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ENERGY USE IN IRRIGATION IN KANSAS: A COMPUTER SIMULATION

by

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INTRODUCTION

Energy usage in agriculture has become a topic deserving attention, study, and research. With the relatively rapid depletion of fossil fuel resources in the United States, energy conservation measures have become increasingly important, as well as energy source alternatives. The fuel used on the farm for agricultural production was only approximately 3 per cent of the total fuel usage in the United States in 1974 (Gunkel, et. al., 1974). However, it is still important for the agricultural industry to minimize its energy usage. As energy becomes less available, its cost rises. Energy saving techniques will bring production costs down, as well as help extend the availability of fossil fuels.

Irrigation is an energy intensive agricultural process. It is estimated that two to three times the energy is required to grow a crop on irrigated land as opposed to dry land (Dvoskin, et. al., 1975). Approximately 11 per cent of the crops grown in Kansas in 1974 were irrigated, while irrigation pumping consumed approximately 25 per cent of the total energy used in agriculture in Kansas (Federal Energy Admisistration, 1974). Irrigation pumping is estimated to have used 40 per cent of the total energy usage in crop production in Kansas in 1974 (excluding energy required to produce and transport fertilizers). An average of 10×10^6 BTU per acre irrigated was required for pumping irrigation water in 1974.

There are other inputs of energy required to irrigate crops, in addition to energy required to deliver water to the crops. Energy

above and beyond the amount required for dryland crops is used for:

1. Building, transporting, installing, and maintaining irrigation systems.
2. Additional tillage and harvest requirements.
3. Additional fertilizer and pesticide requirements.

The intent of this paper is to examine only the pumping energy requirements. The analysis includes the development of an analytical procedure for calculating energy usage on a county by county basis in Kansas. With the digital computer, the model developed was utilized to estimate energy usage while using the latest available data. In addition, several case studies were made while assuming various input conditions.

REVIEW OF LITERATURE

Estimating energy usage in irrigation is not new to engineers, as several state and federal agencies request this information, as well as agencies in the private business sector. Energy estimates for all farming practices are listed by state by the Federal Energy Administration (FEA). This data was developed by the Economic Research Service. The FEA report is a national report, and the estimates pertaining to irrigation for each state can probably be traced back to the irrigation engineering specialists in the extension departments of that state's agricultural college.

A study by Dvoskin and others (1975) focused on energy usage by irrigation pumping in the 17 western states, where 88 per cent of the irrigated cropland and an even larger percentage of energy usage for irrigation was concentrated. The 17 states were further broken down into 57 producing regions for the purposes of that study. It was stated in the paper "The major objective of this study is to develop an analytical procedure which will determine the energy use on irrigated cropland." The analytical procedure developed by Dvoskin was designed to be applicable to analyzing changes in assumptions regarding water source, irrigation method, energy conversion efficiency, and fuel substitutions. The study did not, however, analyze any of these situations.

Gordon Sloggett (1974) has used the same approach in estimating energy usage for all 50 states. In addition, several individual states have conducted studies on energy used in irrigation as a part of studies

on energy use in agriculture as a whole. Among these are California (Cervinka, et. al., 1974) and Nebraska (Lane, et, al., 1973).

Projected fuel savings due to energy savings techniques have been made for Kansas. However, an extensive analysis of energy use in irrigation in Kansas, using a flexible model that could estimate previous energy usage as well as make case studies based on predicted variables and current data had not been developed.

PROCEDURE

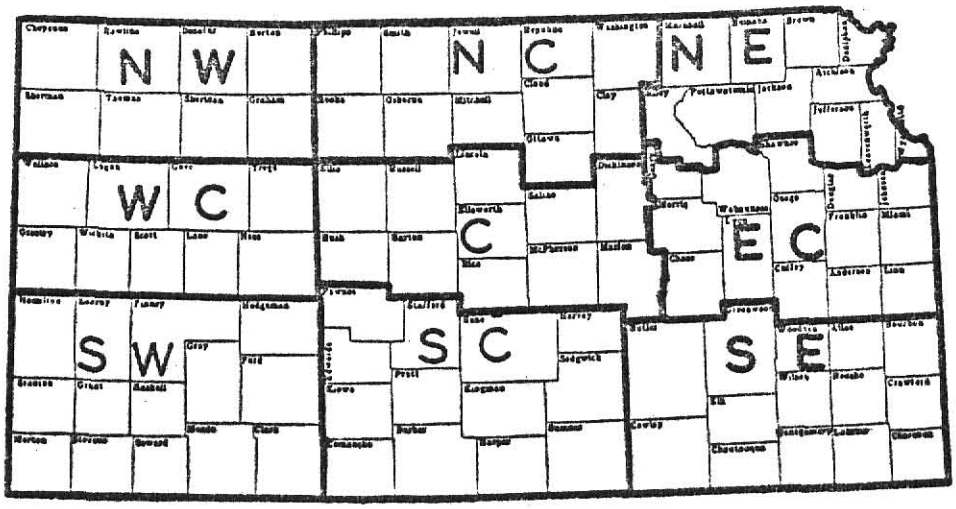
General Procedure

Following is a description of the procedure used to determine the energy usage by irrigation pumping in Kansas. The energy usage was calculated for 1975, the latest year for which all data were available. The energy use was calculated on a county by county basis. The state of Kansas was broken down into 9 districts, as shown in Figure 1. The total energy use, in BTU, was calculated for each county, as well as the usage of natural gas, diesel fuel, liquid propane gas, and electricity. Calculations made for various case studies are shown in the results section.

An alphabetical listing of counties showing the county number and the district in which the county is located is shown in Table 1.

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District	District No.
Northwest	1
West central	2
Southwest	3
North central	4
Central	5
South central	6
Northeast	7
East central	8
Southeast	9

Figure 1. Map of Kansas Showing Districts Used.*

*Map reproduced from 1975-76 Kansas Farm Facts (Kansas State Board of Agriculture, 1976).

Table 1. County Numbers and Locations.

County No.	County	District	County No.	County	District	County No.	County	District
1	Allen	SE	36	Greeley	SW	71	Osborne	NC
2	Anderson	NE	37	Greenwood	SE	72	Ottawa	NC
3	Atchison	NE	38	Hamilton	SW	73	Pawnee	SC
4	Barber	SC	39	Harper	SC	74	Phillips	NW
5	Barton	SC	40	Harvey	SC	75	Pottawatomie	NE
6	Bourbon	SE	41	Haskell	SW	76	Pratt	SC
7	Brown	NE	42	Hodgeman	SW	77	Rawlins	NW
8	Butler	SC	43	Jackson	NE	78	Reno	SC
9	Chase	NE	44	Jefferson	NE	79	Republic	NC
10	Chautauqua	SE	45	Jewell	NC	80	Rice	SC
11	Cherokee	SE	46	Johnson	NE	81	Riley	NE
12	Cheyenne	NW	47	Kearny	SW	82	Rooks	NW
13	Clark	SW	48	Kingman	SC	83	Rush	SC
14	Clay	NC	49	Kiowa	SC	84	Russell	NC
15	Cloud	NC	50	Labette	SE	85	Saline	NC
16	Coffey	NE	51	Lane	SW	86	Scott	SW
17	Comanche	SC	52	Leavenworth	NE	87	Sedgwick	SC
18	Cowley	SC	53	Lincoln	NC	88	Seward	SW
19	Crawford	SE	54	Linn	NE	89	Shawnee	NE
20	Decatur	NW	55	Logan	NW	90	Sheridan	NW
21	Dickinson	NC	56	Lyon	NE	91	Sherman	NW
22	Doniphan	NE	57	McPherson	SC	92	Smith	NC
23	Douglas	NE	58	Marion	NE	93	Stafford	SC
24	Edwards	SC	59	Marshall	SC	94	Stanton	SW
25	Elk	SE	60	Meade	SW	95	Stevens	SW
26	Ellis	NW	61	Miami	NE	96	Sumner	SC
27	Ellsworth	SC	62	Mitchell	NC	97	Thomas	NW
28	Finney	SW	63	Montgomery	SE	98	Trego	NW
29	Ford	SW	64	Morris	NE	99	Wabaunsee	NE
30	Franklin	NE	65	Morton	SW	100	Wallace	NW
31	Geary	NE	66	Nemaha	NE	101	Washington	NC
32	Fove	NW	67	Neosho	SE	102	Wichita	SW
33	Fraham	NW	68	Ness	SW	103	Wilson	SE
34	Grant	SW	69	Norton	NW	104	Woodson	SE
35	Gray	SW	70	Osage	NE	105	Wyandotte	NE

Energy Use Equations

The amount of energy used for pumping irrigation water is a function of many variables. These variables include the depth the water is pumped out of the ground, the pressure required at the pump, the efficiency of the pumping unit, and the quantity of water pumped. In turn, there are many variables which affect each of these conditions. The depth the water is pumped is a function of the depth to water in the static condition and the drawdown, or the distance the water table is lowered due to pumping. The pressure required at the pump is dependent upon the pressure required at the discharge point, and the amount of pressure lost between the pump and discharge point. The efficiency of the pumping unit is a function of the efficiency of conversion of fuel energy to mechanical energy and the pumping efficiency, which is defined as the amount of mechanical work done in pumping the water divided by the amount of mechanical work input. The quantity of water pumped depends upon the number of acres irrigated, and the quantity of water applied per acre (which is in turn dependent upon the crop irrigated, the weather, and the irrigation efficiency). A further breakdown of variables could be made, depending upon the degree of accuracy desired.

The energy use for irrigation in Kansas was calculated from the following equation.

$$ER = \sum_{i=1}^{n} \frac{(PD_N + PR) \times (A_i) \times WR \times K}{(EFF_{pump,i}) \times (EFF_{irr})} \qquad (1)$$

where:

ER = the total energy requirement for the area under consideration, BTU

n = the number of fuel sources considered (natural gas, electricity, liquid propane, and diesel fuel in this study)

PD_N = the net pumping depth; the depth to water plus the drawdown, ft.

PR = the average additional pressure requirement for the water distribution systems, ft. of water

$$PR = \frac{\sum_{k=1}^{s} PR_k \times A_k}{\sum_{k=1}^{s} A_k} \qquad (2)$$

where:

s = the number of irrigation distribution types considered

PR_k = the pressure requirement of irrigation distribution type k (center pivot, gated pipe, big gun, etc.), ft. of water

A_k = acres irrigated by irrigation distribution type k

A_i = the number of acres irrigated by systems using energy source i

WR = the average net water requirements for crops in the area, ft.

$$WR = \frac{\sum_{j=1}^{m} A_j \times WR_j}{\sum_{j=1}^{m} A_j} \qquad (3)$$

where:

m = the number of crops irrigated

A_j = the number of acres of crop j irrigated

WR_j = the net water requirement of crop j

K = a constant, 62.4 lb./sq. ft. x 43,560 sq. ft./acre x 1 BTU/778 ft. lb.

$EFF_{pump,i}$ = the overall average pumping efficiency for energy source i

EFF_{irr} = the irrigation efficiency for the area (application efficiency)

$$EFF_{irr} = \frac{EFF_{irr,sp} \times A_{sp} + EFF_{irr,gr} \times A_{gr}}{A} \quad (4)$$

where:

$EFF_{irr,sp}$ = sprinkler irrigation application efficiency

$EFF_{irr,gr}$ = gravity system irrigation application efficiency

A_{sp} = acres irrigated by sprinkler systems

A_{gr} = acres irrigated by gravity systems

A = total acres irrigated for the area

Pumping Depth

The net pumping depth is defined as the distance irrigation water must be lifted during pumping. The net pumping depth is a function of the static water level of the aquifer, and the drawdown. The static water level will vary during the year due to rainfall, recharge and depletion by influent and effluent streams, and pumping of water. The drawdown, or depth that the water recedes during pumping, also varies. The drawdown is a function of the permeability of the aquifer, the pumping rate, and length of time elapsed since the start of pumping. Linsley (1975) states "true equilibrium conditions occur only after a very long period of pumping at constant rate". Other wells which pump in the same vicinity will affect the drawdown at the well in question, as will nearby streams.

A method to determine the drawdown of a well, which assumes equilibrium conditions exist, is obtained by defining what is called the specific capacity of the aquifer. The specific capacity is defined as the pumping rate that would give one unit length of drawdown, typical units for specific capacity being gallons per minute per foot of drawdown.

If the pumping rate is then divided by the specific capacity, the quotient is the drawdown. The specific capacity would be determined experimentally.

The Theis method (Linsley, et. al., 1975) can be used to determine the drawdown of a well at a given time t (days since pumping began). This method requires a constant pumping rate, q (gallons per minute), a known transmissibility T (cubic feet per day per foot), a known storage constant S_c (dimensionless), and the distance r from the pumped well (r is equal to the radius of the well unless the calculation is made for an observation well, where r would be the distance from the pumped well to the observation well). The drawdown, Z_r, is given by the relation:

$$Z_r = \frac{q}{4 \times \pi \times T} \times \int_u^{\infty} \frac{e^{-u}}{u} du \qquad (5)$$

$$\text{where } u = \frac{r^2 \times S_c}{4 \times T \times t} \quad \text{and is dimensionless.} \qquad (6)$$

The integral in equation 5 is designated as W(u), and values of W(u) are generally given for various values of u. However, T and S_c values are generally not readily available, and are typically determined by test wells, using measured drawdowns at known time intervals.

As data on the specific capacity and pumping rates, or on the transmissibility, storage coefficient, and well radius were not available for areas other than a few selected counties, another method of estimating pumping depths had to be found.

No matter what method of calculation would be used to determine drawdown, the depth to water would also be required. The most extensive data on depths to water in Kansas was found to be contained in the water

level reports prepared by the Kansas Geological Survey (Pabst and Jenkins, 1974, 1976). These reports cover only the western third of the state. However, the 1975 Kansas Irrigation Survey (Hay, 1975) showed 78 per cent of the irrigation in Kansas was practiced in the counties listed in the water depth reports.

The water levels listed in these reports were measured in January, when the pumping was minimal and when the effects of the irrigation season had receded. Municipal, industrial, and domestic uses were continuous but contributed in a minor way to the total withdrawl. Therefore, the depth to water as given in the Kansas Geological Survey Journals represented the static water level. For purposes of this study, the drawdown due to pumping as well as the static water level was desired. From presonal contact with DeLynn Hay, John Kramer, and E. D. Jenkins, the consencus was that, as a rule of thumb, the drawdown could typically be calculated as being one-half of the saturated thickness. As the depth to bedrock was also listed in the water level reports, a saturated thickness could be calculated as the difference in depth to water and the depth to bedrock. As a check on this method of calculation of the drawdown, it was compared with the value obtained by dividing the pumping rate by the specific capacity for those areas where the specific capacity was known.

As reported by Gutentag (1976), the average specific capacity of 30 wells in Scott and Lane counties in 1971-1972 was found to be 18 gpm per ft. of drawdown. Hay (1977) and Bossert (1977) have estimated the average pumping rate for this area at 600 gpm. This would result in a drawdown of 33.3 ft. The water level records for 1973 show an average saturated thickness of 67.3 ft. for Scott county and 44.7 ft.

for Lane county (see Appendix A). A drawdown of one-half the saturated thickness would be 33.7 ft. for Scott county and 22.4 ft. for Lane county.

Findings reported by Hanson (1955) show drawdown as being 27 per cent of the saturated thickness (depth of well minus static water level). This was an average for 44 wells in 8 southwest Kansas counties. He does not give the length of time since the start of pumping that the drawdown was measured.

In calculating the pumping depth in western Kansas, it was assumed the drawdown was equal to one-half the saturated thickness of the aquifer. In view of the fact that aquifer properties were not available across the state, the assumption that drawdown is equal to one-half of the saturated thickness appears to be valid for purposes of this study. The 1975 values for net pumping depth as calculated in Appendix A were used for calculating 1975 energy use estimates.

Water Levels and Saturated Thicknesses in Western Kansas

The reports on water level changes in western Kansas indicate that water is being mined from the Ogallala formation; that is more water is being removed than is replaced. The decline of the water level increases the depth the water needs to be pumped for irrigation, therfore the energy requirements for irrigation are increased. A change in water level also affects the properties of the aquifer to some extent.

A declining water table is of greatest concern in those areas where the saturated thickness is small. This is the case in west central Kansas, where the saturated thickness has declined as much as

50 per cent from 1950 to 1974 (Pabst and Jenkins, 1974). Decreased well yields have been observed in these areas. The areas with the greatest decline in the water table generally coincide with the areas of greatest pumping (Pabst and Jenkins, 1974). The water table had risen in a few places, presumably where little or no pumping had taken place. The decline in the water table was not uniform over western Kansas, just as the base year depth to water was not uniform for western Kansas. The base year was listed in the water level reports as being the year when the water table had not yet been significantly affected by irrigation pumping. The base year was listed as being 1940 in southwest Kansas and 1950 in northwest and west central Kansas.

After a visit with Jesse McNellis, a hydrologist with the United States Geological Survey, it was decided that obtaining the water level records for computer analysis would be beneficial to this study. These records were contained on cards, there being two cards per well record. There were 24 counties for which well records were obtained, with a range of 7 to 103 records per county, and an average of 50 records per county. There were 1201 records in all. These records were transfered to disk drive for ease in handling. The pertinent data contained in the well records were the well location, the depth to bedrock, and the depth to water for the base year, the year 1966, and the years 1973 through 1977. The records for northwest Kansas also listed the depth to water in 1972. The records were analyzed on a county by county basis, as nearly all other data pertinent to this study were listed on a county by county basis.

Not all well records contained an entry for the depth to water for every year, and not all records showed an entry for the depth to bedrock. Because of this incompleteness, the data were analyzed in two different ways. In one method, all well records were read that contained the essential information for the calculation being made at that time. For example, if the average depth to water in 1975 was being calculated for Finney county, all records that listed a depth to water in Finney county in 1975 were used. The second method of analyzing the data was to read only those records that were complete. Complete records listed a depth to bedrock plus a depth to water for 1940 (or 1950), 1966, 1973, 1974, 1975, 1976, and 1977. Six hundred fifty nine out of the 1201 records were complete.

The most representative water level and saturated thickness for any one county at any one particular year would be the average of these values obtained from as many samples as possible. Therefore, values obtained from the first of the aforementioned methods should be used when analyzing any one particular year. However, when comparing the water level for one year with that of another year, it would be essential that the same wells be used in the analysis. In calculations of this type, values obtained by the second method should be used.

The following values were calculated for each of 7 years, for each county that data were available for, and by both methods.

1. The average depth to water.
2. The maximum depth to water.

3. The minimum depth to water.
4. The coefficient of variation (the standard deviation as a per cent of the mean).
5. The average saturated thickness.
6. The maximum saturated thickness.
7. The minimum saturated thickness.
8. The coefficient of variation of the saturated thickness.
9. The net pumping depth, which was calculated as the average depth to water plus one-half the average saturated thickness.

The coefficient of variation for both the depth to water and the saturated thickness indicated the nonuniformity of the data. The depth to water within any one county varied considerably, as did the saturated thickness. The coefficient of variation of the depth to water in Hamilton county was greater than 100 per cent for some years, which meant the standard deviation was greater than the mean. As no depth to water could have a negative value, it also indicated the distribution did not approach a Gaussian distribution. Reference to individual well depths and their locations verified the fact that some of the test wells were along the Arkansas River and had a shallow depth, while others not affected by the River had a much greater depth to water, as well as a much greater saturated thickness.

The results of the computer analysis of the well records are shown in Appendices A and B.

Pumping Depths in Central and Eastern Kansas

Information on pumping depths for districts other than the three western districts was obtained from Groundwater Management District

managers, and Kansas State University experiment field personnel and extension personnel.

The greatest development of irrigation in Kansas outside of the western third of Kansas has occurred in the region surrounding the Sandyland Experiment Field at St. John in Stafford county. With the exception of the western three districts and Republic county, the Kansas Irrigation Survey (Hay, 1975) lists only Stafford and its surrounding counties of Barton, Pawnee, Edwards, and Pratt as having greater than 23,000 acres of irrigation. Two methods of determining the pumping depth for this area are shown below.

Theis non-equilibrium method (Sloan, 1977).

Depth to water = 20 ft.

Transmissibility = T = 1.0×10^5 gal/day/ft.

Storage constant = $S_c = 0.15$

Time since pumping began = t = 60 days (average irrigation season)

Distance from well = r = 0.5 ft. (12 in. well casing)

Pumping rate = q = 1000 gpm

With this convention of units, $u = \dfrac{1.87 \times r^2 \times S_c}{T \times t} = 1.17 \times 10^{-8}$

W(u) = 17.96 (read from table in Linsley, 1975)

Z_r = drawdown = 114.6 x q x W(u) / T = 20.6 ft.

The net pumping depth would then be 20 ft. + 20.6 ft. = 40.6 ft. This assumed there was no interference from neighboring wells.

Using the specific capacity method, the following values were obtained. The specific capacity of wells in this area was found to be approximately 44 gallons per minute per foot of drawdown (TenEyck, 1968). At a pumping rate of 1000 gpm, the drawdown would be 22.7 ft. If the

same 20 ft. depth to water is assumed, the net pumping depth would be 42.7 ft.

From personal communication with county agents and other extension personnel, the general feeling was that the average pumping depth for this area was greater than calculated. It was desirable to use an average pumping depth for all counties in a district for all districts where the water level records were not available. The depth to water in irrigated areas located in the northern part of the Equus Beds (McPherson county) would be greater than 50 feet and would increase the average depth for its district. Therefore, an average depth of 50 feet was assumed for the net pumping depth in the central and south central districts.

Surface water is an important source of irrigation water in north central Kansas, where several irrigation districts operate. There were five districts operating in Kansas in 1977, and two others were in the planning stages. From 1976 reports by the operating districts, Table 2 was constructed.

The water source for irrigation in the north central district, other than surface water, was from wells located along the Republican River, where the pumping depth was estimated at 60 feet. As a substantial amount of water used for irrigation in this district was supplied by surface water, the average pumping depth for this district was set at 40 feet.

The water source for pumping in the eastern third of the state was mainly from wells along rivers, or pumping from the rivers themselves (surface water). The average pumping depth for this part of

the state was set at 50 feet. According to the Kansas Irrigation Survey (Hay, 1975), only 1.2 per cent of the irrigation in Kansas occured in the eastern third of the state in 1975.

Table 2. Summary for Five Kansas Irrigation Districts.

Irrigation District	County	Acres Irrigated	Power Source
Cedar Bluff	Ellis	5,953	Gravity
	Trego		
Kansas Bostwick	Republic	32,310	Primarily gravity; 5 electric pumps with an average net pumping depth of 22 ft.
	Jewell	8,897	
Almena	Phillips	3,244	Gravity and pumps
	Norton	2,210	
Webster	Osborne	7,992	Gravity
	Rooks	547	
Kirwin	Smith	9,063	Gravity
	Osborne	1,853	
	Phillips	553	

Overall Pumping Efficiency

The overall pumping efficiency has been defined as the work done by a pumping unit divided by the energy required to perform that work.

$$Eff_{pump,i} = \frac{W_p}{E_p} \qquad (7)$$

where:

$Eff_{pump,i}$ = the overall pumping efficiency as defined in equation 1

W_p = the work done, and is calculated by multiplying the gross pumping depth (pumping lift plus the pressure requirement, in ft.) by the quantity of water pumped (cubic ft.), and by the density of water (62.4 lb. per cubic ft.)

E_p = the energy content per unit of fuel used multiplied by the quantity of fuel used

The overall pumping efficiency can be further broken down into the efficiency of the power unit (be it diesel, gas, etc.) in converting chemical (or electrical in the case of an electric motor) energy to mechanical energy, and the pump efficiency (the work done, W_p, divided by the mechanical energy input to the pump).

$$Eff_{pump,i} = n_{pu} \times n_p \qquad (8)$$

where:

n_{pu} = efficiency of the power unit

n_p = pump efficiency

Results of a study by Hanson (1955) indicated that there was a wide variation in overall efficiencies for all energy sources. He attributed the range of efficiencies to mismatching of the pump to the well (oversizing of equipment), wear of the pump bowls, improper adjustment of the pump impellers, mismatching of the pump bowls to

the well conditions, improper carburetor settings on the internal combustion units, and improper regulation of the speed of the engine with respect to the pumping conditions. Average values for 17 electric, 10 natural gas, 7 diesel, and 12 LP gas units are listed in Table 3.

Other studies have been done which agree very closely with the overall pumping efficiencies listed by Hanson. These values are compared in Table 3. The Nebraska Pumping Plant Standards (Gilley and Watts, 1976) are also given in Table 3. These Standards represent a performance level that properly designed, selected, installed, adjusted, and operated units can be expected to obtain if pumps, engines or motors, and drives have average or above average efficiency. The Pumping Plant Standards can be exceeded if all components are above average in efficiency. The performance of 209 units was measured at an average of 75 per cent of the Nebraska Standards by Schluesener and Sulek (as reported in Gilley and Watts, 1976).

Since the results given in Hanson's thesis correlated so closely with the other test values listed, and were results from a test made in Kansas, it was assumed that the average pumping plant in Kansas operated at these efficiencies.

Table 3. Efficiencies of Pumping Plants

Data Source	Power Unit Efficiencies, per cent				Overall Efficiencies, per cent			
	Diesel	Nat. gas	LP gas	Electricity*	Diesel	Nat. gas	LP gas	Electricity*
Hanson (1955)	Only overall efficiencies listed				16.2	12.4	13.5	52.3
Dvoskin (1975)**	26.8	19.5	24.0	88.0	16.1	11.7	14.4	52.8
75 per cent of Nebraska Standards#	Not applicable				15.6	12.8	13.7	51.0
Nebraska Standards+	27.7	22.6	24.2	90.7	20.8	17.0	18.2	68.0

*Does not include the efficiency of conversion from fossil fuel to electricity.

**The overall efficiency as listed is equal to the power unit efficiency times a pump efficiency of 60 per cent.

#Tests in Nebraska showed the average pump operated at 75 per cent of the Nebraska Standards (Gilley and Watts, 1976).

+Taken from Gilley and Watts (1976), using 136,670 BTU per gal. of diesel fuel, 96,500 BTU per gal. of LP gas, and 3413 BTU per KWH for electricity. Overall efficiencies based upon a 75 per cent pump efficiency.

Irrigation Efficiency

Irrigation efficiency is defined as the percentage of irrigation water applied that is available for consumptive use by the crop. Consumptive use includes water used by the crop and water evaporated from crop foliage and from adjacent soil (Soil Conservation Service, 1970). If the applied water is measured at the field, the efficiency is called field irrigation efficiency. If the applied water is measured at the farm headgate, the efficiency is termed farm irrigation efficiency. Farm irrigation efficiencies vary between installations with the condition of the land and water transmission lines, the type of system used, the condition of the irrigation system, and the amount and rate of application.

Typical farm irrigation efficiencies are listed in the Kansas Irrigation Guide (Soil Conservation Service, 1975). The range of farm irrigation efficiencies is shown in Table 4. The range for gravity systems was listed as being from 50 per cent for an average system with no treatment to 85 per cent for a system with tailwater recovery, proper land leveling, delivery pipeline, and proper drainage system. An average of 60 per cent was used for gravity systems (Gilley and Watts, 1976).

Sprinkler irrigation systems vary in irrigation efficiency due to variations in evaporation of the spray, evaporation from soil and plant surfaces, and various degrees of non-uniform distribution. If application rates exceed soil intake rates, surface runoff becomes a factor in reducing the irrigation efficiency. An average farm irrigation efficiency for sprinkler systems was assumed to be 75 per cent (Gilley and Watts, 1976).

Table 4. Farm Irrigation Efficiencies for Gravity Systems*

Efficiency	Condition of Irrigation System
50 per cent	The average efficiency for a system with no treatment.
60 per cent	Partial treatment such as land leveling, irrigation pipeline, etc.
70 per cent	Land leveling, delivery pipeline, and drainage system to design standards.
85 per cent	Tailwater recovery, system with proper land leveling, delivery pipeline, and drainage system.

*Reproduced from Kansas Irrigation Guide (Soil Conservation Service, 1975)

Water Requirements

The irrigation water requirements for a crop differ with locality and fluctuate from time to time. The temperature, precipitation, growing season, latitude, sunlight, and soil conditions, as well as other climatic variables, all affect the water requirements. The SCS (Soil Conservation Service) used the Blaney-Criddle formula to calculate water requirements for various crops. The Blaney-Criddle formula states the mean monthly temperature, the number of daylight hours, and a crop consumptive use coefficient determine the amount of water consumptively used by growing crops. The amount of water required for irrigation is the difference between the consumptive use during the growing season and the amount of water supplied by precipitation and moisture utilized that had previously been stored in

the crop's root zone. In order to predict the short term water requirements for a crop, the SCS related the crop consumptive use coefficient to two additional coefficients; a climatic coefficient that was directly related to the mean air temperature of the period of the growing season being analyzed, and a coefficient that reflected the growth stage of the crop (Soil Conservation Service, 1970).

The Kansas Irrigation Guide lists irrigation water requirements for various crops for six locations in Kansas. These values have been obtained by applying the modified Blaney-Criddle formula and incorporating weather data from the corresponding location. The irrigation requirements are listed as the net irrigation water requirement; the water need of the specified crop over and above rainfall if inadequate water is not to limit crop growth and yields at any time during the growing season. Of course, the amount of precipitation will directly affect the irrigation water requirements. Therefore, the Guide lists net irrigation water requirements for average years (these net water applications would be sufficient or overly sufficient five years out of ten) and for dry years (these net water applications would be sufficient or overly sufficient eight years out of ten).

For this study, the state of Kansas was divided into nine districts while the Guide gives water requirements for six locations. Therefore, some judgement had to be made as to what water requirements should pertain to each district. The arrangement shown in Figure 2 seemed the most appropriate.

Not all nine crops used in this study were listed in the Guide. Again, a judgement had to be made. The values given for corn were used for both corn grain and corn silage. The values for sorghum were used for both

District No.	District	Values Used
1	Northwest	Water requirements listed for Colby
2	West central	Average of Colby and Garden City water requirements
3	Southwest	Garden City water requirements
4	North central	Concordia water requirements
5	Central	Average of Concordia and Hutchinson water requirements
6	South central	Hutchinson water requirements
7	Northeast	Topeka water requirements
8	East central	Topeka water requirements
9	Southeast	Columbus water requirements

Figure 2. The SCS Water Requirement Locations Used to Represent District Water Requirements.

sorghum grain and sorghum silage. Where they were not listed, irrigation water requirements for soybeans and dry beans were assumed to be the same as the water requirements for sorghum. The normal year water requirements are shown in Table 5.

Acres Irrigated

Perhaps the most uncertain of all variables involved in the calculation of energy use in irrigation was the number of acres irrigated. This was brought out in the contrasting values obtained from two independent sources of data on irrigated acres. The first source for irrigated acreage was the 1975 Kansas Irrigation Survey (Hay, 1975). This survey indicated a total of 3,033,101 acres of land were available for irrigation in Kansas. A survey by the Agricultural Stabilization and Conservation Service (ASCS) conducted during the same time period (January, 1976) indicated that 2,954,904 acres were under irrigation. The United States Department of Agriculture Statistical Reporting Service (SRS) estimated there were 2,912,400 acres available for irrigation in January, 1976. However, these are actually not three individual studies. From personal communication with the ASCS state office and with DeLynn Hay, who put out the 1975 Kansas Irrigation Survey, it was apparent that many of the county agents colaborated with the county ASCS offices in getting the number of acres irrigated in their county. The SRS stated in their report "This estimate is based on surveys conducted by this office and by the Kansas Extension Service". The survey mentioned would be the 1975 Kansas Irrigation Survey, which is shown in Appendix J.

Table 5. Normal Year Water Requirements.

WATER REQUIREMENTS FOR VARIOUS CROPS IN KANSAS, VALUES GIVEN IN INCHES PER YEAR

DISTRICT	ALFALFA	CORN	SORGHUM	WHEAT	BEETS	BEANS	SOYBEANS
NORTHWEST	20.8	15.1	11.0	8.9	15.6	11.0	11.0
WEST CENTRAL	21.6	15.5	11.5	9.7	16.4	11.5	11.5
SOUTHWEST	22.5	16.0	11.9	10.4	17.1	11.9	11.9
NORTH CENTRAL	17.0	11.3	8.7	6.1	0.0	0.0	8.7
CENTRAL	18.1	11.5	8.7	6.7	0.0	0.0	8.9
SOUTH CENTRAL	19.1	11.9	8.8	7.3	0.0	0.0	9.1
NORTHEAST	15.0	7.5	5.1	3.2	0.0	0.0	5.9
EAST CENTRAL	15.0	7.5	5.1	3.2	0.0	0.0	5.9
SOUTHEAST	11.6	7.5	5.5	0.0	0.0	0.0	6.0

The second independent source for the number of acres irrigated was the Statistical Reporting Service Crop Reports (Kansas State Board of Agriculture, 1976). For the purposes of this study, it was desirable to have the acres irrigated divided into acres of specific crops irrigated. The SRS publishes crop reports for the individual crops throughout the year as they obtain their data. The yearly summary for all crops is then published in the Farm Facts booklet. Irrigated acreages are given for each of three crops; corn grain, grain sorghum, and wheat. These acreages are divided into acres irrigated per county. Counties are lumped together to form nine districts in Kansas. These are the districts that have been used in this report. The SRS does not list the number of acres irrigated for crops other than the three mentioned earlier. A quick check from the 1975-76 Farm Facts booklet indicated the three crops accounted for 1,915,700 acres of irrigation, or only 63 per cent of the acreage available for irrigation as given by the Kansas Irrigation Survey. Part of the discrepancy was due to the fact that the Survey includes some land available for irrigation that is not irrigated every year. However, that type of land would not account for the 37 per cent discrepancy.

If all crops were included in the estimates of acres irrigated, the acreage would undoubtedly more nearly approach the Survey results. The five Crops and Soils Area Extension Specialists of Kansas State University were contacted and asked to make estimates for additional crops irrigated in their areas. Not all personnel felt comfortable in giving estimates for all counties in their area. Therefore, many county agents were also contacted.

It was safe to assume that all corn silage, sugar beets, edible dry beans, and soybeans grown in the western third of the state were irrigated. Other estimates for other crops were taken from the extension personnel (area and county extension). The final estimates based on 1975 data, considering nine crops, yielded a total of 2,328,775 acres under irrigation in Kansas, or 77 per cent of the Survey total.

As the SRS typically does not list acreage irrigated unless that acreage is 2000 acres per county, the irrigated acres grown for sorghum grain and corn grain did not show for some counties where undoubtedly some of these crops were irrigated (less than 2000 acres irrigated). Also, district totals shown in this report may not correspond to district totals shown in the SRS data for the three major irrigated crops, even though the SRS data were used exclusively in obtaining these numbers. This is due to the fact that the SRS included acreage for counties with less than 2000 acres irrigated in their district total, while this study did not include county data for the three major crops if it was not broken down by county in the SRS data.

It was felt that the true number of acres irrigated lies somewhere between the total obtained by adding up crops irrigated and the total reported in the Kansas Irrigation Survey. The SRS reports seem to be low particularly on the figures given for corn grain acreage under irrigation. In Edwards county, the SRS reported 17,300 acres of corn grain irrigated in 1976, while the county agent estimated 52,000 acres of that crop were irrigated. The county agent's estimate was for the 1977 crop, and indicated that irrigation was developing rapidly, but he was surprised at the low SRS figure. The SRS made its estimates from returns of questionnaires sent out to farmers.

It typically has sent out approximately 20,000 questionnaires (one to every four or five farmers) and has received 6000 to 8000 in return (Johnson, 1977).

The SRS irrigated acres listed for the three major crops were used for all counties; they were not modified in any way. Figures listed for other crops are estimates from the extension sources. The estimated acreage of nine crops irrigated is shown by districts in Table 6. The total of these nine crops is shown next to the 1975 Kansas Irrigation Survey total for irrigable acres. County by county figures are shown in Appendix D.

Breakdown of Energy Sources

In order to estimate the energy usage of the various fuels, the number of acres irrigated by each type of power source was needed. The most complete breakdown of this information was found in the 1975 Kansas Irrigation Survey shown in Appendix J. The number of units that operated on natural gas, diesel fuel, liquid propane (LP) gas, and electricity are given by county. Units powered by gasoline were not listed in the Survey. Sloggett (1976) estimated 22,400 acres were irrigated by gasoline pumps in Kansas in 1974. This was less than one per cent of his total estimation of irrigated acreage in Kansas.

As gasoline was found to be a relatively unimportant power source for irrigation in Kansas and a breakdown of gasoline units per county was not available, gasoline estimates have been omitted from this study.

It has been assumed that each pumping unit listed in the Survey irrigated the same number of acres. It has further been assumed that each unit pumped water from the average gross pumping depth of its county.

ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

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Table 6. District Estimates of Nine Crops Irrigated in Kansas.

DISTRICT	IRR WHEAT 1975 ACRES	IRR SORGHUM GRAIN 1975 ACRES	IRR CORN GRAIN 1975 ACRES	IRR BEETS 1975 ACRES	IRR BEANS 1975 ACRES	IRR CORN SILAGE 1975 ACRES	IRR SORGHUM SILAGE 1975 ACRES	IRR SOYBEANS 1975 ACRES	IRR ALFALFA HAY 1975 ACRES	TOTAL IRR ACRES	TOTAL IRR ACRES 1975 KS IRR SUR
NORTHWEST	14600.	13120.	170600.	21100.	9700.	26300.	13100.	900.	35300.	304720.	409417.
WEST CENTRAL	71900.	53800.	172600.	7350.	3300.	26100.	15530.	1500.	20100.	372180.	454000.
SOUTHWEST	313730.	225600.	525700.	14550.	0.	77700.	4000.	4300.	75500.	1241050.	1633594.
NORTH CENTRAL	1500.	10120.	75200.	0.	0.	0.	0.	0.	5000.	91820.	131186.
CENTRAL	5900.	39740.	25000.	0.	0.	5700.	0.	2500.	10700.	89540.	94329.
SOUTH CENTRAL	29900.	50040.	54200.	0.	0.	13350.	2900.	4090.	38100.	192580.	274920.
NORTHEAST	0.	0.	2500.	0.	0.	0.	0.	0.	3000.	5500.	9705.
EAST CENTRAL	0.	0.	5700.	0.	0.	1200.	775.	1900.	4000.	13575.	14410.
SOUTHEAST	0.	0.	0.	0.	0.	1350.	800.	3700.	1300.	7150.	11540.
STATE TOTAL	437500.	392420.	1031500.	43000.	13000.	151700.	37105.	18890.	193000.	2318115.	3033101.

