (mm):

$$d = \frac{d_n}{(E_a/100)} = \frac{19.2}{0.88} = 21.8 \text{ mm}$$

Minimum set operating time (hrs):

With 21.8 mm to apply and a soil intake rate of 14 mm/hr, this gives 1.56 hrs <u>minimum set time</u> (so as not to exceed the soil intake rate).

Nominal set operating time (hrs)

Make the nominal set time equal to <u>2.0 hours</u> for convenience. With 0.5 hrs to move each set, there are a total of <u>2.5 hrs/set</u>.

Number of sets per day:

With 24 hrs per day, there can be 24/2.5 = 9.6 sets/day. Round this down to a whole number: <u>8 sets per day</u>, giving a total daily operations time of 8(2.5) = 20 hrs.

Area per 200-m lateral per irrigation (ha):

(3 days/irrigation)(8 sets/day) = <u>24 sets/irrigation</u>

Lateral spacing on mainline is S_l = 12 m. Lateral length is 180 m. The area per lateral is:

(12 m/set)(24 sets)(180 m/lateral) = <u>5.18 ha/lateral</u>

Number of 180-m laterals required:

$$\frac{25\text{ ha}}{5.18\text{ ha/lateral}} = 4.83\text{ laterals}$$

Round up to a whole number to obtain 5 laterals for the system. Alternatively, round up to 6 laterals if laterals will operate on both sides of the mainline, thereby balancing the number of laterals on each side.

Approximate number of irrigations per year:

Assuming zero effective rainfall during the growing season:

$$\frac{U - P_e}{d_n} = \frac{559\text{ mm - 0 mm}}{19.2\text{ mm/irrig}} = 29.1\text{ irrigations}$$

We could do a seasonal analysis of the probability of rainfall exceedance, but we can already surmise that most of the rain will fall during times other than the peak-use period. So, to be conservative in our design, we assume no seasonal effective rainfall. On the other hand, it is very unlikely that a farmer in Logan, Utah would irrigate a corn field 29 times in a season, which could indicate a nonzero contribution from rain and or the possibility that the effective root depth for sweet corn is somewhat more than 0.5 m. Also, there may be a significant residual water content (from snowmelt and rain) in the soil at the beginning of the growing season.

System flow capacity (lps):

At 8 sets/day and 2.0 hours set time, there are 16 hours of system operation per day:

$$Q_s = 2.78\frac{Ad}{fT} = 2.78\frac{(25\text{ ha})(21.8\text{ mm})}{(3\text{ days})(16\text{ hrs/day})} = 31.6\text{ lps}$$

This gives a capacity of 31.6/25 = 1.26 lps per ha, which is a reasonable value.