KS650.1980 Water budget guide for depression areas to determine hydrology criteria for wetlands

This provides a procedure for determining the drainage area size needed to supply 7 or 15 days inundation in depression areas. The procedure uses the 50 percent chance runoff maps shown in Exhibits KS19-1 to KS19-5, the evaporation losses for the inundation period plus an additional 3 days, the soil water holding capacity at 18 inches, and the direct rainfall on the depression. The following formula is used to determine the minimum drainage area (acres) required to meet the inundation period for the depression:

$A_D = (P_L \times P_S \times P_A) / 50\%$ Chance Runoff Equation 1

Where:
- A_D = Minimum drainage area (acres) required
- P_L = Total water losses from depression
- P_S = Depression storage factor for shape--usually 1.13
- P_A = Depression area (acres)--measured at the nearly level bottom
- 50% Chance runoff is determined from Exhibits KS19-1 to KS19-5 for the curve number of the drainage area and corresponding location in the state.

The total water losses, P_L, are calculated using the following equation:

$P_L = EVAP_n + S_{w18} + PERM_i - R_d$ Equation 2

Where:
- $EVAP_n$ = Average evaporation for n days
- n = Critical duration plus 3 days
- S_{w18} = Soil water holding capacity at 18-inch depth for soil in depression
- $PERM_i$ = Total infiltration (inches) for critical duration i
- R_d = Direct rainfall on depression (inches)

$EVAP_n$ is the average evaporation for the critical duration plus 3 days. For playas in Kansas, the critical duration is 7 days. For other depressions, the critical duration is 15 days. The 3 additional days are used to account for antecedent rainfall on the depression prior to the critical duration. The average annual evaporation for each county is shown on the map in Exhibit KS19-6. This value is converted to monthly rates using the percentage shown in the bar graph in Exhibit KS19-7. Exhibits KS19-6 and KS19-7 are both references from the electronic Field Office Technical Guide (eFOTG). The upper portion of Exhibit KS19-8 shows an example of how these are used to compute the $EVAP_n$ for any county.

S_{w18} is the soil water holding capacity of the soil in the depression. This information is found in the soil survey for all soils which may be found in depressions. The soil survey gives this information in the table, “Physical and Chemical Properties of Soils,” and is shown as available water capacity (inches of water/inch of soil depth) by horizons. The total available capacity at the 18-inch depth is calculated from these ranges. The lower portion of Exhibit KS19-8 also shows a table with these values.

$PERM_i$ is the total infiltration loss, in inches, for the depression area. It is determined by using the permeability rate of the soil in inches/hour for the critical duration. The permeability rate used can be from the soil survey, laboratory tests, field tests, or other appropriate data.

Example: Field data from a Meade County playa study showed Ness soils had an average permeability of 0.01 inches/hour.

$PERM_i$ = 0.01 inches/hour x 24 hours/day x 7 days
= 1.68 inches

R_d is the direct rainfall on the depression area. It is the average precipitation amount needed to cause the 50 percent chance runoff for the given runoff curve number. The runoff was determined using differing antecedent rainfall conditions throughout the year. Table KS19-1 is the criteria used in Kansas.

Table KS19-1 Antecedent Runoff Conditions (ARC) II Criteria

From Julian Day	To Julian Day	Time Period Days	Rainfall Amount (inches) >=	Rainfall Amount (inches) <=
1	90	5	0.5	1.1
91	120	10	1.2	1.9
121	151	8	1.2	1.9
152	258	5	1.4	2.1
259	305	8	1.4	2.1
306	366	5	0.5	1.1

This criterion was used to analyze 30 years of rainfall data to develop the 50 percent chance, 7-day runoff curves. The 15-day runoff amounts were also checked but, in most cases, did not vary from the 7-day amounts. The 7-day curves will be used as documentation for wetland hydrology in Kansas.