Breakdown of Distribution Units

In order to determine the average pressure requirement for each county, and the average irrigation efficiency for each county, the breakdown into the number of acres irrigated by various distribution systems was desired. Again, the 1975 Kansas Irrigation Survey (Hay, 1975) was found to contain the most thorough data. The distribution systems were broken down into the following types: open ditch, gated pipe, center pivot, tow line and side roll, traveling big gun, and other sprinkler. The number of acres irrigated by each system was listed for each county. The open ditch and gated pipe were considered as gravity systems, while the remainder were classified as sprinkler systems.

Pressure Requirements

The average pressure requirement for a county was found by multiplying the pressure requirement for each system by the number of acres irrigated by that system, adding the results of the multiplications, and then dividing by the total number of acres irrigated in the county (equation 2). The pressure requirements shown in Table 7 were used. No additional pressure requirements were added to account for line losses in conveying the water from the pump to the distribution unit.

Table 7. Pressure Requirements for Various Distribution Systems*

System Type	Pressure Required, ft. of water	Pressure Required, psi
Open Ditch	0	0
Gated Pipe	20	9
Center Pivot	196	85
Tow Line and Side Roll	175	76
Traveling Big Gun	312	135
Other Sprinkler	160	69

*Source: Dvoskin, et. al., 1975

Promising Future Data Sources

Water Rights Data

The Division of Water Resources, Kansas State Board of Agriculture requires all water users (other than for domestic purposes) to acquire a water right. Questionaires have been sent by the Division to these water right holders on an annual basis since 1965. The records made from the returned questionaires included the annual volume and rates pumped, the number of acres irrigated, the depth to water for wells, the depth of the well and the acres harvested and yield for up to five crops.

These records would have been very useful had they been accurate and complete. "There is a great deal of variance in the completeness and accuracy of the data sent back by the respondents" (Kansas State Board of Agriculture, undated). Not all questionaires are returned.

In the future, these data should become more reliable, as those not reporting on their water use may lose their water right. At the time of this study, the rights were in numerical order on the computer tape, and were in the process of being sorted into county sets. With the number of rights in existance, the county format would have been essential in order for the rights to have been useful in a county by county study.

Remote Crop Sensing

As mentioned earlier, the acreage irrigated for all crops grown in Kansas was rather uncertain. One method of improving these estimates in the future may be by utilizing remote sensing data provided by the National Aeronautics and Space Administration. The Large Area Crop Inventory Experiment (LACIE) project was designed to estimate acreage for crops grown worldwide (MacDonald, 1976). Land Satellite (Landsat) imagery has been used successfully to identify crop types and to determine if these crops are irrigated. A study utilizing this imagery (Hoffman, et. al., 1976) found irrigated row crops easily distinguishable from dryland crops because the moisture stress and growing patterns were different. However, it was not found reliable to seperate the irrigated row crops into corn, beets, grain sorghum, etc. The study also found alfalfa hard to distinguish as irrigated or not irrigated due to the amount of rain received early in the growing season.

RESULTS AND DISCUSSION OF RESULTS

Estimates for 1975

Using 1975 crop estimates, the 1975 Kansas Irrigation Survey, 1975 net pumping depths, and normal year water requirements (after checking weather records, it was decided the normal year water requirements would represent the actual water requirements reasonably well), the estimate of the actual 1975 energy use in Kansas irrigation was calculated. It was estimated that 2,318,000 acres were irrigated, consuming $26,727 \times 10^9$ BTU. This was an average of 1.15×10^7 BTU per acre. The calculated district summaries of the 1975 usage are shown in Table 8. County by county results are given in Appendix D.

Energy and U.S. Agriculture, 1974 Data Base (Federal Energy Administration, 1976) reported $23,825 \times 10^9$ BTU were used for irrigation in Kansas in 1974. This number was generated by Sloggett (1976). The Kansas State Corporation Commission (1976) requires all rural electric companies to report the electrical use for irrigation by their customers. For the year 1975, this use was reported at 134,065,687 KWH. The estimated use reported for 1976 was found to be 225,836,363 KWH (Anschutz, 1977). The 1975 electrical use has been estimated at 232,000,000 KWH in this study. The numbers reported by the electric cooperatives should be the most accurate available. The estimate produced in this paper is very close to the 1976 Kansas Electrical Irrigation Survey number for statewide use. However, the usage does not agree very well between the two studies on a county by county basis.

The numbers produced by the computational technique used in this paper are only as good as the data provided, and the assumptions made. The 1975 electrical use figures produced in this study may have been higher than those reported in the Electrical Irrigation Survey for several reasons. It was assumed that each pump listed in the Kansas Irrigation Survey pumped the same quantity of water, from the same depth. In reality, the electric power units may have been used on more shallow wells, or pumps which did not irrigate as large an area as pumps powered by other sources. There also was some discrepancy between the Electrical Irrigation Survey and Kansas Irrigation Survey on the number of pumps. An example would be Steven's county, where the Kansas Irrigation Survey reported 46 electrical pumps, and the Electrical Irrigation Survey one pump. The computer analysis yielded an estimate of 11,915,000 KWH used, while the 1976 Electrical Irrigation Survey reported 24,400 KWH used in that county.

Table 8. District Summaries of 1975 Estimated Energy Usage.*

DISTRICT	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
NORTHWEST	166.	65.	231.	3804.	64.	5952.	479.8	3129.	1879.	476.	606.	168.	1879.	3501.	6276.	49270.
WEST CENTRAL	147.	30.	178.	4322.	61.	7064.	438.3	3006.	2438.	239.	194.	136.	2438.	1755.	2006.	39901.
SOUTHWEST	257.	53.	310.	14713.	63.	23248.	2520.9	18976.	17442.	898.	309.	327.	17442.	6605.	3198.	95749.
NORTH CENTRAL	40.	65.	105.	858.	65.	1329.	48.8	283.	45.	119.	99.	20.	45.	874.	1026.	5961.
CENTRAL	50.	70.	120.	797.	64.	1237.	51.8	269.	95.	46.	89.	39.	95.	341.	923.	11472.
SOUTH CENTRAL	50.	129.	179.	1870.	69.	2695.	168.9	974.	458.	275.	150.	90.	458.	2020.	1558.	26476.
NORTHEAST	50.	96.	146.	53.	66.	80.	4.1	13.	0.	6.	1.	5.	0.	46.	15.	1607.
EAST CENTRAL	50.	84.	134.	106.	64.	165.	7.7	41.	8.	14.	14.	5.	8.	103.	142.	1453.
SOUTHEAST	50.	232.	282.	43.	73.	60.	5.9	36.	0.	8.	27.	1.	0.	58.	281.	378.
STATE TOTAL	198.	57.	255.	26565.	64.	41829.	3726.1	26727.	22364.	2081.	1489.	793.	22364.	15302.	15425.	232267.

*An explanation of the column headings is shown on the following page.

Explanation of the Column Headings in Table 8.

Column	Column Heading	Explanation
1	District and County	The area that the values in columns 2 through 17 pertain to.
2	Net Pumping Depth, Ft.	The estimated average depth to water plus the drawdown.
3	Pressure Head, Ft.	The average pressure required at the pump, ft. of water.
4	Gross Pumping Depth, Ft.	The net pumping depth plus the pressure head.
5	Net Water Used, 100 Acre-Ft.	The amount of water that would have been required by the irrigated crops to meet their net water requirements.
6	Irrigation Efficiency, %	The average irrigation efficiency for all systems.
7	Gross Water Used, 100 Acre-Ft.	The net water used divided by the irrigation efficiency.
8	Net Energy Used, 1×10^9 BTU	The amount of energy required to lift the gross water used the net pumping depth and supply it at the required pressure head (assuming 100 per cent work efficiency).
9	Gross Energy Used 1×10^9 BTU	The net energy used divided by the average work efficiency.
10	Nat. Gas Used, 1×10^9 BTU	The amount of energy contained in the estimated natural gas used.
11	Diesel Fuel Used, 1×10^9 BTU	The amount of energy contained in the estimated diesel fuel used.
12	LP Gas Used, 1×10^9 BTU	The amount of energy contained in the estimated LP gas used.
13	Electricity Used, 1×10^9 BTU	The amount of energy contained in the estimated electricity used.
14	Nat. Gas Used, 1000 MCF	The estimated quantity of natural gas used.
15	Diesel Fuel Used, 1000 Gal.	The estimated quantity of diesel fuel used.
16	LP Gas Used, 1000 Gal.	The estimated quantity of LP gas used.
17	Electricity Used, 1000 KWH	The estimated quantity of electricity used.

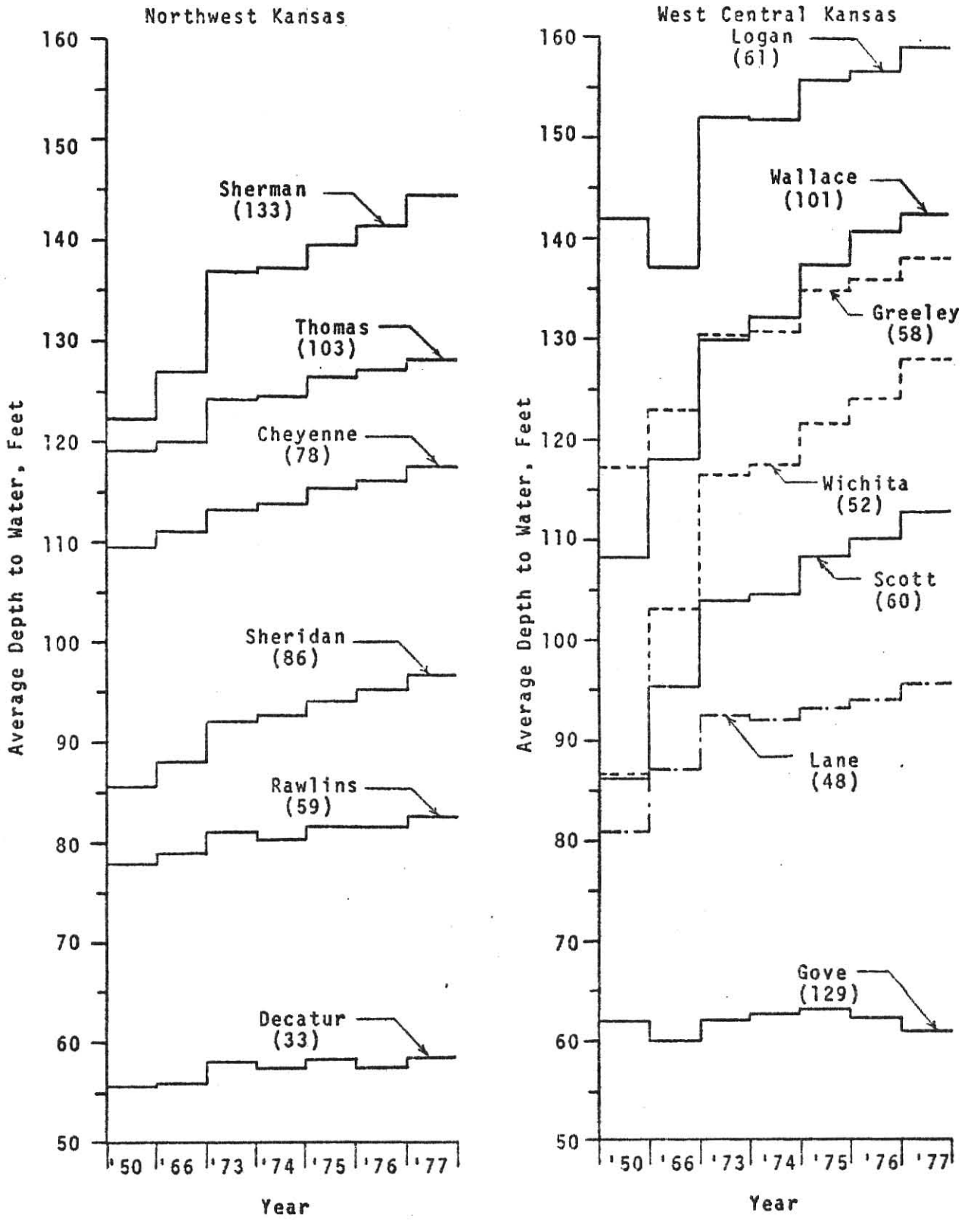
Analysis of Water Level Data

Depth to Water Data

The decline of the water table can be seen in the plots shown in Figures 3 and 4. The average depth to water for each of 24 western Kansas counties has been plotted for the base year, 1966, and 1973 through 1977. The values have been read from the computer printout as shown in Appendix B.

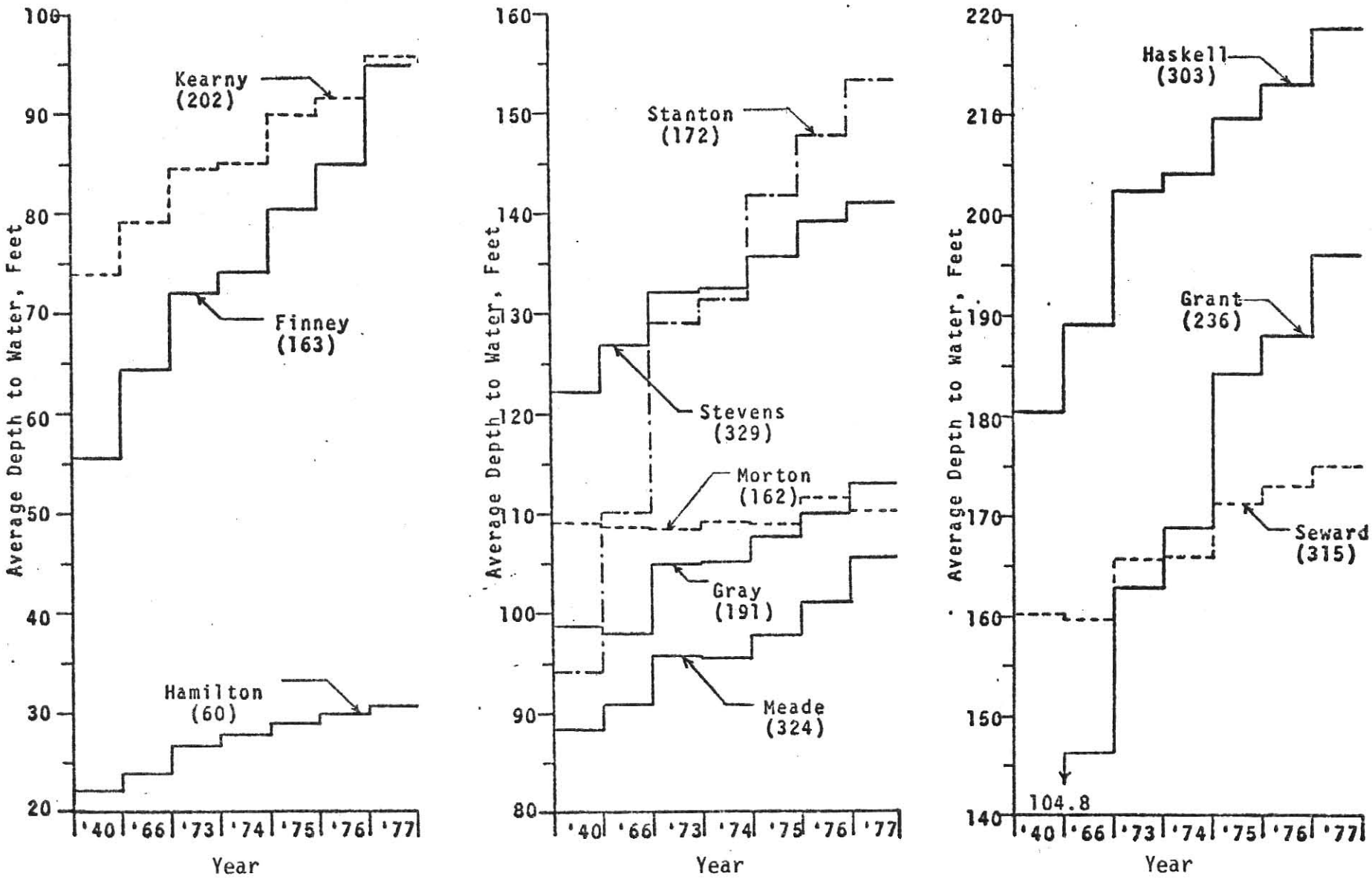
The numbers in parenthesis directly beneath the county names indicate the average remaining saturated thickness for that county, as of 1977. The water levels are averages obtained from analyzing records obtained from the United States Geological Survey. Only those records which were complete were included when calculating the averages. The USGS made water level measurements in January, when the effects of irrigation pumping should be minimal.

The results as shown for Logan and Gove counties in west central Kansas should be viewed cautiously as only one record was complete in each of those counties. Lane and Morton counties had only three and six complete records, respectively. The number of complete records ranged from 14 to 59 for the other counties. For a further analysis of the USGS records refer to Appendices A and B.



Numbers in parenthesis below county names indicate the average remaining saturated thickness as of Jan., 1977.

Figure 3. Average Depth to Water for 13 Northwest and West Central Kansas Counties for the Years 1950, 1966, and 1973 Through 1977.



Numbers in parenthesis below county names indicate the average remaining saturated thickness as of January, 1977.

Figure 4. Average Depth to Water for Eleven Southwest Kansas Counties for the Years 1940, 1966, and 1973

Increasing Energy Use Due to the Declining Water Table

The declining water table leads to an increase in the pumping depth and therefore an increase in energy usage. To determine the degree of effect the decline in the water table has had on the amount of energy used in irrigation in western Kansas, one program was run using the net pumping depth for the base year (1940 or 1950), and another program was run using the net pumping depth for the year 1977. All other data remained constant for the two runs. The net pumping depths were taken from the program where only complete records were read (Appendix B). This insured that the same wells were used in determining the water level for all years. It would be worth noting that since the net pumping depth was calculated as the depth to water plus one-half the saturated thickness, a one foot increase in the depth to water (a decline of one foot of the water table) would result in an increase of only one-half foot in the net pumping depth. Water level records were not available for Graham and Norton counties in the northwest district, Trego and Ness counties in the west central district, and Hodgeman, Ford, and Clark counties in the southwest district. It was assumed that the pumping depth for any one year for these counties was the same as the average pumping depth of the other counties in its district for that year. A district by district comparison of energy usage using the base year water levels and 1977 water levels is shown in Table 9. County results are shown in Appendices E and F.

The increase in energy usage due to the decline of the water table does not appear to have been significant on a yearly basis in the past.

However, the water level records show the water table has been declining more each year. The energy usage may increase several per cent each year in some areas due to the decline of the water table.

The energy use calculated as shown in Appendices E and F should not be compared with the 1975 estimates shown in Appendix D, as the pumping depths used in the 1975 estimates may not have been averages of the same wells.

Table 9. Comparison of Energy Usage Using the Base Year Water Levels and 1977 Water Levels.

District	Gross Energy Usage Using Base Year Pumping Depth, 1 x 10^9 BTU	Gross Energy Usage Using 1977 Pumping Depth, 1 x 10^9 BTU	Per cent Increase
Northwest	3,021	3,109	2.9
West Central	2,935	3,192	8.8
Southwest	17,779	18,881	6.2

Energy Savings Possible by Improving the Irrigation Efficiency

Irrigation efficiency has been defined as the percentage of irrigation water applied that is available for comsumptive use by the crop. The average farm irrigation efficiency was estimated at 60 per cent for the state for gravity systems. Some systems would operate at less than the average, while others that had improvements such as land leveling, delivery pipelines, and a drainage system with a tailwater recovery system would operate at an efficiency higher than the average. The achievable maximum efficiency was assumed to be 85 per cent for gravity systems with all of the improvements mentioned.

Increasing the gravity system (open ditch and gated pipe systems) farm irrigation efficiency from 60 per cent to 85 per cent on a statewide basis would save a considerable amount of the energy required to pump irrigation water, as well as a considerable amount of irrigation water, as Table 10 indicates.

Table 10. Comparison of Energy and Water Usage Using 60 per cent and 85 per cent Farm Irrigation Efficiency for Gravity Systems.*

Gross BTU Used, 60 per cent Efficiency	$26,727 \times 10^9$
Gross BTU Used, 85 per cent Efficiency	$20,500 \times 10^9$
Per cent Savings	23.3
Gross Water Used (acre-ft.), 60 per cent Efficiency	4,182,900
Gross Water Used (acre-ft.), 85 per cent Efficiency	3,218,700
Per cent Savings	23.3

*County by county results for 85 per cent efficiency shown in Appendix G.
County by county results for 60 per cent efficiency shown in Appendix D.

In order to obtain a high irrigation efficiency, it would also be essential to limit the application of water to the amount that can be stored in the root zone of the soil. Any additional water would be lost through deep percolation. Procedures which determine the time of irrigation and the amount of application are known as Irrigation Scheduling. This would require monitoring of the soil moisture at least once every week, and after every rainfall. This monitoring could be accomplished with the use of a soil probe or electrical resistance blocks

which determine soil moisture. A water balance would then be made. The amount of water removed from the root zone by evapotranspiration would be replenished by irrigation. Commercial scheduling services have developed computer programs to specify irrigation rates, using data provided by the soil monitoring. A study of 32 systems in southwest Nebraska revealed a savings of 12 per cent of the water pumped (and therefore energy used) would have been accomplished with irrigation scheduling (Watts, undated). It was found that some fields were under-irrigated, and would have received more water had they been scheduled, while some were greatly over-irrigated.

Most methods of irrigation scheduling rely on completely refilling the root zone each irrigation. This would not leave room for moisture should rainfall occur. A more efficient method than the ordinary irrigation scheduling has been developed for areas where several inches of precipitation falls during the growing season. This method has been termed Programmed Soil Moisture Depletion. The root zone is not completely refilled with each irrigation, allowing room for potential rainfall. Enough moisture is stored for the crop to draw upon when peak consumptive use exceeds the irrigation. The root zone is partially refilled by irrigation after the peak consumptive use period. Fischback (1975) listed the necessary requirements for this procedure to be effective.

1. The soil must be 5 ft. deep and hold 1.5 in. of water per ft. of depth.
2. A continuous water supply must be available.
3. The soil must be at field capacity to a 5 ft. depth at the start of the growing season.

4. Irrigation must be applied before the soil moisture deficit exceeds 2 in. in the root zone.

5. Soil moisture must be monitored.

6. A water meter and rain gauge are required to measure the amount of water applied.

An additional benefit of the Programmed Soil Moisture Depletion technique is the reduction in the amount of nitrate leaching. If the fertilizer isn't applied until late May or early June (corn crop), the nitrogen will be stored in the upper foot of soil, where the plant roots are located. The irrigation water won't percolate deeper than two feet until late in the irrigation season, when the crop will have utilized nearly all of the nitrogen. When over-irrigation occurs, water carries nitrogen with it below the root zone. For each inch of water that penetrates below the root zone, from five to 60 pounds of nitrogen per acre are lost. To produce one pound of nitrogen, 24.3 cubic feet of natural gas and 0.46 KWH of electricity are required. Heerman (as given in Gilley and Watts, 1976) reported an average deep percolation of 3.6 inches in eastern Colorado. If each inch carried an average of 15 pounds of nitrogen per acre, 1215 cubic feet of natural gas and 23 KWH of electricity would be lost per acre (Gilley and Watts, 1976). Nearly all of this energy could be saved by the Programmed Soil Moisture Depletion method. Data taken in Nebraska for the years 1971 through 1974 showed no reduction in yield when using this method (Fischback, 1975).

Automatic irrigation systems which can be set to deliver a constant flow of water for a specified time to an irrigation set have the

advantage of being able to deliver accurate quantities of water to a field. An automatic gated pipe system developed by Haise and Kruse (Fischback, 1975) obtained an application efficiency of 91 per cent. This system utilized a runoff reuse pond. The uniformity coefficient was 92 for the system. The uniformity coefficient, C_u, will be high (near 100 per cent) for effective, well designed irrigation systems with a high farm irrigation efficiency.

$$C_u = (1 - y/d) \times 100 \qquad (9)$$

where:

C_u = uniformity coefficient, per cent

y = the average of the absolute values of the deviations in depth of water stored

d = the average depth of water stored

The irrigation efficiency will not reach 100 per cent due to the fact that some water will be lost to evaporation and seepage, and due to the fact that a 100 per cent uniformity coefficient is not attainable. Although a runoff reuse system can significantly increase the irrigation efficiency, Schneider (1976) reported losses of up to 40 per cent of the runoff in the recovery process due to seepage and evaporation.

Increasing the irrigation efficiency conserves both water and energy. As these natural rescources become in short supply, it will become increasingly attractive to the irrigator to improve his irrigation efficiency. District summaries of energy usage in irrigation in Kansas assuming 85 per cent irrigation efficiency for gravity systems are shown in Table 11. All other data remained the same as the 1975 estimates shown in Appendix D.

Table 11. District Summaries of Energy Usage Using 85 per cent Irrigation Efficiency for Gravity Systems.

DISTRICT	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
NORTHWEST	166.	65.	231.	3804.	82.	4618.	373.4	2433.	1460.	367.	475.	132.	1460.	2695.	4919.	38556.
WEST CENTRAL	147.	31.	178.	4322.	84.	5135.	319.9	2187.	1760.	180.	145.	101.	1760.	1325.	1503.	29597.
SOUTHWEST	255.	54.	310.	14713.	83.	17781.	1923.8	14470.	13276.	698.	245.	251.	13276.	5134.	2537.	73670.
NORTH CENTRAL	40.	67.	107.	858.	82.	1049.	39.3	228.	36.	97.	78.	16.	36.	717.	809.	4748.
CENTRAL	50.	73.	123.	797.	82.	973.	41.8	217.	76.	39.	70.	32.	76.	288.	721.	9341.
SOUTH CENTRAL	50.	133.	183.	1870.	79.	2381.	152.5	885.	418.	252.	135.	79.	418.	1854.	1404.	23269.
NORTHEAST	50.	97.	147.	53.	81.	66.	3.4	11.	0.	5.	1.	5.	0.	38.	13.	1335.
EAST CENTRAL	50.	93.	143.	106.	82.	128.	6.4	34.	6.	13.	11.	4.	6.	96.	114.	1129.
SOUTHEAST	50.	241.	291.	43.	76.	57.	5.8	36.	0.	8.	27.	1.	0.	56.	280.	349.
STATE TOTAL	195.	60.	255.	26565.	83.	32187.	2866.2	20500.	17033.	1660.	1187.	621.	17033.	12203.	12300.	181993.

Energy Savings Possible By Improving the Overall Pumping Efficiency

If all pumps were brought up to the Nebraska Pumping Standards, the energy use would have been reduced from 26,727 x 10^9 BTU to 19,648 x 10^9 BTU in 1975, a savings of 26.5 per cent. District summaries for energy usage assuming Nebraska Standards are shown in Table 12. Complete results are shown in Appendix G.

The Nebraska Pumping Standards have generally been accepted throughout the United States. These Standards represent a practical performance level which can be obtained by a pumping unit in good condition and properly adjusted. The Nebraska Standards were obtained by multiplying the efficiency of the power source by a standard pump efficiency of 75 per cent.

The values listed by Hanson (1955) and used as the typical performance levels of pumps in Kansas are 78 per cent of the Nebraska Standards for diesel fuel, 74 per cent for propane, 73 per cent for natural gas, and 77 per cent for electricity.

Pumping plants require periodic adjustments and maintenance to perform at peak performance. Many irrigators will not hesitate to expect 10 years of performance from a pump without maintenance. Less than $100 will normally bring a power plant to the desired performance level when adjusted by a trained technician (Watts, undated).

Table 12. District Summaries of Energy Usage Using Nebraska Standards for Pumping Efficiency.

DISTRICT	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
NORTHWEST	166.	65.	231.	3804.	64.	5952.	479.8	2320.	1371.	371.	449.	129.	1371.	2726.	4655.	37895.
WEST CENTRAL	147.	30.	178.	4322.	61.	7064.	438.3	2212.	1778.	186.	144.	105.	1778.	1367.	1488.	30689.
SOUTHWEST	257.	53.	310.	14713.	63.	23248.	2520.9	13902.	12722.	700.	229.	251.	12722.	5144.	2372.	73642.
NORTH CENTRAL	40.	65.	105.	858.	65.	1329.	48.8	214.	32.	93.	73.	16.	32.	680.	761.	4585.
CENTRAL	50.	70.	120.	797.	64.	1237.	51.8	201.	69.	36.	66.	30.	69.	266.	685.	8823.
SOUTH CENTRAL	50.	129.	179.	1870.	69.	2695.	168.9	729.	334.	214.	112.	69.	334.	1573.	1156.	20363.
NORTHEAST	50.	96.	146.	53.	66.	80.	4.1	10.	0.	5.	1.	4.	0.	36.	11.	1236.
EAST CENTRAL	50.	84.	134.	106.	64.	165.	7.7	31.	6.	11.	10.	4.	6.	80.	105.	1118.
SOUTHEAST	50.	232.	282.	43.	73.	60.	5.9	27.	0.	6.	20.	1.	0.	45.	209.	291.
STATE TOTAL	198.	57.	255.	26565.	64.	41829.	3726.1	19648.	16313.	1621.	1104.	610.	16313.	11918.	11442.	178640.

Additional Energy Use in a Dry Year

The weather conditions have a great effect on the amount of water, and energy, used for irrigation. If the dry years water requirements (these net water applications would be sufficient or overly sufficient eight years out of ten) are used as opposed to normal year water requirements, the energy usage would increase from 26,727 x 10^9 BTU to 30,810 x 10^9 BTU. This increase would be 15.3 per cent. District summaries of energy usage usage assuming dry years water requirements are shown in Table 13. County by county results are shown in Appendix I. All other data remained the same as in the 1975 estimates.

Energy Savings Possible by Installing Reduced Pressure Systems

Calculation of energy savings due to introduction of reduced pressure center pivot sprinkler systems would require the number of acres irrigated by each of the different pressure levels of sprinklers for each county if a county by county analysis was desired. Not all systems in all counties would be adaptable to reduced pressure or low pressure sprinkler systems. While conventional systems operate at around 75 psi at the pivot, reduced pressure systems operate at approximately 60 psi, and low pressure systems operate at under 35 psi (Kramer, et. al., 1977). The lower the pressure, the less area is wetted by the sprinkler. Therefore, the application rate becomes greater. If this type of system is not used on soils with a high intake rate, runoff can become a problem.

The topography of the land also becomes crucial when considering low pressure systems. The relative difference in pressure in a system due to differences in elevation results in a nonuniform application rate.

Table 13. District Summaries of Energy Usage Using Dry Years Water Requirements.

DISTRICT	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
NORTHWEST	166.	65.	231.	4400.	64.	6885.	556.2	3621.	2175.	551.	701.	194.	2175.	4051.	7261.	56939.
WEST CENTRAL	147.	30.	173.	4991.	61.	8158.	506.1	3471.	2816.	275.	223.	157.	2816.	2025.	2314.	46047.
SOUTHWEST	257.	53.	310.	16894.	63.	26693.	2894.6	21789.	20030.	1031.	354.	375.	20030.	7575.	3666.	109906.
NORTH CENTRAL	40.	65.	105.	558.	65.	1545.	56.8	329.	52.	139.	115.	24.	52.	1020.	1193.	6915.
CENTRAL	50.	70.	120.	955.	64.	1483.	62.0	323.	113.	56.	107.	47.	113.	410.	1106.	13728.
SOUTH CENTRAL	50.	130.	180.	2224.	69.	3205.	201.1	1160.	544.	329.	179.	107.	544.	2421.	1860.	31386.
NORTHEAST	50.	96.	146.	66.	66.	102.	5.2	17.	0.	8.	2.	7.	0.	59.	20.	2062.
EAST CENTRAL	50.	84.	134.	137.	64.	214.	10.0	53.	10.	19.	18.	6.	10.	136.	185.	1855.
SOUTHEAST	50.	232.	282.	56.	72.	77.	7.5	47.	0.	10.	35.	2.	0.	74.	360.	501.
STATE TOTAL	197.	57.	254.	30722.	64.	48361.	4298.5	30810.	25740.	2417.	1734.	919.	25740.	17775.	17965.	269338.

Nonuniformity is present in all systems, but is magnified in low pressure systems. Kramer (1977) estimated reduced pressure nozzles could be installed on 41 per cent of the center pivot systems for a savings of 5.77 x 10^9 BTU, and low pressure nozzles would be applicable to 16 per cent of the center pivots in Kansas for a savings of 626 x 10^9 BTU. The combined savings possible would be 4.5 per cent of the 1975 estimated energy use.

Combined Energy Savings Techniques

In order to estimate the combined savings due to both improving the irrigation efficiency (gravity systems) from 60 per cent to 85 per cent and improving the pumping efficiency to meet Nebraska standards, the energy savings cannot merely be added. Increasing the irrigation effeciency alone would save 6,227 x 10^9 BTU and improving pumping efficiency alone would save 7,083 x 10^9 BTU, while together they would save 11,659 x 10^9 BTU.

Energy use would have 76.7 per cent of the 1975 estimated use if systems had had an irrigation efficiency of 85 per cent (gravity systems). Energy use would have been 73.5 per cent of the 1975 estimated use if Nebraska Pumping Standards had been met. If both criteria had been met, the estimated use would have been 0.767 x 0.735 x 100 = 56.4 per cent of the 1975 estimated use.

If the reduced pressure savings would have been included, the energy use would have been lowered to 0.973 x 0.564 x 100 = 54.9 per cent of the 1975 estimated usage for the state of Kansas. This means that if currently available technology were applied to all irrigation systems, an energy savings of approximately 45 per cent could be achieved for the

pumping of irrigation water. The amount of this savings which would be economically feasible to obtain has not been determined in this study.

Additional Calculations

Other calculations can be made using figures listed in the results. For example, the amount of electricity required should it be the only source of energy available could be calculated. Assuming 1975 conditions for all other data, the net energy use was estimated at 3726×10^9 BTU for the state (taken from Appendix D). This estimate would have been the energy use required had all pumping units been 100 per cent efficient. Electric pumping units were assumed to be 52.3 per cent efficient. The electric use would then have been:

$$\frac{3726 \times 10^9 \text{ BTU}}{0.523 \text{ (efficiency)}} \times \frac{1 \text{ KWH}}{3413 \text{ BTU}} = 2.09 \times 10^9 \text{ KWH.} \qquad (10)$$

Calculations of this could be made for any fuel, any county, or any district.

Estimated Energy Usage Assuming all Acreage is Irrigated

It was mentioned previously that the total acreage of crops irrigated obtained by adding the individual Statistical Reporting Service estimates for corn, wheat, and grain sorghum, and the extension personnel's estimates for six other crops did not equal the total acreage available for irrigation as listed in the Kansas Irrigation Survey. A computer run was made assuming all the acreage listed in the Survey was under irrigation. It was assumed that the ratio of each crop irrigated to the total acres irrigated for each county remained the same as in the SRS and extension

estimates. All other data remained the same as the 1975 estimates as shown in Appendix D. The estimated gross energy use was calculated at 35,563 x 10^9 BTU should all acres available for irrigation be irrigated.

Energy Use by Month

Water requirements were given on a month by month basis in the Kansas 1975 Irrigation Guide. Therefore, the monthly energy requirement by irrigation pumping could be calculated just as the yearly requirement was, only substituting monthly water requirement data for yearly water requirement data. All other data remained the same as the 1975 estimates as shown in Appendix D. The state totals of the results of these computer outputs are shown in graphical form in Figure 5. District and county values are not shown in this report.

Pre-irrigation (irrigation before planting) has not been considered by the Soil Conservation Service (1975) when calculating monthly water requirements for corn. Where this practice is common, the monthly water use and energy use would be altered to some extent. The total water use would not necessarily increase, as the net water requirement as calculated was equal to the water requirement of the crop minus any rainfall minus any moisture drawn out of the soil. In the western part of the state no stored soil moisture was assumed to be present at the start of the growing season. If a pre-irrigation were applied, the water use would be increased in the month of that irrigation, but would be decreased during the time the crop utilized that soil moisture.

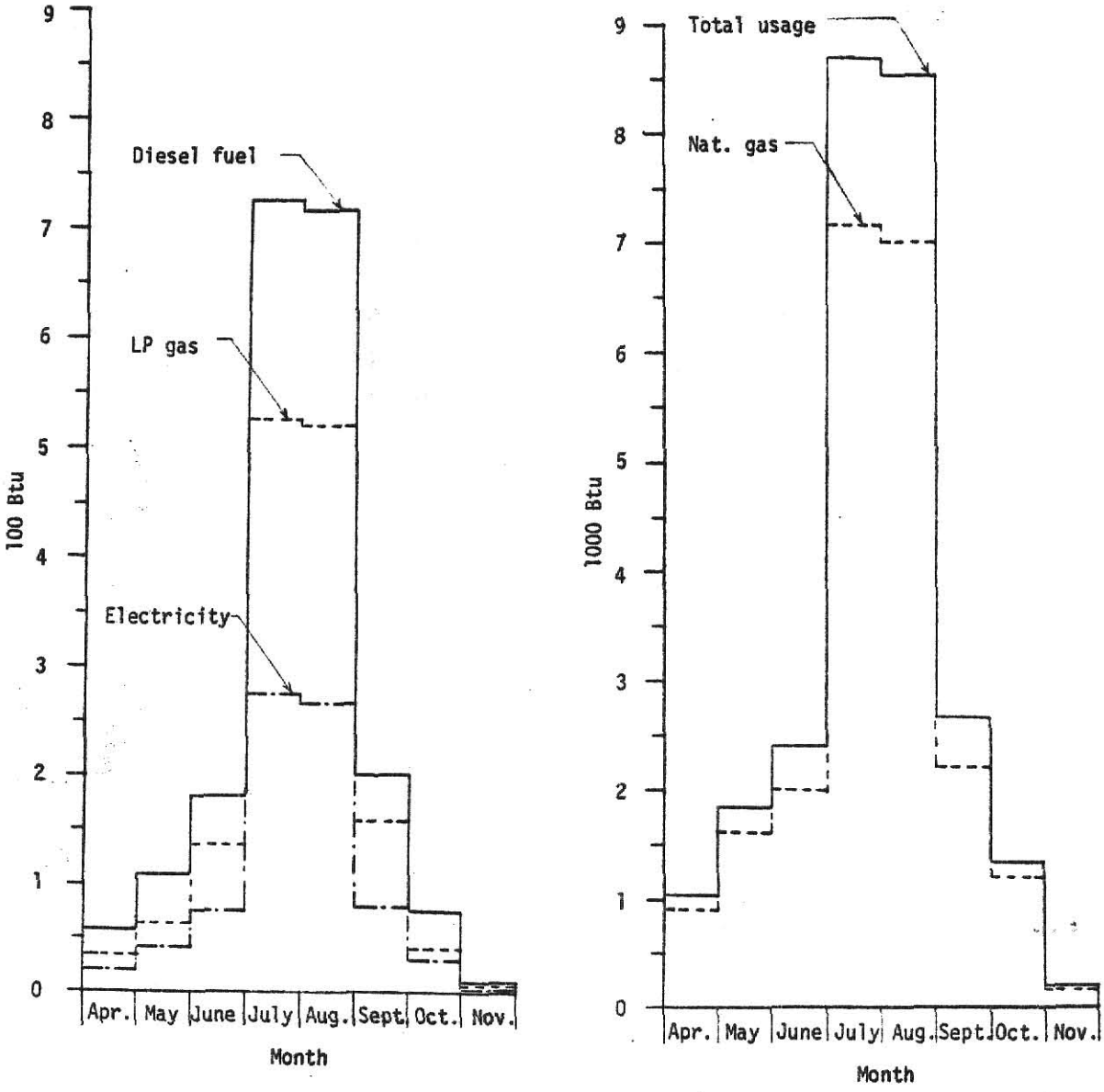


Figure 5. Statewide Energy Use Calculated by Month for 1975.

