652.0408 State supplement

This section contains examples and procedures using materials from this chapter along with other State approved material.

(a) Leaching Requirements

Usually, it is not the salt in irrigation water that affects crop yields; it is the accumulated salt in the soil. The salt content of irrigated soils is often several times that of the irrigation water. This occurs because water is used by the plants or evaporates from the irrigated soil leaving the salts behind to accumulate. This concentration of salts in the root zone can be measured in similar terms as salinity in irrigation water, by electrical conductivity expressed in millimhos per centimeter (mmhos/cm).

The most effective method of removing these sal5s is by leaching, which is the process of passing additional water through the soil to transport the salts below the root zone.

The leaching requirement is defined as the required percentage of applied irrigation water which must percolate through the soil beyond the root zone in order to prevent a salt build-up with in the root zone. This percentage of applied water depends upon both the salinity of the irrigation water and the salt concentration in the root zone which a given crop can tolerate. The leaching requirement to maintain a given salt concentrating in the root zone with an irrigation water of a given salinity can be determined by following table. This table gives the percent of applied water that must percolate below the root zone.

LEACHING REQUIREMENTS

Based on formula (ECw)/(5ECe-ECw)

Irrigation water ECw MMOHS	Alfalfa Leaching Requirement (%)	Barley Leaching Requirement (%)	Corn Leaching Requirement (%)	Sorghum Leaching Requirement (%)	Wheat Leaching Requirement (%)	Potatoes Leaching Requirement (%)
.5	1.5	1	3.5	2	2	4
1.0	3	2	7	4	3.5	9
1.5	4.5	3.5	11	6	5	14
2.0	6	5	15	9	7	19
2.5	8	6	20	11	9	25
3.0	9	7	25	14	11	
3.5	11	8		16	13	
4.0	13	10		19	15	
4.5	15	11		22	18	
5.0	17	13		25	20	
Tolerable Level of Salts (EC)*	5 MMHOS	9 MMHOS	3 MMHOS	5 MMHOS	6 MMHOS	2.5 MMHOS

These leaching requirements will change if there is any previous accumulations or deposition of salts or if the soil is gypsiferous saline-alkali soil.

*At a 10% reduction in yield

Example

When irrigating corn with irrigation water containing 2.5 mmhos/cm conductivity, the table indicates that 20 percent of the applied irrigation water must be percolated below the root zone to maintain the salt concentration in the soil of less than 3 mmhos/cm conductivity. To demonstrate how the leaching requirement might affect irrigation. If 30 inches of net irrigation are required and the 20 percent leaching is required. Then the leaching requirement would be :

30/(1.00 – 0.20) = 37.5 inches.

This would result in and irrigation efficiency of 80%. Most sprinkler irrigation designs have a design efficiency of 70%, thus leaching is accomplished in this example with out additional irrigation water being needed.

With out leaching, salt concentration in the root zone would build.

(b) Wetland/water body Kc (crop coefficient)

Evaporation from the open water areas of a wetland can be much different from that of the vegetated area and should be calculated separately. This is especially true in a temperate climate. In a temperate climate there may be portions of the fall, winter, and spring where the vegetation is dead and therefore becomes a "protective" mulch above the wet soil or water and thereby reduces the Kc dramatically. Researchers have measured a Kc of less than 0.2 for dead cattail vegetation in northern Utah. During the summer, the tall, lush cattail or bulrush vegetation can approach a Kc of even 1.4 in an arid climate based on grass reference due to the tall roughness and general "Oasis" effect of transport of sensible heat and dry air from outside of the wetland.

It is correct in presuming that the "Kc end" (end season) value can be used until the "greenup" of the following year. However, in a freezing climate, the Kc can go even lower than a typical Kc end (not a problem in California). The value of the Kc during non-growing season will of course change with precipitation frequency and is best estimated using a daily calculation time step and a Kc procedure that separately includes the evaporation of water from the soil and vegetation surface (interception).

Evaporation from water can be very different and is a strong function of the water depth, the turbidity, and variation in temperature during the year. Shallow (say less than 1 m) or turbid water will intercept solar radiation near the water surface and therefore will facilitate the conversion of radiation to evaporation at the surface in near real time (but will be impacted by night-time evaporation and carry over of heat from hot to cool days). In deep water, however, the radiation from the sun is transmitted deeply into the water and is converted directly into heat which can only be transported to the water surface to supply evaporation by convection within the water body (and a little conduction). This can be an extremely slow process for deep, cold water bodies such as in the Rocky Mountain area of the USA. A simple calculation using specific heat of water times the depth of water will indicate the tremendous storage capacity for heat in deep lakes. Researchers have measured "Kc's" for evaporation from Bear Lake, Utah of less than 0.40 in the summer months due to the heat storage effect. Bear Lake is quite deep, extremely clear, and has a cold winter.