The above table indicates that the drainage area soils are in Antecedent Rainfall Condition (ARC) I if the total rainfall in the previous 5 days is less than 1.4 inches. The soils are in ARC III if the previous 5-day rainfall exceeds 2.1 inches. These amounts are used to determine the total 5-day rainfall required to produce the 50 percent chance runoff. The corresponding curve numbers for ARCs I and III can be found in Table 10-1 in National Engineering Handbook Part 630, *Hydrology*. The following equation is used to determine the precipitation needed to produce the desired runoff:

$$P = P_5 + P_{50\%} \qquad \text{Equation 3}$$

Where: P = Precipitation amount for specific ARC
P_5 = Previous 5-day rainfall total
P50% = Rainfall total to produce runoff amount

Example: 50 percent chance runoff is 0.10 inch for Curve Number (CN) of 75 in Thomas County. Corresponding ARC I CN is 57 and ARC III CN is 88 from Exhibit KS19-9. The required rainfall to produce 0.10 inch of runoff for each ARC is as follows: CN = 57, $P_{50\%}$ = 2.45 inches; CN = 75, $P_{50\%}$ = 1.30 inches; and CN = 88, $P_{50\%}$ = 0.70 inch. The rainfall amounts can be determined from tables in Technical Release No. 16 or similar documentation.

$$P_{ARC\ I} = P_5 + P_{50\%} = 0.0 + 2.45 = 2.45 \text{ inches}$$

$$P_{ARC\ II} = 1.4 + 1.30 = 2.70 \text{ inches}$$

$$P_{ARC\ III} = 2.1 + 0.70 = 2.80 \text{ inches}$$

This should be repeated for at least three CN curves that have a runoff value. R_d is the average of all precipitation values for all three conditions.

R_d = (2.45 + 2.70 + 2.80) / 3 = 7.95/3 = 2.65 inches

Exhibit KS19-9 gives an example of the R_d calculation for three CNs that have runoff.

In addition to the storage requirements for ponding for the critical duration, it has been determined that a minimum storage depth is required to meet the critical duration losses. These losses would be evaporation and infiltration for the critical duration and one-

half of the soil water capacity at 18 inches. The minimum storage depth is represented by the following equation:

$P_D = EVAP_i + PERM_i + (S_{w18} / 2)$ Equation 4

Where: i = Critical duration, 7 or 15 days

Depressions that do not meet the minimum storage depth requirements will not meet the hydrology criteria for wetlands.

Example: A nearly circular playa in Thomas County has 125 acres of drainage area that is all range. The soils are all hydrologic group B with 40 percent of the range in fair condition and 60 percent in poor condition. The playa has a nearly level bottom that is 2.2 acres in size with uniform slopes out of the bottom. The total storage depth in the playa is 1.8 feet. Using the equations given, determine if the drainage area is adequate to maintain ponding for the critical duration for the 50 percent chance runoff.

Solution: Thomas County is in the playa region of Kansas; therefore, the critical duration (i) is 7 days. From Exhibit KS19-6, the average annual evaporation is 59 inches. The Pleasant soils in the bottom of the playa have a permeability of 0.01 inch/hour, therefore:

$PERM_i$ = 7 days x 24 hours/day x 0.01 inches/hr.
= 1.68 inches

From Exhibit KS19-8, the S_{w18} of Pleasant soil is 3.08 inches, and the average daily evaporation is 0.223 inch.

$EVAP_i$ = 7 days x 0.223 inch/day = 1.56 inches
$EVAP_n$ = 10 days x 0.223 inch/day = 2.23 inches

Check to see if playa meets minimum depth--Equation 4:

$P_D = EVAP_i + PERM_i + (S_{w18} / 2)$
= 1.56 + 1.68 + (3.08/2)
= 4.78 inches

Actual depth is greater than minimum depth.

Compute the total water losses (P_L) using Equation 2:

$P_L = EVAP_n + S_{w18} + PERM_i - R_d$

Where: R_d = 2.64 (from Exhibit KS19-9)
P_L = 2.23 + 3.08 + 1.68 - 2.64
= 4.35 inch

Compute the minimum drainage area required to meet losses using Equation 1:

$A_D = (P_L \times P_S \times P_A)$ / 50% chance runoff
= (4.35 inches x 1.13 x 2.2 acres) / 0.10 inch
= 10.81 acre-inches / 0.10 inch
= 108.1 acres

Actual drainage area of 125 acres exceeds the minimum drainage area required to meet critical duration losses--108 acres. Therefore, this playa meets wetland hydrology criteria.