Guide to Using the Computer Program

As more current data become available, new estimates can be made for energy use by irrigation pumping. Other individuals may want to make additional case studies utilizing the program. For these reasons, a guide to using the computer program has been provided. The computer program itself is shown in Appendix C. Comment statements have been inserted in the program to aid in its use. The programming has been done in Watfiv.

I. Data cards. The following data were read into the program from data cards, in the following order.

   A. The 1975 Kansas Irrigation Survey. Read by an unformatted READ.

      1. One county per card. Enter the county number as an INTEGER (counties are numbered as shown in Table 1), followed by the county name (CHARACTER type), district number (districts are numbered as shown in Figure 1), and the 13 values reported in the Survey (entered in REAL type).

      2. Enter 105 cards, one for each of the 105 counties in Kansas.

   B. Crop acreage data. Unformatted READ. Read in subroutine CROPSS.

      1. The first card contains the crop identification which consists of five words of CHARACTER type of up to eight letters per word. Example: 'IRR' 'SORGHUM' 'GRAIN' '1975' 'ACRES'

      2. The second card contains the number of acres of that crop grown for each county in district one (the values are given in order of the county with the lowest county number to the county with the highest county number). REAL type.

      3. The third card contains an entry for the number of acres grown for each county in district two, . . ., the tenth card contains an entry for the number of acres grown for each county in district nine. These acreages can be very readily entered from SRS crop data.

      4. The eleventh card contains an entry for the acreage of the crop grown for each district, in the order of districts one through nine. The district totals will be generated in the program and will be written over the totals entered on the data cards, so it effectively does not matter what is entered on the eleventh card.

5. If N crops are read, enter N x 11 cards.

C. Crop water equirement data. Unformatted READ. Read in subroutine WATREQ.

1. The first card contains the names (CHARACTER type) of the N number of crops that you are listing water requirements for (up to eight characters per word, one word per name). The name of the crop must be exactly the same as the second word of the crop identification under part B, number one, if the values for acreage and water requirements are to be matched. However, the order of crops for which acreages are listed need not be the same as the order of crops for which water requirements are listed.

2. The next six cards contain the water requirements (REAL type) for districts one, three, four, six, seven, and nine, respectively. The water requirement values (in inches) for the crops must be in the same order as the crop names in part one. Each card will contain N number of entries. This number (N) must be equal to the number (N) of crops acreages were listed for under part B.

II. Other variables. Wherever stars appear on a comment card in the program, essential data values follow. These data values can be changed for purposes of case studies. The following data are listed in the program in that manner.

A. Overall pumping efficiencies.

B. Pumping depths for districts one through nine.

C. Pressure requirements for the different distribution systems.

D. Irrigation efficiencies for gravity and sprinkler systems.

E. Individual county pumping depths.

F. N, the number of crops listed under part I, B and C.

1. To change N, the number of crops read, the dimensions of the following arrays will also have to be changed. If N crops are read, dimension as follows. CROPS(N), CROP(5,N+2), WATER(9,N), A(105,N+1), DIS(10,N+1).

2. Also change the data statements as follows.
DATA (CROP(I,N+1),I=1,5)/'TOTAL','IRR','ACRES',' ',' '/
DATA (CROP(I,N+2),I=1,5)/'TOTAL','IRR','ACRES','1975 KS','IRR SUR'/

III. Printing options. The subroutine CROPSS prints the crop data that it reads, unless its print section is removed. The subroutine WATREQ prints the water requirement data that it reads, unless its print section is removed. Refer to these subroutines for additional comments and locations of print routines.

SUMMARY

A computer model has been developed that will calculate energy use for irrigation in Kansas on a county by county basis. The model has been utilized to estimate energy use by four fuels for 1975. In addition, case studies have been made to determine the affect of various changes in the factors determining energy use. Energy savings possible by improving irrigation and pumping efficiencies have been calculated. Additional energy use due to a dry year has been calculated. The statewide energy use has been plotted on a monthly basis. The water levels for 24 western Kansas counties were plotted versus the years 1940 (or 1950), 1966, and 1973 through 1977. The affect of the decline of the water table on energy use was investigated.

Others may have additional case studies they would like to make in order to investigate the effects of an energy savings technique, or the effects of other changes in the factors determing energy use in irrigation. As more accurate and current data become available, more accurate and current estimates may be desired. For these reasons, the computer program has been listed in Appendix C, and a guide to using the program is contained in the body of the theses.

A summary of the 1975 estimated energy use for irrigation in Kansas is shown in Table 14, along with possible energy savings for various practices.

Table 14. Statewide Summary

1975 Estimated Use	
Water	4,183,000 acre-ft.
Energy	26,727 x 10^9 BTU
Natural gas	22,364 x 10^9 BTU
Diesel fuel	2,081 x 10^9 BTU
LP gas	1,489 x 10^9 BTU
Electricity	793 x 10^9 BTU
Estimated Savings Corresponding to Various Practices	
Increase Gravity System Efficiency to 85 per cent.	23 per cent
Bring Pumping Plants up to Nebraska Standards	27 per cent
Install Low Pressure or Reduced Pressure Sprinkler Systems Where Applicable	4.5 per cent
Implement All of the Above Practices	46 per cent

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Appendix A: Computer Program and Printout Analyzing All USGS Well Records for 24 Western Kansas Counties

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      $JOB            ,TIME=(,29),PAGES=25
      C     THIS PROGRAM CALCULATES THE DEPTH TO WATER VALUES FOR A PARTICULAR YEAR BY
      C     READING ALL RECORDS THAT HAVE AN ENTRY FOR DEPTH TO WATER FOR THAT YEAR,
      C     AND CALCULATES THE AVG. SAT THICKNESS FOR A PARTICULAR YEAR BY READING ALL
      C     RECORDS THAT HAVE AN ENTRY FOR BOTH DEPTH TO BEDROCK AND THE DEPTH TO
      C     WATER FOR THAT YEAR


1           INTEGER ZZ,Y,X,W,V,V1
2           CHARACTER*12 COUNTY(105)
3           CHARACTER*80 CARD(2)
4           INTEGER COUNTE(105)
5           DIMENSION D77(7,103),ST(7,103),USGS(7,24,9),  NUSGS(7,24,3), N(7),
           XN1(7),D77I(7),D772(103),ST2(103)
6           CHARACTER*13 DIST(3)
7           CHARACTER*12 C1
8           DATA DIST/'NORTHWEST','WEST CENTRAL','SOUTHWEST'/
9           DATA USGS/1512*0./,NUSGS/504*0/,D77/721*0./,ST/721*0./
      C     COUNTY CONTAINS THE COUNTY NAMES FOR THE 105 COUNTIES
      C     CARD IS A STORAGE FOR THE TWO CARDS READ FOR EACH WELL RECORD.
      C     SINCE 2 DIFFERENT FORMATS WERE USED IN THE USGS RECORDS, THE FORMAT OF THE
      C     DATA WAS UNKNOWN UNTIL THE COUNTY NUMBER WAS READ.  RATHER THAN READ THE
      C     DATA CARDS TWICE (ONCE TO FIND OUT THEIR FORMAT, ONCE TO READ THE DATA),
      C     THE CARDS WERE READ INTO THE CHARACTER FIELD CARD, AND THEN THE DATA WAS
      C     READ FROM THE CARD ARRAY (CORE-TO-CORE I/O).
      C     COUNTE CONTAINS THE REGION NO. FOR EACH COUNTY
      C     D77 IS A WORKING ARRAY, IT CONTAINS THE DEPTH TO WATER FOR THE 7 YEARS FOR
      C     UP TO 103 WELLS FOR A COUNTY.
      C     ST IS A WORKING ARRAY, IT CONTAINS THE SATURATED THICKNESS FOR THE 7 YEARS
      C     FOR UP TO 103 WELLS FOR A COUNTY.
      C     USGS CONTAINS THE FIRST 9 COLUMNS OF NUMERIC OUTPUT FOR THE 7 YEARS FOR
      C     THE 24 COUNTIES.
      C     NUSGS CONTAINS THE LAST 2 COLUMNS OF NUMERIC OUTPUT + THE COUNTY NO. FOR
      C     THE 7 YEARS FOR THE 24 COUNTIES.
      C     N AND N1 ARE ARRAYS THAT CONTAIN, FOR A PARTICULAR COUNTY, THE NUMBER OF
      C     RECORDS THAT CONTAINED A DEPTH TO WATER ENTRY FOR YEAR I, AND THE NUMBER
      C     OF RECORDS THAT CONTAINED DEPTHS BOTH TO WATER AND BEDROCK.
      C     D77I IS A WORKING ARRAY TO STORE THE 7 YEARS OF DEPTHS TO WATER FOR 1 WELL
      C     RECORD.
      C     D772 IS A WORKING ARRAY TO STORE UP TO 103 DEPTH RECORDS FOR 1 YEAR FOR 1
      C     COUNTY.
      C     ST2 IS A WORKING ARRAY TO STORE UP TO 103 SATURATED THICKNESS RECORDS FOR
      C     1 YEAR FOR 1 COUNTY.

      C     READ COUNTY NAME AND REGION.
10          DO 2 I=1,105
11          READ, M,C1,NR
12          COUNTY(M)=C1
13        2 COUNTE(M)=NR

14          ZZ=1
      C     SET M1=28.  THIS IS THE COUNTY NUMBER OF THE FIRST COUNTY READ IN THE DATA
15          M1=28
16        1 DO 11 I=1,7
17          N(I)=1
18       11 N1(I)=1
19          IF (M1.NE.28) GO TO 10
20          DO 13 I=1,7
21          N(I)=0
22       13 N1(I)=0
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      GO TO 5
   10 DO 12 I=1,7
      D77(I,N(I))=D77I(I)
      ST(I,N1(I))=DB-D77(I,N(I))
      IF (D77(I,N(I)).LT.1) N1(I)=N1(I)-1
      IF (D77(I,N(I)).LT.1) GO TO 4
      IF (DB.LT.1) N1(I)=N1(I)-1
    4 IF (D77(I,N(I)).LT.1) N(I)=N(I)-1
   12 CONTINUE
    5 READ (12,6000) CARD(1)
      READ (12,6000) CARD(2)
C     READ COUNTY NUMBER, DUMMY NUMBER  GREATER THAN 105 WAS SET AT END OF DATA
C     TO INDICATE END OF DATA SET.
      READ (CARD,2000) M
      IF (M.GT.105) GO TO 20
C     COUNTIES IN REGION 1 PLUS COUNTIES 32 AND 55 HAD A SLIGHTLY DIFFERENT
C     FORMAT ON THE DATA CARDS.
      IF (COUNTE(M).EQ.1) READ (CARD,1000) M,DB,(D77I(I),I=1,7)
      IF (COUNTE(M).EQ.1) GO TO 6
      IF (M.EQ.32) READ (CARD,1000) M,DB,(D77I(I),I=1,7)
      IF (M.EQ.32) GO TO 6
      IF (M.EQ.55) READ (CARD,1000) M,DB,(D77I(I),I=1,7)
      IF (M.EQ.55) GO TO 6
    7 READ (CARD,1002) M,DB,(D77I(I),I=1,7)
C     IF END OF DATA SET FOR THE COUNTY, EXIT FROM READ AND STORE LOOP.  THE
C     LAST RECORD READ WILL THEN BE THE FIRST RECORD FOR THE NEXT COUNTY.
    6 IF (M.NE.M1) GO TO 20
      DO 14 I=1,7
      N(I)=N(I)+1
   14 N1(I)=N1(I)+1
      GO TO 10
   20 DO 21 I=1,7
      DO 22 J=1,103
      D772(J)=D77(I,J)
   22 ST2(J)=ST(I,J)
      N2=N(I)
      N3=N1(I)
      CALL DEV (N2,D772,SDD77,D77AVG,D77MIN,D77MAX)
      CALL DEV(N3,ST2,SDST,STAVG,STMIN,STMAX)
   24 DPUMP=D77AVG+STAVG/2.
C     D77AVG CONTAINS THE AVG. DEPTH TO WATER.
      USGS(I,ZZ,1)=D77AVG
C     D77MAX CONTAINS THE MAX DEPTH TO WATER.
      USGS(I,ZZ,2)=D77MAX
C     D77MIN CONTAINS THE MIN DEPTH TO WATER.
      USGS(I,ZZ,3)=D77MIN
C     SDD77 CONTAINS THE COEFF. OF VARIATION OF THE DEPTH TO WATER.
      USGS(I,ZZ,4)=SDD77
C     STAVG CONTAINS THE AVG. SAT. THICKNESS.
      USGS(I,ZZ,5)=STAVG
C     STMAX CONTAINS THE MAX. SAT. THICKNESS.
      USGS(I,ZZ,6)=STMAX
C     STMIN CONTAINS THE MIN. SAT. THICKNESS.
      USGS(I,ZZ,7)=STMIN
C     SDST CONTAINS THE COEFF. OF VARIATION OF THE SAT. THICKNESS.
      USGS(I,ZZ,8)=SDST
C     DPUMP CONTAINS THE PUMPING DEPTH (AVG. DEPTH TO WATER + 1/2 THE AVG. SAT.
C     THICKNESS).
      USGS(I,ZZ,9)=DPUMP
      NUSGS(I,ZZ,1)=N(I)
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67          NUSGS(I,ZZ,3)=M1
68       21 NUSGS(I,ZZ,2)=N1(I)
      C     IF END OF DATA HAS BEEN REACHED, EXIT FROM LOOP.
69          IF (M.GT.105) GO TO 30
      C     SET M1=NEXT COUNTY.
70          M1=M
71          ZZ=ZZ+1
72          GO TO 1

      C     SORT AND PRINT THE CALCULATED VALUES
73       30 DO 31 L=1,7
74          IF (L.EQ.1) NYEAR1=1950
75          IF (L.EQ.1) NYEAR2=1940
76          IF (L.EQ.2) NYEAR1=NYEAR2=1966
77          IF (L.GT.2) NYEAR1=NYEAR2=L+1970
78          WRITE (6,4000) NYEAR1,NYEAR2
79          DO 40 I=1,3
80          WRITE (6,5000) DIST(I)
81          X=0
82          V1=0
83          DO 51 K=1,24
84          Y=106
85          DO 50 J=1,24
86          IF (COUNTE(NUSGS(1,J,3)).NE.I) GO TO 50
87          IF (NUSGS(1,J,3).LE.X) GO TO 50
88          IF (NUSGS(1,J,3).LT.Y) V=J
89          IF (NUSGS(1,J,3).LT.Y) Y=NUSGS(1,J,3)
90       50 CONTINUE
91          IF (V1.EQ.V) GO TO 51
92          WRITE (6,3000) COUNTY(V),(USGS(L,V,K),K=1,9),(NUSGS(L,V,K),K=1,2)
93          V1=V
94       51 X=Y
95       40 CONTINUE
96       31 CONTINUE
97          WRITE (6,8000)
98     1000 FORMAT (I3,34X,F3.0,4X,F3.0,1X,F6.2,8X,F6.2,1X,F6.2/17X,3(1X,F6.2))
            X)
99     1002 FORMAT (I3,34X,F3.0,4X,F3.0,4(1X,F6.3)/18X,F6.2,1X,F6.2)
100    2000 FORMAT (I3)
101    3000 FORMAT(' ',A12,F6.1,2F7.1,F8.1,F11.1,3F7.1,F9.1,I6,I8)
102    4000 FORMAT ('1RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WER
            1E FOR THE YEAR',I5/' RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR T
            2HE YEAR',I5/'0DISTRICT AND  AVG    MAX    MIN   COEFF OF    AVG
            3 MAX    MIN   COEFF OF   NET    ',          'NO OF   NO OF'/
            4                                                    ' COUNTY
            5  DEPTH  DEPTH  DEPTH  VARIATION   SAT    SAT    SAT   VARIATION P
            6UMP    ',          'USGS    SAT '/
            7                          '                TO     TO     TO    OF
            8 DEPTH   THICK- THICK- THICK-  OF SAT   DEPTH   ',          'DEPT
            9H   THICK-'/
            X    '              WATER  WATER  WATER  TO WATER    NESS   NESS
            1NESS   THICK-          ',          'RECORDS  NESS'/
            2                      '              FEET   FEET   FEET   PERCENT
            3    FEET   FEET   FEET   NESS, %  FEET    ',          'READ   REC
            4ORDS')
103    5000 FORMAT ('0',A13/)
104    6000 FORMAT (A80)
105    8000 FORMAT ('1')
106         STOP
107         END
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108         SUBROUTINE DEV(N,A,SD,MEAN,MIN,MAX)
      C     SUBROUTINE TO CALCULATE THE STANDARD DEVIATION OF AN ARRAY OF VALUES
      C     ENTER N, THE NUMBER OF VALUES
      C     ENTER A, THE ARRAY OF VALUES
      C     RETURNS SD, THE STANDARD DEVIATION AS A PERCENT OF THE MEAN (THE COEFFIC-
      C     IENT OF VARIATION).
      C     RETURNS MEAN, THE MEAN OF THE VALUES
      C     RETURNS MIN, MINIMUM VALUE, AND MAX, MAXIMUM VALUE
      C     THE MAXIMUM NUMBER OF VALUES, N, IS 103
109         REAL MEAN,MIN,MAX
110         DIMENSION A(103)
111         SUM=0.
112         MIN=A(1)
113         MAX=A(1)
114         DO 10 I=1,N
115         SUM=SUM+A(I)
116         IF (A(I).LT.MIN) MIN=A(I)
117         IF (A(I).GT.MAX) MAX=A(I)
118      10 CONTINUE
119         MEAN=SUM/N
120         SQ=0.
121         DO 20 I=1,N
122      20 SQ=SQ+(A(I)-MEAN)*(A(I)-MEAN)
123         SD=(SQ/(N-1))**0.5/MEAN*100.
124         RETURN
125         END

      $ENTRY
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RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1950
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1940

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	NO OF SAT THICK-NESS RECORDS
NORTHWEST											
CHEYENNE	132.2	235.0	6.0	54.8	88.4	180.0	2.0	60.5	176.4	56	56
DECATUR	59.5	133.0	7.0	77.3	38.3	101.0	14.0	51.7	78.7	38	37
RAWLINS	87.8	217.0	5.0	81.6	68.4	141.0	17.0	55.3	122.0	42	42
SHERIDAN	83.9	162.0	4.0	55.5	95.6	158.0	30.0	34.0	131.7	54	54
SHERMAN	120.9	183.0	5.0	29.4	154.2	240.0	46.0	20.1	198.0	92	92
THOMAS	114.1	182.0	11.0	32.4	111.8	179.0	20.0	29.5	170.1	66	64
WEST CENTRAL											
GOVE	95.2	117.0	62.0	22.1	75.8	128.0	48.0	42.5	133.1	5	5
GREELEY	118.5	196.0	31.0	27.6	70.6	139.0	8.0	45.7	153.8	35	35
LANE	85.2	121.0	51.0	21.3	54.9	87.0	7.0	31.0	112.7	23	23
LOGAN	107.5	148.0	45.0	35.6	80.0	134.0	17.0	53.2	147.5	6	6
SCOTT	79.4	145.0	5.0	42.8	88.9	183.0	24.0	43.2	123.8	85	85
WALLACE	114.6	216.0	65.0	29.7	131.2	302.0	10.0	54.7	180.2	50	49
WICHITA	85.9	140.0	21.0	22.3	88.9	141.0	14.0	32.1	130.3	92	91
SOUTHWEST											
FINNEY	56.1	117.0	6.0	48.8	248.0	464.0	6.0	50.3	180.1	93	93
GRANT	97.3	237.0	15.0	58.9	326.7	439.0	220.0	17.3	260.6	56	56
GRAY	88.5	167.0	6.0	44.9	188.9	396.0	18.0	49.0	182.9	53	53
HAMILTON	41.1	213.0	6.0	130.2	65.6	225.0	2.0	89.4	74.0	29	27
HASKELL	181.6	247.0	57.0	23.0	347.4	433.0	259.0	11.6	355.2	54	54
KEARNY	73.2	223.0	5.0	86.0	236.8	383.0	25.0	52.6	191.6	35	35
MEADE	95.6	191.0	6.0	65.3	341.6	484.0	116.0	22.7	266.4	34	34
MORTON	94.3	179.0	27.0	42.5	126.6	262.0	20.0	56.2	157.7	18	14
SEWARD	146.9	213.0	5.0	41.3	346.0	559.0	235.0	25.8	319.8	30	30
STANTON	96.8	199.0	42.0	44.1	248.7	387.0	9.0	43.8	221.1	29	29
STEVENS	126.3	224.0	60.0	28.0	348.1	537.0	150.0	27.8	300.4	41	41

RECORDS FCR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1966
RECORDS FOR THE SOUTHWEST DISTRICT WERE FCR THE YEAR 1966

DISTRICT AND CCUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATICN OF DEPTH TO WATER PERCENT	AVG SAT THICK- NESS FEET	MAX SAT THICK- NESS FEET	MIN SAT THICK- NESS FEET	CCEFF OF VARIATION CF SAT THICK- NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	NO OF S.T THICK- NESS RECORDS
NORTHWEST											
CHEYENNE	132.0	235.2	5.4	56.1	84.7	179.4	2.1	62.7	174.3	54	54
DECATUR	58.3	135.1	7.4	78.6	36.0	88.4	6.9	46.7	76.3	37	36
RAWLINS	87.8	219.3	7.9	81.5	65.0	139.5	17.3	56.3	120.4	41	41
SHERIDAN	85.1	154.4	6.9	55.1	91.7	165.6	32.1	35.1	131.0	52	52
SHERMAN	124.9	201.3	6.2	29.8	151.3	235.4	45.4	20.8	200.5	84	84
THOMAS	113.3	187.7	5.1	34.1	110.3	173.1	25.9	28.7	168.5	63	63
WEST CENTRAL											
GOVE	64.3	94.1	11.2	60.2	76.4	130.0	31.8	54.9	102.5	4	4
GREELEY	127.4	198.5	73.0	27.1	65.0	126.3	10.0	46.8	159.9	18	18
LANE	86.9	89.3	83.9	2.7	44.6	67.1	8.9	55.9	109.2	4	4
LOGAN	126.9	150.0	102.0	16.6	93.1	132.0	51.5	36.7	173.4	4	4
SCOTT	94.6	151.6	10.4	34.9	75.3	171.8	28.3	46.2	132.3	52	52
WALLACE	124.5	233.9	76.0	30.5	111.9	282.5	8.7	53.7	180.5	35	34
WICHITA	101.7	134.0	26.1	17.7	76.4	124.8	13.8	32.0	139.9	67	67
SOUTHWEST											
FINNEY	64.8	132.6	6.0	44.7	216.2	456.0	5.3	53.7	172.9	80	78
GRANT	139.2	253.6	65.5	37.4	285.7	419.0	184.4	17.8	282.0	58	53
GRAY	89.8	163.9	7.9	44.7	197.9	392.9	25.8	47.1	188.7	41	41
HAMILTON	76.4	240.4	5.4	93.4	58.4	221.3	7.8	91.5	105.5	43	31
HASKELL	192.3	263.0	60.1	22.6	335.1	429.0	255.9	12.6	359.9	46	46
KEARNY	80.9	237.0	7.2	86.0	214.4	381.0	31.2	58.1	188.1	34	30
MEADE	90.7	175.5	6.4	67.0	334.5	415.1	161.7	17.4	257.9	30	30
MORTON	97.6	183.1	18.0	45.7	123.5	274.0	43.6	61.6	159.4	28	13
SEWARD	150.2	222.8	5.7	40.7	338.6	578.4	234.6	29.1	319.5	25	25
STANTON	133.4	236.5	48.6	37.7	230.1	368.9	8.9	44.4	248.4	45	29
STEVENS	132.8	236.4	55.6	31.1	330.4	529.0	138.5	31.3	297.9	36	36

RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1973
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1973

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	NO OF S.T THICK-NESS RECORDS
NORTHWEST											
CHEYENNE	131.1	236.7	5.3	58.5	82.0	177.4	1.8	65.1	172.1	50	50
DECATUR	60.3	133.5	10.7	74.3	34.0	83.3	5.3	50.8	77.3	37	36
RAWLINS	90.0	218.5	11.2	78.8	62.9	138.4	14.2	58.8	121.4	41	41
SHERIDAN	91.4	157.5	6.6	52.6	90.7	162.5	30.8	33.0	136.8	52	52
SHERMAN	138.2	202.3	16.2	22.7	142.0	224.4	45.8	23.1	209.1	71	71
THOMAS	117.3	191.1	8.8	33.9	104.3	166.6	22.2	31.4	169.5	50	49
WEST CENTRAL											
GOVE	82.2	120.0	10.9	49.0	67.5	127.8	32.1	50.9	115.9	6	6
GREELEY	128.7	190.5	35.5	25.4	56.8	115.5	14.4	47.2	157.1	24	24
LANE	90.3	121.4	51.7	20.7	44.7	80.7	9.0	40.0	112.6	15	15
LOGAN	108.8	161.1	46.7	41.3	61.8	120.9	12.5	72.0	139.8	6	6
SCOTT	98.8	158.1	8.1	35.3	67.3	165.1	24.1	52.1	132.5	69	68
WALLACE	135.4	237.4	81.2	25.9	101.6	283.1	2.9	63.6	186.2	41	40
WICHITA	111.3	142.2	34.7	21.0	63.0	112.0	13.7	33.8	142.8	90	89
SOUTHWEST											
FINNEY	71.1	136.8	6.9	43.1	192.8	427.9	3.8	53.9	167.5	70	68
GRANT	155.2	266.1	36.7	31.3	272.3	398.7	173.3	18.7	291.3	57	51
GRAY	89.9	166.0	6.8	46.3	186.7	386.1	26.4	48.4	183.3	47	47
HAMILTON	81.8	264.4	7.6	90.2	56.1	215.8	7.2	94.9	109.8	42	29
HASKELL	200.6	285.3	71.4	24.5	324.4	420.2	244.6	12.6	362.8	48	48
KEARNY	79.0	249.0	10.1	89.0	207.3	376.9	19.9	61.7	182.7	33	29
MEADE	95.1	179.9	6.3	66.4	333.5	414.1	161.5	17.4	261.8	28	28
MORTON	106.2	176.7	18.1	46.3	122.4	274.7	27.0	65.8	167.4	26	13
SEWARD	168.7	231.6	8.7	30.8	326.8	573.9	226.1	31.8	332.1	22	22
STANTON	139.6	248.3	56.4	32.9	204.5	346.2	10.6	47.2	241.9	36	27
STEVENS	132.6	246.5	56.3	32.2	340.4	528.4	121.7	31.7	302.8	36	36

RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1974
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1974

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	NO OF SAT THICK-NESS RECORDS
NORTHWEST											
CHEYENNE	130.2	236.9	5.6	59.3	79.4	177.8	1.2	67.1	169.9	49	49
DECATUR	58.9	135.7	8.4	77.4	33.3	85.0	3.9	49.0	75.6	34	33
RAWLINS	87.8	218.7	10.5	82.3	63.8	138.0	17.0	58.4	119.7	38	38
SHERIDAN	94.4	157.3	6.8	50.4	89.6	162.7	30.9	33.3	139.2	52	52
SHERMAN	136.7	203.2	6.5	25.3	140.0	224.1	51.8	21.1	206.7	73	73
THOMAS	120.8	188.0	8.3	29.2	105.4	165.9	22.7	30.6	173.5	53	53
WEST CENTRAL											
GOVE	82.5	120.8	11.0	48.9	67.2	127.3	32.0	50.9	116.1	6	6
GREELEY	127.7	190.8	34.0	25.7	57.8	114.5	14.0	45.3	156.6	23	23
LANE	93.4	121.6	61.0	17.7	47.8	80.7	14.9	33.5	117.3	13	13
LOGAN	108.9	160.9	46.4	41.3	61.7	121.1	12.8	71.9	139.8	6	6
SCOTT	99.3	159.3	8.4	34.7	66.2	159.6	23.9	48.8	132.4	62	61
WALLACE	131.8	239.2	38.0	26.2	103.0	284.5	1.2	64.0	183.3	37	37
WICHITA	113.3	143.1	34.8	19.8	61.3	99.2	13.8	33.9	144.0	87	86
SOUTHWEST											
FINNEY	75.8	170.0	7.4	40.2	224.8	446.2	4.0	55.1	188.2	90	87
GRANT	165.2	272.1	38.2	29.6	264.9	387.0	179.7	18.6	297.6	57	50
GRAY	95.8	178.4	5.3	44.6	186.5	386.0	28.2	49.1	189.1	47	47
HAMILTON	81.4	263.2	7.5	94.0	51.1	216.8	6.8	92.7	106.9	43	31
HASKELL	204.4	288.4	73.8	24.2	321.6	415.5	242.2	12.6	365.2	51	51
KEARNY	82.5	244.3	10.2	87.1	158.2	351.5	19.8	63.7	181.6	34	30
MEADE	98.0	180.7	4.9	64.1	330.2	414.1	161.0	17.8	263.1	27	27
MORTON	111.2	178.4	18.8	42.5	120.3	274.7	31.2	73.6	171.3	24	11
SEWARD	161.2	237.0	7.1	36.8	331.6	576.6	225.0	30.9	327.0	24	24
STANTON	151.1	253.2	58.0	32.1	205.7	343.8	10.7	47.0	253.9	42	26
STEVENS	133.6	247.8	56.3	32.3	343.2	528.6	120.4	30.4	305.2	36	36

RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1975
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1975 .

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	NO OF SAT THICK-NESS RECORDS
NORTHWEST											
CHEYENNE	136.3	244.1	5.6	57.2	78.4	177.4	0.9	66.7	175.5	52	52
DECATUR	61.5	137.1	10.9	77.3	33.4	89.1	1.8	53.9	78.1	34	33
RAWLINS	89.5	203.8	10.9	77.7	63.0	137.3	20.2	58.5	121.1	39	39
SHERIDAN	96.2	157.5	7.3	50.4	87.8	162.5	30.4	33.6	140.2	52	52
SHERMAN	136.8	204.5	7.5	27.3	140.9	222.0	49.3	20.5	207.2	87	87
THOMAS	122.3	191.4	8.9	33.2	104.6	164.5	22.0	29.0	174.6	60	59
WEST CENTRAL											
GOVE	81.9	121.7	11.2	45.1	66.3	126.9	31.8	47.0	115.1	7	7
GREELEY	134.0	194.5	36.8	25.2	52.6	112.2	9.5	52.3	160.3	23	23
LANE	91.9	122.8	56.9	19.7	43.1	79.4	7.8	41.6	113.5	15	15
LOGAN	97.1	165.4	10.5	54.3	57.5	116.6	12.9	69.6	125.9	8	8
SCOTT	102.9	161.3	12.0	33.1	64.9	162.5	23.5	52.5	135.4	63	61
WALLACE	137.2	246.9	81.4	24.1	99.6	277.3	1.1	67.1	187.0	36	35
WICHITA	116.1	145.7	35.0	21.7	58.1	102.1	11.4	36.2	145.1	80	79
SOUTHWEST											
FINNEY	80.6	171.5	6.4	39.5	224.0	441.1	3.7	54.2	192.6	88	85
GRANT	181.3	277.6	42.7	25.4	244.1	366.3	143.4	21.2	303.4	58	51
GRAY	97.9	167.3	7.4	41.7	181.6	384.1	27.6	48.7	188.7	52	52
HAMILTON	85.6	267.2	8.0	88.9	55.0	209.4	7.2	90.3	113.0	43	30
HASKELL	212.1	296.3	75.4	24.4	317.2	416.3	240.6	12.5	370.7	53	53
KEARNY	87.5	257.1	12.0	82.1	205.3	375.5	18.0	62.1	190.2	36	33
MEADE	100.8	191.5	6.3	64.1	333.3	483.6	124.3	22.5	267.5	35	35
MORTON	109.1	188.6	21.6	45.9	110.9	275.3	20.4	72.8	164.6	30	15
SEWARD	156.1	222.1	7.1	40.5	339.5	575.2	222.4	29.9	325.9	25	25
STANTON	149.9	238.5	61.4	30.5	205.1	299.5	8.1	41.9	252.4	36	25
STEVENS	141.1	257.0	56.9	31.2	335.7	536.8	114.9	32.4	309.0	36	36

RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1976
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1976

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	NO OF SAT THICK-NESS RECORDS
NORTHWEST											
CHEYENNE	133.3	247.1	5.7	58.9	81.6	176.8	0.7	63.2	174.2	49	49
DECATUR	65.5	138.4	9.3	72.8	37.2	87.6	4.3	49.2	84.0	30	29
RAWLINS	92.8	218.4	9.1	79.6	61.5	135.7	20.1	54.6	123.5	33	33
SHERIDAN	95.1	158.1	7.2	52.7	86.6	161.9	31.9	32.6	138.4	53	53
SHERMAN	141.1	205.1	16.2	23.4	137.7	219.2	51.8	21.6	209.9	82	82
THOMAS	124.6	188.3	9.4	29.2	106.8	168.6	21.6	27.3	178.0	58	57
WEST CENTRAL											
GOVE	80.6	125.1	9.3	52.2	67.4	127.6	33.7	50.9	114.3	6	6
GREELEY	136.4	194.4	38.5	24.2	52.8	109.6	10.2	51.9	162.8	24	24
LANE	93.0	122.8	63.5	18.4	42.0	78.5	7.9	42.7	114.0	15	15
LOGAN	82.3	156.6	11.5	61.7	48.5	98.9	13.1	79.1	106.6	6	6
SCOTT	103.8	156.4	11.2	33.0	63.3	159.8	20.7	54.9	135.5	64	62
WALLACE	142.2	246.9	38.0	26.8	95.0	274.0	2.3	73.4	189.7	42	41
WICHITA	118.7	150.7	35.2	22.0	57.7	99.5	9.0	35.5	147.5	80	79
SOUTHWEST											
FINNEY	84.8	173.5	8.6	36.9	217.4	439.7	2.9	58.6	193.5	89	81
GRANT	185.2	277.9	44.1	26.2	239.9	341.7	131.1	21.7	305.2	58	52
GRAY	102.4	169.4	8.1	39.2	179.6	381.9	27.0	49.7	192.2	50	50
HAMILTON	86.4	279.1	8.3	88.6	52.8	202.2	6.7	90.8	112.8	44	31
HASKELL	213.3	302.5	78.1	24.6	312.5	412.7	237.9	13.2	369.5	49	49
KEARNY	87.4	255.0	11.3	78.5	215.9	373.5	18.7	59.0	195.4	39	36
MEADE	102.1	194.3	6.4	63.5	328.8	483.5	122.8	22.9	266.5	34	34
MORTON	109.7	201.7	22.6	48.6	118.7	271.7	13.3	69.5	169.1	26	13
SEWARD	158.1	237.8	7.2	40.4	338.1	570.4	221.3	29.6	327.1	28	28
STANTON	157.1	252.2	62.7	30.1	191.8	328.2	11.0	46.3	253.0	38	26
STEVENS	144.2	253.9	58.5	31.3	328.9	530.8	106.8	31.6	308.6	33	33

RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1977
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1977

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	NO OF SAT THICK-NESS RECORDS
NORTHWEST											
CHEYENNE	140.0	243.9	6.8	55.8	82.0	174.1	2.4	62.2	181.0	48	48
DECATUR	58.8	139.1	11.2	77.6	34.2	86.9	6.8	52.8	75.9	35	34
RAWLINS	92.7	230.1	10.9	79.5	60.6	134.9	16.0	58.2	123.0	41	41
SHERIDAN	95.2	163.8	7.6	54.3	85.2	157.2	30.0	33.4	137.8	52	52
SHERMAN	141.5	209.4	8.7	26.0	135.0	217.6	51.1	21.6	209.0	82	82
THOMAS	126.1	193.5	8.4	28.7	101.9	160.4	22.6	29.8	177.0	61	60
WEST CENTRAL											
GOVE	77.1	124.9	9.7	59.3	64.5	129.0	33.3	59.0	109.4	5	5
GREELEY	134.4	198.7	39.7	24.3	51.8	105.5	18.6	45.4	160.3	35	35
LANE	93.4	123.8	64.8	19.4	47.7	77.0	13.3	30.8	117.2	23	23
LOGAN	102.2	169.1	10.9	60.6	55.6	112.9	11.9	68.7	130.0	6	6
SCOTT	105.3	163.2	9.7	32.0	60.8	160.5	12.5	57.0	135.7	79	77
WALLACE	145.5	243.2	81.4	24.4	101.9	270.8	12.6	70.3	196.5	47	46
WICHITA	121.4	154.4	36.2	21.8	51.9	96.8	7.1	38.9	147.4	89	88
SOUTHWEST											
FINNEY	92.1	176.9	9.8	38.0	212.3	436.7	1.6	58.9	198.2	98	90
GRANT	193.6	284.2	47.1	25.1	230.2	339.3	115.1	23.1	308.7	59	51
GRAY	105.0	171.0	9.2	39.8	177.7	376.7	27.1	49.8	193.8	50	50
HAMILTON	74.5	272.1	9.5	103.6	55.0	206.4	11.1	87.2	102.0	36	29
HASKELL	223.7	309.0	80.3	23.1	303.6	408.4	235.7	12.7	375.5	51	51
KEARNY	90.9	255.8	12.5	75.1	211.7	371.1	17.5	59.5	196.7	40	36
MEADE	108.5	192.5	7.9	57.6	327.2	483.9	120.5	23.6	272.1	33	33
MORTON	113.1	202.0	20.7	46.5	107.6	270.4	13.0	75.6	166.9	30	15
SEWARD	163.4	236.9	7.4	39.3	330.3	551.4	218.4	27.9	328.5	27	26
STANTON	165.1	259.9	67.1	29.1	192.3	326.0	7.9	45.5	261.3	43	28
STEVENS	144.6	256.8	57.9	31.4	331.1	524.9	108.5	33.2	310.1	37	37

Appendix B: Computer Program and Printout Analyzing Only Complete USGS Well Records for 24 Western Kansas Counties

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$JOB          ,TIME=(,29),PAGES=25
C     THIS PROGRAM READS ONLY THE USGS RECORDS THAT HAVE AN ENTRY FOR THE DEPTH
C     TO BEDROCK PLUS AN ENTRY FOR DEPTH TO WATER FOR EVERY YEAR (1940 OR 1950,
C     1966, 1973, 1974, 1975, 1976, 1977).