Much of the stored heat in Bear Lake returns to the surface in the fall months as the lake cools. During this later period, the vapor pressure deficit of the air is less, so that less of the energy is converted into evaporation as it would be during summer, and more is used to warm the cooler air. Therefore over the course of a year, a smaller ratio of total solar radiation is converted to evaporation for a clear, deep lake as opposed to a shallow or turbid lake, and therefore the Kc is lower than for a shallow lake.

The FAO 56, a revision of the FAO 24 publication on Crop Evapotranspiration, suggests two different Kc's. The first one is for shallow water bodies (and "usually" water bodies near wetlands are shallow, fortunately, otherwise there would be no emergent vegetation). The other set of Kc's is for deep lakes. For open water less than 2m deep, or for all water bodies in tropical climates having little change in water temperature, FAO 56 suggests using a Kc of 1.05 for all months. This coefficient is based on the grass reference. For deep-water bodies (say greater than 2m deep) in temperate climates with winters, the FAO 56 suggests using a Kc = 1.25 for the fall and winter and .65 for spring and summer. Of course, these average values will vary, as discussed above, with actual depth, turbidity, and variation in climate during the year.

The Kc for wetland varies substantially with the "clothesline" effect caused by occurrences of limited stands of wetland vegetation that are surrounded by vegetation or other cover that is evaporating at a lower rate. This is common for wetland vegetation that occurs along roadways or canals. In this instance the Kc can go as high as 1.8.

The FAO 56 publication suggests an average Kc during midseason of 1.2 for large areas (greater than 2 acres) for cattails and bulrushes in subhumid climates. For semi-arid and arid climates the mid season Kc increases to 1.3 to 1.4. For an average Kc at the beginning and end of the growing season 0.3 is suggested for cattails and bulrushes in a killing frost climate, and 0.6 without a killing frost. An average Kc for wetlands having short vegetation is 1.05 to 1.10.

Conversion between alfalfa and pasture reference crop coefficients (Kc's).

The revised FAO 56 suggests that the ratio of alfalfa reference to grass reference (ETr/ETo) varies from about 1.05 for humid, calm conditions to 1.2 for semi-arid, moderately windy conditions, and to 1.35 for arid, windy conditions. The first condition is dominated by net radiation, which is similar between the references. The latter two values are influenced more by the differences in aerodynamic roughness and bulk surface resistance.

An equation for predicting the conversion between the two references that is in the revision is the following:

ETo/ETr = 1.2 + [0.04 (u2-2) -0.004 (RHmin-45)] (h/3) ^0.3

Where u2 is average wind speed at 2m in m/s, RHmin is daily minimum relative humidity, % , and h is height of the alfalfa (generally 0.5 m is used for the alfalfa reference and 0.12 m is used for grass). The "0.3" exponent is used on the h/3 term to indicate the effect of roughness (height) on the impact of dryness and windiness on the ratio. This same "adjustment" expression is used in the revision to adjust Kc's for all crops for climate for use with the grass reference ET_o.

The above equation happens to predict a ratio ETo/ETr = 1.24 at Kimberly, Idaho, where u2=2.2 m/s during the summer period and RHmin averages 30 percent. This is similar to values of ET_R/ET_O that have been measured by Dr. Jim Wright at Kimberly using weighing lysimeters.

RHmin can be predicted from daily or monthly dewpoint temperature as

$$RHmin = 100\, e^{\circ}(Tdew)/e^{\circ}(Tmax)$$

Where e°() is the saturation vapor function. If no Tdew data are available,

$$RHmin = 100\, e^{\circ}(Tmin)/e^{\circ}(Tmax)$$

Where Tmin and Tmax are average daily minimum and maximum air temperatures.

$$e^{o} = \exp\left(\frac{16.78T - 116.9}{T + 237.3}\right) \quad \text{T in °C}$$

Prepared by Dr. Rick Allen, Utah State University, 5/12/98, in response to a question raised by Dr. Dean Reynolds on SOWACS and Irrigation-L discussion groups.

(c) Examples

The following is an example of how to calculate a weighted consumptive use

Given: 80 acres of Alfalfa, 40 acres Wheat, and 20 acres Beans
The monthly consumptive use for each of the crops is given in the following table.