Exhibit KS19-1 Annual 7-Day Runoff, 50% Chance RCN 65

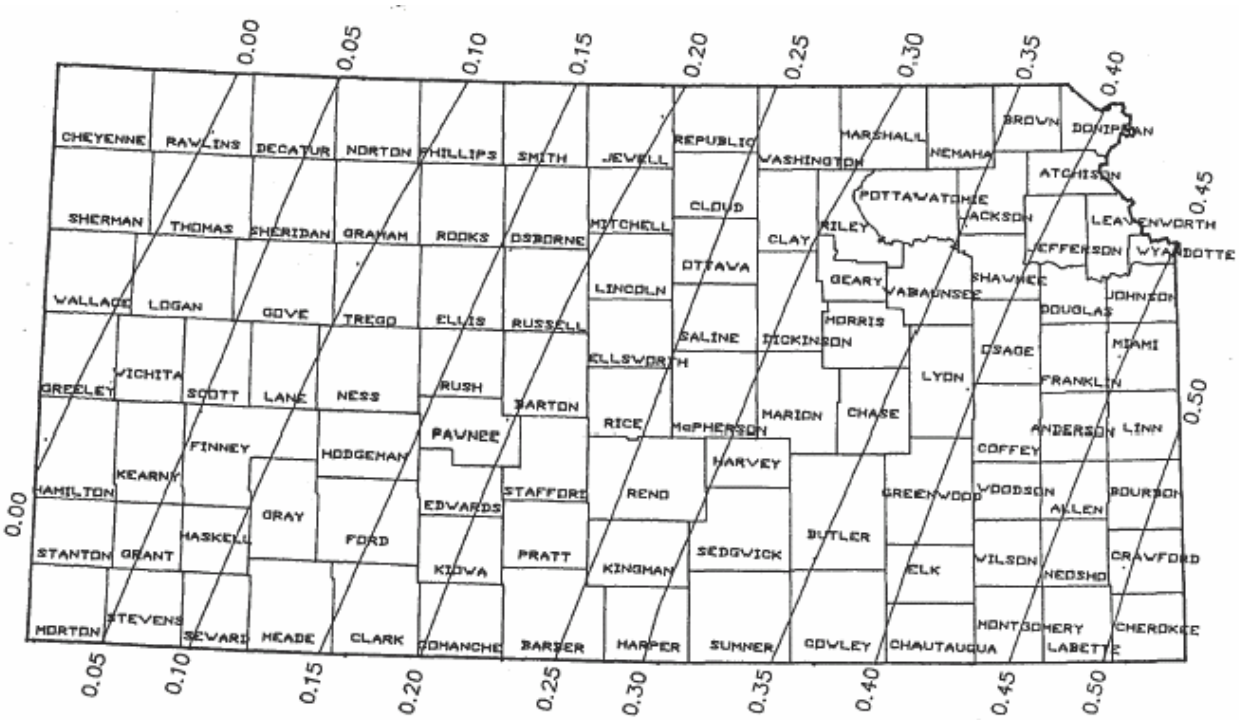

Exhibit KS19-2 Annual 7-Day Runoff, 50% Chance RCN 70

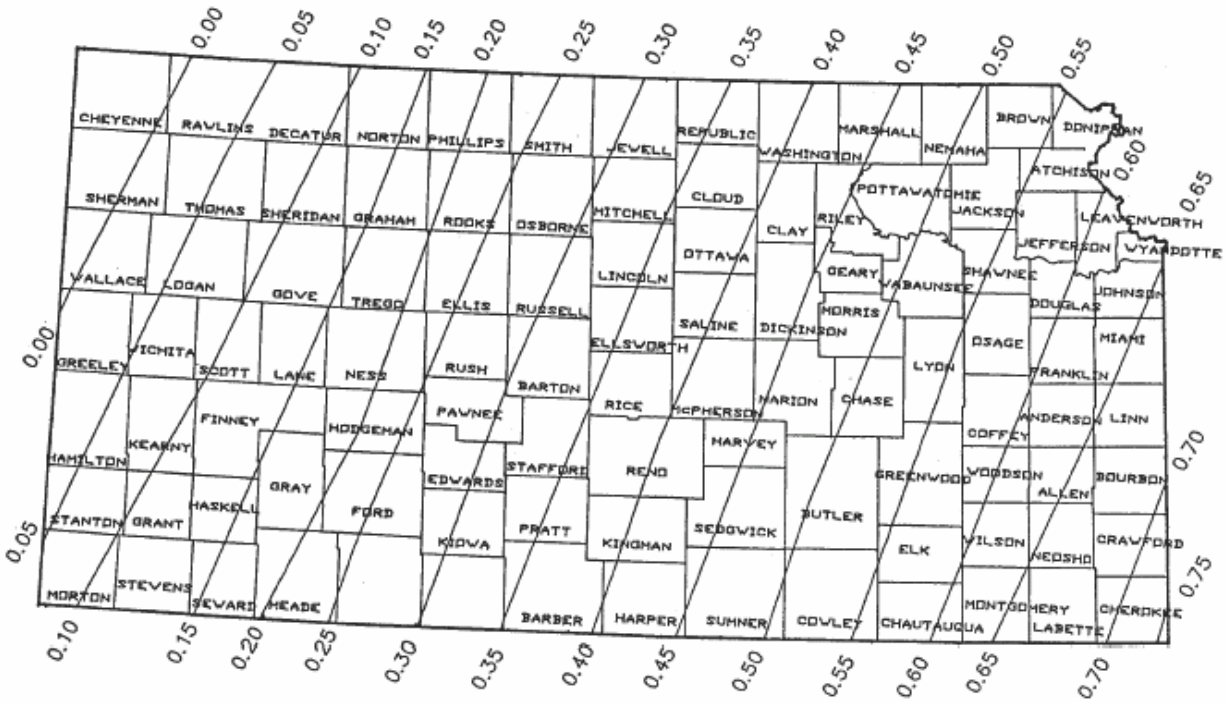

Exhibit KS19-3 Annual 7-Day Runoff, 50% Chance RCN 75

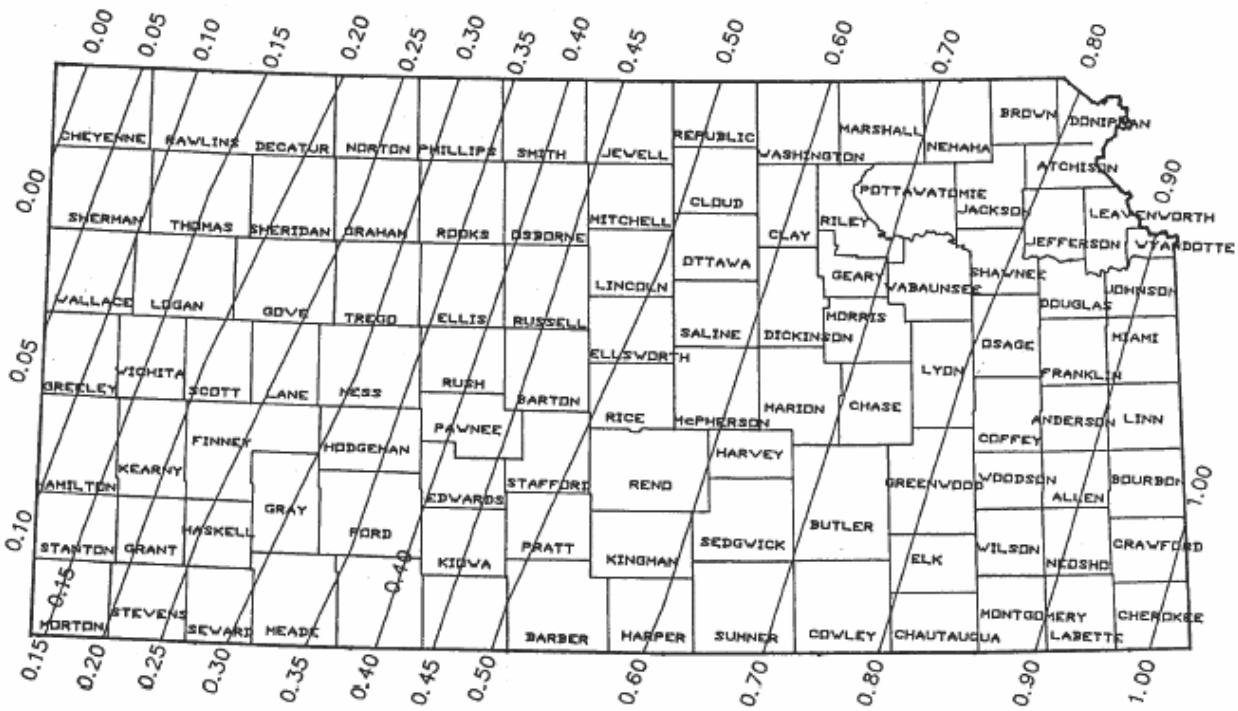

Exhibit KS19-4 Annual 7-Day Runoff, 50% Chance RCN 80

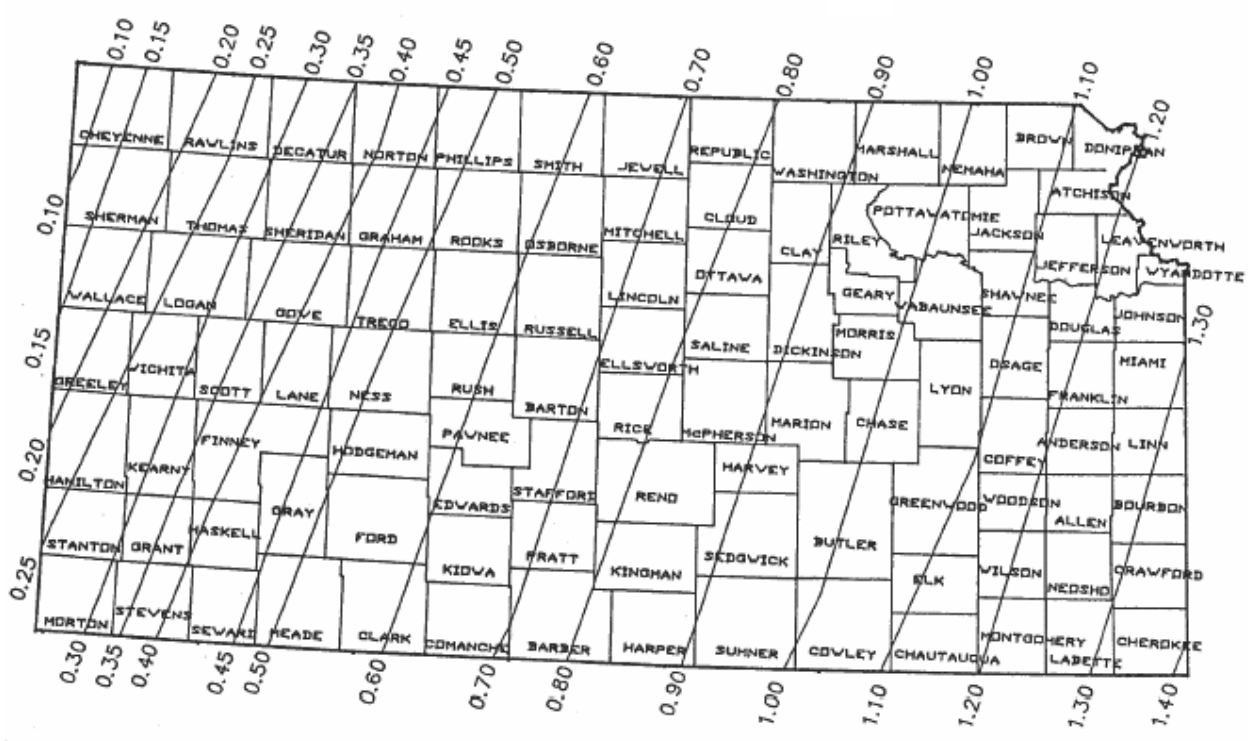