      INTEGER ZZ,Y,X,W,V,V1
      CHARACTER*12 COUNTY(105)
      CHARACTER*80 CARD(2)
      INTEGER COUNTE(105)
      DIMENSION D77(7,103),ST(7,103),USGS(7,24,9),NUSGS(7,24,3),D77I(7),
     XD772(103),ST2(103)
      CHARACTER*13 DIST(3)
      CHARACTER*12 C1
      DATA DIST/'NORTHWEST','WEST CENTRAL','SOUTHWEST'/
      DATA USGS/1512*0./,NUSGS/504*0/,D77/721*0./,ST/721*0./
C     COUNTY CONTAINS THE COUNTY NAMES FOR THE 105 COUNTIES
C     CARD IS A STORAGE FOR THE TWO CARDS READ FOR EACH WELL RECORD.
C     SINCE 2 DIFFERENT FORMATS WERE USED IN THE USGS RECORDS, THE FORMAT OF THE
C     DATA WAS UNKNOWN UNTIL THE COUNTY NUMBER WAS READ.  RATHER THAN READ THE
C     DATA CARDS TWICE (ONCE TO FIND OUT THEIR FORMAT, ONCE TO READ THE DATA),
C     THE CARDS WERE READ INTO THE CHARACTER FIELD CARD, AND THEN THE DATA WAS
C     READ FROM THE CARD ARRAY (CORE-TO-CORE I/O).
C     COUNTE CONTAINS THE REGION NO. FOR EACH COUNTY
C     D77 IS A WORKING ARRAY, IT CONTAINS THE DEPTH TO WATER FOR THE 7 YEARS FOR
C     UP TO 103 WELLS FOR A COUNTY.
C     ST IS A WORKING ARRAY, IT CONTAINS THE SATURATED THICKNESS FOR THE 7 YEARS
C     FOR UP TO 103 WELLS FOR A COUNTY.
C     USGS CONTAINS THE FIRST 9 COLUMNS OF NUMERIC OUTPUT FOR THE 7 YEARS FOR
C     THE 24 COUNTIES.
C     NUSGS CONTAINS THE LAST 2 COLUMNS OF NUMERIC OUTPUT + THE COUNTY NO. FOR
C     THE 7 YEARS FOR THE 24 COUNTIES.
C     D77I IS A WORKING ARRAY TO STORE THE 7 YEARS OF DEPTHS TO WATER FOR 1 WELL
C     RECORD.
C     D772 IS A WORKING ARRAY TO STORE UP TO 103 DEPTH RECORDS FOR 1 YEAR FOR 1
C     COUNTY.
C     ST2 IS A WORKING ARRAY TO STORE UP TO 103 SATURATED THICKNESS RECORDS FOR
C     1 YEAR FOR 1 COUNTY.

C     READ COUNTY NAME AND REGION.
      DO 2 I=1,105
      READ, M,C1,NR
      COUNTY(M)=C1
    2 COUNTE(M)=NR

      ZZ=1
C     SET M1=28.  THIS IS THE COUNTY NUMBER OF THE FIRST COUNTY READ IN THE DATA
      M1=28
C     N=NO. OF COMPLETE RECORDS READ.  N1 IS THE TOTAL NO. OF RECORDS READ.
C     N=1 SINCE ONE CARD HAS BEEN READ FOR THAT COUNTY (EXCEPT FIRST COUNTY)
    1 N=1
      N1=1
      IF (M1.NE.28) GO TO 10
C     N=N1=0 FOR FIRST COUNTY SINCE NO CARDS HAVE YET BEEN READ.
      N=0
      N1=0
      GO TO 5

C     LINES 22-26 STORE 7 YEARS OF DATA, DEPTH TO WATER IN D77, SAT THICKNESS IN
C     ST.
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```
22      10 DO 12 I=1,7
23         D77(I,N)=D77I(I)
24         ST(I,N)=DB-D77(I,N)
     C     IF NO RECORD EXISTS FOR ANY YEAR, DECRIMENT NO. OF RECORDS READ.
25         IF (D77(I,N).LT.1) GO TO 4
26      12 CONTINUE

     C     IF NO RECORD EXISTS FOR DEPTH TO BEDROCK, DECRIMENT NO. OF RECORDS READ.
27         IF (DB.LT.1) N=N-1
28         GO TO 5
29       4 N=N-1
     C     READ THE TWO CARDS THAT REPRESENT THE DATA FOR 1 WELL, INTO CHARACTER
     C     FIELD.
30       5 READ (12,6000) CARD(1)
31         READ (12,6000) CARD(2)
     C     READ COUNTY NUMBER, DUMMY NUMBER  GREATER THAN 105 WAS SET AT END OF DATA
     C     TO INDICATE END OF DATA SET.
32         READ (CARD,2000) M
33         IF (M.GT.105) GO TO 20
     C     COUNTIES IN REGION 1 PLUS COUNTIES 32 AND 55 HAD A SLIGHTLY DIFFERENT
     C     FORMAT ON THE DATA CARDS.

     C     LINES 34-40 READ THE COUNTY NO., DEPTH TO BEDROCK, PLUS THE 7 WELL DEPTHS
     C     FOR ONE RECORD.
34         IF (COUNTE(M).EQ.1) READ (CARD,1000) M,DB,(D77I(I),I=1,7)
35         IF (COUNTE(M).EQ.1) GO TO 6
36         IF (M.EQ.32) READ (CARD,1000) M,DB,(D77I(I),I=1,7)
37         IF (M.EQ.32) GO TO 6
38         IF (M.EQ.55) READ (CARD,1000) M,DB,(D77I(I),I=1,7)
39         IF (M.EQ.55) GO TO 6
40       7 READ (CARD,1002) M,DB,(D77I(I),I=1,7)

     C     IF END OF DATA SET FOR THE COUNTY, EXIT FROM READ AND STORE LOOP.  THE
     C     LAST RECORD READ WILL THEN BE THE FIRST RECORD FOR THE NEXT COUNTY.
41       6 IF (M.NE.M1) GO TO 20
42         N=N+1
43         N1=N1+1
44         GO TO 10
45      20 DO 21 I=1,7
46         DO 22 J=1,103
47         D772(J)=D77(I,J)
48      22 ST2(J)=ST(I,J)
     C     MORE THAN 1 RECORD MUST BE READ BEFORE DEV CAN BE CALLED.
49         IF (N.GT.1) GO TO 23
50         SDD77=SDST=0.
51         D77AVG=D77MAX=D77MIN=D772(1)
52         STAVG=STMIN=STMAX=ST2(1)
     C     IF NO RECORDS WERE READ, ALL VALUES EQUAL 0.
53         IF (N.EQ.0) D77AVG=D77MIN=D77MAX=STAVG=STMIN=STMAX=0.
54         GO TO 24
55      23 CALL DEV (N,D772,SDD77,D77AVG,D77MIN,D77MAX)
56         CALL DEV (N,ST2,SDST,STAVG,STMIN,STMAX)
57      24 DPUMP=D77AVG+STAVG/2.
     C     D77AVG CONTAINS THE AVG. DEPTH TO WATER.
58         USGS(I,ZZ,1)=D77AVG
     C     D77MAX CONTAINS THE MAX DEPTH TO WATER.
59         USGS(I,ZZ,2)=D77MAX
     C     D77MIN CONTAINS THE MIN DEPTH TO WATER.
60         USGS(I,ZZ,3)=D77MIN
     C     SDD77 CONTAINS THE COEFF. OF VARIATION OF THE DEPTH TO WATER.
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61          USGS(I,ZZ,4)=SDD77
      C     STAVG CONTAINS THE AVG. SAT. THICKNESS.
62          USGS(I,ZZ,5)=STAVG
      C     STMAX CONTAINS THE MAX. SAT. THICKNESS.
63          USGS(I,ZZ,6)=STMAX
      C     STMIN CONTAINS THE MIN. SAT. THICKNESS.
64          USGS(I,ZZ,7)=STMIN
      C     SDST CONTAINS THE COEFF. OF VARIATION OF THE SAT. THICKNESS.
65          USGS(I,ZZ,8)=SDST
      C     DPUMP CONTAINS THE PUMPING DEPTH (AVG. DEPTH TO WATER + 1/2 THE AVG. SAT.
      C     THICKNESS).
66          USGS(I,ZZ,9)=DPUMP
67          NUSGS(I,ZZ,1)=N
68          NUSGS(I,ZZ,3)=M1
69       21 NUSGS(I,ZZ,2)=N1
      C     IF END OF DATA HAS BEEN REACHED, EXIT FROM LOOP.
70          IF (M.GT.105) GO TO 30
      C     SET M1=NEXT COUNTY.
71          M1=M
72          ZZ=ZZ+1
73          GO TO 1

      C     SORT AND PRINT THE CALCULATED VALUES
74       30 DO 31 L=1,7
75          IF (L.EQ.1) NYEAR1=1950
76          IF (L.EQ.1) NYEAR2=1940
77          IF (L.EQ.2) NYEAR1=NYEAR2=1966
78          IF (L.GT.2) NYEAR1=NYEAR2=L+1970
79          WRITE (6,4000) NYEAR1,NYEAR2
80          DO 40 I=1,3
81          WRITE (6,5000) DIST(I)
82          X=0
83          V1=0
84          DO 51 K=1,24
85          Y=106
86          DO 50 J=1,24
87          IF (COUNTY(NUSGS(1,J,3)).NE.I) GO TO 50
88          IF (NUSGS(1,J,3).LE.X) GO TO 50
89          IF (NUSGS(1,J,3).LT.Y) V=J
90          IF (NUSGS(1,J,3).LT.Y) Y=NUSGS(1,J,3)
91       50 CONTINUE
92          IF (V1.EQ.V) GO TO 51
93          WRITE (6,3000) COUNTY(Y),(USGS(L,V,K),K=1,9),(NUSGS(L,V,K),K=1,2)
94          V1=V
95       51 X=Y
96       40 CONTINUE
97       31 CONTINUE
98          WRITE (6,8000)
99     1000 FORMAT (I3,34X,F3.0,4X,F3.0,1X,F6.2,8X,F6.2,1X,F6.2/17X,3(1X,F6.2))
            X)
100    1002 FORMAT (I3,34X,F3.0,4X,F3.0,4(1X,F6.3)/18X,F6.2,1X,F6.2)
101    2000 FORMAT (I3)
102    3000 FORMAT(' ',A12,F6.1,2F7.1,F8.1,F11.1,3F7.1,F9.1,I6,I8)
103    4000 FORMAT ('1RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WER
            1E FOR THE YEAR',I5/' RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR T
            2HE YEAR',I5/'0DISTRICT AND  AVG    MAX    MIN   COEFF OF    AVG
            3 MAX    MIN   COEFF OF   NET    ',          'NO OF   TOTAL'/
            4                                                  ' COUNTY
            5  DEPTH  DEPTH  DEPTH  VARIATION   SAT    SAT    SAT   VARIATION P
            6UMP    ',          'USGS    NC OF'/
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     7                                '                  TO      TC      TO    OF
     8 DEPTH   THICK- THICK- THICK-  OF SAT   DEPTH   ',            'DEPT
     9H  RECCRDS'/
     X    '              WATER  WATER  WATER  TO WATER     NESS   NESS
     1NESS   THICK-          ',           'RECCRDS      '/
     2                       '                FEET   FEET   FEET   PERCENT
     3    FEET   FEET   FEET   NESS, %  FEET    ',           'READ')
104  5000 FORMAT ('0',A13/)
105  6000 FORMAT (A80)
106  8000 FORMAT ('1')
107       STOP
108       END
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109       SUBROUTINE DEV(N,A,SD,MEAN,MIN,MAX)
      C   SUBROUTINE TO CALCULATE THE STANDARD DEVIATION OF AN ARRAY OF VALUES
      C   ENTER N, THE NUMBER OF VALUES
      C   ENTER A, THE ARRAY OF VALUES
      C   RETURNS SD, THE STANDARD DEVIATION AS A PERCENT OF THE MEAN (THE COEFFIC-
      C   IENT OF VARIATION).
      C   RETURNS MEAN, THE MEAN OF THE VALUES
      C   RETURNS MIN, MINIMUM VALUE, AND MAX, MAXIMUM VALUE
      C   THE MAXIMUM NUMBER OF VALUES, N, IS 103
110       REAL MEAN,MIN,MAX
111       DIMENSION A(103)
112       SUM=0.
113       MIN=A(1)
114       MAX=A(1)
115       DO 10 I=1,N
116       SUM=SUM+A(I)
117       IF (A(I).LT.MIN) MIN=A(I)
118       IF (A(I).GT.MAX) MAX=A(I)
119    10 CONTINUE
120       MEAN=SUM/N
121       SQ=0.
122       DO 20 I=1,N
123    20 SQ=SQ+(A(I)-MEAN)*(A(I)-MEAN)
124       SD=(SQ/(N-1))**0.5/MEAN*100.
125       RETURN
126       END

      $ENTRY
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RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1950
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1940

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	TOTAL NO OF RECORDS
NORTHWEST											
CHEYENNE	109.5	232.0	7.0	69.8	86.1	180.0	2.0	67.3	152.6	34	56
DECATUR	55.7	133.0	10.0	82.2	36.1	88.0	14.0	40.8	73.7	26	38
RAWLINS	78.0	204.0	5.0	88.7	63.1	138.0	27.0	55.0	109.6	28	42
SHERIDAN	85.8	162.0	4.0	51.9	97.3	158.0	30.0	33.8	134.4	40	57
SHERMAN	122.3	183.0	12.0	26.3	155.2	240.0	56.0	19.5	199.9	59	92
THOMAS	119.1	182.0	11.0	25.5	112.3	179.0	20.0	32.0	175.2	37	66
WEST CENTRAL											
GOVE	62.0	62.0	62.0	0.0	128.0	128.0	128.0	0.0	126.0	1	7
GREELEY	117.3	183.0	72.0	23.5	79.0	138.0	25.0	35.5	156.8	14	36
LANE	86.3	90.0	84.0	3.7	57.3	67.0	50.0	15.2	115.0	3	24
LOGAN	142.0	142.0	142.0	0.0	78.0	78.0	78.0	0.0	181.0	1	8
SCOTT	81.0	130.0	6.0	41.9	91.4	177.0	39.0	39.2	126.7	37	90
WALLACE	108.3	216.0	65.0	31.9	134.8	299.0	55.0	43.0	175.7	25	51
WICHITA	86.8	118.0	48.0	13.6	93.6	141.0	14.0	31.6	133.6	55	93
SOUTHWEST											
FINNEY	55.6	115.0	6.0	48.8	201.8	441.0	6.0	53.8	156.5	53	103
GRANT	104.8	237.0	41.0	52.8	327.2	430.0	220.0	16.6	268.4	40	64
GRAY	99.7	167.0	16.0	32.6	205.3	396.0	18.0	51.4	201.4	30	53
HAMILTON	22.0	101.0	6.0	109.0	68.6	225.0	14.0	82.2	56.4	21	45
HASKELL	180.5	247.0	57.0	23.0	341.3	426.0	259.0	12.0	351.2	36	54
KEARNY	74.1	223.0	12.0	89.8	223.5	360.0	50.0	52.6	185.8	26	40
MEADE	88.3	167.0	6.0	66.1	341.6	424.0	162.0	18.6	259.1	24	35
MORTON	109.2	179.0	68.0	38.7	162.7	262.0	80.0	51.6	190.5	6	30
SEWARD	160.1	205.0	5.0	28.7	329.8	559.0	235.0	27.4	325.0	17	31
STANTON	94.2	176.0	42.0	45.3	231.2	355.0	9.0	44.1	209.8	18	45
STEVENS	122.2	213.0	60.0	28.6	347.4	509.0	161.0	25.5	296.0	25	41

RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1966
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1966

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	TOTAL NO OF RECORDS
NORTHWEST											
CHEYENNE	111.0	231.8	6.8	69.6	84.6	179.4	2.1	68.6	153.3	34	56
DECATUR	56.0	135.1	8.0	82.4	35.8	88.4	6.9	42.4	73.9	26	38
RAWLINS	79.0	202.9	7.9	87.2	62.1	139.5	23.7	56.4	110.1	28	42
SHERIDAN	88.1	154.4	6.9	51.3	95.0	165.6	32.1	34.3	135.6	40	57
SHERMAN	126.8	201.3	15.8	25.8	150.7	235.4	52.3	20.8	202.2	59	92
THOMAS	119.9	187.7	5.1	27.3	111.5	173.1	25.9	31.5	175.6	37	66
WEST CENTRAL											
GOVE	60.0	60.0	60.0	0.0	130.0	130.0	130.0	0.0	125.0	1	7
GREELEY	123.0	198.5	73.0	25.8	73.3	126.3	28.0	36.3	159.6	14	36
LANE	87.2	89.3	83.9	3.3	56.5	67.1	50.7	16.2	115.4	3	24
LOGAN	137.1	137.1	137.1	0.0	82.9	82.9	82.9	0.0	178.5	1	8
SCOTT	95.3	143.6	10.4	35.6	77.1	170.4	34.2	44.8	133.9	37	90
WALLACE	118.0	233.9	76.0	30.1	125.1	282.5	37.1	47.4	180.5	25	51
WICHITA	103.1	126.6	55.6	15.4	77.3	124.8	13.8	31.9	141.8	55	93
SOUTHWEST											
FINNEY	64.4	132.6	6.0	43.0	193.0	435.7	5.3	55.3	160.9	53	103
GRANT	146.3	253.2	76.8	34.3	285.7	377.3	203.8	16.0	289.2	40	64
GRAY	98.0	163.9	18.9	33.1	206.0	392.9	25.8	50.2	201.0	30	53
HAMILTON	23.7	121.4	5.4	123.1	67.0	221.3	13.9	82.1	57.2	21	45
HASKELL	189.1	260.8	60.1	23.5	332.8	429.0	255.9	12.4	355.5	39	54
KEARNY	79.2	237.0	7.2	92.6	218.3	357.3	53.0	55.4	188.4	26	40
MEADE	90.8	170.3	6.4	62.7	339.1	415.1	161.7	18.3	260.3	24	35
MORTON	108.9	183.1	69.4	47.3	162.9	274.0	66.9	57.5	190.4	6	30
SEWARD	159.7	203.6	5.7	31.0	330.2	578.4	234.6	29.6	324.8	17	31
STANTON	110.3	192.7	48.6	36.2	215.1	314.5	8.9	43.6	217.8	18	45
STEVENS	126.7	230.2	55.6	31.1	343.0	529.0	142.1	28.0	298.2	25	41

RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1973
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1973

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	TOTAL NO OF RECORDS
NORTHWEST											
CHEYENNE	113.3	232.1	5.9	69.6	82.4	177.4	1.8	68.8	154.4	34	56
DECATUR	58.2	133.5	10.7	78.0	33.6	83.3	5.3	45.9	75.0	26	38
RAWLINS	81.2	203.9	11.2	84.3	60.0	138.4	18.6	58.6	111.2	28	42
SHERIDAN	92.1	157.5	6.6	50.8	91.0	162.5	30.8	33.5	137.6	40	57
SHERMAN	136.8	202.3	16.2	24.1	140.7	224.4	51.8	22.1	207.2	59	92
THOMAS	124.1	191.1	8.8	27.4	107.2	166.6	22.2	31.5	177.7	37	66
WEST CENTRAL											
GOVE	62.2	62.2	62.2	0.0	127.8	127.8	127.8	0.0	126.1	1	7
GREELEY	130.3	190.5	90.8	20.4	66.0	115.5	27.3	35.1	163.3	14	36
LANE	92.5	96.5	85.6	6.5	51.2	65.4	43.5	24.1	118.1	3	24
LOGAN	152.0	152.0	152.0	0.0	68.0	68.0	68.0	0.0	186.0	1	8
SCOTT	104.0	151.7	10.4	33.1	68.4	161.3	29.2	48.5	138.2	37	90
WALLACE	130.0	237.4	89.8	25.3	113.0	283.1	33.6	55.5	186.6	25	51
WICHITA	116.5	142.2	56.6	19.8	63.9	99.8	13.7	33.5	148.5	55	93
SOUTHWEST											
FINNEY	72.0	136.8	6.9	39.4	185.4	427.9	3.8	57.6	164.7	53	103
GRANT	162.7	266.1	102.0	28.1	269.3	360.9	190.9	17.4	297.4	40	64
GRAY	105.0	166.0	20.7	31.6	199.0	386.1	26.4	50.3	204.5	30	53
HAMILTON	26.7	133.9	7.6	121.4	63.9	215.8	13.3	83.1	58.7	21	45
HASKELL	202.4	285.3	71.4	23.6	319.4	420.2	244.6	12.7	362.2	39	54
KEARNY	84.5	249.0	11.5	90.0	213.1	353.3	46.2	57.5	191.0	26	40
MEADE	95.8	179.9	6.3	63.3	334.1	414.1	161.5	18.3	262.8	24	35
MORTON	108.8	174.6	68.2	46.1	163.0	274.7	62.0	59.0	190.3	6	30
SEWARD	165.6	206.3	8.7	30.3	324.3	571.9	226.1	30.2	327.8	17	31
STANTON	129.2	216.3	56.4	34.3	196.2	295.1	10.6	44.6	227.3	18	45
STEVENS	132.0	240.3	56.3	33.1	337.7	528.4	121.7	29.7	300.8	25	41

RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1974
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1974

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	TOTAL NO OF RECORDS
NORTHWEST											
CHEYENNE	113.8	232.5	5.6	69.7	81.8	177.8	1.2	68.6	154.7	34	56
DECATUR	57.6	135.1	8.4	79.7	34.2	85.0	3.9	46.3	74.7	26	38
RAWLINS	80.4	204.4	10.5	85.7	60.7	138.0	21.5	56.6	110.8	28	42
SHERIDAN	92.9	157.3	6.8	51.0	90.2	162.7	30.9	33.1	138.0	40	57
SHERMAN	137.2	203.2	16.2	23.8	140.3	224.1	51.8	22.0	207.4	59	92
THOMAS	124.5	188.0	8.3	27.2	106.8	165.9	22.7	31.4	177.9	37	66
WEST CENTRAL											
GOVE	62.8	62.8	62.8	0.0	127.3	127.3	127.3	0.0	126.4	1	7
GREELEY	133.7	190.8	90.9	20.3	65.6	114.5	27.4	34.8	163.5	14	36
LANE	92.3	96.0	86.0	6.0	51.3	65.0	44.0	23.1	118.0	3	24
LOGAN	151.7	151.7	151.7	0.0	68.3	68.3	68.3	0.0	185.8	1	8
SCOTT	104.7	159.3	10.7	32.9	67.7	159.6	28.5	48.6	138.5	37	90
WALLACE	132.1	239.2	92.4	25.3	110.9	281.9	31.8	56.0	187.6	25	51
WICHITA	117.5	143.1	56.7	15.8	63.0	99.2	13.8	33.8	148.9	55	93
SOUTHWEST											
FINNEY	74.2	137.6	7.4	38.6	183.3	426.5	4.0	58.0	165.8	53	103
GRANT	168.8	272.1	109.8	26.2	263.2	354.5	184.9	17.6	300.4	40	64
GRAY	105.2	165.9	21.4	31.9	198.8	386.0	28.2	50.0	204.6	30	53
HAMILTON	27.7	151.0	7.5	130.2	62.9	216.8	13.9	83.6	59.2	21	45
HASKELL	204.1	288.4	73.8	23.5	317.8	415.5	242.2	12.6	363.0	39	54
KEARNY	85.0	244.3	11.8	88.4	212.6	351.5	49.8	57.3	191.3	26	40
MEADE	95.7	180.7	4.9	64.7	334.2	414.1	161.0	18.3	262.8	24	35
MORTON	109.2	175.4	67.9	46.8	162.6	274.7	57.6	59.9	190.5	6	30
SEWARD	165.5	206.7	7.1	30.3	324.0	570.1	225.0	30.0	327.9	17	31
STANTON	131.5	218.9	58.0	33.8	193.9	291.1	10.7	44.3	228.4	18	45
STEVENS	132.5	242.4	56.3	33.0	337.2	528.6	120.4	29.9	301.1	25	41

RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1975
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1975

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	TOTAL NO OF RECORDS
NORTHWEST											
CHEYENNE	115.2	239.2	6.3	69.4	80.5	177.4	0.9	69.9	155.4	34	56
DECATUR	58.5	136.0	10.9	78.6	33.3	82.7	1.8	46.2	75.1	26	38
RAWLINS	81.6	203.8	11.4	84.4	59.5	137.3	20.5	59.0	111.4	28	42
SHERIDAN	94.1	157.5	7.3	50.8	88.9	162.5	30.4	33.3	138.6	40	57
SHERMAN	139.6	204.5	18.7	23.4	137.9	222.0	49.3	22.5	208.6	59	92
THOMAS	126.3	191.4	8.9	27.5	105.0	164.5	22.0	31.4	173.8	37	66
WEST CENTRAL											
GOVE	63.1	63.1	63.1	0.0	126.9	126.9	126.9	0.0	126.6	1	7
GREELEY	134.9	193.2	99.7	19.2	61.4	112.2	25.3	37.7	165.6	14	36
LANE	93.1	97.1	85.8	6.8	50.5	65.2	42.9	25.2	118.4	3	24
LOGAN	155.7	155.7	155.7	0.0	64.3	64.3	64.3	0.0	187.9	1	8
SCOTT	108.3	161.3	12.0	31.9	64.1	157.9	23.5	51.2	140.4	37	90
WALLACE	137.3	246.9	98.2	24.2	105.8	276.2	24.1	59.3	190.2	25	51
WICHITA	121.5	145.7	57.1	15.9	58.9	95.4	11.4	35.6	151.0	55	93
SOUTHWEST											
FINNEY	80.4	138.9	8.2	36.2	177.0	422.8	3.7	59.7	168.9	53	103
GRANT	184.1	277.6	124.0	23.1	247.9	346.2	160.1	19.4	308.1	40	64
GRAY	107.7	167.3	23.4	31.1	196.4	334.1	27.6	50.8	205.9	30	53
HAMILTON	28.9	137.3	3.0	120.4	61.7	209.4	12.0	83.4	59.8	21	45
HASKELL	209.6	296.3	75.4	24.0	312.3	416.3	240.6	12.9	365.7	39	54
KEARNY	89.9	257.1	14.3	85.7	207.6	347.9	40.0	59.2	193.7	26	40
MEADE	97.7	181.9	6.3	63.0	332.2	411.4	160.4	18.3	263.8	24	35
MORTON	108.9	177.3	63.5	48.2	162.9	275.3	55.7	59.8	190.4	6	30
SEWARD	171.3	209.8	7.1	30.1	318.6	560.6	222.4	30.5	330.6	17	31
STANTON	141.9	225.8	61.4	32.3	183.5	286.0	8.1	46.0	233.6	18	45
STEVENS	135.7	257.0	56.9	34.2	334.0	531.9	114.9	30.9	302.7	25	41

RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1976
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1976

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	TOTAL NO OF RECORDS
NORTHWEST											
CHEYENNE	116.2	233.7	6.3	68.6	79.4	176.8	0.7	70.4	155.9	34	56
DECATUR	57.7	135.1	9.3	79.4	34.1	83.1	4.3	44.7	74.8	26	38
RAWLINS	81.6	206.2	9.1	85.4	59.5	135.7	20.1	57.7	111.4	28	42
SHERIDAN	55.2	158.1	7.2	51.8	87.9	161.9	33.2	33.0	139.1	40	57
SHERMAN	141.4	205.1	16.2	23.4	136.1	219.2	51.8	22.8	209.5	59	92
THOMAS	127.0	188.3	9.4	26.8	104.4	168.6	21.6	31.5	179.2	37	66
WEST CENTRAL											
GOVE	62.4	62.4	62.4	0.0	127.6	127.6	127.6	0.0	126.2	1	7
GREELEY	135.8	194.4	95.4	19.7	60.5	109.6	27.0	37.2	166.0	14	36
LANE	94.1	98.0	86.3	7.2	49.5	64.7	42.0	26.4	118.9	3	24
LOGAN	156.6	156.6	156.6	0.0	63.4	63.4	63.4	0.0	188.3	1	8
SCOTT	110.2	156.4	12.1	31.0	62.2	155.5	25.2	51.6	141.3	37	90
WALLACE	140.8	246.9	99.9	22.7	102.3	265.8	24.1	60.7	191.9	25	51
WICHITA	124.0	150.7	52.8	16.8	56.4	90.7	9.0	35.1	152.2	55	93
SOUTHWEST											
FINNEY	84.9	140.4	8.6	36.1	172.5	417.5	2.9	60.5	171.2	53	103
GRANT	187.9	277.9	118.3	22.9	244.1	341.7	149.0	19.5	310.0	40	64
GRAY	110.0	169.3	25.3	30.6	194.0	381.9	27.0	50.7	207.0	30	53
HAMILTON	29.8	139.0	8.3	120.5	60.9	202.2	11.9	81.9	60.2	21	45
HASKELL	213.0	302.5	78.1	23.8	308.8	412.7	237.9	13.1	367.5	39	54
KEARNY	91.5	255.0	15.7	83.4	206.0	345.3	43.1	59.0	194.5	26	40
MEADE	101.2	188.5	6.4	60.6	328.7	406.3	159.0	18.3	265.5	24	35
MORTON	111.6	187.1	65.2	48.6	160.2	271.7	45.9	61.7	191.7	6	30
SEWARD	173.0	213.7	7.2	29.6	317.0	558.7	221.3	30.5	331.5	17	31
STANTON	147.7	231.3	62.7	32.3	177.7	280.1	11.0	46.8	236.5	18	45
STEVENS	139.1	250.4	58.5	32.9	330.6	527.4	106.8	31.2	304.4	25	41

RECORDS FOR THE NORTHWEST AND WEST CENTRAL DISTRICTS WERE FOR THE YEAR 1977
RECORDS FOR THE SOUTHWEST DISTRICT WERE FOR THE YEAR 1977

DISTRICT AND COUNTY	AVG DEPTH TO WATER FEET	MAX DEPTH TO WATER FEET	MIN DEPTH TO WATER FEET	COEFF OF VARIATION OF DEPTH TO WATER PERCENT	AVG SAT THICK-NESS FEET	MAX SAT THICK-NESS FEET	MIN SAT THICK-NESS FEET	COEFF OF VARIATION OF SAT THICK-NESS, %	NET PUMP DEPTH FEET	NO OF USGS DEPTH RECORDS READ	TOTAL NO OF RECORDS
NORTHWEST											
CHEYENNE	117.5	232.1	6.8	68.4	78.1	174.1	2.4	70.6	156.6	34	56
DECATUR	58.6	135.7	11.2	77.5	33.2	83.2	6.8	45.6	75.2	26	38
RAWLINS	82.6	209.4	11.2	84.3	58.5	134.9	19.2	58.3	111.9	28	42
SHERIDAN	96.8	162.8	7.6	51.3	86.3	157.2	31.4	32.8	139.9	40	57
SHERMAN	144.5	209.4	16.9	22.8	133.0	217.6	51.1	23.4	211.0	59	92
THOMAS	128.2	193.5	8.4	27.5	103.1	160.4	22.6	31.5	179.8	37	66
WEST CENTRAL											
GOVE	61.0	61.0	61.0	0.0	129.0	129.0	129.0	0.0	125.5	1	7
GREELEY	138.0	195.9	96.5	20.2	58.3	105.5	26.8	39.3	167.2	14	36
LANE	95.7	100.5	87.1	7.8	48.0	63.9	39.5	28.8	119.7	3	24
LOGAN	158.9	158.9	158.9	0.0	61.1	61.1	61.1	0.0	189.4	1	8
SCOTT	112.8	156.7	11.1	30.2	59.6	154.2	16.1	54.2	142.6	37	90
WALLACE	142.4	243.2	99.2	22.9	100.7	267.9	27.8	60.4	192.7	25	51
WICHITA	128.0	154.4	57.3	17.0	52.4	88.5	7.1	38.7	154.2	55	93
SOUTHWEST											
FINNEY	94.7	159.8	9.8	36.8	162.8	418.4	1.6	62.7	176.1	53	103
GRANT	196.0	284.2	120.2	22.2	236.1	339.3	138.3	20.9	314.0	40	64
GRAY	112.9	171.0	25.8	30.3	191.1	376.7	27.1	51.0	208.5	30	53
HAMILTON	30.6	142.4	9.5	121.5	60.1	206.4	11.3	83.0	60.6	21	45
HASKELL	218.6	309.0	80.3	23.7	303.3	408.4	235.7	13.3	370.2	39	54
KEARNY	95.7	255.8	16.1	80.2	201.8	337.6	37.3	59.7	196.6	26	40
MEADE	105.7	191.8	7.9	58.2	324.1	399.5	159.1	18.3	267.8	24	35
MORTON	110.1	180.2	63.5	48.0	161.7	270.4	52.8	59.8	191.0	6	30
SEWARD	175.0	214.6	7.4	29.7	315.0	551.4	218.4	30.8	332.5	17	31
STANTON	153.3	237.4	67.1	31.5	172.1	274.1	7.9	46.7	239.3	18	45
STEVENS	140.9	255.3	57.9	33.1	328.8	524.9	108.5	31.4	305.3	25	41

Appendix C: Computer Program Simulating Energy Use in Irrigation in Kansas

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$JOB            ,TIME=(,25),PAGES=25
C     THIS PROGRAM CALCULATES THE ENERGY USAGE, BY COUNTY, FOR THE 4 FUELS (NAT
C     GAS, LP GAS, DIESEL FUEL, AND ELECTRICITY).  THE PROGRAM CALLS FOR THE
C     SUBROUTINES CROPSS AND WATREQ.


C     TO CHANGE THE NUMBER OF CROPS READ, THE DIMENSIONS OF THE FOLLOWING
C     ARRAYS WILL HAVE TO BE CHANGED.
C     IF N CROPS ARE READ, DIMENSION AS FOLLOWS.
C     CROPS(N),CROP(5,N+2),WATER(9,N),A(105,N+1),DIS(10,N+1)
C     ALSO CHANGE THE DATA STATEMENTS INVOLVING CROP AS FOLLOWS.
C     DATA(CROP(I,N+1), DATA(CROP(I,N+2)

C     ENTER YOUR DATA IN THE FOLLOWING ORDER AND ACCORDING TO THE FOLLOWING
C     FORMAT.
C     1.  KS IRR SURVEY DATA.  UNFORMATED.  ONE COUNTY PER CARD, COUNTY NUMBER
C     FOLLOWED BY COUNTY NAME, DISTRICT, AND THE 13 VALUES REPORTED IN THE
C     SURVEY.  AT LEAST 105 CARDS MUST BE ENTERED.  AN EXAMPLE CARD FOLLOWS.
C     81 'RILEY' 7 1500 800 500 200 0 0 0 15 0 1 7 7 10
C     2.  SRS CROP DATA.  UNFORMATED.  THE FIRST CARD CONTAINS THE CROP NAME,
C     THE SECOND CARD CONTAINS THE ACRES OF THAT CROP GROWN FOR EACH COUNTY IN
C     DISTRICT 1, THE THIRD CARD CONTAINS VALUES FOR DISTRICT 2, . . ., THE 10TH
C     CONTAINS VALUES FOR DISTRICT 9, AND THE 11TH CARD CONTAINS THE 9 DISTRICT
C     TOTALS.  THESE TOTALS WILL BE GENERATED IN THE PROGRAM, SO THE VALUES
C     ENTERED NEED NOT BE CORRECT.  THE COUNTY VALUES MUST BE IN ORDER, FROM
C     LOWEST TO HIGHEST COUNTY NUMBER. THESE NUMBERS CAN BE PUNCHED READILY FROM
C     SRS DATA. IF N CROPS ARE READ, ENTER N*11 CARDS. TWO EXAMPLE CARDS FOLLOW.
C     'IRR' 'SORGHUM' 'GRAIN' '1975' 'ACRES'
C     0 0 3120 0 0 7800 0 2200
C     3.  WATREQ DATA.  UNFORMATED.  THE FIRST CARD CONTAINS THE NAMES OF THE N
C     NUMBER OF CROPS THAT YOU ARE LISTING WATER REQUIREMENTS FOR (UP TO 8
C     CHARACTERS PER WORD).  THE NEXT 6 CARDS CONTAIN THE WATER REQUIREMENTS, IN
C     INCHES PER YEAR, FOR DISTRICTS 1, 3, 4, 6, 7, AND 9, RESPECTIVELY.  THE
C     WATER REQUIREMENT VALUES MUST BE IN THE SAME ORDER AS THE CROP NAMES.  TWO
C     EXAMPLE CARDS FOLLOW.  YOU MUST ENTER THE SAME NUMBER OF WATER
C     REQUIREMENTS AS YOU ENTERED CROPS IN THE PREVIOUS SUBROUTINE, AND THE NAME
C     OF THE CROP ENTERED IN WATREQ MUST BE THE SAME AS THE SECOND WORD ENTRY
C     IN THE ARRAY CROPSS IN ORDER FOR THE WATER REQUIREMENTS TO BE MATCHED WITH
C     THAT CROP.  HOWEVER, THE ORDER OF CROPS READ NEED NOT BE THE SAME IN THE 2
C     SUBROUTINES.  IF YOU DO NOT WISH TO PRINT ALL OF THE WATER REQUIREMENTS,
C     REFER TO THE SUBROUTINE WATREQ.
C     'CORN' 'SORGHUM' 'WHEAT' 'BEETS' 'ALFALFA' 'SOYBEANS' 'BEANS' 'GRASS' ' '
C     17.42 12.88 10.73 18.10 23.70 12.9 12.9 20.12 0.