Crop	May	June	July	August	September
Alfalfa	3.57	5.17	7.65	6.10	3.26
Wheat	3.41	5.57	4.30	0.03	
Beans	0.48	3.12	7.50	5.29	

Find: The average daily weighted consumptive

Solution:

Step 1. Find the maximum monthly water demand

Crop	May	June	July	August	September
Alfalfa	3.57	5.17	7.65	6.10	3.26
Wheat	3.41	5.57	4.30	0.03	
Beans	0.48	3.12	7.50	5.29	
Totals	7.46	13.86	19.45	11.42	3.26

Maximum month is July at 19.45”

Step 2. Multiply the July consumptive use by the acres for each crop then add the three together

Alfalfa *80 acres x 7.65in = 612 ac-in*
Wheat *40 acres x 4.30in = 172 ac-in*
Beans *20 acres x 7.50in = 150 ac-in*
Total *934 ac-in*

Then divide by the total number of acres $\frac{934 ac - in}{140 ac} = 6.67 inches$

Step 3. Convert into a daily value by dividing by the number of days in the month

$\frac{6.67 inches}{31 days} = 0.22 in / day$ This then can be used in future calculation.

It should be noted that this is an average daily consumptive use. In irrigation systems, information on peak period consumptive use is needed for proper design. When selecting a peak consumptive use several factors need to be considered:

1. **Soil Water** – when the crop evapotranspiration demands are higher than the irrigation system capacity plus rainfall, soil water can be used to provide the difference. This will reduce the peak consumptive use needed for the system. In order to do this a careful accounting of the soil water status is required.
2. **Net Irrigation Application** – the net irrigation application affects the water readily available to the plants and the wetted surface evaporation. Thus, the smaller net irrigation applications will result in a greater daily use rate for a given period of time. Conversely higher net irrigation applications will result in a lower use rate.
3. **Frequency distribution** – the design capacity of an irrigation system for a field depends on the expected crop consumptive use at a given probability level. This is demonstrated by Figure 4-3. Many factors must be considered in developing the probabilty distribution. The Probabilty level selected for design purposes should be based on an economic analysis considering the reduction in crop yield.
4. **Time Averaging** – an analysis of daily mean consumptive use records for any month at any location will show that the mean consumptive use for the any consecutive 5-day period will be greater than for a consecutive 10-day period. Likewise the 10-day period will be greater than a 15-day period, and so on. So the shorter the period is in days, the greater the consumptive use rate. Figure 4-4 illustrates this principle.

In the past, the formula $U_p = 0.034 * U_m^{1.09} * I^{-0.09}$ has been used to estimate peak consumptive use. This relationship should only be used for general estimates and where other peak consumptive use methods cannot be applied. For a full discussion on Peak ET_c or consumptive use see National Engineering Handbook Part 623 Chapter 2, pages 2-197 through 2-209.

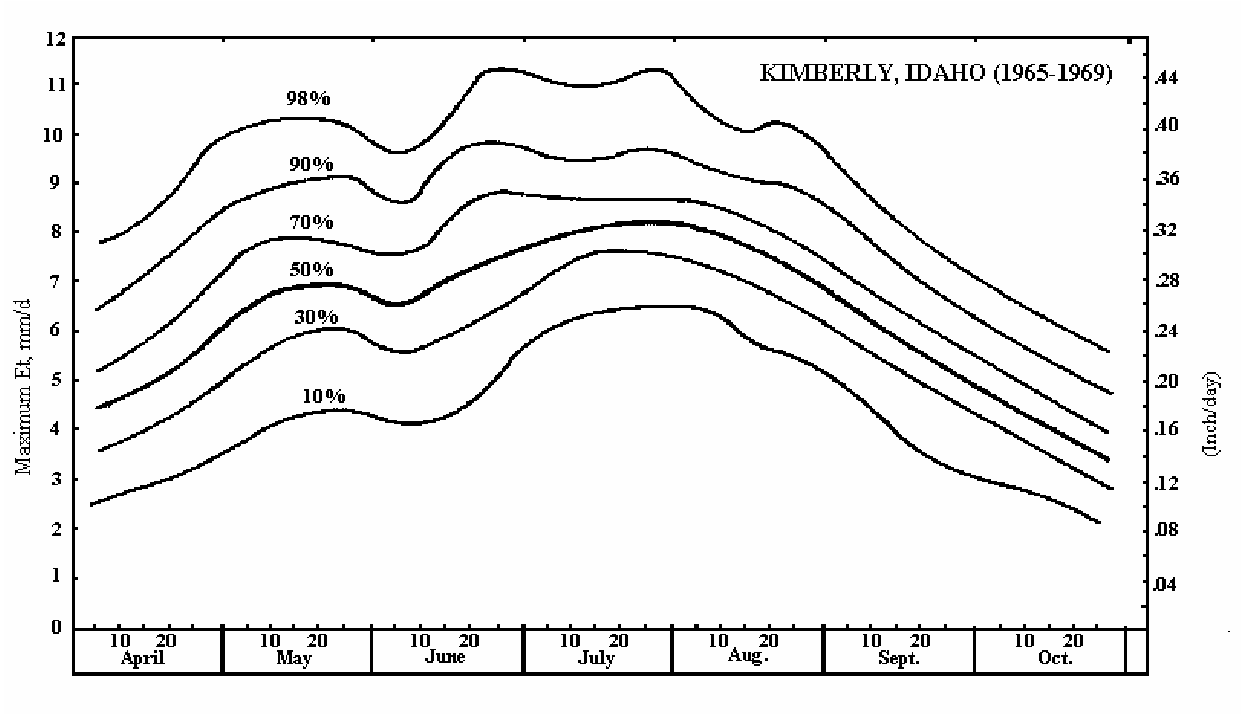

Fig. 4.3. Frequency Distributions for Estimated Daily Maximum E_t for Well-Watered Crop of Alfalfa with Full Cover Calculated for Kimberly, Idaho (from Wright and Jensen, 1972)