Exhibit KS19-5 Annual 7-Day Runoff, 50% Chance RCN 85

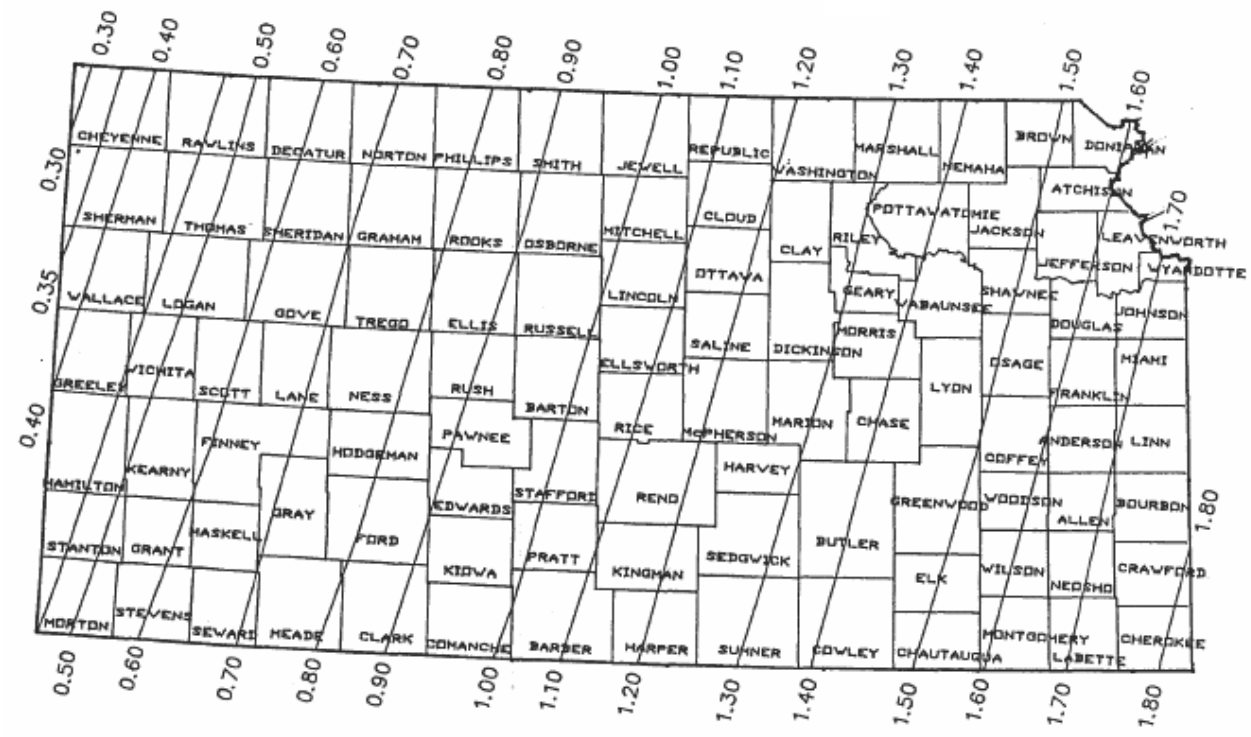

Exhibit KS19-6 Average Annual Evaporation in Inches

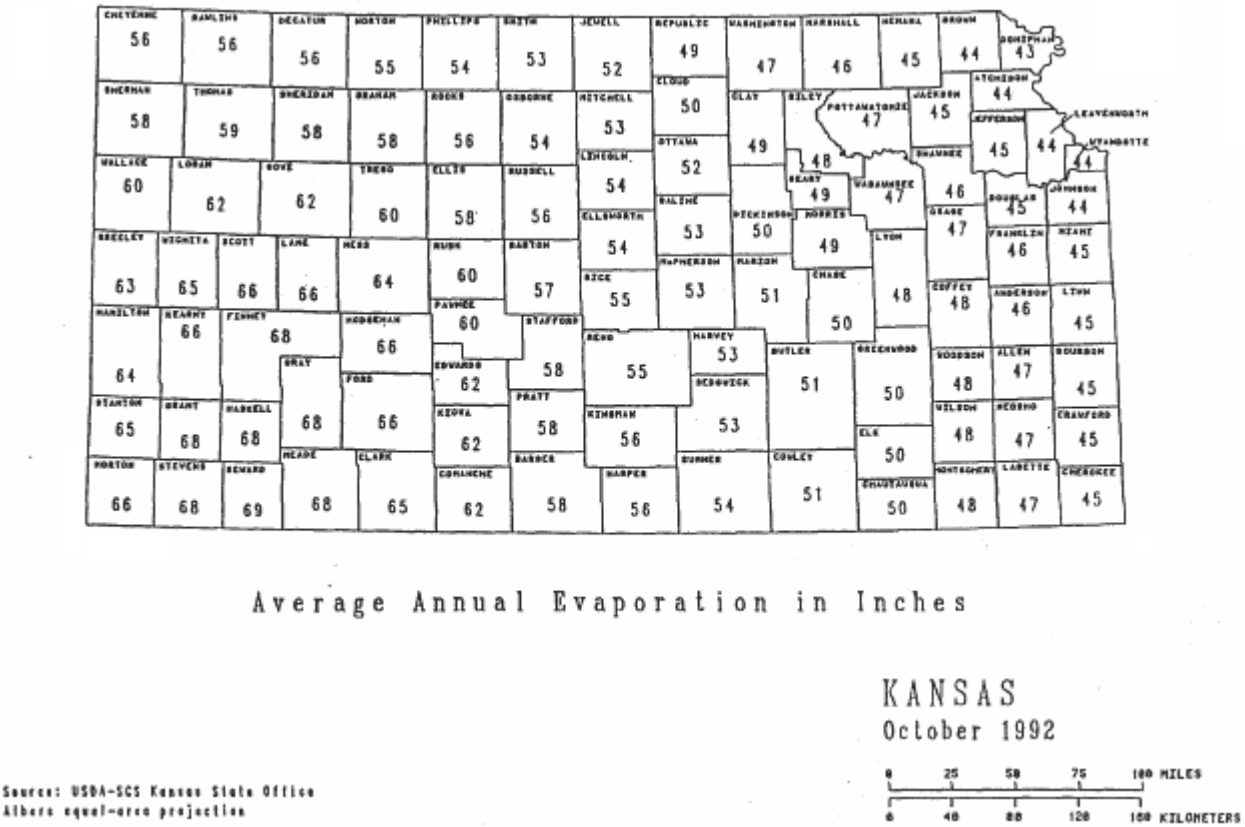

Exhibit KS19-7 Average Annual Evaporation

Average Annual Evaporation

Average annual evaporation rates are used in designing some conservation practices. To have an understanding of what the evaporation rate is in each county in the state, a map of Kansas on the following page has the average annual evaporation rates by county. They are taken from the Annual Free Water Surface Evaporation map in National Oceanic and Atmospheric Administration (NOAA) Technical Report National Weather Service (NWS) 33, "Evaporation Atlas for the Contiguous 48 United States," dated June 1983. These rates represent average annual evaporation from ponds and reservoirs.

To facilitate conversion of the average annual evaporation rate to monthly rates, a percentage-by-month bar graph is shown below. The percentages are based on NOAA Technical Report NWS 34, "Mean Monthly, Seasonal, and Annual Pan Evaporation for the United States", dated December 1982, using five stations in Kansas that have annual evaporation measurements. The Kansas data is on page 67 of the report.

Example: Determine the average July evaporation rate for Butler County, Kansas.

Solution: From the state map, determine an average annual evaporation rate of 51 inches.

From the bar graph, read 15% of the average annual evaporation occurs in the month of July.

Calculate the average July evaporation rate
= (51 inches)*(15%)
= 7.6 inches.