C     QUANTITIES OF FUELS USED ARE BASED ON 1000 BTU/SCF OF NAT GAS, 96,500 BTU/
C     GAL OF L-P GAS, 136,670 BTU/GAL OF DIESEL FUEL, 3413 BTU/KWH ELECTRICITY

1           DIMENSION EFF(4),WATER(9,9),USAGE(105,12),A(105,10),DEPTH(9),D(13)
           1,DIS(10,10),DTOT(10,13),USETOT(10,12)
2           CHARACTER*8 CROPS(9),CROP(5,11)
3           CHARACTER*12 COUNTY(105),C1
4           CHARACTER*13 DIST(9)
5           COMMON DATA(105,13),CCUNTY,CCUNTE
6           INTEGER COUNTE(105),R
7           CHARACTER*12 FUEL(4)
C     EFF CONTAINS THE EFFICIENCIES (IN PERCENT) FOR THE 4 FUELS LISTED.
C     GAS, DIESEL, LP GAS, ELECTRICITY).
C     WATER CONTAINS THE WATER REQUIREMENTS FOR THE 9 DISTRICTS AND N NUMBER OF
C     CROPS.
C     USAGE(I,1) CONTAINS THE GROSS PUMPING DEPTH IN FT
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C     USAGE(I,2) CONTAINS THE NET ACRE FT APPLIED
C     USAGE(I,3) CONTAINS THE IRRIGATION EFFICIENCY
C     USAGE(I,4) CONTAINS THE GROSS ACRE FT APPLIED
C     USAGE(I,5) CONTAINS THE NET BTU REQUIRED
C     USAGE(I,6) CONTAINS THE NATURAL GAS REQUIREMENT IN BTU
C     USAGE(I,7) CONTAINS THE DIESEL FUEL REQUIREMENT IN BTU
C     USAGE(I,8) CONTAINS THE LP GAS REQUIREMENT IN BTU
C     USAGE(I,9) CONTAINS THE ELECTRICITY REQUIREMENT IN BTU
C     USAGE(I,10) CONTAINS THE NET PUMPING DEPTH IN FT
C     USAGE(I,11) CONTAINS THE PRESSURE HEAD REQUIRED IN FT
C     USAGE(I,12) CONTAINS THE DIFFERENCE IN ACRES BETWEEN SURVEYS AS A % OF THE
C     KS IRRIGATION SURVEY
C     A CONTAINS THE ACRES OF EACH CROP GROWN FOR THE 105 COUNTIES + THE TOTALS
C     DEPTH CONTAINS THE NET PUMPING DEPTH FOR DISTRICT (I)
C     D IS A WORKING ARRAY TO READ AND TRANSFER KANSAS IRR SURVEY DATA.
C     DIS CONTAINS THE 9 DISTRICT TOTALS AND THE STATE TOTAL FOR SRS DATA
C     DTOT CONTAINS THE 9 DISTRICT TOTALS AND STATE TOTAL FOR KS IRR SURVEY DATA
C     USETOT CONTAINS THE 9 DISTRICT TOTALS AND STATE TOTAL FOR USAGE
C     CROPS CONTAINS THE NAME OF EACH CROP WATER REQUIREMENTS ARE LISTED FOR
C     CROP CONTAINS THE CROP GROWN IN SRS REPORT
C     COUNTY CONTAINS THE ALPHABETICAL LIST OF 105 COUNTIES.  I IS THE COUNTY
C     NUMBER FOR COUNTY (I).
C     C1 IS A WORKING VARIABLE TO READ AND TRANSFER COUNTY NAMES.
C     DIST CONTAINS THE NAME OF EACH DISTRICT
C     DATA CONTAINS THE 13 VALUES LISTED IN THE KS IRR SURVEY FOR THE 105
C     COUNTIES.
C     COUNTE(I) CONTAINS THE REGION FOR COUNTY(I)
C     FUEL CONTAINS THE NAMES OF THE 4 FUELS USED (NAT GAS, DIESEL, LP GAS,
C     ELECTRICITY).

C  ******
C     ENTER YOUR OVERALL PUMPING EFFICIENCIES FOR EACH ENERGY SOURCE HERE (NAT
C     GAS, DIESEL, LP GAS, ELECTRICITY).
C     THESE ARE THE EFFICIENCIES LISTED IN HANSON'S THESIS.
8        DATA EFF/12.4,16.2,13.5,52.3/

C  ******
C     ENTER THE PUMPING DEPTHS FOR DISTRICTS ONE THROUGH NINE HERE (NW, WC, SW,
C     NC, C, SC, NE, EC, SE).
9        DATA DEPTH/150.,140.,250.,40.,50.,50.,50.,50.,50./

C  ******
C     ENTER YOUR PRESSURE REQUIREMENTS HERE (OPEN DITCH, GATED PIPE, CENTER
C     PIVOT, TOW LINE AND SIDE ROLL, BIG GUN, OTHER SPRINKLER).
C     PRESSURE REQUIREMENTS, FT. OF WATER.
10       POD=0.
11       PGP=20.
12       PCP=196.
13       PTLSR=175.
14       PBG=312.
15       POS=160.

C  ******
C     ENTER IRRIGATION EFFICIENCIES HERE, IN PERCENT.  ENTER EFFICIENCIES F1
C     FOR GRAVITY SYSTEMS AND F2 FOR SPRINKLER SYSTEMS.
16       F1=60.
17       F2=75.

18       DATA FUEL/'NATURAL GAS','DIESEL FUEL','LP GAS','ELECTRICITY'/
19       DATA DIST/'NORTHWEST','WEST CENTRAL','SOUTHWEST','NORTH CENTRAL','
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     XCENTRAL','SOUTH CENTRAL','NORTHEAST','EAST CENTRAL','SOUTHEAST'/
20       DATA DTOT/130*0./
21       DATA USETOT/120*0./
22       DATA (CROP(I,10),I=1,5)/'TOTAL','IRR','ACRES',' ','    '/
23       DATA (CROP(I,11),I=1,5)/'TOTAL','IRR','ACRES','1975 KS','IRR SUR'/

C        READ KS IRR SURVEY DATA.
24       DO 2 I=1,105
25       READ, M,C1,R,(D(J),J=1,13)
26       COUNTY(M)=C1
27       DO 3 J=1,13
28       DTOT(R,J)=DTOT(R,J)+D(J)
29       DTOT(10,J)=DTOT(10,J)+D(J)
30     3 DATA(M,J)=D(J)
31     2 COUNTE(M)=R

C        SET PUMPING DEPTHS FOR EACH COUNTY. (CONSTANT DEPTHS PER DISTRICT).
32       DO 1 I=1,105
33     1 USAGE(I,10)=DEPTH(COUNTE(I))

C  ******
C        ENTER INDIVIDUAL COUNTY PUMPING DEPTHS HERE.
C        PUMPING DEPTHS ARE FROM 1975 WELL DATA WHERE ALL COMPLETE RECORDS FOR ONE
C        YEAR WERE READ.
34       USAGE(12,10)=175.5
35       USAGE(20,10)=78.1
36        USAGE(77,10)=121.1
37       USAGE(90,10)=140.2
38       USAGE(91,10)=207.2
39       USAGE(97,10)=174.6
40       USAGE(32,10)=115.1
41       USAGE(36,10)=160.3
42       USAGE(51,10)=113.5
43       USAGE(55,10)=125.9
44       USAGE(86,10)=135.4
45       USAGE(100,10)=187.
46       USAGE(102,10)=145.1
47       USAGE(28,10)=192.6
48        USAGE(34,10)=303.4
49       USAGE(35,10)=188.7
50       USAGE(38,10)=113.
51       USAGE(41,10)=370.7
52       USAGE(47,10)=190.2
53       USAGE(60,10)=267.5
54       USAGE(65,10)=164.6
55       USAGE(88,10)=325.9
56       USAGE(94,10)=252.4
57       USAGE(95,10)=309.

C        CALCULATE TOTAL HEAD REQUIREMENT FOR EACH COUNTY.
58       DO 10 I=1,105
59       M1=I
60       IF (DATA(I,1).LT.1) PRESS=0.
61       IF (DATA(I,1).LT.1) GO TO 4
C        CALCULATE AVERAGE PRESSURE HEAD REQUIREMENT FOR EACH COUNTY.
62       PRESS=(DATA(M1,2)*PGD+DATA(M1,3)*PGP+DATA(M1,4)*PCP+DATA(M1,5)*PTL
        XSR+DATA(M1,6)*PBG+DATA(M1,7)*PDS)/DATA(M1,1)
63     4 USAGE(I,11)=PRESS
64    10 USAGE(I,1)=USAGE(I,10)+USAGE(I,11)
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C  ******
C     ENTER N, THE NUMBER OF CROPS.
65       N=9

66       M=N+1
67       L=N+2

68       CALL CROPSS (N,A,DIS,CROP,DIST,DTOT,M,L)

69       CALL WATREQ(N,CROPS,WATER,DIST)

C     ENTER LOOP FOR CALCULATIONS, BY DISTRICT
70       DO 120 L=1,9
71       IF (L.EQ.1) WRITE (6,2000)
72       IF (L.EQ.4) WRITE (6,2000)
73       IF (L.EQ.7) WRITE (6,2000)
74       WRITE (6,3001) DIST(L)
75   170 DO 130 I=1,105
76       IF (COUNTE(I).NE.L) GO TO 130
77       ACREFT=0.
78       M=COUNTE(I)
C     CALCULATE AMOUNT OF WATER PUMPED.
79       DO 20 J=1,N
80       DO 30 K=1,N
81       IF (CROP(2,J).EQ.CROPS(K)) ACREFT=ACREFT+A(I,J)*WATER(M,K)/12.
82    30 CONTINUE
83    20 CONTINUE
84       IF (DATA(I,1).LT.1) USAGE(I,3)=USAGE(I,4)=0.
85       USAGE(I,2)=ACREFT
86       IF (DATA(I,1).LT.1) GO TO 60
C     CALCULATE IRRIGATION EFFICIENCY.
87       USAGE(I,3)=(DATA(I,2)+DATA(I,3))/DATA(I,1)*F1+(DATA(I,4)+DATA(I,5)
        X+DATA(I,6)+DATA(I,7))/DATA(I,1)*F2
88       USAGE(I,4)=USAGE(I,2)/USAGE(I,3)*100.
89    60 USAGE(I,5)=USAGE(I,4)*43560*62.4*.0012854*USAGE(I,1)
C     CALCULATE TOTAL NUMBER OF WELLS.
90       WELLS=DATA(I,9)+DATA(I,10)+DATA(I,11)+DATA(I,12)
91       IF (WELLS.LT.0.5) GO TO 70
92       DO 40 J=1,4
C     CALCULATE BTU USAGE FOR THE FOUR FUELS.
93    40 USAGE(I,5+J)=DATA(I,8+J)/WELLS*USAGE(I,5)/EFF(J)*100.
94       GO TO 80
95    70 DO 90 J=6,9
96    90 USAGE(I,J)=0.
97    80 USAGE(I,12)=DATA(I,1)
98       DO 50 J=1,N
99    50 USAGE(I,12)=USAGE(I,12)-A(I,J)
C     SUM FOR DISTRICT AND STATE TOTALS.
100      DO 100 J=2,9
101      USETOT(10,J)=USETOT(10,J)+USAGE(I,J)
102  100 USETOT(L,J)=USETOT(L,J)+USAGE(I,J)
103      USETOT(10,12)=USETOT(10,12)+USAGE(I,12)
104      USETOT(10,11)=USETOT(10,11)+USAGE(I,11)*USAGE(I,4)
105      USETOT(L,12)=USETOT(L,12)+USAGE(I,12)
106      USETOT(L,11)=USETOT(L,11)+USAGE(I,11)*USAGE(I,4)
107      IF (DATA(I,1).LT.1) GO TO 109
108      USAGE(I,12)=USAGE(I,12)/DATA(I,1)*100.
109      GO TO 110
C     IF NO ACREAGE LISTED FOR KS IRR SURVEY, BUT ACREAGE IS LISTED UNDER SRS,
C     DIFFERENCE IN ACRES AS A PERCENT OF KS IRR SURVEY IS INFINITE.
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110     109 IF (USAGE(I,12).GT.1) USAGE(I,12)=1.E10
111     110 WRITE (6,1000) CCUNTY(I), USAGE(I,10), USAGE(I,11),(USAGE(I,J),J=1
            1,5), USAGE(I,6)+USAGE(I,7)+USAGE(I,8)+USAGE(I,9), (USAGE(I,J),J=6,
            29),USAGE(I,6),USAGE(I,7)/1.36E8, USAGE(I,8)/9.65E7,USAGE(I,9)*2.93
            3E-7
112     130 CONTINUE
      C     CALCULATE DISTRICT TOTALS.
113         IF (USETCT(L,4).LT.1) USETOT(L,1)=USETOT(L,3)=0.
114         IF (USETCT(L,4).LT.1) GO TO 140
115         USETOT(L,1)=USETCT(L,5)/USETOT(L,4)/43560./62.4/.0012854
116         USETOT(L,3)=USETCT(L,2)/USETCT(L,4)*100.
117     140 IF (USETCT(L,4).LT.1) USETOT(L,11)=0.
118         IF (USETCT(L,4).LT.1) GO TO 141
119         USETOT(L,11)=USETCT(L,11)/USETOT(L,4)
120     141 USETOT(L,10)=USETOT(L,1)-USETCT(L,11)
121         IF (DTOT(L,1).LT.1) USETOT(L,12)=0.
122         IF (DTOT(L,1).LT.1) GO TO 149
123         USETOT(L,12)=USETCT(L,12)/DTOT(L,1)*100.
124         GO TO 150
125     149 IF (USETCT(L,12).GT.1) USETCT(L,12)=1.E10
126     150 WRITE (6,4000) USETOT(L,10), USETOT(L,11), (USETOT(L,J),J=1,5), USETOT
            1ETOT(L,6) +USETOT(L,7)+USETCT(L,8)+USETCT(L,9), (USETOT(L,J),J=6,9
            2), USETOT(L,6),USETOT(L,7)/1.36E8, USETOT(L,8)/9.65E7, USETOT(L,9)
            3*2.93E-7
127     120 CONTINUE
      C     CALCULATE STATE TOTALS.
128         USETOT(10,1)=USETCT(10,5)/USETOT(10,4)/43560./62.4/.0012854
129         USETOT(10,3)=USETCT(10,2)/USETOT(10,4)*100.
130         USETOT(10,11)=USETOT(10,11)/USETOT(10,4)
131         USETOT(10,10)=USETOT(10,1)-USETCT(10,11)
132         USETOT(10,12)=USETOT(10,12)/DTOT(10,1)*100.
133         WRITE (6,5001) USETCT(10,10), USETOT(10,11), (USETOT(10,J),J=1,5),
           1USETOT(10,6)+USETCT(10,7)+USETOT(10,8)+USETCT(10,9), (USETOT(10,J)
           2,J=6,9),USETOT(10,6), USETOT(10,7)/1.36E8, USETOT(10,8)/9.65E7,
           3USETOT(10,9)*2.93E-7

      C     WRITE DISTRICT TOTALS FOLLOWED BY STATE TOTALS.
134         WRITE (6,6000)
135         DO 160 L=1,9
136     160 WRITE (6,7000) DIST(L),USETOT(L,10),USETOT(L,11),(USETOT(L,J),J=1,
            25),USETOT(L,6)+USETCT(L,7)+USETCT(L,8)+USETCT(L,9),(USETOT(L,J),J=
            36,9),USETOT(L,6),USETOT(L,7)/1.36E8,USETOT(L,8)/9.65E7,USETOT(L,9)
            3*2.93E-7
137         WRITE (6,5000) USETCT(10,10), USETOT(10,11), (USETOT(10,J),J=1,5),
           1USETOT(10,6)+USETCT(10,7)+USETOT(10,8)+USETOT(10,9), (USETOT(10,J)
           2,J=6,9),USETCT(10,6), USETOT(10,7)/1.36E8, USETOT(10,8)/9.65E7,
           3USETOT(10,9)*2.93E-7

      C     WRITE COUNTY FIGURES ALPHABETICALLY, NOT DIVIDED INTO DISTRICTS.
138         DO 200 I=1,105
139         IF (I.EQ.1) WRITE (6,6001)
140         IF (I.EQ.54) WRITE (6,6001)
141         WRITE (6,1000) CCUNTY(I), USAGE(I,10), USAGE(I,11),(USAGE(I,J),J=1
           1,5), USAGE(I,6)+USAGE(I,7)+USAGE(I,8)+USAGE(I,9), (USAGE(I,J),J=6,
            29),USAGE(I,6),USAGE(I,7)/1.36E8, USAGE(I,8)/9.65E7,USAGE(I,9)*2.93
            3E-7
142     200 CONTINUE
143         WRITE (6,5000) USETOT(10,10), USETOT(10,11), (USETOT(10,J),J=1,5),
           1USETOT(10,6)+USETCT(10,7)+USETOT(10,8)+USETOT(10,9), (USETOT(10,J)
           2,J=6,9),USETOT(10,6), USETOT(10,7)/1.36E8, USETOT(10,8)/9.65E7,
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      3USETOT(10,9)*2.93E-7
144         WRITE (6,8000)

145   3001 FORMAT (' ',A13/)
146   1000 FORMAT (' ',A12,3F6.0,-2PF7.0,0PF5.0,-2PF7.0,-9PF7.1,6F7.0,0PF7.0,
          1F7.0,F8.0)
147   4000 FORMAT ('0DIST TOTAL  ',3F6.0,-2PF7.0,0PF5.0,-2PF7.0,-9PF7.1,6F7.0
          1,0PF7.0,F7.0,F8.0/)
148   5000 FORMAT ('0STATE TOTAL ',3F6.0,-2PF7.0,0PF5.0,-2PF7.0,-9PF7.1,6F7.0
          1,0PF7.0,F7.0,F8.0)
149   5001 FORMAT (' STATE TOTAL ',3F6.0,-2PF7.0,0PF5.0,-2PF7.0,-9PF7.1,6F7.0
          1,0PF7.0,F7.0,F8.0)
150   7000 FORMAT (' ',A13,F5.0,   2F6.0,-2PF7.0,0PF5.0,-2PF7.0,-9PF7.1,6F7.0
          1,0PF7.0,F7.0,F8.0)
151   2000 FORMAT ('1','DISTRICT AND  NET  PRESS GROSS   NET   IRR  GROSS   N
          1ET   GROSS   NAT  DIESEL    LP   ELECT   NAT  DIESEL   LP    ELECT
          2          '/' COUNTY       PUMP   HEAD  PUMP  WATER  EFF  WATER E
          3NERGY ENERGY   GAS   FUEL    GAS   USED    GAS   FUEL    GAS    US
          4ED        '/'              DEPTH       DEPTH   USED        USED
          5USED   USED   USED   USED    USED         USED   USED   USED    10
          600        '/'             FT.   FT.   FT.    100    %    100     1
          7E9    1E9    1E9    1E9    1E9    1E9   1000   1000   1000    KWH
          8          '/'                                ACRE-FT     ACRE-FT
          9BTU    BTU    BTU    BTU    BTU    BTU    MCF   GALS   GALS')
152   6000 FORMAT ('1','DISTRICT      NET  PRESS GROSS   NET   IRR  GROSS   N
          1ET   GROSS   NAT  DIESEL    LP   ELECT   NAT  DIESEL   LP    ELECT
          2          '/'              PUMP   HEAD  PUMP  WATER  EFF  WATER E
          3NERGY ENERGY   GAS   FUEL    GAS   USED    GAS   FUEL    GAS    US
          4ED        '/'              DEPTH       DEPTH   USED        USED
          5USED   USED   USED   USED    USED         USED   USED   USED    10
          600        '/'             FT.   FT.   FT.    100    %    100     1
          7E9    1E9    1E9    1E9    1E9    1E9   1000   1000   1000    KWH
          8          '/'                                ACRE-FT     ACRE-FT
          9BTU    BTU    BTU    BTU    BTU    BTU    MCF   GALS   GALS'/)
153   6001 FORMAT ('1','COUNTY        NET  PRESS GROSS   NET   IRR  GROSS   N
          1ET   GROSS   NAT  DIESEL    LP   ELECT   NAT  DIESEL   LP    ELECT
          2          '/'              PUMP   HEAD  PUMP  WATER  EFF  WATER E
          3NERGY ENERGY   GAS   FUEL    GAS   USED    GAS   FUEL    GAS    US
          4ED        '/'              DEPTH       DEPTH   USED        USED
          5USED   USED   USED   USED    USED         USED   USED   USED    10
          600        '/'             FT.   FT.   FT.    100    %    100     1
          7E9    1E9    1E9    1E9    1E9    1E9   1000   1000   1000    KWH
          8          '/'                                ACRE-FT     ACRE-FT
          9BTU    BTU    BTU    BTU    BTU    BTU    MCF   GALS   GALS'/)
154   8000 FORMAT ('1')
155         STOP
156         END
```

```
157         SUBROUTINE CROPSS(B,A,DIS,CROP,DIST,DTOT,C,N)

      C     ENTER B, THE NO. OF CROPS YOU ARE READING.
      C     SUBROUTINE RETURNS A, THE ACRES OF CROPS GROWN FOR THE 105 COUNTIES + THE
      C     TOTAL OF THE B NO. OF CROPS.
      C     SUBROUTINE RETURNS DIS, THE 9 DISTRICT TOTALS + THE STATE TOTAL FOR THE B
      C     NO. OF CROPS, PLUS THE DISTRICT TOTALS AND STATE TOTAL FOR ALL CROPS
      C     GROWN.
      C     SUBROUTINE RETURNS CROP, THE NAMES OF THE B NO. OF CROPS (5 WORDS PER NAME
      C     ) + TWO 5 WORD TOTAL HEADINGS (SEE DATA STATEMENT, MAIN PROGRAM).
      C     ENTER DIST, THE NAMES OF THE DISTRICTS (FOR OUTPUT PURPOSES).
      C     ENTER DTOT, THE DIST AND STATE TOTALS FOR THE KS IRR SURVEY (USED IN WRITE
      C     ROUTINE ONLY).
      C     ENTER C, C=B+1.
      C     ENTER N, N=B+2=C+1.
      C     SUBROUTINE USES KS IRR SURVEY IRRIGATED ACRES (DATA) AND COUNTY NAMES
      C     (COUNTY) AND COUNTY REGIONS (COUNTE) IN THE WRITE ROUTINE.

158         COMMON DATA(105,13),COUNTY,COUNTE
159         CHARACTER*12 COUNTY(105)
160         INTEGER COUNTE(105)
161         INTEGER B,C
162         DIMENSION A(105,C),A1(14),NN(9),DIS(10,C),DTOT(10,13)
163         CHARACTER*8 CROP(5,N)
164         CHARACTER*13 DIST(9)
      C     COUNTY CONTAINS THE ALPHABETICAL LIST OF THE 105 COUNTIES
      C     COUNTE(I) CONTAINS THE REGION FOR COUNTY(I)
      C     A CONTAINS THE ACRES OF EACH CROP GROWN FOR THE 105 COUNTIES + THE TOTALS
      C     FOR THE CROPS GROWN PER COUNTY.
      C     A1 IS A WORKING ARRAY TO READ SRS DATA
      C     NN CONTAINS THE NUMBER OF COUNTIES IN EACH DISTRICT
      C     DIS CONTAINS THE 9 DISTRICT TOTALS AND THE STATE TOTAL FOR SRS DATA
      C     DTOT CONTAINS THE 9 DISTRICT TOTALS AND STATE TOTAL FOR KS IRR SURVEY DATA
      C     CROP CONTAINS THE CROP GROWN, AND IS THE COLUMN HEADING FOR OUTPUT
      C     DIST CONTAINS THE NAME OF EACH DISTRICT

165         DATA NN/8,9,14,11,11,13,11,14,14/
166         DO 60 K=1,B
167         READ, (CROP(L,K),L=1,5)
168         DO 40 I=1,9
169         L=NN(I)
170         READ, (A1(J),J=1,L)
171         NN1=1
172         DO 50 J=1,105
173         IF (COUNTE(J).EQ.I) A(J,K)=A1(NN1)
174      50 IF (COUNTE(J).EQ.I) NN1=NN1+1
175      40 CONTINUE
176         READ, (DIS(J,K),J=1,10)
177      60 CONTINUE
178         DO 100 I=1,105
179         A(I,C)=0.
180         DO 110 J=1,B
181     110 A(I,C)=A(I,C)+A(I,J)
182     100 CONTINUE
183         DIS(10,C)=0.
184         DO 75 I=1,C
185      75 DIS(10,I)=0.
186         DO 71 I=1,9
187         DO 74 K=1,B
```

```
      74 DIS(I,K)=0.
         DO 72 J=1,105
         IF (COUNTE(J).NE.I) GO TO 72
         DO 73 K=1,8
         DIS(10,K)=DIS(10,K)+A(J,K)
      73 DIS(I,K)=DIS(I,K)+A(J,K)
      72 CONTINUE
         DIS(I,C)=0.
         DO 120 J=1,8
         DIS(I,C)=DIS(I,C)+DIS(I,J)
     120 DIS(10,C)=DIS(10,C)+DIS(I,J)
      71 CONTINUE

C     THE FOLLOWING (THROUGH STATEMENT 8000) IS A WRITE ROUTINE.  IT MAY BE
C     REMOVED IF NO OUTPUT IS DESIRED FROM THIS SUBROUTINE.
         DO 70 I=1,9
         IF (I.EQ.1) GO TO 160
         IF (I.EQ.4) GO TO 160
         IF (I.EQ.7) GO TO 160
         GO TO 170
     160 WRITE (6,5004) (CROP(1,M),M=1,N)
         WRITE (6,5005) (CROP(2,M),M=1,N)
         WRITE (6,5001) (CROP(3,M),M=1,N)
         WRITE (6,5001) (CROP(4,M),M=1,N)
         WRITE (6,5001) (CROP(5,M),M=1,N)
         WRITE (6,4999) DIST(I)
         GO TO 171
     170 WRITE (6,5000) DIST(I)
     171 DO 80 J=1,105
         IF (COUNTE(J).EQ.I) WRITE (6,6000) COUNTY(J),(A(J,K),K=1,C),DATA(J
        X,1)
      80 CONTINUE
         WRITE (6,7000) (DIS(I,K),K=1,C),DTOT(I,1)
      70 CONTINUE
         WRITE (6,8000) (DIS(10,K),K=1,C),DTOT(10,1)
         WRITE (6,5002) (CROP(1,M),M=1,N)
         DO 130 L=2,5
     130 WRITE (6,5001) (CROP(L,M),M=1,N)
         WRITE (6,5003)
         DO 140 I=1,9
     140 WRITE (6,6001) DIST(I),(DIS(I,K),K=1,C),DTOT(I,1)
         WRITE (6,8000) (DIS(10,K),K=1,C),DTOT(10,1)
    4999 FORMAT (' ',A13/)
    5000 FORMAT ('0',A13/)
    5001 FORMAT (' ',15X,20(1X,A8))
    5002 FORMAT ('1DISTRICT       ',20(1X,A8))
    5003 FORMAT (' ')
    5004 FORMAT ('1DISTRICT AND   ',20(1X,A8))
    5005 FORMAT (' COUNTY',9X,20(1X,A8))
    6000 FORMAT (' ',A13,20F9.0)
    6001 FORMAT (' ',A13,20F9.0)
    7000 FORMAT ('0DIST TOTAL   ', 20F9.0)
    8000 FORMAT ('0STATE TOTAL  ', 20F9.0)
         RETURN
         END
```

```
239         SUBROUTINE WATREQ(N,CROPS,WATER,DIST)

      C     ENTER N, THE NUMBER OF CROP REQUIREMENTS YOU ARE LISTING
      C     CROPS CONTAINS THE NAME OF EACH CROP WATER REQUIREMENTS ARE LISTED FOR
      C     THE WATER REQUIREMENT IN INCHES FOR DISTRICT I, CROP J ARE RETURNED IN
      C     WATER(I,J)
      C     ENTER DIST, THE NAMES OF THE DISTRICTS.

240         CHARACTER*13 DIST(9)
241         CHARACTER*8 CROPS(N)
242         DIMENSION WATER(9,N)
243         READ, (CROPS(I),I=1,N)
244         READ, (WATER(1,I),I=1,N)
245         READ, (WATER(3,I),I=1,N)
246         READ, (WATER(4,I),I=1,N)
247         READ, (WATER(6,I),I=1,N)
248         READ, (WATER(7,I),I=1,N)
249         READ, (WATER(9,I),I=1,N)
250         DO 10 I=1,N
251         WATER(2,I)=(WATER(1,I)+WATER(3,I))/2.
252         WATER(5,I)=(WATER(4,I)+WATER(6,I))/2.
253        10 WATER(8,I)= WATER(7,I)


      C     THE FOLLOWING (THROUGH STATEMENT #3000) IS A WRITE ROUTINE.  IT MAY BE
      C     REMOVED IF NO OUTPUT IS DESIRED FROM THIS SUBROUTINE.
      C     IF NOT ALL CROPS ARE TO BE PRINTED, DECRIMENT M HERE.  EXAMPLE-IF M=M-2
      C     THE LAST 2 CROPS ENTERED WILL BE DELETED FROM OUTPUT.
254         M=N
255         M=M-2
256         WRITE (6,1000) (CROPS(I),I=1,M)
257         WRITE (6,3000)
258         DO 20 I=1,9
259        20 WRITE (6,2000) DIST(I),(WATER(I,J),J=1,M)
260      1000 FORMAT ('1WATER REQUIREMENTS FOR VARIOUS CROPS IN KANSAS, VALUES G
               IVEN IN INCHES PER YEAR'//'0DISTRICT     ',20A8)
261      2000 FORMAT (' ',A13,F5.1,20F8.1)
262      3000 FORMAT (' ')
263         RETURN
264         END