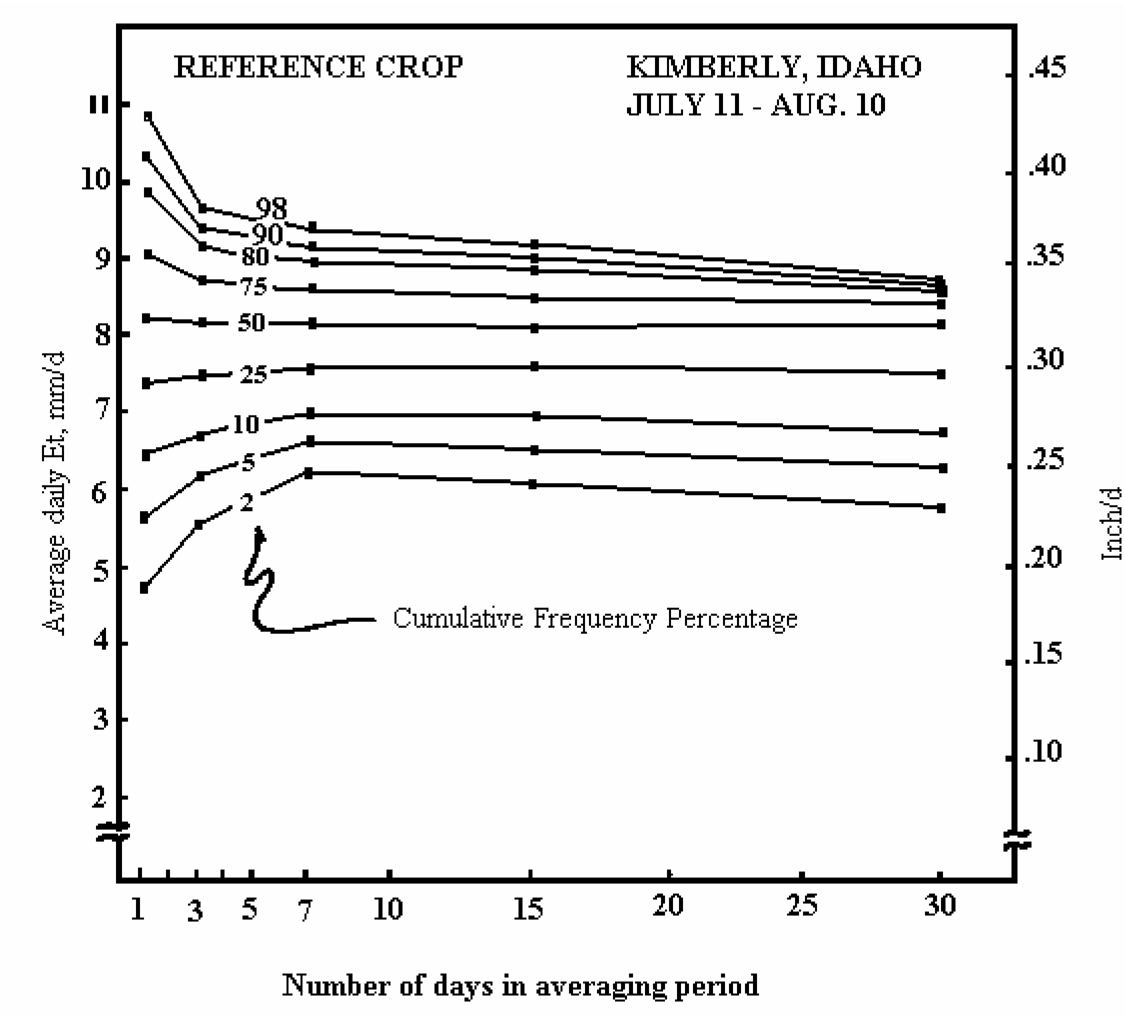

Fig. 4.4. Cumulative Frequency Percentages of Average daily E_t Estimated from Meteorological Data with Combination Equation for 1-Day, 3-Day, 7-Day, 15-Day, and 30-Day Averaging Periods for the Peak Period at Kimberly, Idaho (from Wright and Jensen, 1972)