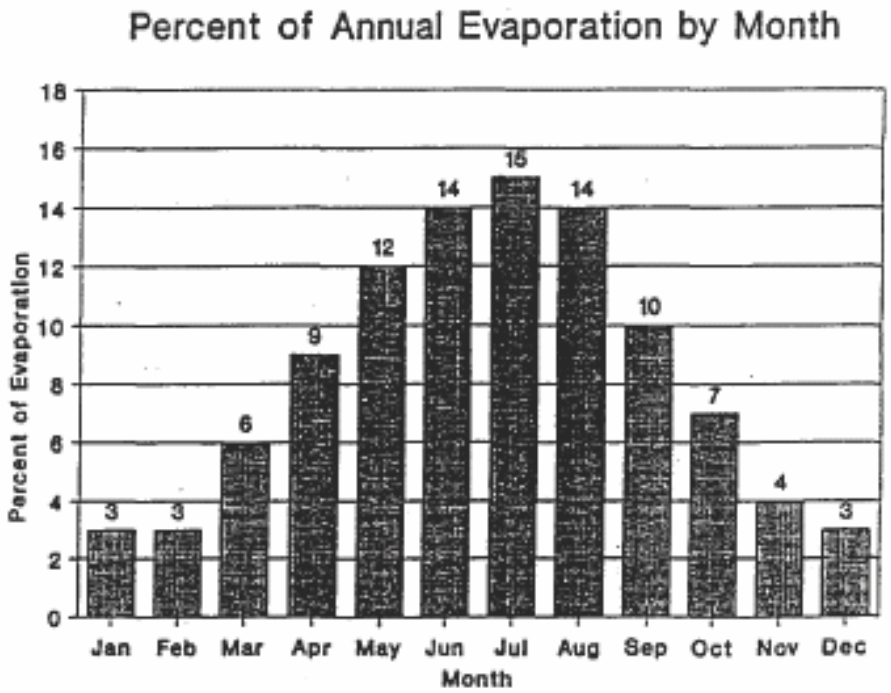

Exhibit KS19-8 County Evaporation Rates - Soil Water Holding Capacity

Evaporation rates by month, daily, 10 days, and 18 days.
Average annual evaporation in THOMAS County is 59 inches.

MONTH	% OF ANNUAL BY MONTH	MONTH (INCHES)	DAILY AVE. (INCHES)	10-DAY AVE. (INCHES)	18-DAY AVE. (INCHES
APRIL	9	5.31	0.18	1.77	3.19
MAY	12	7.08	0.23	2.28	4.11
JUNE	14	8.26	0.28	2.75	4.96
JULY	15	8.85	0.29	2.85	5.14
AUGUST	14	8.26	0.27	2.66	4.80
SEPTEMBER	10	5.90	0.20	1.97	3.54
OCTOBER	7	4.13	0.13	1.33	2.40
TOTAL		47.8	1.56	15.63	28.13
DAILY AVERAGE			0.223		
10-DAY AVERAGE			2.23		
18-DAY AVERAGE			4.02		

SOIL WATER HOLDING CAPACITY
FOR PLEASANT SOIL
(From SOILS-5 data)

0 to 5 inches	0.20 IN/IN	
5 to 50 inches	0.16 IN/IN	

SWHC at 18 inch depth = 3.08 inches

Exhibit KS19-9 Example of R_d Calculation for CNs That Have Runoff

Average precipitation amount needed to cause the 50% chance runoff for a given runoff CN
Precipitations are computed using Equation 3, $P = P_5 + P_{50\%}$

Thomas County

	Weighted Curve Number 70 **Runoff 0.03**			Weighted Curve Number 75 **Runoff 0.10**			Weighted Curve Number 80 **Runoff 0.20**		
	CN			CN			CN		
ARC I	51	(0.0) + 2.50)	= 2.50	57	(0.0 + 2.45)	= 2.45	63	(0.0 + 2.37)	= 2.37
ARC II	70	(1.4 + 1.25)	= 2.65	75	(1.4 + 1.30)	= 2.70	80	(1.4 + 1.32)	= 2.72
ARC III	85	(2.1 + 0.60)	= 2.70	88	(2.1 + 0.70)	= 2.80	91	(2.1 + 0.75)	= 2.85
Total		T1	= 7.85		T2	= 7.95		T3	= 7.94

Average rainfall required to produce 50% chance runoff = (T1 + T2 + T3) / 9 = 2.64 inches