      $ENTRY
```

Appendix D: Computer Output, Estimates for 1975

DISTRICT AND COUNTY	IRR WHEAT 1975 ACRES	IRR SORGHUM GRAIN 1975 ACRES	IRR CORN GRAIN 1975 ACRES	IRR BEETS 1975 ACRES	IRR BEANS 1975 ACRES	IRR CORN SILAGE 1975 ACRES	IRR SORGHUM SILAGE 1975 ACRES	IRR SOYBEANS 1975 ACRES	IRR ALFALFA HAY 1975 ACRES	TOTAL IRR ACRES	TOTAL IRR ACRES 1975 KS IRR SUR
NORTHWEST											
CHEYENNE	500.	0.	28200.	1850.	2250.	3100.	300.	0.	4500.	40700.	60000.
DECATUR	100.	0.	7800.	0.	0.	1700.	2500.	100.	5000.	17200.	11169.
GRAHAM	0.	3120.	5100.	0.	0.	1600.	1500.	100.	1500.	12920.	12800.
NORTON	0.	0.	6800.	0.	0.	900.	2500.	100.	6500.	16800.	7480.
RAWLINS	500.	0.	8800.	0.	0.	1100.	2200.	0.	4500.	17100.	15000.
SHERIDAN	2900.	7800.	31700.	1400.	50.	7700.	2500.	200.	6500.	60750.	72968.
SHERMAN	7100.	0.	50000.	17600.	7200.	5000.	400.	0.	4000.	91300.	130000.
THOMAS	3500.	2200.	32200.	250.	200.	5200.	1200.	400.	2800.	47950.	100000.
DIST TOTAL	14600.	13120.	170600.	21100.	9700.	26300.	13100.	900.	35300.	304720.	409417.
WEST CENTRAL											
GOVE	3200.	2800.	7500.	0.	0.	2100.	3500.	0.	3000.	22100.	21500.
GREELEY	5800.	2900.	18600.	600.	200.	2100.	700.	100.	400.	31400.	32750.
LANE	1300.	3400.	7400.	0.	0.	2300.	250.	100.	1900.	16650.	22050.
LOGAN	2100.	4600.	9300.	0.	0.	1300.	900.	100.	1200.	19500.	10100.
NESS	3300.	3200.	0.	0.	0.	200.	2000.	600.	2800.	12100.	8320.
SCOTT	22800.	16100.	38000.	0.	0.	5900.	2900.	100.	2800.	88600.	143500.
TREGO	0.	0.	0.	0.	0.	400.	3500.	200.	3000.	7100.	3500.
WALLACE	12500.	6000.	32300.	6750.	1100.	5100.	80.	0.	2300.	66130.	72000.
WICHITA	20900.	14800.	59500.	0.	2000.	6700.	1700.	300.	2700.	108600.	140280.
DIST TOTAL	71900.	53800.	172600.	7350.	3300.	26100.	15530.	1500.	20100.	372180.	454000.
SOUTHWEST											
CLARK	0.	0.	0.	0.	0.	100.	10.	0.	2400.	2510.	4664.
FINNEY	64000.	44200.	77000.	1850.	0.	15000.	300.	700.	24000.	227050.	225000.
FORD	8400.	5700.	20800.	0.	0.	2200.	600.	300.	4500.	42500.	80000.
GRANT	30400.	22900.	39800.	3150.	0.	7500.	280.	0.	4100.	108130.	165000.
GRAY	33900.	27000.	70200.	0.	0.	8000.	160.	1700.	7200.	148160.	177280.
HAMILTON	4100.	5300.	9500.	450.	0.	2200.	180.	0.	2800.	24530.	30000.
HASKELL	47000.	20000.	91400.	2600.	0.	10800.	130.	100.	6000.	178030.	230000.
HODGEMAN	4500.	4400.	8500.	0.	0.	3500.	200.	300.	3300.	24700.	22250.
KEARNY	4200.	3400.	25800.	2200.	0.	5100.	230.	100.	5700.	46730.	122800.
MEADE	18300.	20100.	29200.	0.	0.	3100.	160.	300.	8200.	79360.	91000.
MORTON	14300.	11000.	17700.	0.	0.	3100.	500.	0.	600.	47200.	75600.
SEWARD	21500.	19000.	30200.	300.	0.	5000.	240.	400.	2700.	79340.	100000.
STANTON	40400.	11900.	70800.	4000.	0.	8100.	110.	400.	1900.	137610.	180000.
STEVENS	22700.	30700.	34800.	0.	0.	4000.	900.	0.	2100.	95200.	130000.
DIST TOTAL	313700.	225600.	525700.	14550.	0.	77700.	4000.	4300.	75500.	1241050.	1633594.

DISTRICT AND COUNTY	IRR WHEAT 1975 ACRES	IRR SORGHUM GRAIN 1975 ACRES	IRR CORN GRAIN 1975 ACRES	IRR BEETS 1975 ACRES	IRR BEANS 1975 ACRES	IRR CORN SILAGE 1975 ACRES	IRR SORGHUM SILAGE 1975 ACRES	IRR SOYBEANS 1975 ACRES	IRR ALFALFA HAY 1975 ACRES	TOTAL IRR ACRES	TOTAL IRR ACRES 1975 KS IRR SUR
NORTH CENTRAL											
CLAY	0.	0.	6900.	0.	0.	0.	0.	0.	1000.	7900.	12546.
CLOUD	0.	2200.	5100.	0.	0.	0.	0.	0.	2000.	9300.	15000.
JEWELL	0.	0.	8000.	0.	0.	0.	0.	0.	0.	8000.	10490.
MITCHELL	0.	0.	2000.	0.	0.	0.	0.	0.	300.	2300.	4300.
OSBORNE	700.	4420.	3600.	0.	0.	0.	0.	0.	0.	8720.	8000.
OTTAWA	200.	0.	2000.	0.	0.	0.	0.	0.	0.	2200.	4000.
PHILLIPS	0.	0.	3100.	0.	0.	0.	0.	0.	0.	3100.	6500.
REPUBLIC	400.	3500.	36000.	0.	0.	0.	0.	0.	1000.	40900.	50500.
ROOKS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	500.
SMITH	200.	0.	4200.	0.	0.	0.	0.	0.	0.	4400.	11550.
WASHINGTON	0.	0.	4300.	0.	0.	0.	0.	0.	700.	5000.	7800.
DIST TOTAL	1500.	10120.	75200.	0.	0.	0.	0.	0.	5000.	91820.	131186.
CENTRAL											
BARTON	3200.	5900.	5200.	0.	0.	0.	0.	0.	9000.	23300.	30000.
DICKINSON	0.	4100.	2500.	0.	0.	700.	0.	0.	0.	7300.	3605.
ELLIS	0.	3000.	3300.	0.	0.	0.	0.	0.	0.	6300.	8600.
ELLSWORTH	0.	0.	0.	0.	0.	100.	0.	0.	0.	100.	1000.
LINCOLN	0.	0.	0.	0.	0.	500.	0.	0.	0.	500.	3800.
MCPHERSON	500.	13300.	6000.	0.	0.	2000.	0.	2500.	1500.	25800.	17000.
MARION	1200.	0.	0.	0.	0.	200.	0.	0.	0.	1400.	1000.
RICE	0.	4100.	3300.	0.	0.	1000.	0.	0.	200.	8600.	11424.
RUSH	800.	6440.	2600.	0.	0.	800.	0.	0.	0.	10640.	11400.
RUSSELL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SALINE	200.	2900.	2100.	0.	0.	400.	0.	0.	0.	5600.	6500.
DIST TOTAL	5900.	39740.	25000.	0.	0.	5700.	0.	2500.	10700.	89540.	94329.
SOUTH CENTRAL											
BARBER	2600.	0.	0.	0.	0.	100.	0.	0.	100.	2800.	1010.
COMANCHE	7200.	0.	0.	0.	0.	100.	0.	0.	0.	7300.	3500.
EDWARDS	0.	9500.	7600.	0.	0.	1800.	0.	690.	12000.	31590.	64550.
HARPER	0.	0.	0.	0.	0.	100.	0.	0.	0.	100.	1500.
HARVEY	0.	3000.	2500.	0.	0.	1000.	0.	1500.	500.	8500.	10600.
KINGMAN	1000.	0.	0.	0.	0.	300.	0.	0.	0.	1300.	6726.
KIOWA	11900.	6800.	3200.	0.	0.	1600.	0.	0.	0.	23500.	23000.
PAWNEE	0.	9000.	15700.	0.	0.	2300.	1400.	1000.	19000.	48400.	55500.
PRATT	0.	2400.	8000.	0.	0.	1600.	1500.	0.	2000.	15500.	40931.
RENO	0.	0.	2200.	0.	0.	1200.	0.	0.	1000.	4400.	10103.
SEDGWICK	7200.	8600.	5500.	0.	0.	1250.	0.	500.	0.	23050.	11000.
STAFFORD	0.	10740.	9500.	0.	0.	1600.	0.	400.	3500.	25740.	45000.
SUMNER	0.	0.	0.	0.	0.	400.	0.	0.	0.	400.	1500.
DIST TOTAL	29900.	50040.	54200.	0.	0.	13350.	2900.	4090.	38100.	192580.	274920.

DISTRICT AND COUNTY	IRR WHEAT 1975 ACRES	IRR SORGHUM GRAIN 1975 ACRES	IRR CORN GRAIN 1975 ACRES	IRR BEETS 1975 ACRES	IRR BEANS 1975 ACRES	IRR CORN SILAGE 1975 ACRES	IRR SORGHUM SILAGE 1975 ACRES	IRR SOYBEANS 1975 ACRES	IRR ALFALFA HAY 1975 ACRES	TOTAL IRR ACRES	TOTAL IRR ACRES 1975 KS IRR SUR
NORTHEAST											
ATCHINSON	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BROWN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	160.
DONIPHAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	275.
JACKSON	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	200.
JEFFERSON	0.	0.	0.	0.	0.	0.	0.	0.	1000.	1000.	1200.
LEAVENWORTH	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	120.
MARSHALL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1850.
NEMAHA	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	400.
POTTAWATOMIE	0.	0.	2500.	0.	0.	0.	0.	0.	2000.	4500.	4000.
RILEY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1500.
WYANDOTTE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DIST TOTAL	0.	0.	2500.	0.	0.	0.	0.	0.	3000.	5500.	9705.
EAST CENTRAL											
ANDERSON	0.	0.	0.	0.	0.	200.	75.	500.	0.	775.	100.
CHASE	0.	0.	0.	0.	0.	200.	100.	0.	0.	300.	300.
COFFEY	0.	0.	0.	0.	0.	200.	100.	200.	0.	500.	480.
DOUGLAS	0.	0.	0.	0.	0.	0.	0.	0.	1000.	1000.	160.
FRANKLIN	0.	0.	0.	0.	0.	300.	200.	700.	0.	1200.	1800.
GEARY	0.	0.	0.	0.	0.	0.	0.	0.	500.	500.	380.
JOHNSON	0.	0.	0.	0.	0.	0.	0.	0.	200.	200.	1120.
LINN	0.	0.	0.	0.	0.	200.	0.	300.	0.	500.	75.
LYON	0.	0.	0.	0.	0.	0.	100.	0.	0.	100.	0.
MIAMI	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	90.
MORRIS	0.	0.	0.	0.	0.	100.	0.	0.	0.	100.	250.
OSAGE	0.	0.	0.	0.	0.	0.	200.	200.	0.	400.	115.
SHAWNEE	0.	0.	5700.	0.	0.	0.	0.	0.	2000.	7700.	8560.
WABAUNSEE	0.	0.	0.	0.	0.	0.	0.	0.	300.	300.	980.
DIST TOTAL	0.	0.	5700.	0.	0.	1200.	775.	1900.	4000.	13575.	14410.
SOUTHEAST											
ALLEN	0.	0.	0.	0.	0.	300.	100.	300.	0.	700.	1050.
BOURBON	0.	0.	0.	0.	0.	100.	0.	200.	0.	300.	120.
BUTLER	0.	0.	0.	0.	0.	300.	0.	0.	0.	300.	1200.
CHAUTAUQUA	0.	0.	0.	0.	0.	100.	0.	0.	200.	300.	500.
CHEROKEE	0.	0.	0.	0.	0.	0.	0.	500.	0.	500.	1000.
COWLEY	0.	0.	0.	0.	0.	100.	0.	0.	0.	100.	2000.
CRAWFORD	0.	0.	0.	0.	0.	0.	100.	400.	0.	500.	500.
ELK	0.	0.	0.	0.	0.	100.	100.	100.	300.	600.	150.
GREENWOOD	0.	0.	0.	0.	0.	200.	250.	0.	400.	850.	1000.
LABETTE	0.	0.	0.	0.	0.	0.	100.	400.	0.	500.	500.
MONTGOMERY	0.	0.	0.	0.	0.	150.	150.	500.	400.	1200.	1350.
NEOSHO	0.	0.	0.	0.	0.	0.	0.	300.	0.	300.	1200.
WILSON	0.	0.	0.	0.	0.	0.	0.	1000.	0.	1000.	720.
WOODSON	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	250.
DIST TOTAL	0.	0.	0.	0.	0.	1350.	800.	3700.	1300.	7150.	11540.
STATE TOTAL	437500.	392420.	1031500.	43000.	13000.	151700.	37105.	18890.	193000.	2318115.	3033101.

DISTRICT	IRR WHEAT 1975 ACRES	IRR SORGHUM GRAIN 1975 ACRES	IRR CORN GRAIN 1975 ACRES	IRR BEETS 1975 ACRES	IRR BEANS 1975 ACRES	IRR CORN SILAGE 1975 ACRES	IRR SORGHUM SILAGE 1975 ACRES	IRR SOYBEANS 1975 ACRES	IRR ALFALFA HAY 1975 ACRES	TOTAL IRR ACRES	TOTAL IRR ACRES 1975 KS IRR SUR
NORTHWEST	14600.	13120.	170600.	21100.	9700.	26300.	13100.	900.	35300.	304720.	409417.
WEST CENTRAL	71900.	53800.	172600.	7350.	3300.	26100.	15530.	1500.	20100.	372180.	454000.
SOUTHWEST	313700.	225600.	525700.	14550.	0.	77700.	4000.	4300.	75500.	1241050.	1633594.
NORTH CENTRAL	1500.	10120.	75200.	0.	0.	0.	0.	0.	5000.	91820.	131186.
CENTRAL	5900.	39740.	25000.	0.	0.	5700.	0.	2500.	10700.	89540.	94329.
SOUTH CENTRAL	29900.	50040.	54200.	0.	0.	13350.	2900.	4090.	38100.	192580.	274920.
NORTHEAST	0.	0.	2500.	0.	0.	0.	0.	0.	3000.	5500.	9705.
EAST CENTRAL	0.	0.	5700.	0.	0.	1200.	775.	1900.	4000.	13575.	14410.
SOUTHEAST	0.	0.	0.	0.	0.	1350.	800.	3700.	1300.	7150.	11540.
STATE TOTAL	437500.	392420.	1031500.	43000.	13000.	151700.	37105.	18890.	193000.	2318115.	3033101.

WATER REQUIREMENTS FOR VARIOUS CROPS IN KANSAS, VALUES GIVEN IN INCHES PER YEAR

DISTRICT	ALFALFA	CORN	SORGHUM	WHEAT	BEETS	BEANS	SOYBEANS
NORTHWEST	20.8	15.1	11.0	8.9	15.6	11.0	11.0
WEST CENTRAL	21.6	15.5	11.5	9.7	16.4	11.5	11.5
SOUTHWEST	22.5	16.0	11.9	10.4	17.1	11.9	11.9
NORTH CENTRAL	17.0	11.3	8.7	6.1	0.0	0.0	8.7
CENTRAL	18.1	11.5	8.7	6.7	0.0	0.0	8.9
SOUTH CENTRAL	19.1	11.8	8.8	7.3	0.0	0.0	9.1
NORTHEAST	15.0	7.5	5.1	3.2	0.0	0.0	5.9
EAST CENTRAL	15.0	7.5	5.1	3.2	0.0	0.0	5.9
SOUTHEAST	11.6	7.5	5.5	0.0	0.0	0.0	6.0

DISTRICT AND COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
NORTHWEST																
CHEYENNE	176.	85.	261.	522.	65.	797.	72.6	442.	351.	22.	27.	42.	351.	165.	279.	12199.
DECATUR	78.	62.	140.	230.	64.	360.	17.7	101.	14.	11.	65.	10.	14.	80.	678.	2968.
GRAHAM	150.	119.	269.	153.	68.	224.	21.0	133.	4.	4.	116.	8.	4.	31.	1204.	2318.
NORTON	150.	36.	186.	233.	62.	375.	24.4	97.	39.	0.	27.	30.	39.	0.	284.	8912.
RAWLINS	121.	49.	170.	226.	63.	361.	21.5	147.	78.	33.	32.	4.	78.	240.	330.	1203.
SHERIDAN	140.	55.	195.	744.	63.	1180.	80.4	533.	220.	232.	69.	12.	220.	1705.	718.	3493.
SHERMAN	207.	54.	261.	1111.	63.	1767.	161.0	1147.	779.	99.	239.	31.	779.	726.	2472.	9079.
THOMAS	175.	87.	261.	584.	66.	889.	81.2	529.	393.	75.	30.	31.	393.	553.	312.	9100.
DIST TOTAL	166.	65.	231.	3804.	64.	5952.	479.8	3129.	1879.	476.	606.	168.	1879.	3501.	6276.	49270.
WEST CENTRAL																
GOVE	115.	72.	187.	264.	65.	410.	26.8	133.	43.	50.	20.	21.	43.	365.	208.	6018.
GREELEY	160.	22.	182.	367.	60.	609.	38.8	306.	258.	5.	2.	1.	298.	35.	24.	435.
LANE	114.	34.	147.	206.	61.	337.	17.3	118.	104.	0.	6.	7.	104.	0.	67.	1962.
LOGAN	126.	48.	174.	229.	62.	368.	22.4	155.	90.	0.	58.	6.	90.	0.	604.	1858.
NESS	140.	16.	156.	135.	60.	224.	12.1	89.	78.	4.	5.	2.	78.	27.	54.	654.
SCOTT	135.	20.	156.	985.	60.	1632.	88.6	645.	572.	49.	7.	17.	572.	361.	70.	4966.
TREGO	140.	111.	251.	95.	68.	140.	12.3	57.	14.	23.	9.	11.	14.	170.	91.	3100.
WALLACE	187.	44.	231.	787.	62.	1266.	102.2	702.	494.	107.	75.	26.	494.	787.	778.	7568.
WICHITA	145.	17.	162.	1254.	60.	2081.	117.8	802.	744.	1.	11.	46.	744.	11.	110.	13341.
DIST TOTAL	147.	30.	178.	4322.	61.	7064.	438.3	3006.	2438.	239.	194.	136.	2438.	1755.	2006.	39901.
SOUTHWEST																
CLARK	250.	110.	360.	47.	68.	69.	8.6	65.	30.	2.	32.	1.	30.	12.	332.	151.
FINNEY	193.	76.	269.	2708.	65.	4138.	388.4	3058.	3038.	24.	29.	7.	3038.	176.	298.	2176.
FORD	250.	108.	358.	530.	68.	785.	98.1	709.	593.	61.	36.	19.	593.	445.	377.	5497.
GRANT	303.	31.	334.	1246.	62.	2014.	235.2	1897.	1897.	0.	0.	0.	1897.	0.	0.	0.
GRAY	189.	85.	273.	1758.	66.	2684.	256.3	1701.	1137.	396.	95.	74.	1137.	2909.	984.	21542.
HAMILTON	113.	41.	154.	305.	63.	487.	26.2	151.	130.	0.	3.	19.	130.	0.	26.	5466.
HASKELL	371.	29.	400.	2121.	61.	3469.	484.5	3713.	3518.	149.	0.	46.	3518.	1094.	0.	13499.
HODGEMAN	250.	38.	288.	310.	62.	502.	50.6	211.	0.	125.	37.	48.	0.	519.	388.	14173.
KEARNY	190.	65.	255.	624.	64.	970.	86.6	663.	629.	11.	13.	10.	629.	80.	136.	2826.
MEADE	268.	44.	311.	948.	62.	1528.	166.0	1283.	1203.	41.	26.	13.	1203.	301.	269.	3711.
MORTON	165.	30.	195.	527.	61.	863.	58.8	464.	435.	22.	7.	1.	435.	161.	68.	248.
SEWARD	326.	64.	390.	906.	64.	1421.	193.6	1407.	1332.	29.	0.	45.	1332.	214.	0.	13223.
STANTON	252.	25.	277.	1618.	61.	2638.	255.4	2045.	2041.	0.	0.	5.	2041.	0.	0.	1321.
STEVENS	309.	53.	362.	1067.	63.	1682.	212.7	1569.	1458.	40.	31.	41.	1458.	294.	319.	11915.
DIST TOTAL	257.	53.	310.	14713.	63.	23248.	2520.9	18976.	17442.	898.	309.	327.	17442.	6605.	3198.	95749.

DISTRICT AND COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
NORTH CENTRAL																
CLAY	40.	65.	105.	79.	64.	124.	4.6	25.	3.	3.	16.	3.	3.	21.	168.	867.
CLOUD	40.	130.	170.	92.	69.	134.	7.9	49.	4.	37.	8.	1.	4.	269.	85.	222.
JEWELL	40.	14.	54.	75.	61.	124.	2.3	16.	0.	5.	12.	0.	0.	35.	120.	0.
MITCHELL	40.	43.	83.	23.	62.	37.	1.1	8.	0.	1.	7.	0.	0.	5.	70.	33.
OSBORNE	40.	17.	57.	69.	61.	114.	2.3	14.	0.	6.	8.	1.	0.	41.	78.	189.
OTTAWA	40.	109.	149.	20.	67.	30.	1.5	11.	9.	1.	1.	0.	9.	7.	6.	129.
PHILLIPS	40.	54.	94.	29.	64.	45.	1.5	9.	8.	0.	0.	1.	8.	2.	4.	234.
REPUBLIC	40.	70.	110.	380.	65.	582.	22.4	116.	18.	55.	33.	13.	18.	407.	344.	3801.
ROCKS	40.	196.	236.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
SMITH	40.	3.	43.	40.	60.	67.	1.0	5.	0.	1.	3.	1.	0.	9.	31.	225.
WASHINGTON	40.	124.	164.	50.	69.	73.	4.2	27.	4.	10.	12.	1.	4.	76.	122.	261.
DIST TOTAL	40.	65.	105.	858.	65.	1329.	48.8	283.	45.	119.	99.	20.	45.	874.	1026.	5961.
CENTRAL																
BARTON	50.	94.	144.	246.	66.	370.	18.7	96.	42.	12.	27.	15.	42.	90.	275.	4458.
DICKINSON	50.	151.	201.	61.	71.	86.	6.0	38.	12.	20.	4.	1.	12.	150.	46.	337.
ELLIS	50.	18.	68.	54.	61.	87.	2.1	10.	0.	4.	5.	2.	0.	27.	50.	464.
ELLSWORTH	50.	63.	113.	1.	64.	1.	0.1	0.	0.	0.	0.	0.	0.	1.	1.	3.
LINCOLN	50.	69.	119.	5.	63.	8.	0.3	1.	0.	0.	0.	0.	0.	1.	2.	118.
MCPHERSON	50.	35.	85.	218.	61.	355.	10.6	67.	17.	3.	43.	4.	17.	24.	442.	1196.
MARION	50.	59.	109.	9.	63.	14.	0.5	3.	0.	3.	0.	0.	0.	21.	4.	0.
RICE	50.	127.	177.	74.	69.	107.	6.6	22.	4.	1.	7.	9.	4.	9.	76.	2781.
RUSH	50.	27.	77.	84.	61.	138.	3.7	18.	14.	0.	0.	4.	14.	3.	3.	1045.
RUSSELL	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
SALINE	50.	79.	129.	46.	66.	70.	3.2	13.	5.	2.	2.	4.	5.	14.	24.	1068.
DIST TOTAL	50.	70.	120.	797.	64.	1237.	51.8	269.	55.	46.	89.	39.	95.	341.	923.	11472.
SOUTH CENTRAL																
BARBER	50.	213.	263.	18.	75.	25.	2.3	17.	9.	0.	8.	0.	9.	0.	86.	0.
COMANCHE	50.	195.	245.	45.	75.	60.	5.1	30.	14.	0.	13.	3.	14.	0.	131.	955.
EDWARDS	50.	160.	210.	358.	72.	497.	36.5	226.	179.	14.	14.	20.	179.	101.	141.	5727.
HARPER	50.	170.	220.	1.	73.	1.	0.1	1.	0.	0.	0.	0.	0.	2.	2.	8.
HARVEY	50.	100.	150.	76.	67.	114.	5.9	34.	5.	9.	17.	3.	5.	67.	181.	832.
KINGMAN	50.	198.	248.	9.	75.	12.	1.0	7.	2.	5.	0.	0.	2.	35.	3.	11.
KIOWA	50.	187.	237.	169.	74.	228.	18.9	106.	46.	35.	14.	11.	46.	256.	142.	3160.
PAWNEE	50.	86.	136.	563.	66.	856.	40.5	191.	82.	25.	45.	39.	82.	183.	469.	11358.
PRATT	50.	184.	234.	154.	74.	208.	17.0	115.	55.	31.	25.	3.	55.	231.	261.	952.
RENO	50.	153.	203.	49.	72.	69.	4.9	29.	16.	8.	4.	2.	16.	55.	37.	683.
SEDGWICK	50.	67.	117.	177.	64.	277.	11.3	69.	37.	24.	4.	4.	37.	180.	43.	1268.
STAFFORD	50.	160.	210.	246.	72.	342.	25.0	148.	14.	124.	6.	5.	14.	909.	60.	1403.
SUMNER	50.	48.	98.	4.	62.	6.	0.2	0.	0.	0.	0.	0.	0.	0.	0.	121.
DIST TOTAL	50.	129.	179.	1870.	69.	2695.	168.9	974.	458.	275.	150.	90.	458.	2020.	1558.	26476.

DISTRICT AND COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
NORTHEAST																
ATCHINSON	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
BROWN	50.	175.	225.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
DONIPHAN	50.	312.	362.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
JACKSON	50.	160.	210.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
JEFFERSON	50.	58.	108.	13.	62.	20.	0.8	3.	0.	2.	0.	1.	0.	16.	0.	226.
LEAVENWORTH	50.	90.	140.	0.	68.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MARSHALL	50.	103.	153.	0.	67.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
NEMAHA	50.	160.	210.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
POTTAWATOMIE	50.	109.	159.	41.	68.	60.	3.3	10.	0.	4.	1.	5.	0.	30.	15.	1381.
RILEY	50.	33.	83.	0.	62.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
WYANDOTTE	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
DIST TOTAL	50.	96.	146.	53.	66.	80.	4.1	13.	0.	6.	1.	5.	0.	46.	15.	1607.
EAST CENTRAL																
ANDERSON	50.	236.	286.	4.	75.	5.	0.5	3.	0.	3.	0.	0.	0.	24.	0.	0.
CHASE	50.	233.	283.	2.	71.	2.	0.2	1.	0.	1.	0.	0.	0.	11.	0.	0.
COFFEY	50.	179.	229.	3.	70.	4.	0.3	2.	2.	0.	0.	0.	2.	0.	0.	0.
DOUGLAS	50.	130.	180.	13.	66.	19.	1.2	2.	0.	0.	0.	2.	0.	0.	0.	669.
FRANKLIN	50.	227.	277.	6.	71.	9.	0.8	6.	0.	3.	3.	0.	0.	21.	29.	0.
GEARY	50.	20.	70.	6.	60.	10.	0.3	2.	0.	0.	2.	0.	0.	0.	20.	0.
JOHNSON	50.	197.	247.	3.	75.	3.	0.3	1.	0.	1.	1.	0.	0.	4.	8.	57.
LINN	50.	312.	362.	3.	75.	4.	0.5	3.	0.	3.	0.	0.	0.	21.	0.	0.
LYON	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MIAMI	50.	312.	362.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MORRIS	50.	187.	237.	1.	69.	1.	0.1	1.	1.	0.	0.	0.	1.	0.	0.	0.
OSAGE	50.	312.	362.	2.	75.	2.	0.3	2.	0.	1.	1.	0.	0.	7.	12.	0.
SHAWNEE	50.	37.	87.	61.	61.	99.	3.0	16.	5.	2.	7.	2.	5.	14.	69.	675.
WABAUNSEE	50.	39.	89.	4.	62.	6.	0.2	1.	0.	0.	0.	0.	0.	1.	5.	53.
DIST TOTAL	50.	84.	134.	106.	64.	165.	7.7	41.	8.	14.	14.	5.	8.	103.	142.	1453.
SOUTHEAST																
ALLEN	50.	0.	50.	4.	60.	6.	0.1	0.	0.	0.	0.	0.	0.	2.	0.	42.
BOURBON	50.	312.	362.	2.	75.	2.	0.3	2.	0.	0.	2.	0.	0.	0.	21.	0.
BUTLER	50.	230.	280.	2.	75.	3.	0.2	0.	0.	0.	0.	0.	0.	0.	0.	0.
CHAUTAUQUA	50.	178.	228.	3.	75.	3.	0.3	1.	0.	1.	0.	0.	0.	6.	0.	76.
CHEROKEE	50.	252.	302.	3.	72.	3.	0.4	2.	0.	2.	1.	0.	0.	13.	6.	0.
COWLEY	50.	19.	69.	1.	60.	1.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	2.
CRAWFORD	50.	312.	362.	2.	75.	3.	0.4	3.	0.	0.	3.	0.	0.	0.	32.	0.
ELK	50.	312.	362.	4.	75.	6.	0.8	6.	0.	0.	6.	0.	0.	0.	58.	0.
GREENWOOD	50.	254.	304.	6.	72.	9.	0.9	4.	0.	1.	2.	1.	0.	10.	18.	258.
LABETTE	50.	266.	316.	2.	75.	3.	0.4	2.	0.	1.	1.	0.	0.	8.	14.	0.
MONTGOMERY	50.	257.	307.	8.	75.	11.	1.1	8.	0.	1.	7.	0.	0.	10.	70.	0.
NEOSHO	50.	293.	343.	2.	75.	2.	0.2	2.	0.	0.	2.	0.	0.	0.	18.	0.
WILSON	50.	270.	320.	5.	75.	7.	0.7	5.	0.	1.	4.	0.	0.	8.	45.	0.
WOODSON	50.	0.	50.	0.	60.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
DIST TOTAL	50.	232.	282.	43.	73.	60.	5.9	36.	0.	8.	27.	1.	0.	58.	281.	378.
STATE TOTAL	198.	57.	255.	26565.	64.	41829.	3726.1	26727.	22364.	2081.	1489.	793.	22364.	15302.	15425.	232267.

DISTRICT	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
NORTHWEST	166.	65.	231.	3804.	64.	5952.	479.8	3129.	1879.	476.	606.	168.	1879.	3501.	6276.	49270.
WEST CENTRAL	147.	30.	178.	4322.	61.	7064.	438.3	3006.	2438.	239.	194.	136.	2438.	1755.	2006.	39901.
SOUTHWEST	257.	53.	310.	14713.	63.	23248.	2520.9	18976.	17442.	898.	309.	327.	17442.	6605.	3198.	95749.
NORTH CENTRAL	40.	65.	105.	858.	65.	1329.	48.8	283.	45.	119.	99.	20.	45.	874.	1026.	5961.
CENTRAL	50.	70.	120.	797.	64.	1237.	51.8	269.	95.	46.	89.	39.	95.	341.	923.	11472.
SOUTH CENTRAL	50.	129.	179.	1870.	69.	2655.	168.9	974.	458.	275.	150.	90.	458.	2020.	1558.	26476.
NORTHEAST	50.	96.	146.	53.	66.	80.	4.1	13.	0.	6.	1.	5.	0.	46.	15.	1607.
EAST CENTRAL	50.	84.	134.	106.	64.	165.	7.7	41.	8.	14.	14.	5.	8.	103.	142.	1453.
SOUTHEAST	50.	232.	282.	43.	73.	60.	5.9	36.	0.	8.	27.	1.	0.	58.	281.	378.
STATE TOTAL	198.	57.	255.	26565.	64.	41829.	3726.1	26727.	22364.	2081.	1489.	793.	22364.	15302.	15425.	232267.

COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
ALLEN	50.	0.	50.	4.	60.	6.	0.1	0.	0.	0.	0.	0.	0.	2.	0.	42.
ANDERSON	50.	236.	286.	4.	75.	5.	0.5	3.	0.	3.	0.	0.	0.	24.	0.	0.
ATCHINSON	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
BARBER	50.	213.	263.	18.	75.	25.	2.3	17.	9.	0.	8.	0.	9.	0.	86.	0.
BARTON	50.	94.	144.	246.	66.	370.	18.7	96.	42.	12.	27.	15.	42.	90.	275.	4458.
BOURBON	50.	312.	362.	2.	75.	2.	0.3	2.	0.	0.	2.	0.	0.	0.	21.	0.
BROWN	50.	175.	225.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
BUTLER	50.	230.	280.	2.	75.	3.	0.2	0.	0.	0.	0.	0.	0.	0.	0.	0.
CHASE	50.	233.	283.	2.	71.	2.	0.2	1.	0.	1.	0.	0.	0.	11.	0.	0.
CHAUTAUQUA	50.	178.	228.	3.	75.	3.	0.3	1.	0.	1.	0.	0.	0.	6.	0.	76.
CHEROKEE	50.	252.	302.	3.	72.	3.	0.4	2.	0.	2.	1.	0.	0.	13.	6.	0.
CHEYENNE	176.	85.	261.	522.	65.	797.	72.6	442.	351.	22.	27.	42.	351.	165.	279.	12199.
CLARK	250.	110.	360.	47.	68.	69.	8.6	65.	30.	2.	32.	1.	30.	12.	332.	151.
CLAY	40.	65.	105.	79.	64.	124.	4.6	25.	3.	3.	16.	3.	3.	21.	168.	867.
CLOUD	40.	130.	170.	92.	69.	134.	7.9	49.	4.	37.	8.	1.	4.	269.	85.	222.
COFFEY	50.	179.	229.	3.	70.	4.	0.3	2.	2.	0.	0.	0.	2.	0.	0.	0.
COMANCHE	50.	195.	245.	45.	75.	60.	5.1	30.	14.	0.	13.	3.	14.	0.	131.	955.
COWLEY	50.	19.	69.	1.	60.	1.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	2.
CRAWFORD	50.	312.	362.	2.	75.	3.	0.4	3.	0.	0.	3.	0.	0.	0.	32.	0.
DECATUR	78.	62.	140.	230.	64.	360.	17.7	101.	14.	11.	65.	10.	14.	80.	678.	2968.
DICKINSON	50.	151.	201.	61.	71.	86.	6.0	38.	12.	20.	4.	1.	12.	150.	46.	337.
DONIPHAN	50.	312.	362.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
DOUGLAS	50.	130.	180.	13.	66.	19.	1.2	2.	0.	0.	0.	0.	2.	0.	0.	669.
EDWARDS	50.	160.	210.	358.	72.	497.	36.5	226.	179.	14.	14.	20.	179.	101.	141.	5727.
ELK	50.	312.	362.	4.	75.	6.	0.8	6.	0.	0.	6.	0.	0.	0.	58.	0.
ELLIS	50.	18.	68.	54.	61.	87.	2.1	10.	0.	4.	5.	2.	0.	27.	50.	464.
ELLSWORTH	50.	63.	113.	1.	64.	1.	0.1	0.	0.	0.	0.	0.	0.	1.	1.	3.
FINNEY	193.	76.	269.	2708.	65.	4138.	388.4	3098.	3038.	24.	29.	7.	3038.	176.	298.	2176.
FORD	250.	108.	358.	530.	68.	785.	98.1	709.	593.	61.	36.	19.	593.	445.	377.	5497.
FRANKLIN	50.	227.	277.	6.	71.	9.	0.8	6.	0.	3.	3.	0.	0.	21.	29.	0.
GEARY	50.	20.	70.	6.	60.	10.	0.3	2.	0.	0.	2.	0.	0.	0.	20.	0.
GOVE	115.	72.	187.	264.	65.	410.	26.8	133.	43.	50.	20.	21.	43.	365.	208.	6018.
GRAHAM	150.	119.	269.	153.	68.	224.	21.0	133.	4.	4.	116.	8.	4.	31.	1204.	2318.
GRANT	303.	31.	334.	1246.	62.	2014.	235.2	1897.	1897.	0.	0.	0.	1897.	0.	0.	0.
GRAY	189.	85.	273.	1758.	66.	2684.	256.3	1701.	1137.	396.	95.	74.	1137.	2909.	984.	21542.
GREELEY	160.	22.	182.	367.	60.	609.	38.8	306.	298.	5.	2.	1.	298.	35.	24.	435.
GREENWOOD	50.	254.	304.	6.	72.	9.	0.9	4.	0.	1.	2.	1.	0.	10.	18.	258.
HAMILTON	113.	41.	154.	305.	63.	487.	26.2	151.	130.	0.	3.	19.	130.	0.	26.	5466.
HARPER	50.	170.	220.	1.	73.	1.	0.1	1.	0.	0.	0.	0.	0.	2.	2.	8.
HARVEY	50.	100.	150.	76.	67.	114.	5.9	34.	5.	9.	17.	3.	5.	67.	181.	832.
HASKELL	371.	29.	400.	2121.	61.	3469.	484.5	3713.	3518.	149.	0.	46.	3518.	1094.	0.	13499.
HODGEMAN	250.	38.	288.	310.	62.	502.	50.6	211.	0.	125.	37.	48.	0.	919.	388.	14173.
JACKSON	50.	160.	210.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
JEFFERSON	50.	58.	108.	13.	62.	20.	0.8	3.	0.	2.	0.	1.	0.	16.	0.	226.
JEWELL	40.	14.	54.	75.	61.	124.	2.3	16.	0.	5.	12.	0.	0.	35.	120.	0.
JOHNSON	50.	197.	247.	3.	75.	3.	0.3	1.	0.	1.	1.	0.	0.	4.	8.	57.
KEARNY	190.	65.	255.	624.	64.	970.	86.6	663.	629.	11.	13.	10.	629.	80.	136.	2826.
KINGMAN	50.	198.	248.	9.	75.	12.	1.0	7.	2.	5.	0.	0.	2.	35.	3.	11.
KIOWA	50.	187.	237.	169.	74.	228.	18.9	106.	46.	35.	14.	11.	46.	256.	142.	3160.
LABETTE	50.	266.	316.	2.	75.	3.	0.4	2.	0.	1.	1.	0.	0.	8.	14.	0.
LANE	114.	34.	147.	206.	61.	337.	17.3	118.	104.	0.	6.	7.	104.	0.	67.	1962.
LEAVENWORTH	50.	90.	140.	0.	68.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
LINCOLN	50.	69.	119.	5.	63.	8.	0.3	1.	0.	0.	0.	0.	0.	1.	2.	118.

COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
LINN	50.	312.	362.	3.	75.	4.	0.5	3.	0.	3.	0.	0.	0.	21.	0.	0.
LOGAN	126.	48.	174.	229.	62.	368.	22.4	155.	90.	0.	58.	6.	90.	0.	604.	1858.
LYON	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MCPHERSON	50.	35.	85.	218.	61.	355.	10.6	67.	17.	3.	43.	4.	17.	24.	442.	1196.
MARION	50.	59.	109.	9.	63.	14.	0.5	3.	0.	3.	0.	0.	0.	21.	4.	0.
MARSHALL	50.	103.	153.	0.	67.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MEADE	268.	44.	311.	948.	62.	1528.	166.0	1283.	1203.	41.	26.	13.	1203.	301.	269.	3711.
MIAMI	50.	312.	362.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MITCHELL	40.	43.	83.	23.	62.	37.	1.1	8.	0.	1.	7.	0.	0.	5.	70.	33.
MONTGOMERY	50.	257.	307.	8.	75.	11.	1.1	8.	0.	1.	7.	0.	0.	10.	70.	0.
MORRIS	50.	187.	237.	1.	69.	1.	0.1	1.	1.	0.	0.	0.	1.	0.	0.	0.
MORTON	165.	30.	195.	527.	61.	863.	58.8	464.	435.	22.	7.	1.	435.	161.	68.	248.
NEMAHA	50.	160.	210.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
NEOSHO	50.	293.	343.	2.	75.	2.	0.2	2.	0.	0.	2.	0.	0.	0.	18.	0.
NESS	140.	16.	156.	135.	60.	224.	12.1	85.	78.	4.	5.	2.	78.	27.	54.	654.
NORTON	150.	36.	186.	233.	62.	375.	24.4	97.	39.	0.	27.	30.	39.	0.	284.	8912.
OSAGE	50.	312.	362.	2.	75.	2.	0.3	2.	0.	1.	1.	0.	0.	7.	12.	0.
OSBORNE	40.	17.	57.	69.	61.	114.	2.3	14.	0.	6.	8.	1.	0.	41.	78.	189.
OTTAWA	40.	109.	149.	20.	67.	30.	1.5	11.	9.	1.	1.	0.	9.	7.	6.	129.
PAWNEE	50.	86.	136.	563.	66.	856.	40.5	191.	82.	25.	45.	39.	82.	183.	469.	11358.
PHILLIPS	40.	54.	94.	29.	64.	45.	1.5	9.	8.	0.	0.	1.	8.	2.	4.	234.
POTTAWATOMIE	50.	109.	159.	41.	68.	60.	3.3	10.	0.	4.	1.	5.	0.	30.	15.	1381.
PRATT	50.	184.	234.	154.	74.	208.	17.0	115.	55.	31.	25.	3.	55.	231.	261.	952.
RAWLINS	121.	49.	170.	226.	63.	361.	21.5	147.	78.	33.	32.	4.	78.	240.	330.	1203.
RENO	50.	153.	203.	49.	72.	69.	4.9	29.	16.	8.	4.	2.	16.	55.	37.	683.
REPUBLIC	40.	70.	110.	380.	65.	582.	22.4	119.	18.	55.	33.	13.	18.	407.	344.	3801.
RICE	50.	127.	177.	74.	69.	107.	6.6	22.	4.	1.	7.	9.	4.	9.	76.	2781.
RILEY	50.	33.	83.	0.	62.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
ROCKS	40.	196.	236.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
RUSH	50.	27.	77.	84.	61.	138.	3.7	18.	14.	0.	0.	4.	14.	3.	3.	1045.
RUSSELL	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
SALINE	50.	79.	129.	46.	66.	70.	3.2	13.	5.	2.	2.	4.	5.	14.	24.	1068.
SCOTT	135.	20.	156.	985.	60.	1632.	88.6	645.	572.	49.	7.	17.	572.	361.	70.	4966.
SEDGWICK	50.	67.	117.	177.	64.	277.	11.3	69.	37.	24.	4.	4.	37.	180.	43.	1268.
SEWARD	326.	64.	390.	906.	64.	1421.	193.6	1407.	1332.	29.	0.	45.	1332.	214.	0.	13223.
SHAWNEE	50.	37.	87.	61.	61.	99.	3.0	16.	5.	2.	7.	2.	5.	14.	69.	675.
SHERIDAN	140.	55.	195.	744.	63.	1180.	80.4	533.	220.	232.	69.	12.	220.	1705.	718.	3493.
SHERMAN	207.	54.	261.	1111.	63.	1767.	161.0	1147.	779.	99.	239.	31.	779.	726.	2472.	9079.
SMITH	40.	3.	43.	40.	60.	67.	1.0	5.	0.	1.	3.	1.	0.	9.	31.	225.
STAFFORD	50.	160.	210.	246.	72.	342.	25.0	148.	14.	124.	6.	5.	14.	909.	60.	1403.
STANTON	252.	25.	277.	1618.	61.	2638.	255.4	2045.	2041.	0.	0.	5.	2041.	0.	0.	1321.
STEVENS	309.	53.	362.	1067.	63.	1682.	212.7	1569.	1458.	40.	31.	41.	1458.	294.	319.	11915.
SUMNER	50.	48.	98.	4.	62.	6.	0.2	0.	0.	0.	0.	0.	0.	0.	0.	121.
THOMAS	175.	87.	261.	584.	66.	889.	81.2	529.	393.	75.	30.	31.	393.	553.	312.	9100.
TREGO	140.	111.	251.	95.	68.	140.	12.3	57.	14.	23.	9.	11.	14.	170.	91.	3100.
WABAUNSEE	50.	39.	89.	4.	62.	6.	0.2	1.	0.	0.	0.	0.	0.	1.	5.	53.
WALLACE	187.	44.	231.	787.	62.	1266.	102.2	702.	494.	107.	75.	26.	494.	787.	778.	7568.
WASHINGTON	40.	124.	164.	50.	69.	73.	4.2	27.	4.	10.	12.	1.	4.	76.	122.	261.
WICHITA	145.	17.	162.	1254.	60.	2081.	117.8	802.	744.	1.	11.	46.	744.	11.	110.	13341.
WILSON	50.	270.	320.	5.	75.	7.	0.7	5.	0.	1.	4.	0.	0.	8.	45.	0.
WOODSON	50.	0.	50.	0.	60.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
WYANDOTTE	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
STATE TOTAL	198.	57.	255.	26565.	64.	41829.	3726.1	26727.	22364.	2081.	1489.	793.	22364.	15302.	15425.	232267.

Appendix E: Computer Output, Energy Use Using the Base Year Water Levels as Input Data

```
      $JOB           ,TIME=(,25),PAGES=25
      C$PRINTOFF
      C$PRINTON

      C  ******
      C     ENTER YOUR OVERALL PUMPING EFFICIENCIES FOR EACH ENERGY SOURCE HERE (NAT
      C     GAS, DIESEL, LP GAS, ELECTRICITY).
      C     THESE ARE THE EFFICIENCIES LISTED IN HANSON'S THESIS.
    8       DATA EFF/12.4,16.2,13.5,52.3/

      C  ******
      C     ENTER THE PUMPING DEPTHS FOR DISTRICTS ONE THROUGH NINE HERE (NW, WC, SW,
      C     NC, C, SC, NE, EC, SE).
      C     THE PUMPING DEPTHS FOR THE FIRST THREE DISTRICTS ARE THE AVERAGES OBTAINED
      C     FROM 1940-50 WELL DATA WHERE ONLY RECORDS COMPLETE FOR EVERY YEAR WERE
      C     READ.
    9       DATA DEPTH/140.9,145.,227.3,40.,50.,50.,50.,50.,50./

      C  ******
      C     ENTER YOUR PRESSURE REQUIREMENTS HERE (OPEN DITCH, GATED PIPE, CENTER
      C     PIVOT, TOW LINE AND SIDE ROLL, BIG GUN, OTHER SPRINKLER).
      C     PRESSURE REQUIREMENTS, FT. OF WATER.
   10       POD=0.
   11       PGP=20.
   12       PCP=196.
   13       PTLSR=175.
   14       PBG=312.
   15       POS=160.

      C  ******
      C     ENTER IRRIGATION EFFICIENCIES HERE, IN PERCENT.  ENTER EFFICIENCIES F1
      C     FOR GRAVITY SYSTEMS AND F2 FOR SPRINKLER SYSTEMS.
   16       F1=60.
   17       F2=75.

      C$PRINTOFF
      C$PRINTON

      C  ******
      C     ENTER INDIVIDUAL COUNTY PUMPING DEPTHS HERE.
      C     PUMPING DEPTHS ARE FROM 1940-50 WELL DATA WHERE ONLY RECORDS COMPLETE FOR
      C     EVERY YEAR WERE READ.
   34       USAGE(12,10)=152.6
   35       USAGE(20,10)=73.7
   36       USAGE(77,10)=109.6
   37       USAGE(90,10)=134.4
   38       USAGE(91,10)=199.9
   39       USAGE(97,10)=175.2
   40       USAGE(22,10)=126.0
   41       USAGE(36,10)=156.8
   42       USAGE(51,10)=115.0
   43       USAGE(55,10)=181.0
   44       USAGE(86,10)=126.7
   45       USAGE(100,10)=175.7
   46       USAGE(102,10)=133.6
   47       USAGE(28,10)=156.5
   48       USAGE(34,10)=268.4
   49       USAGE(35,10)=201.4
   50       USAGE(38,10)=56.4
   51       USAGE(41,10)=351.2
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52          USAGE(47,10)=185.8
53          USAGE(60,10)=259.1
54          USAGE(65,10)=190.5
55          USAGE(88,10)=325.0
56          USAGE(94,10)=209.8
57          USAGE(95,10)=296.0

      C$PRINTOFF
      C$PRINTON

      C  ******
      C       ENTER N, THE NUMBER OF CROPS.
65          N=9

      C$PRINTOFF

      $ENTRY
```

DISTRICT AND COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
NORTHWEST																
CHEYENNE	153.	85.	238.	522.	65.	797.	66.2	403.	320.	20.	25.	38.	320.	150.	254.	11127.
DECATUR	74.	62.	136.	230.	64.	360.	17.1	98.	14.	11.	63.	10.	14.	78.	656.	2874.
GRAHAM	141.	119.	260.	153.	68.	224.	20.3	128.	4.	4.	112.	8.	4.	30.	1163.	2239.
NORTON	141.	36.	177.	233.	62.	375.	23.2	92.	37.	0.	26.	29.	37.	0.	270.	8477.
RAWLINS	110.	49.	159.	226.	63.	361.	20.0	137.	73.	30.	30.	4.	73.	224.	307.	1122.
SHERIDAN	134.	55.	189.	744.	63.	1180.	78.0	517.	213.	225.	67.	12.	213.	1654.	697.	3389.
SHERMAN	200.	54.	254.	1111.	63.	1767.	156.5	1115.	757.	96.	232.	30.	757.	706.	2403.	8825.
THOMAS	175.	87.	262.	584.	66.	889.	81.4	531.	394.	75.	30.	31.	394.	554.	312.	9121.
DIST TOTAL	158.	65.	223.	3804.	64.	5952.	462.8	3021.	1813.	462.	585.	161.	1813.	3397.	6063.	47174.
WEST CENTRAL																
GOVE	126.	72.	198.	264.	65.	410.	28.4	141.	45.	52.	21.	22.	45.	386.	220.	6368.
GREELEY	157.	22.	179.	367.	60.	609.	38.0	300.	292.	5.	2.	1.	292.	35.	23.	426.
LANE	115.	34.	149.	206.	61.	337.	17.5	119.	106.	0.	7.	7.	106.	0.	68.	1982.
LOGAN	181.	48.	229.	229.	62.	368.	29.5	204.	119.	0.	77.	8.	119.	0.	796.	2445.
NESS	145.	16.	161.	135.	60.	224.	12.5	92.	81.	4.	5.	2.	81.	27.	56.	675.
SCOTT	127.	20.	147.	985.	60.	1632.	83.7	609.	540.	46.	6.	16.	540.	341.	66.	4688.
TREGO	145.	111.	256.	95.	68.	140.	12.5	58.	15.	24.	9.	11.	15.	174.	93.	3161.
WALLACE	176.	44.	220.	787.	62.	1266.	97.2	667.	470.	102.	71.	25.	470.	748.	740.	7197.
WICHITA	134.	17.	150.	1254.	60.	2081.	109.4	745.	691.	1.	10.	42.	691.	10.	102.	12394.
DIST TOTAL	143.	30.	174.	4322.	61.	7064.	428.7	2935.	2358.	234.	209.	134.	2358.	1720.	2163.	39338.
SOUTHWEST																
CLARK	227.	110.	337.	47.	68.	69.	8.1	61.	29.	2.	30.	0.	29.	11.	311.	142.
FINNEY	157.	76.	233.	2708.	65.	4138.	336.2	2682.	2630.	21.	25.	6.	2630.	153.	258.	1883.
FORD	227.	108.	335.	530.	68.	785.	91.9	664.	556.	57.	34.	18.	556.	417.	353.	5148.
GRANT	268.	31.	299.	1246.	62.	2014.	210.5	1698.	1698.	0.	0.	0.	1698.	0.	0.	0.
GRAY	201.	85.	286.	1758.	66.	2684.	268.3	1780.	1150.	414.	99.	77.	1190.	3044.	1030.	22543.
HAMILTON	56.	41.	97.	305.	63.	487.	16.5	95.	82.	0.	2.	12.	82.	0.	17.	3453.
HASKELL	351.	29.	380.	2121.	61.	3469.	460.8	3532.	3347.	141.	0.	44.	3347.	1040.	0.	12841.
HODGEMAN	227.	38.	266.	310.	62.	502.	46.6	194.	0.	115.	35.	45.	0.	846.	358.	13058.
KEARNY	186.	65.	251.	624.	64.	970.	85.1	651.	618.	11.	13.	9.	618.	79.	134.	2778.
MEADE	259.	44.	303.	948.	62.	1528.	161.5	1246.	1171.	40.	25.	12.	1171.	293.	262.	3611.
MORTON	191.	30.	221.	527.	61.	863.	66.6	526.	493.	25.	7.	1.	493.	182.	77.	281.
SEWARD	325.	64.	389.	906.	64.	1421.	193.1	1403.	1329.	29.	0.	45.	1329.	214.	0.	13193.
STANTON	210.	25.	235.	1618.	61.	2638.	216.2	1731.	1727.	0.	0.	4.	1727.	0.	0.	1118.
STEVENS	296.	53.	349.	1067.	63.	1682.	205.0	1513.	1406.	39.	30.	39.	1406.	283.	308.	11487.
DIST TOTAL	238.	53.	291.	14713.	63.	23248.	2366.5	17779.	16274.	892.	300.	312.	16274.	6562.	3106.	91535.

Appendix F: Computer Output, Energy Use Using 1977 Water Levels as Input Data

```
      $JOB            ,TIME=(,25),PAGES=25
      C$PRINTOFF
      C$PRINTON

      C  ******
      C     ENTER YOUR OVERALL PUMPING EFFICIENCIES FOR EACH ENERGY SOURCE HERE (NAT
      C     GAS, DIESEL, LP GAS, ELECTRICITY).
      C     THESE ARE THE EFFICIENCIES LISTED IN HANSON'S THESIS.
    8       DATA EFF/12.4,16.2,13.5,52.3/

      C  ******
      C     ENTER THE PUMPING DEPTHS FOR DISTRICTS ONE THROUGH NINE HERE (NW, WC, SW,
      C     NC, C, SC, NE, EC, SE).
      C     THE PUMPING DEPTHS FOR THE FIRST THREE DISTRICTS ARE THE AVERAGES OBTAINED
      C     FROM 1977 WELL DATA WHERE ONLY RECORDS COMPLETE FOR EVERY YEAR WERE READ.
    9       DATA DEPTH/145.7,155.9,242.,40.,50.,50.,50.,50.,50./

      C  ******
      C     ENTER YOUR PRESSURE REQUIREMENTS HERE (OPEN DITCH, GATED PIPE, CENTER
      C     PIVOT, TOW LINE AND SIDE ROLL, BIG GUN, OTHER SPRINKLER).
      C     PRESSURE REQUIREMENTS, FT. OF WATER.
   10       POD=0.
   11       PGP=20.
   12       PCP=196.
   13       PTLSR=175.
   14       PBG=312.
   15       POS=160.

      C  ******
      C     ENTER IRRIGATION EFFICIENCIES HERE, IN PERCENT.  ENTER EFFICIENCIES F1
      C     FOR GRAVITY SYSTEMS AND F2 FOR SPRINKLER SYSTEMS.
   16       F1=60.
   17       F2=75.

      C$PRINTOFF
      C$PRINTON

      C  ******
      C     ENTER INDIVIDUAL COUNTY PUMPING DEPTHS HERE.
      C     PUMPING DEPTHS ARE FROM 1977 WELL DATA WHERE ONLY RECORDS COMPLETE FOR
      C     EVERY YEAR WERE READ.
   34       USAGE(12,10)=156.6
   35       USAGE(20,10)= 75.2
   36       USAGE(77,10)=111.9
   37       USAGE(90,10)=139.9
   38       USAGE(91,10)=211.
   39       USAGE(97,10)=179.8
   40       USAGE(32,10)=125.5
   41       USAGE(36,10)=167.2
   42       USAGE(51,10)=119.7
   43       USAGE(55,10)=189.4
   44       USAGE(86,10)=142.6
   45       USAGE(100,10)=192.7
   46       USAGE(102,10)=154.2
   47       USAGE(28,10)=176.1
   48       USAGE(34,10)=314.
   49       USAGE(35,10)=208.5
   50       USAGE(38,10)= 60.6
   51       USAGE(41,10)=370.2
   52       USAGE(47,10)=196.6
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53          USAGE(60,10)=267.8
54          USAGE(65,10)=191.
55          USAGE(88,10)=332.5
56          USAGE(94,10)=239.3
57          USAGE(95,10)=305.3

      C$PRINTOFF
      C$PRINTON

      C  ******
      C      ENTER N, THE NUMBER OF CROPS.
65          N=9

      C$PRINTOFF

      $ENTRY
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DISTRICT AND COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
NORTHWEST																
CHEYENNE	157.	85.	242.	522.	65.	797.	67.3	410.	326.	21.	25.	39.	326.	153.	258.	11314.
DECATUR	75.	62.	137.	230.	64.	360.	17.3	99.	14.	11.	64.	10.	14.	78.	664.	2906.
GRAHAM	146.	119.	265.	153.	68.	224.	20.7	130.	4.	4.	114.	8.	4.	31.	1185.	2281.
NORTON	146.	36.	182.	233.	62.	375.	23.9	94.	38.	0.	27.	30.	38.	0.	277.	8707.
RAWLINS	112.	49.	161.	226.	63.	361.	20.3	139.	74.	31.	30.	4.	74.	227.	312.	1138.
SHERIDAN	140.	55.	195.	744.	63.	1180.	80.3	532.	220.	232.	69.	12.	220.	1702.	717.	3487.
SHERMAN	211.	54.	265.	1111.	63.	1767.	163.4	1164.	791.	100.	242.	31.	791.	737.	2508.	9211.
THOMAS	180.	87.	267.	584.	66.	889.	82.8	540.	401.	77.	31.	32.	401.	564.	318.	9281.
DIST TOTAL	164.	65.	229.	3804.	64.	5952.	476.0	3109.	1867.	475.	602.	165.	1867.	3493.	6239.	48325.
WEST CENTRAL																
GOVE	126.	72.	198.	264.	65.	410.	28.3	141.	45.	52.	21.	22.	45.	385.	219.	6352.
GREELEY	167.	22.	189.	367.	60.	609.	40.3	318.	309.	5.	2.	2.	309.	37.	25.	451.
LANE	120.	34.	154.	206.	61.	337.	18.1	123.	109.	0.	7.	7.	109.	0.	70.	2044.
LOGAN	189.	48.	238.	229.	62.	368.	30.5	211.	123.	0.	80.	9.	123.	0.	825.	2534.
NESS	156.	16.	171.	135.	60.	224.	13.4	98.	86.	4.	6.	2.	86.	29.	59.	721.
SCOTT	143.	20.	163.	985.	60.	1632.	92.8	675.	598.	51.	7.	18.	598.	377.	74.	5196.
TREGO	156.	111.	267.	95.	68.	140.	13.0	60.	15.	25.	9.	11.	15.	181.	97.	3296.
WALLACE	193.	44.	237.	787.	62.	1266.	104.7	719.	506.	110.	77.	26.	506.	806.	797.	7754.
WICHITA	154.	17.	171.	1254.	60.	2081.	124.4	847.	786.	2.	11.	48.	786.	11.	116.	14091.
DIST TOTAL	158.	30.	189.	4322.	61.	7064.	465.4	3192.	2578.	248.	220.	145.	2578.	1827.	2281.	42440.
SOUTHWEST																
CLARK	242.	110.	352.	47.	68.	69.	8.5	63.	30.	2.	31.	1.	30.	12.	324.	148.
FINNEY	176.	76.	252.	2708.	65.	4138.	364.5	2908.	2852.	23.	27.	7.	2852.	165.	280.	2042.
FORD	242.	108.	350.	530.	68.	785.	95.9	693.	580.	59.	36.	18.	580.	435.	368.	5374.
GRANT	314.	31.	345.	1246.	62.	2014.	242.6	1957.	1957.	0.	0.	0.	1957.	0.	0.	0.
GRAY	209.	85.	293.	1758.	66.	2684.	274.9	1824.	1219.	424.	102.	79.	1219.	3119.	1055.	23102.
HAMILTON	61.	41.	101.	305.	63.	487.	17.2	99.	85.	0.	2.	12.	85.	0.	17.	3603.
HASKELL	370.	29.	399.	2121.	61.	3469.	483.8	3708.	3514.	149.	0.	46.	3514.	1092.	0.	13482.
HODGEMAN	242.	38.	280.	310.	62.	502.	49.2	205.	0.	121.	36.	47.	0.	893.	378.	13780.
KEARNY	197.	65.	262.	624.	64.	970.	88.8	679.	645.	11.	13.	10.	645.	82.	139.	2897.
MEADE	268.	44.	311.	948.	62.	1528.	166.1	1284.	1205.	41.	26.	13.	1205.	301.	269.	3714.
MORTON	191.	30.	221.	527.	61.	863.	66.8	527.	494.	25.	7.	1.	494.	182.	77.	281.
SEWARD	333.	64.	397.	906.	64.	1421.	196.8	1431.	1355.	30.	0.	46.	1355.	218.	0.	13447.
STANTON	239.	25.	264.	1618.	61.	2638.	243.4	1949.	1944.	0.	0.	4.	1944.	0.	0.	1258.
STEVENS	305.	53.	358.	1067.	63.	1682.	210.5	1553.	1443.	40.	31.	40.	1443.	291.	316.	11794.
DIST TOTAL	256.	53.	309.	14713.	63.	23248.	2509.1	18881.	17322.	924.	311.	324.	17322.	6792.	3225.	94923.

Appendix G: Computer Output, Energy Use Assuming 85 per cent Irrigation Efficiency for Gravity Systems

COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
ALLEN	50.	0.	50.	4.	85.	5.	0.1	0.	0.	0.	0.	0.	0.	1.	0.	29.
ANDERSON	50.	236.	286.	4.	75.	5.	0.5	3.	0.	3.	0.	0.	0.	24.	0.	0.
ATCHINSON	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
BARBER	50.	213.	263.	18.	75.	25.	2.3	17.	9.	0.	8.	0.	9.	0.	66.	0.
BARTON	50.	94.	144.	246.	81.	305.	15.4	79.	34.	10.	22.	13.	34.	74.	227.	3675.
BOURBON	50.	312.	362.	2.	75.	2.	0.3	2.	0.	0.	2.	0.	0.	0.	21.	0.
BROWN	50.	175.	225.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
BUTLER	50.	230.	280.	2.	75.	3.	0.2	0.	0.	0.	0.	0.	0.	0.	0.	0.
CHASE	50.	233.	283.	2.	78.	2.	0.2	1.	0.	1.	0.	0.	0.	10.	0.	0.
CHAUTAUQUA	50.	178.	228.	3.	75.	3.	0.3	1.	0.	1.	0.	0.	0.	6.	0.	76.
CHEROKEE	50.	252.	302.	3.	77.	3.	0.3	2.	0.	2.	1.	0.	0.	12.	5.	0.
CHEYENNE	176.	85.	261.	522.	81.	642.	58.5	356.	283.	18.	22.	34.	283.	133.	224.	9824.
CLARK	250.	110.	360.	47.	80.	58.	7.3	55.	26.	1.	27.	0.	26.	10.	281.	128.
CLAY	40.	65.	105.	79.	82.	96.	3.5	19.	2.	2.	13.	2.	2.	16.	130.	671.
CLOUD	40.	130.	170.	92.	79.	117.	6.9	43.	3.	32.	7.	1.	3.	235.	74.	194.
COFFEY	50.	179.	229.	3.	78.	3.	0.3	2.	2.	0.	0.	0.	2.	0.	0.	0.
COMANCHE	50.	195.	245.	45.	75.	60.	5.1	30.	14.	0.	13.	3.	14.	0.	131.	955.
COWLEY	50.	19.	69.	1.	85.	1.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	2.
CRAWFORD	50.	312.	362.	2.	75.	3.	0.4	3.	0.	0.	3.	0.	0.	0.	32.	0.
DECATUR	78.	62.	140.	230.	82.	280.	13.7	78.	11.	8.	51.	8.	11.	62.	527.	2306.
DICKINSON	50.	151.	201.	61.	78.	78.	5.5	35.	11.	19.	4.	1.	11.	137.	42.	307.
DONIPHAN	50.	312.	362.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
DOUGLAS	50.	130.	180.	13.	81.	15.	1.0	2.	0.	0.	0.	2.	0.	0.	0.	541.
EDWARDS	50.	160.	210.	358.	77.	465.	34.1	211.	168.	13.	13.	18.	168.	94.	132.	5355.
ELK	50.	312.	362.	4.	75.	6.	0.8	6.	0.	0.	6.	0.	0.	0.	58.	0.
ELLIS	50.	18.	68.	54.	84.	64.	1.5	7.	0.	3.	4.	1.	0.	20.	37.	339.
ELLSWORTH	50.	63.	113.	1.	82.	1.	0.0	0.	0.	0.	0.	0.	0.	0.	1.	3.
FINNEY	193.	76.	269.	2708.	81.	3327.	312.3	2491.	2443.	19.	23.	6.	2443.	142.	240.	1749.
FORD	251.	108.	358.	530.	80.	662.	82.8	598.	501.	51.	31.	16.	501.	376.	318.	4638.
FRANKLIN	50.	227.	277.	6.	78.	8.	0.8	5.	0.	3.	3.	0.	0.	19.	26.	0.
GEARY	50.	20.	70.	6.	85.	7.	0.2	1.	0.	0.	1.	0.	0.	0.	14.	0.
GOVE	115.	72.	187.	264.	82.	322.	21.1	105.	34.	39.	16.	16.	34.	287.	164.	4738.
GRAHAM	150.	119.	269.	193.	79.	193.	18.2	114.	4.	4.	100.	7.	4.	27.	1040.	2081.
GRANT	303.	31.	334.	1246.	84.	1488.	173.8	1402.	1402.	0.	0.	0.	1402.	0.	0.	0.
GRAY	180.	95.	273.	1758.	81.	2162.	206.6	1371.	916.	319.	77.	59.	916.	2344.	793.	17358.
GREELEY	150.	22.	182.	367.	85.	433.	27.6	218.	212.	3.	2.	1.	212.	25.	17.	309.
GREENWOOD	50.	254.	304.	6.	77.	8.	0.9	4.	0.	1.	2.	1.	0.	10.	17.	241.
HAMILTON	113.	41.	154.	305.	83.	366.	19.7	113.	97.	0.	2.	14.	97.	0.	20.	4109.
HARPER	50.	170.	220.	1.	76.	1.	0.1	1.	0.	0.	0.	0.	0.	2.	2.	7.
HARVEY	50.	100.	150.	76.	81.	94.	4.9	28.	4.	8.	14.	2.	4.	56.	149.	687.
HASKELL	371.	29.	400.	2121.	84.	2518.	351.6	2695.	2554.	108.	0.	33.	2554.	794.	0.	9798.
HODGEMAN	250.	38.	288.	310.	84.	369.	37.2	155.	0.	92.	28.	36.	0.	675.	286.	10418.
JACKSON	50.	160.	210.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
JEFFERSON	50.	58.	108.	13.	82.	15.	0.6	2.	0.	2.	0.	1.	0.	12.	0.	169.
JEWELL	40.	14.	54.	75.	85.	89.	1.7	12.	0.	3.	8.	0.	0.	25.	86.	0.
JOHNSON	50.	197.	247.	3.	75.	3.	0.3	1.	0.	1.	1.	0.	0.	4.	8.	57.
KEARNY	190.	65.	255.	624.	82.	760.	67.8	519.	493.	9.	10.	8.	493.	63.	107.	2214.
KINGMAN	50.	198.	248.	9.	75.	12.	1.0	7.	2.	5.	0.	0.	2.	35.	3.	11.
KIOWA	50.	187.	237.	169.	76.	224.	18.5	104.	46.	34.	13.	11.	46.	252.	139.	3106.
LABETTE	50.	266.	316.	2.	75.	3.	0.4	2.	0.	1.	1.	0.	0.	8.	14.	0.
LANE	114.	34.	147.	206.	84.	245.	12.6	86.	76.	0.	5.	5.	76.	0.	49.	1427.
LEAVENWORTH	50.	90.	140.	0.	80.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
LINCOLN	50.	69.	119.	5.	83.	6.	0.2	1.	0.	0.	0.	0.	0.	1.	2.	90.

COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
LINN	50.	312.	362.	3.	75.	4.	0.5	3.	0.	3.	0.	0.	0.	21.	0.	0.
LOGAN	126.	48.	174.	229.	83.	275.	16.7	116.	67.	0.	44.	5.	67.	0.	452.	1389.
LYON	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MCPHERSON	50.	35.	85.	218.	84.	259.	7.7	49.	13.	2.	31.	3.	13.	18.	322.	871.
MARION	50.	59.	109.	9.	83.	10.	0.4	3.	0.	2.	0.	0.	0.	16.	3.	0.
MARSHALL	50.	103.	153.	0.	80.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MEADE	268.	44.	311.	948.	84.	1133.	123.1	951.	892.	30.	19.	9.	892.	223.	200.	2752.
MIAMI	50.	312.	362.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MITCHELL	40.	43.	83.	23.	84.	28.	0.8	6.	0.	1.	5.	0.	0.	4.	52.	24.
MONTGOMERY	50.	257.	307.	8.	75.	11.	1.1	9.	0.	1.	7.	0.	0.	10.	70.	0.
MORRIS	50.	187.	237.	1.	79.	1.	0.1	1.	1.	0.	0.	0.	1.	0.	0.	0.
MORTON	165.	30.	195.	527.	84.	625.	42.6	336.	315.	16.	5.	1.	315.	116.	49.	179.
NEMAHA	50.	160.	210.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
NEOSHO	50.	293.	343.	2.	75.	2.	0.2	2.	0.	0.	2.	0.	0.	0.	18.	0.
NESS	140.	16.	156.	135.	85.	159.	8.7	64.	56.	3.	4.	2.	56.	19.	38.	467.
NORTON	150.	36.	186.	233.	84.	279.	18.2	72.	29.	0.	20.	23.	29.	0.	211.	6631.
OSAGE	50.	312.	362.	2.	75.	2.	0.3	2.	0.	1.	1.	0.	0.	7.	12.	0.
OSBORNE	40.	17.	57.	69.	84.	82.	1.6	10.	0.	4.	5.	0.	0.	30.	56.	137.
OTTAWA	40.	109.	149.	20.	80.	25.	1.3	9.	7.	1.	0.	0.	7.	6.	5.	108.
PAWNEE	50.	86.	136.	563.	81.	693.	32.8	154.	66.	20.	37.	31.	66.	148.	380.	9196.
PHILLIPS	40.	54.	94.	29.	82.	35.	1.2	7.	6.	0.	0.	1.	6.	2.	3.	184.
POTTAWATOMIE	50.	109.	159.	41.	80.	51.	2.8	9.	0.	3.	1.	4.	0.	26.	13.	1165.
PRATT	50.	184.	234.	154.	76.	204.	16.7	113.	54.	31.	25.	3.	54.	227.	256.	933.
RAWLINS	121.	49.	170.	226.	83.	272.	16.2	111.	59.	25.	24.	3.	59.	181.	248.	906.
RENO	50.	153.	203.	49.	77.	64.	4.5	27.	15.	7.	3.	2.	15.	51.	35.	634.
REPUBLIC	40.	70.	110.	380.	81.	466.	18.0	95.	14.	44.	27.	10.	14.	326.	276.	3046.
RICE	50.	127.	177.	74.	79.	94.	5.8	19.	3.	1.	6.	8.	3.	8.	67.	2439.
RILEY	50.	33.	83.	0.	84.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
ROOKS	40.	196.	236.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
RUSH	50.	27.	77.	84.	85.	99.	2.7	13.	10.	0.	0.	3.	10.	7.	2.	751.
RUSSELL	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
SALINE	50.	79.	129.	46.	81.	57.	2.6	11.	4.	2.	2.	3.	4.	12.	20.	866.
SCOTT	135.	20.	156.	985.	85.	1162.	63.1	459.	407.	35.	5.	12.	407.	257.	53.	3537.
SEDGWICK	50.	67.	117.	177.	82.	214.	8.9	54.	28.	19.	3.	3.	28.	139.	34.	983.
SEWARD	326.	64.	390.	906.	83.	1058.	149.6	1087.	1030.	23.	0.	35.	1030.	166.	0.	10218.
SHAWNEE	50.	37.	87.	61.	84.	72.	2.2	11.	4.	1.	5.	2.	4.	10.	51.	493.
SHERIDAN	140.	55.	195.	744.	83.	896.	61.1	405.	167.	176.	53.	9.	167.	1295.	545.	2653.
SHERMAN	207.	54.	261.	1111.	83.	1337.	121.9	869.	590.	75.	181.	23.	590.	550.	1871.	6872.
SMITH	40.	3.	43.	40.	85.	48.	0.7	4.	0.	1.	2.	1.	0.	6.	22.	159.
STAFFORD	50.	160.	210.	246.	77.	320.	23.4	139.	13.	116.	5.	4.	13.	850.	56.	1312.
STANTON	252.	25.	277.	1618.	84.	1924.	186.3	1492.	1489.	0.	0.	3.	1489.	0.	0.	964.
STEVENS	309.	53.	362.	1067.	83.	1291.	163.2	1204.	1119.	31.	24.	31.	1119.	225.	245.	9144.
SUMNER	50.	48.	98.	4.	83.	5.	0.2	0.	0.	0.	0.	0.	0.	0.	0.	90.
THOMAS	175.	87.	261.	584.	81.	719.	65.7	428.	318.	61.	24.	25.	318.	447.	252.	7363.
TREGO	140.	111.	251.	95.	80.	119.	10.4	48.	12.	20.	7.	9.	12.	144.	77.	2628.
WABAUNSEE	50.	39.	89.	4.	84.	4.	0.1	1.	0.	0.	0.	0.	0.	1.	4.	39.
WALLACE	187.	44.	231.	787.	84.	942.	76.0	522.	367.	80.	56.	19.	367.	585.	578.	5629.
WASHINGTON	40.	124.	164.	50.	79.	63.	3.6	23.	3.	9.	10.	1.	3.	66.	105.	226.
WICHITA	145.	17.	162.	1254.	85.	1478.	83.6	569.	528.	1.	8.	32.	528.	8.	78.	9474.
WILSON	50.	270.	320.	5.	75.	7.	0.7	5.	0.	1.	4.	0.	0.	8.	45.	0.
WOODSON	50.	0.	50.	0.	85.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
WYANDOTTE	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
STATE TOTAL	195.	60.	255.	26565.	83.	32187.	2866.2	20500.	17033.	1660.	1187.	621.	17033.	12203.	12300.	181993.

Appendix H: Computer Output, Energy Use Assuming Nebraska Standards for Pumping Efficiencies

COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
ALLEN	50.	0.	50.	4.	60.	6.	0.1	0.	0.	0.	0.	0.	0.	1.	0.	32.
ANDERSON	50.	236.	286.	4.	75.	5.	0.5	3.	0.	3.	0.	0.	0.	19.	0.	0.
ATCHISON	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
BARBER	50.	213.	263.	18.	75.	25.	2.3	13.	7.	0.	6.	0.	7.	0.	64.	0.
BARTON	50.	94.	144.	246.	66.	370.	18.7	71.	30.	10.	20.	12.	30.	70.	204.	3429.
BOURBON	50.	312.	362.	2.	75.	2.	0.3	2.	0.	0.	2.	0.	0.	0.	16.	0.
BROWN	50.	175.	225.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
BUTLER	50.	230.	280.	2.	75.	3.	0.2	0.	0.	0.	0.	0.	0.	0.	0.	0.
CHASE	50.	233.	283.	2.	71.	2.	0.2	1.	0.	1.	0.	0.	0.	8.	0.	0.
CHAUTAUQUA	50.	178.	228.	3.	75.	3.	0.3	1.	0.	1.	0.	0.	0.	5.	0.	59.
CHEROKEE	50.	252.	302.	3.	72.	3.	0.4	2.	0.	1.	0.	0.	0.	10.	4.	0.
CHEYENNE	176.	85.	261.	522.	65.	797.	72.6	326.	256.	17.	20.	32.	256.	128.	207.	9382.
CLARK	250.	110.	360.	47.	68.	69.	8.6	48.	22.	1.	24.	0.	22.	10.	246.	116.
CLAY	40.	65.	105.	79.	64.	124.	4.6	19.	2.	2.	12.	2.	2.	17.	125.	667.
CLOUD	40.	131.	170.	92.	69.	134.	7.9	38.	3.	29.	6.	1.	3.	210.	63.	171.
COFFEY	50.	179.	229.	3.	70.	4.	0.3	2.	2.	0.	0.	0.	2.	0.	0.	0.
COMANCHE	50.	195.	245.	45.	75.	60.	5.1	22.	10.	0.	9.	3.	10.	0.	97.	734.
COWLEY	50.	19.	69.	1.	60.	1.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	2.
CRAWFORD	50.	312.	362.	2.	75.	3.	0.4	2.	0.	0.	2.	0.	0.	0.	24.	0.
DECATUR	78.	62.	140.	230.	64.	360.	17.7	75.	10.	8.	49.	8.	10.	62.	503.	2282.
DICKINSON	50.	151.	201.	61.	71.	86.	6.0	29.	9.	16.	3.	1.	9.	117.	34.	259.
DONIPHAN	50.	312.	362.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
DOUGLAS	50.	130.	180.	13.	66.	19.	1.2	2.	0.	0.	0.	2.	0.	0.	0.	515.
EDWARDS	50.	160.	210.	358.	72.	497.	36.5	167.	131.	11.	10.	15.	131.	79.	105.	4405.
ELK	50.	312.	362.	4.	75.	6.	0.8	4.	0.	0.	4.	0.	0.	0.	43.	0.
ELLIS	50.	18.	68.	54.	61.	87.	2.1	8.	0.	3.	4.	1.	0.	21.	37.	357.
ELLSWORTH	50.	63.	113.	1.	64.	1.	0.1	0.	0.	0.	0.	0.	0.	0.	1.	3.
FINNEY	193.	76.	269.	2708.	65.	4138.	398.4	2262.	2216.	19.	21.	6.	2216.	137.	221.	1673.
FORD	230.	108.	358.	530.	68.	785.	98.1	521.	433.	47.	27.	14.	433.	347.	279.	4228.
FRANKLIN	50.	227.	277.	6.	71.	9.	0.8	4.	0.	2.	2.	0.	0.	16.	21.	0.
GEARY	50.	20.	70.	6.	60.	10.	0.3	1.	0.	0.	1.	0.	0.	0.	15.	0.
GOVE	116.	72.	187.	264.	65.	410.	26.4	101.	31.	39.	15.	16.	31.	284.	154.	4629.
GRAHAM	150.	119.	269.	153.	68.	224.	21.0	95.	3.	3.	86.	6.	3.	24.	893.	1782.
GRANT	303.	31.	334.	1246.	62.	2014.	235.2	1383.	1383.	0.	0.	0.	1383.	0.	0.	0.
GRAY	139.	85.	223.	1758.	66.	2664.	256.3	1264.	829.	308.	70.	57.	829.	2266.	730.	16568.
GREELEY	160.	22.	182.	367.	60.	609.	38.8	224.	217.	4.	2.	1.	217.	27.	18.	334.
GREENWOOD	50.	254.	304.	6.	72.	9.	0.9	3.	0.	1.	1.	1.	0.	8.	13.	199.
HAMILTON	113.	41.	154.	305.	63.	487.	26.2	111.	95.	0.	2.	14.	95.	0.	20.	4204.
HARPER	50.	170.	220.	1.	73.	1.	0.1	0.	0.	0.	0.	0.	0.	2.	2.	6.
HARVEY	50.	100.	150.	76.	67.	114.	5.9	26.	4.	7.	13.	2.	4.	52.	134.	640.
HASKELL	371.	29.	400.	2121.	61.	3469.	484.5	2718.	2566.	116.	0.	35.	2566.	852.	0.	10393.
HODGEMAN	253.	38.	288.	310.	62.	502.	50.6	162.	0.	97.	28.	37.	0.	715.	288.	10901.
JACKSON	50.	160.	210.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
JEFFERSON	50.	58.	108.	13.	62.	20.	0.8	2.	0.	2.	0.	1.	0.	12.	0.	174.
JEWELL	40.	14.	54.	75.	61.	124.	2.3	12.	0.	4.	9.	0.	0.	29.	89.	0.
JOHNSON	50.	197.	247.	3.	75.	3.	0.3	1.	0.	0.	1.	0.	0.	3.	6.	43.
KEARNY	190.	65.	255.	624.	64.	970.	86.6	484.	459.	9.	10.	7.	459.	63.	101.	2174.
KINGMAN	50.	198.	248.	9.	75.	12.	1.0	5.	1.	4.	0.	0.	1.	27.	2.	8.
KIOWA	50.	187.	237.	169.	74.	228.	18.9	79.	34.	27.	10.	8.	34.	199.	105.	2431.
LABETTE	50.	266.	316.	2.	75.	3.	0.4	2.	0.	1.	1.	0.	0.	6.	10.	0.
LANE	114.	34.	147.	206.	61.	337.	17.3	86.	76.	0.	5.	5.	76.	0.	50.	1509.
LEAVENWORTH	50.	90.	140.	0.	68.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
LINCOLN	50.	69.	119.	5.	63.	8.	0.3	1.	0.	0.	0.	0.	0.	1.	1.	91.

COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
LINN	50.	312.	362.	3.	75.	4.	0.5	2.	0.	2.	0.	0.	0.	16.	0.	0.
LOGAN	126.	48.	174.	229.	62.	368.	22.4	114.	66.	0.	43.	5.	66.	0.	448.	1429.
LYON	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MCPHERSON	50.	35.	85.	218.	61.	355.	10.6	50.	13.	3.	32.	3.	13.	19.	328.	920.
MARION	50.	59.	109.	9.	63.	14.	0.5	3.	0.	2.	0.	0.	0.	17.	3.	0.
MARSHALL	50.	103.	153.	0.	67.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MEADE	268.	44.	311.	948.	62.	1528.	166.0	939.	878.	32.	19.	10.	878.	234.	200.	2954.
MIAMI	50.	312.	362.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MITCHELL	40.	43.	83.	23.	62.	37.	1.1	6.	0.	1.	5.	0.	0.	4.	52.	25.
MONTGOMERY	50.	257.	307.	8.	75.	11.	1.1	6.	0.	1.	5.	0.	0.	8.	52.	0.
MORRIS	50.	187.	237.	1.	69.	1.	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.
MORTON	165.	30.	195.	527.	61.	863.	58.8	340.	317.	17.	5.	1.	317.	125.	50.	190.
NEMAHA	50.	160.	210.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
NEOSHO	50.	293.	343.	2.	75.	2.	0.2	1.	0.	0.	1.	0.	0.	0.	14.	0.
NESS	140.	16.	156.	135.	60.	224.	12.1	65.	57.	3.	4.	2.	57.	21.	40.	503.
NORTON	150.	36.	186.	233.	62.	375.	24.4	72.	28.	0.	20.	23.	28.	0.	211.	6854.
OSAGE	50.	312.	362.	2.	75.	2.	0.3	2.	0.	1.	1.	0.	0.	5.	9.	0.
OSBORNE	40.	17.	57.	69.	61.	114.	2.3	10.	0.	4.	6.	0.	0.	32.	58.	146.
OTTAWA	40.	109.	149.	23.	67.	30.	1.5	8.	6.	1.	0.	0.	6.	5.	4.	99.
PAWNEE	50.	86.	136.	563.	66.	856.	40.5	142.	60.	19.	34.	30.	60.	142.	348.	8735.
PHILLIPS	40.	54.	94.	29.	64.	45.	1.5	7.	6.	0.	0.	1.	6.	2.	3.	180.
POTTAWATOMIE	50.	109.	159.	41.	68.	60.	3.3	8.	0.	3.	1.	4.	0.	24.	11.	1062.
PRATT	50.	184.	234.	154.	74.	208.	17.0	86.	40.	25.	19.	2.	40.	180.	193.	732.
RAWLINS	121.	49.	170.	226.	63.	361.	21.5	109.	57.	25.	24.	3.	57.	187.	244.	925.
RENO	50.	153.	203.	49.	72.	69.	4.9	22.	11.	6.	3.	2.	11.	43.	28.	525.
REPUBLIC	40.	70.	110.	380.	65.	582.	22.4	91.	13.	43.	25.	10.	13.	317.	255.	2924.
RICE	50.	127.	177.	74.	69.	107.	6.6	16.	3.	1.	5.	7.	3.	7.	57.	2139.
RILEY	50.	33.	83.	0.	62.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
ROOKS	40.	196.	236.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
RUSH	50.	27.	77.	84.	61.	138.	3.7	14.	10.	0.	0.	3.	10.	2.	2.	804.
RUSSELL	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
SALINE	50.	79.	129.	46.	66.	70.	3.2	10.	4.	2.	2.	3.	4.	11.	18.	822.
SCOTT	135.	20.	156.	985.	60.	1632.	88.6	473.	417.	38.	5.	13.	417.	281.	52.	3920.
SEDGWICK	50.	67.	117.	177.	64.	277.	11.3	52.	27.	19.	3.	3.	27.	140.	32.	975.
SEWARD	326.	64.	390.	906.	64.	1421.	193.6	1029.	972.	23.	0.	35.	972.	167.	0.	10170.
SHAWNEE	50.	37.	87.	61.	61.	99.	3.0	12.	4.	1.	5.	2.	4.	11.	51.	519.
SHERIDAN	140.	55.	195.	744.	63.	1180.	80.4	402.	160.	181.	51.	9.	160.	1328.	532.	2686.
SHERMAN	207.	54.	261.	1111.	63.	1767.	161.0	846.	568.	77.	177.	24.	568.	566.	1834.	6983.
SMITH	40.	3.	43.	40.	60.	67.	1.0	4.	0.	1.	2.	1.	0.	7.	23.	173.
STAFFORD	50.	160.	210.	246.	72.	342.	25.0	114.	10.	96.	4.	4.	10.	708.	45.	1079.
STANTON	257.	25.	277.	1618.	61.	2638.	255.4	1492.	1489.	0.	0.	3.	1489.	0.	0.	1016.
STEVENS	309.	53.	362.	1067.	63.	1682.	212.7	1149.	1063.	31.	23.	31.	1063.	229.	237.	9164.
SUMNER	50.	48.	98.	4.	62.	6.	0.2	0.	0.	0.	0.	0.	0.	0.	0.	93.
THOMAS	175.	87.	261.	584.	66.	889.	81.2	391.	287.	59.	22.	24.	287.	431.	231.	6999.
TREGO	140.	111.	251.	95.	68.	140.	12.3	43.	10.	18.	7.	8.	10.	135.	68.	2384.
WABAUNSEE	50.	39.	89.	4.	62.	6.	0.2	1.	0.	0.	0.	0.	0.	1.	4.	41.
WALLACE	187.	44.	231.	787.	62.	1266.	102.2	519.	360.	83.	56.	20.	360.	613.	577.	5820.
WASHINGTON	40.	124.	164.	50.	69.	73.	4.2	20.	3.	8.	9.	1.	3.	59.	90.	201.
WICHITA	145.	17.	162.	1254.	60.	2081.	117.8	587.	543.	1.	8.	35.	543.	8.	81.	10261.
WILSON	50.	270.	320.	5.	75.	7.	0.7	4.	0.	1.	3.	0.	0.	6.	33.	0.
WOODSON	50.	0.	50.	0.	60.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
WYANDOTTE	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
STATE TOTAL	198.	57.	255.	26565.	64.	41829.	3726.1	19648.	16313.	1621.	1104.	610.	16313.	11918.	11442.	178640.

Appendix I: Computer Output, Energy Use Assuming Dry Years Water Requirements

COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
ALLEN	50.	0.	50.	5.	60.	8.	0.1	0.	0.	0.	0.	0.	0.	2.	0.	54.
ANDERSON	50.	236.	286.	5.	75.	7.	0.7	4.	0.	4.	0.	0.	0.	32.	0.	0.
ATCHISON	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
BARBER	50.	213.	263.	23.	75.	30.	2.8	21.	11.	0.	10.	0.	11.	0.	106.	0.
BARTON	50.	94.	144.	292.	66.	439.	22.2	113.	49.	15.	31.	18.	49.	107.	326.	5281.
BOURBON	50.	312.	362.	2.	75.	3.	0.3	3.	0.	0.	3.	0.	0.	0.	27.	0.
BROWN	50.	175.	225.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
BUTLER	50.	230.	280.	2.	75.	3.	0.3	0.	0.	0.	0.	0.	0.	0.	0.	0.
CHASE	50.	233.	283.	2.	71.	3.	0.3	2.	0.	2.	0.	0.	0.	15.	0.	0.
CHAUTAUQUA	50.	178.	228.	3.	75.	5.	0.4	1.	0.	1.	0.	0.	0.	8.	0.	101.
CHEROKEE	50.	252.	302.	3.	72.	4.	0.5	3.	0.	2.	1.	0.	0.	16.	7.	0.
CHEYENNE	176.	85.	261.	603.	65.	921.	83.8	511.	406.	26.	31.	48.	406.	190.	322.	14091.
CLARK	250.	110.	360.	53.	68.	78.	9.8	73.	35.	2.	36.	1.	35.	14.	377.	172.
CLAY	40.	65.	105.	92.	64.	144.	5.3	29.	3.	3.	19.	3.	3.	25.	195.	1006.
CLOUD	40.	130.	170.	109.	69.	158.	9.4	59.	5.	43.	10.	1.	5.	319.	101.	262.
COFFEY	50.	179.	229.	4.	70.	5.	0.4	3.	3.	0.	0.	0.	3.	0.	0.	0.
COMANCHE	50.	195.	245.	56.	75.	74.	6.3	37.	17.	0.	16.	4.	17.	0.	162.	1183.
COWLEY	50.	19.	69.	1.	60.	1.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	3.
CRAWFORD	50.	312.	362.	3.	75.	4.	0.5	4.	0.	0.	4.	0.	0.	0.	40.	0.
DECATUR	78.	62.	140.	265.	64.	415.	20.3	116.	16.	13.	75.	12.	16.	92.	781.	3419.
DICKINSON	50.	151.	201.	73.	71.	103.	7.3	46.	15.	25.	5.	1.	15.	181.	56.	407.
DONIPHAN	50.	312.	362.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
DOUGLAS	50.	130.	180.	16.	66.	24.	1.5	3.	0.	0.	0.	3.	0.	0.	0.	833.
EDWARDS	50.	160.	210.	420.	72.	583.	42.8	265.	210.	16.	16.	23.	210.	118.	166.	6713.
ELK	50.	312.	362.	6.	75.	8.	1.0	7.	0.	0.	7.	0.	0.	0.	76.	0.
ELLIS	50.	18.	68.	64.	61.	105.	2.5	12.	0.	4.	6.	2.	0.	32.	60.	558.
ELLSWORTH	50.	63.	113.	1.	64.	2.	0.1	0.	0.	0.	0.	0.	0.	1.	1.	4.
FINNEY	193.	76.	269.	3110.	65.	4754.	446.2	3559.	3490.	28.	33.	9.	3490.	203.	342.	2499.
FORD	250.	108.	358.	607.	68.	899.	112.4	812.	680.	69.	42.	21.	680.	510.	431.	6298.
FRANKLIN	50.	227.	277.	8.	71.	11.	1.1	7.	0.	4.	4.	0.	0.	28.	38.	0.
GEARY	50.	20.	70.	8.	60.	13.	0.3	2.	0.	0.	2.	0.	0.	0.	24.	0.
GOVE	115.	72.	187.	305.	65.	472.	30.9	154.	50.	57.	23.	24.	50.	421.	240.	6941.
GRAHAM	150.	119.	269.	178.	68.	259.	24.3	153.	5.	5.	135.	9.	5.	36.	1394.	2683.
GRANT	303.	31.	334.	1433.	62.	2315.	270.4	2181.	2181.	0.	0.	0.	2181.	0.	0.	0.
GRAY	189.	85.	273.	2018.	66.	3080.	294.2	1952.	1305.	454.	109.	84.	1305.	3339.	1129.	24725.
GREELEY	160.	22.	182.	424.	60.	702.	44.8	354.	344.	6.	3.	2.	344.	41.	27.	502.
GREENWOOD	50.	254.	304.	8.	72.	12.	1.2	5.	0.	2.	2.	1.	0.	14.	24.	343.
HAMILTON	113.	41.	154.	350.	63.	558.	30.0	173.	149.	0.	3.	21.	149.	0.	30.	6265.
HARPER	50.	170.	220.	1.	73.	2.	0.1	1.	0.	0.	0.	0.	0.	3.	3.	9.
HARVEY	50.	100.	150.	90.	67.	136.	7.1	41.	6.	11.	21.	3.	6.	81.	216.	996.
HASKELL	371.	29.	400.	2433.	61.	3980.	535.8	4260.	4036.	171.	0.	53.	4036.	1255.	0.	15487.
HODGEMAN	250.	38.	288.	355.	62.	575.	58.0	242.	0.	143.	43.	55.	0.	1053.	445.	16241.
JACKSON	50.	160.	210.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
JEFFERSON	50.	58.	108.	16.	62.	25.	0.9	4.	0.	3.	0.	1.	0.	20.	0.	281.
JEWELL	40.	14.	54.	86.	61.	142.	2.7	19.	0.	6.	13.	0.	0.	41.	138.	0.
JOHNSON	50.	197.	247.	3.	75.	4.	0.4	2.	0.	1.	1.	0.	0.	5.	10.	70.
KEARNY	190.	65.	255.	712.	64.	1108.	98.9	757.	718.	12.	15.	11.	718.	92.	155.	3227.
KINGMAN	50.	198.	248.	11.	75.	15.	1.3	8.	2.	6.	0.	0.	2.	43.	4.	13.
KIOWA	50.	187.	237.	208.	74.	280.	23.2	130.	57.	43.	17.	13.	57.	314.	174.	3879.
LABETTE	50.	266.	316.	3.	75.	4.	0.5	3.	0.	1.	2.	0.	0.	10.	17.	0.
LANE	114.	34.	147.	237.	61.	387.	20.0	135.	120.	0.	7.	8.	120.	0.	77.	2258.
LEAVENWORTH	50.	90.	140.	0.	68.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
LINCOLN	50.	69.	119.	6.	63.	9.	0.4	1.	0.	0.	0.	0.	0.	1.	2.	138.

COUNTY	NET PUMP DEPTH FT.	PRESS HEAD FT.	GROSS PUMP DEPTH FT.	NET WATER USED 100 ACRE-FT	IRR EFF %	GROSS WATER USED 100 ACRE-FT	NET ENERGY USED 1E9 BTU	GROSS ENERGY USED 1E9 BTU	NAT GAS USED 1E9 BTU	DIESEL FUEL USED 1E9 BTU	LP GAS USED 1E9 BTU	ELECT USED 1E9 BTU	NAT GAS USED 1000 MCF	DIESEL FUEL USED 1000 GALS	LP GAS USED 1000 GALS	ELECT USED 1000 KWH
LINN	50.	312.	362.	4.	75.	5.	0.6	4.	0.	4.	0.	0.	0.	27.	0.	0.
LOGAN	126.	48.	174.	264.	62.	424.	25.8	179.	104.	0.	67.	7.	104.	0.	697.	2143.
LYON	50.	0.	50.	1.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MCPHERSON	50.	35.	85.	262.	61.	427.	12.7	81.	21.	4.	51.	5.	21.	29.	531.	1440.
MARION	50.	59.	109.	10.	63.	16.	0.6	4.	0.	3.	0.	0.	0.	26.	5.	0.
MARSHALL	50.	103.	153.	0.	67.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MEADE	268.	44.	311.	1088.	62.	1755.	190.7	1474.	1382.	47.	30.	15.	1382.	345.	309.	4262.
MIAMI	50.	312.	362.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
MITCHELL	40.	43.	83.	27.	62.	43.	1.3	9.	0.	1.	8.	0.	0.	6.	81.	38.
MONTGOMERY	50.	257.	307.	10.	75.	14.	1.5	11.	0.	2.	9.	0.	0.	13.	91.	0.
MORRIS	50.	187.	237.	1.	69.	1.	0.1	1.	1.	0.	0.	0.	1.	0.	0.	0.
MORTON	165.	30.	195.	606.	61.	993.	67.7	534.	501.	25.	8.	1.	501.	185.	78.	285.
NEMAHA	50.	160.	210.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
NEOSHO	50.	293.	343.	2.	75.	2.	0.3	2.	0.	0.	2.	0.	0.	0.	23.	0.
NESS	140.	16.	156.	157.	60.	259.	14.1	103.	91.	4.	6.	3.	91.	31.	62.	758.
NORTON	150.	36.	186.	268.	62.	431.	28.1	111.	45.	0.	32.	35.	45.	0.	327.	10254.
OSAGE	50.	312.	362.	2.	75.	3.	0.4	3.	0.	1.	2.	0.	0.	9.	16.	0.
OSBORNE	40.	17.	57.	83.	61.	136.	2.7	16.	0.	7.	9.	1.	0.	49.	93.	226.
OTTAWA	40.	109.	149.	23.	67.	34.	1.8	12.	10.	1.	1.	1.	10.	8.	7.	148.
PAWNEE	50.	86.	136.	658.	66.	1001.	47.4	223.	96.	29.	53.	45.	96.	214.	549.	13284.
PHILLIPS	40.	54.	94.	33.	64.	52.	1.7	11.	9.	0.	0.	1.	9.	2.	4.	269.
POTTAWATOMIE	50.	109.	159.	52.	68.	78.	4.3	13.	0.	5.	2.	6.	0.	39.	20.	1781.
PRATT	50.	184.	234.	184.	74.	248.	20.3	137.	66.	38.	30.	4.	66.	276.	311.	1135.
RAWLINS	121.	49.	170.	261.	63.	416.	24.8	170.	91.	38.	37.	5.	91.	277.	380.	1387.
RENO	50.	153.	203.	58.	72.	81.	5.7	34.	19.	9.	4.	3.	19.	65.	44.	804.
REPUBLIC	40.	70.	110.	440.	65.	674.	26.0	138.	20.	64.	38.	15.	20.	471.	399.	4404.
RICE	50.	127.	177.	85.	69.	129.	8.0	26.	4.	1.	9.	11.	4.	11.	92.	3342.
RILEY	50.	33.	83.	0.	62.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
ROCKS	40.	156.	236.	0.	75.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
RUSH	50.	27.	77.	102.	61.	168.	4.5	22.	17.	1.	0.	4.	17.	4.	4.	1249.
RUSSELL	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
SALINE	50.	79.	129.	56.	66.	85.	3.8	16.	6.	2.	3.	4.	6.	17.	29.	1289.
SCOTT	135.	20.	156.	1140.	60.	1888.	102.6	746.	662.	57.	8.	20.	662.	417.	81.	5748.
SEDGWICK	50.	67.	117.	216.	64.	338.	13.8	85.	45.	30.	5.	5.	45.	220.	53.	1549.
SEWARD	326.	64.	390.	1042.	64.	1634.	222.6	1618.	1533.	34.	0.	52.	1533.	246.	0.	15210.
SHAWNEE	50.	37.	87.	80.	61.	129.	4.0	21.	6.	2.	9.	3.	6.	18.	91.	886.
SHERIDAN	140.	55.	195.	861.	63.	1366.	93.1	617.	255.	268.	80.	14.	255.	1973.	831.	4042.
SHERMAN	207.	54.	261.	1288.	63.	2048.	186.7	1330.	903.	115.	277.	36.	903.	842.	2866.	10526.
SMITH	40.	3.	43.	47.	60.	77.	1.2	6.	0.	1.	3.	1.	0.	10.	35.	258.
STAFFORD	50.	160.	210.	294.	72.	409.	29.9	177.	17.	148.	7.	6.	17.	1087.	72.	1678.
STANTON	252.	25.	277.	1857.	61.	3027.	293.2	2348.	2342.	0.	0.	5.	2342.	0.	0.	1516.
STEVENS	309.	53.	362.	1229.	63.	1936.	244.9	1807.	1678.	46.	35.	47.	1678.	338.	368.	13717.
SUMNER	50.	48.	98.	5.	62.	8.	0.3	0.	0.	0.	0.	0.	0.	0.	0.	144.
THOMAS	175.	87.	261.	676.	66.	1025.	94.0	613.	455.	87.	35.	36.	455.	640.	361.	10536.
TREGO	140.	111.	251.	109.	68.	161.	14.1	65.	16.	27.	10.	12.	16.	196.	105.	3562.
WABAUNSEE	50.	39.	89.	5.	62.	8.	0.2	1.	0.	0.	1.	0.	0.	2.	6.	66.
WALLACE	187.	44.	231.	908.	62.	1461.	117.9	810.	570.	123.	87.	30.	570.	908.	897.	8731.
WASHINGTON	40.	124.	164.	58.	69.	85.	4.9	31.	4.	12.	14.	1.	4.	88.	141.	303.
WICHITA	145.	17.	162.	1448.	60.	2403.	136.0	926.	859.	2.	12.	53.	859.	12.	127.	15405.
WILSON	50.	270.	320.	6.	75.	8.	0.9	7.	0.	1.	5.	0.	0.	9.	55.	0.
WOODSON	50.	0.	50.	0.	60.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
WYANDOTTE	50.	0.	50.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.
STATE TOTAL	197.	57.	254.	30722.	64.	48361.	4298.5	30810.	25740.	2417.	1734.	919.	25740.	17775.	17965.	269338.

Appendix J: 1975 Kansas Irrigation Survey (Hay, 1975)

1975 KANSAS IRRIGATION SURVEY

COUNTY	TOTAL IRRIGATED ACRES	GRAVITY IRR ACRES: OPEN DITCH	GRAVITY IRR ACRES: GATED PIPE	SPRINKLER IRRIGATED ACRES: CENTER TOW PIVOT	SPRINKLER IRRIGATED ACRES: SIDE LINE ROLL	SPRINKLER IRRIGATED ACRES: BIG GUN	SPRINKLER IRRIGATED ACRES: OTHER SPRINKLER	NUMBER OF WELLS	PUMPING ENERGY SOURCE (NO. OF UNITS): NATURAL GAS	PUMPING ENERGY SOURCE (NO. OF UNITS): DIESEL FUEL	PUMPING ENERGY SOURCE (NO. OF UNITS): LP GAS	PUMPING ENERGY SOURCE (NO. OF UNITS): ELECTRIC POWER	FARMERS IRRIGATING
ALLEN	1050.	1050.	0.	0.	0.	0.	0.	0.	0.	1.	0.	2.	3.
ANDERSON	100.	0.	0.	0.	0.	50.	50.	0.	0.	2.	0.	0.	2.
ATCHINSON	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BARBER	1310.	0.	0.	0.	500.	300.	210.	10.	5.	0.	5.	0.	21.
BARTON	30000.	2000.	15000.	12360.	640.	0.	0.	235.	65.	25.	45.	100.	130.
BOURBON	120.	0.	0.	0.	0.	120.	0.	0.	0.	0.	1.	0.	1.
BROWN	160.	0.	0.	0.	160.	0.	0.	0.	0.	2.	0.	0.	3.
BUTLER	1200.	0.	0.	0.	500.	500.	200.	0.	0.	0.	0.	0.	20.
CHASE	300.	20.	60.	0.	0.	220.	0.	0.	0.	5.	0.	0.	5.
CHAUTAUQUA	500.	0.	0.	250.	0.	0.	250.	0.	0.	2.	0.	2.	3.
CHEROKEE	1000.	100.	100.	0.	0.	800.	0.	0.	0.	8.	2.	0.	10.
CHEYENNE	60000.	0.	38000.	20500.	1000.	500.	0.	420.	252.	21.	21.	126.	200.
CLARK	4694.	0.	2284.	2380.	0.	0.	0.	32.	14.	1.	16.	1.	21.
CLAY	12546.	0.	9364.	2622.	300.	160.	100.	156.	12.	16.	75.	53.	84.
CLOUD	15000.	0.	6000.	6000.	1000.	1000.	1000.	100.	6.	75.	14.	5.	100.
COFFEY	480.	0.	160.	0.	80.	200.	40.	0.	6.	0.	0.	0.	6.
COMANCHE	3500.	0.	0.	3300.	200.	0.	0.	30.	10.	0.	10.	10.	30.
COWLEY	2000.	100.	1900.	0.	0.	0.	0.	1.	2.	2.	1.	1.	10.
CRAWFORD	500.	0.	0.	0.	0.	500.	0.	0.	0.	0.	4.	0.	4.
DECATUR	11169.	163.	8034.	700.	2272.	0.	0.	180.	18.	18.	90.	54.	163.
DICKINSON	3605.	0.	1000.	405.	1200.	500.	500.	20.	5.	11.	2.	2.	40.
DONIPHAN	275.	0.	0.	0.	0.	275.	0.	0.	0.	2.	0.	0.	4.
DOUGLAS	160.	0.	100.	0.	0.	60.	0.	2.	0.	0.	0.	2.	2.
EDWARDS	64550.	0.	12900.	48970.	2600.	80.	0.	575.	350.	35.	29.	161.	150.
ELK	150.	0.	0.	0.	0.	150.	0.	0.	0.	0.	2.	0.	2.
ELLIS	8600.	7500.	300.	500.	200.	0.	100.	35.	0.	10.	11.	14.	84.
ELLSWORTH	1000.	200.	500.	130.	0.	0.	170.	5.	5.	2.	2.	1.	10.
FINNEY	225000.	86130.	57420.	81250.	80.	0.	120.	1500.	1455.	15.	15.	15.	397.
FORD	80000.	500.	39500.	39540.	280.	120.	60.	720.	540.	72.	36.	72.	378.
FRANKLIN	1800.	0.	470.	130.	0.	1200.	0.	0.	0.	10.	8.	0.	18.
GEARY	330.	0.	330.	0.	0.	0.	0.	3.	0.	0.	3.	0.	17.
GOVE	21500.	0.	15000.	5500.	1000.	0.	0.	297.	59.	89.	30.	119.	133.
GRAHAM	12800.	80.	5470.	6800.	450.	0.	0.	122.	3.	4.	91.	24.	69.
GRANT	165000.	93730.	50470.	20800.	0.	0.	0.	560.	560.	0.	0.	0.	212.
GRAY	177280.	1200.	110800.	65000.	200.	80.	0.	1000.	550.	250.	50.	150.	480.
GREELEY	32750.	3200.	29800.	750.	0.	0.	0.	250.	238.	5.	2.	5.	100.
GREENWOOD	1000.	0.	200.	0.	0.	800.	0.	2.	0.	2.	2.	4.	7.
HAMILTON	30000.	14800.	10000.	5070.	90.	40.	0.	228.	140.	0.	3.	85.	55.
HARPER	1500.	0.	200.	600.	400.	100.	200.	23.	2.	11.	7.	3.	18.
HARVEY	10600.	0.	5967.	1830.	1600.	700.	503.	116.	12.	29.	46.	29.	87.
HASKELL	23000.	50000.	162500.	17500.	0.	0.	0.	764.	688.	38.	0.	38.	470.
HODGEMAN	22260.	780.	19000.	2000.	470.	0.	0.	270.	0.	108.	27.	135.	142.
JACKSON	200.	0.	0.	0.	0.	0.	200.	0.	0.	2.	0.	0.	2.
JEFFERSON	1200.	250.	750.	0.	0.	150.	50.	15.	0.	7.	0.	8.	10.
JEWELL	10490.	7000.	3000.	260.	0.	0.	230.	12.	0.	3.	6.	0.	97.
JOHNSON	1120.	0.	0.	320.	0.	200.	600.	0.	0.	6.	7.	7.	20.
KEARNY	122800.	35000.	52420.	35000.	0.	300.	80.	635.	572.	13.	13.	37.	160.
KINGMAN	6726.	50.	0.	6356.	80.	240.	0.	54.	11.	40.	2.	1.	51.
KIOWA	23000.	0.	1200.	21800.	0.	0.	0.	184.	56.	55.	18.	55.	106.
LABETTE	500.	0.	0.	0.	0.	350.	150.	0.	0.	3.	3.	0.	6.
LANE	22050.	600.	19620.	1730.	0.	0.	100.	198.	148.	0.	10.	40.	83.
LEAVENWORTH	120.	0.	60.	0.	0.	0.	60.	0.	0.	3.	0.	0.	4.
LINCOLN	3800.	0.	3000.	320.	80.	400.	0.	7.	2.	1.	1.	8.	12.

COUNTY	TOTAL IRRIGATED ACRES	GRAVITY IRR ACRES		SPRINKLER IRRIGATED ACRES				PUMPING ENERGY SOURCE (NO. OF UNITS)					
		OPEN DITCH	GATED PIPE	CENTER PIVOT	TOW LINE SIDE ROLL	BIG GUN	OTHER SPRINKLER	NUMBER OF WELLS	NATURAL GAS	DIESEL FUEL	LP GAS	ELECTRIC POWER	FARMERS IRRIGATING
LINN	75.	0.	0.	0.	0.	75.	0.	0.	0.	1.	0.	0.	1.
LOGAN	10100.	0.	8500.	1320.	200.	80.	0.	54.	27.	0.	19.	8.	35.
LYON	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MCPHERSON	17000.	100.	15430.	1470.	0.	0.	0.	178.	36.	9.	97.	36.	179.
MARION	1000.	200.	600.	130.	0.	70.	0.	9.	0.	9.	1.	0.	10.
MARSHALL	1550.	0.	950.	700.	100.	0.	100.	2.	0.	3.	13.	0.	14.
MEADE	91000.	1000.	77700.	12000.	300.	0.	0.	426.	383.	17.	9.	17.	187.
MIAMI	90.	0.	0.	0.	0.	90.	0.	0.	0.	0.	1.	0.	1.
MITCHELL	4300.	0.	3700.	0.	100.	100.	400.	20.	0.	4.	31.	2.	37.
MONTGOMERY	1350.	0.	0.	640.	0.	710.	0.	15.	0.	3.	12.	0.	8.
MORRIS	250.	100.	0.	0.	0.	150.	0.	0.	2.	0.	0.	0.	2.
MORTON	75600.	7000.	63320.	5200.	80.	0.	0.	266.	244.	16.	4.	2.	100.
NEMAHA	400.	0.	0.	0.	0.	0.	400.	0.	0.	5.	0.	0.	5.
NEOSHO	1200.	0.	0.	200.	0.	1000.	0.	0.	0.	0.	6.	0.	6.
NESS	8320.	3880.	4200.	160.	80.	0.	0.	104.	83.	5.	6.	10.	70.
NORTON	7480.	3200.	3200.	1000.	0.	0.	80.	132.	26.	0.	20.	86.	87.
OSAGE	115.	0.	0.	0.	0.	115.	0.	0.	0.	2.	2.	0.	4.
OSBORNE	8000.	5540.	1500.	260.	300.	0.	0.	200.	0.	80.	90.	30.	170.
OTTAWA	4000.	0.	2110.	1690.	0.	200.	0.	20.	14.	2.	1.	3.	41.
PAWNEE	55500.	4000.	30300.	20600.	500.	0.	100.	504.	126.	50.	76.	252.	262.
PHILLIPS	6500.	3234.	1386.	500.	0.	30.	1350.	64.	42.	2.	2.	18.	47.
POTTAWATOMIE	4000.	0.	2000.	1600.	100.	100.	200.	50.	0.	10.	3.	37.	35.
PRATT	40931.	0.	2380.	35031.	3320.	40.	160.	321.	129.	96.	64.	32.	250.
RAWLINS	15000.	0.	12300.	1600.	300.	0.	800.	150.	68.	37.	30.	15.	47.
RENO	10103.	0.	2204.	5203.	2613.	83.	0.	100.	40.	25.	10.	25.	95.
REPUBLIC	50500.	30000.	2700.	17000.	400.	200.	200.	185.	18.	74.	37.	56.	370.
RICE	11424.	0.	4434.	6480.	510.	0.	0.	100.	7.	3.	15.	75.	80.
RILEY	1500.	800.	500.	200.	0.	0.	0.	15.	0.	1.	7.	7.	10.
ROOKS	500.	0.	0.	500.	0.	0.	0.	5.	0.	0.	0.	5.	5.
RUSH	11400.	225.	10640.	310.	0.	0.	225.	370.	174.	7.	4.	185.	140.
RUSSELL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SALINE	6500.	0.	4000.	1000.	0.	0.	1500.	40.	8.	4.	4.	24.	70.
SCOTT	143500.	30000.	110000.	3500.	0.	0.	0.	870.	696.	78.	9.	87.	315.
SEDGWICK	11000.	150.	8500.	2500.	100.	200.	50.	180.	72.	63.	9.	36.	85.
SEWARD	100000.	0.	75000.	25000.	0.	0.	0.	410.	350.	10.	0.	50.	150.
SHAWNEE	8560.	0.	7760.	320.	200.	150.	130.	80.	16.	8.	24.	32.	60.
SHERIDAN	72968.	1165.	57692.	11768.	2648.	295.	0.	516.	175.	241.	60.	40.	282.
SHERMAN	130000.	0.	105000.	24000.	1000.	0.	0.	785.	471.	78.	157.	79.	400.
SMITH	11550.	10500.	1000.	50.	0.	0.	0.	10.	0.	2.	4.	4.	36.
STAFFORD	49000.	0.	9000.	32500.	3250.	160.	85.	350.	24.	280.	11.	35.	150.
STANTON	180000.	100000.	63750.	16250.	0.	0.	0.	650.	644.	0.	0.	6.	291.
STEVENS	130000.	50000.	50000.	30000.	0.	0.	0.	460.	391.	14.	9.	46.	220.
SUMNER	1500.	0.	1270.	40.	150.	40.	0.	25.	0.	0.	0.	25.	25.
THOMAS	100000.	0.	62000.	38000.	0.	0.	0.	700.	420.	105.	35.	140.	250.
TREGO	3500.	0.	1700.	1700.	75.	25.	0.	62.	9.	19.	6.	28.	50.
WABAUNSEE	980.	0.	860.	0.	120.	0.	0.	12.	0.	2.	4.	6.	4.
WALLACE	72000.	5000.	56700.	9800.	300.	200.	0.	454.	272.	77.	45.	60.	200.
WASHINGTON	7800.	300.	3000.	4000.	250.	250.	0.	45.	5.	18.	17.	5.	40.
WICHITA	140280.	42000.	96000.	2280.	0.	0.	0.	989.	775.	2.	12.	200.	192.
WILSON	720.	0.	0.	0.	220.	500.	0.	0.	0.	2.	7.	0.	9.
WOODSON	250.	250.	0.	0.	0.	0.	0.	0.	1.	0.	0.	4.	5.
WYANDOTTE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
STATE TOTAL	3033101.	603497.	1644115.	727175.	32603.	14558.	10753.	18689.	11534.	2468.	1683.	3177.	9375.

1975 KANSAS IRRIGATION SURVEY

DISTRICT AND COUNTY	TOTAL IRRIGATED ACRES	GRAVITY IRR ACRES: OPEN DITCH	GRAVITY IRR ACRES: GATED PIPE	SPRINKLER IRRIGATED ACRES: CENTER PIVOT	SPRINKLER IRRIGATED ACRES: TOW LINE SIDE ROLL	SPRINKLER IRRIGATED ACRES: BIG GUN	SPRINKLER IRRIGATED ACRES: OTHER SPRINKLER	NUMBER OF WELLS	PUMPING ENERGY SOURCE (NO. OF UNITS): NATURAL GAS	PUMPING ENERGY SOURCE (NO. OF UNITS): DIESEL FUEL	PUMPING ENERGY SOURCE (NO. OF UNITS): LP GAS	PUMPING ENERGY SOURCE (NO. OF UNITS): ELECTRIC POWER	FARMERS IRRIGATING
NORTHWEST													
CHEYENNE	60000.	0.	38000.	20500.	1000.	500.	0.	420.	252.	21.	21.	126.	200.
DECATUR	11169.	163.	8034.	700.	2272.	0.	0.	180.	18.	18.	90.	54.	163.
GRAHAM	12900.	80.	5470.	6800.	450.	0.	0.	122.	3.	4.	91.	24.	69.
NORTON	7480.	3200.	3200.	1000.	0.	0.	80.	132.	26.	0.	20.	86.	87.
RAWLINS	15000.	0.	12300.	1600.	300.	0.	800.	150.	68.	37.	30.	15.	47.
SHERIDAN	72968.	1165.	57092.	11768.	2648.	295.	0.	516.	175.	241.	60.	40.	282.
SHERMAN	130000.	0.	105000.	24000.	1000.	0.	0.	785.	471.	78.	157.	79.	400.
THOMAS	100000.	0.	62000.	38000.	0.	0.	0.	700.	420.	105.	35.	140.	250.
DIST TOTAL	409417.	4608.	291096.	104368.	7670.	795.	880.	3005.	1433.	504.	504.	564.	1498.
WEST CENTRAL													
GOVE	21500.	0.	15000.	5500.	1000.	0.	0.	297.	59.	89.	30.	119.	133.
GREELEY	32750.	3200.	28800.	750.	0.	0.	0.	250.	238.	5.	2.	5.	100.
LANE	22050.	600.	19620.	1730.	0.	0.	100.	198.	148.	0.	10.	40.	83.
LOGAN	10100.	0.	8500.	1320.	200.	80.	0.	54.	27.	0.	19.	8.	35.
NESS	8320.	3880.	4200.	160.	80.	0.	0.	104.	83.	5.	6.	10.	70.
SCOTT	143500.	30000.	110000.	3500.	0.	0.	0.	870.	696.	78.	9.	87.	315.
TREGO	3500.	0.	1700.	1700.	75.	25.	0.	62.	9.	19.	6.	28.	50.
WALLACE	72000.	5000.	56700.	9800.	300.	200.	0.	454.	272.	77.	45.	60.	200.
WICHITA	140280.	42000.	96000.	2280.	0.	0.	0.	989.	775.	2.	12.	200.	192.
DIST TOTAL	454000.	84680.	340520.	26740.	1655.	305.	100.	3278.	2307.	275.	139.	557.	1178.
SOUTHWEST													
CLARK	4664.	0.	2284.	2380.	0.	0.	0.	32.	14.	1.	16.	1.	21.
FINNEY	225000.	86130.	57420.	81250.	80.	0.	120.	1500.	1455.	15.	15.	15.	397.
FORD	80000.	500.	39500.	39540.	280.	120.	60.	720.	540.	72.	36.	72.	379.
GRANT	165000.	93730.	50470.	20800.	0.	0.	0.	560.	560.	0.	0.	0.	212.
GRAY	177280.	1200.	110800.	65000.	200.	80.	0.	1000.	550.	250.	50.	150.	480.
HAMILTON	30000.	14800.	10000.	5070.	90.	40.	0.	228.	140.	0.	3.	85.	55.
HASKELL	230000.	50000.	162500.	17500.	0.	0.	0.	764.	688.	38.	0.	38.	470.
HODGEMAN	22250.	780.	19000.	2000.	470.	0.	0.	270.	0.	108.	27.	135.	142.
KEARNY	122800.	35000.	52420.	35000.	0.	300.	80.	635.	572.	13.	13.	37.	160.
MEADE	91000.	1000.	77700.	12000.	300.	0.	0.	426.	383.	17.	9.	17.	187.
MORTON	75600.	7000.	63320.	5200.	80.	0.	0.	266.	244.	16.	4.	2.	100.
SEWARD	100000.	0.	75000.	25000.	0.	0.	0.	410.	350.	10.	0.	50.	150.
STANTON	180000.	100000.	63750.	16250.	0.	0.	0.	650.	644.	0.	0.	6.	291.
STEVENS	130000.	50000.	50000.	30000.	0.	0.	0.	460.	391.	14.	9.	46.	220.
DIST TOTAL	1633594.	440140.	834164.	356990.	1500.	540.	260.	7921.	6531.	554.	182.	654.	3264.

1975 KANSAS IRRIGATION SURVEY

DISTRICT AND COUNTY	TOTAL IRRIGATED ACRES	GRAVITY IRR ACRES		SPRINKLER IRRIGATED ACRES				NUMBER OF WELLS	PUMPING ENERGY SOURCE (NO. OF UNITS)				FARMERS IRRIGATING
		OPEN DITCH	GATED PIPE	CENTER PIVOT	TOW LINE SIDE ROLL	BIG GUN	OTHER SPRINKLER		NATURAL GAS	DIESEL FUEL	LP GAS	ELECTRIC POWER	
NORTH CENTRAL													
CLAY	12546.	0.	9364.	2622.	300.	160.	100.	156.	12.	16.	75.	53.	84.
CLOUD	15000.	0.	6000.	6000.	1000.	1000.	1000.	100.	6.	75.	14.	5.	100.
JEWELL	10490.	7000.	3000.	260.	0.	0.	230.	12.	0.	3.	6.	0.	97.
MITCHELL	4300.	0.	3700.	0.	100.	100.	400.	20.	0.	4.	31.	2.	37.
OSBORNE	8000.	5940.	1500.	260.	300.	0.	0.	200.	0.	80.	90.	30.	170.
OTTAWA	4000.	0.	2110.	1690.	0.	200.	0.	20.	14.	2.	1.	3.	41.
PHILLIPS	6500.	3234.	1386.	500.	0.	30.	1350.	64.	42.	2.	2.	18.	47.
REPUBLIC	50500.	30000.	2700.	17000.	400.	200.	200.	185.	18.	74.	37.	56.	370.
ROOKS	500.	0.	0.	500.	0.	0.	0.	5.	0.	0.	0.	5.	5.
SMITH	11550.	10500.	1000.	50.	0.	0.	0.	10.	0.	2.	4.	4.	36.
WASHINGTON	7800.	300.	3000.	4000.	250.	250.	0.	45.	5.	18.	17.	5.	40.
DIST TOTAL	131186.	56974.	33760.	32882.	2350.	1940.	3280.	817.	97.	276.	277.	181.	1027.
CENTRAL													
BARTON	30000.	2000.	15000.	12360.	640.	0.	0.	235.	65.	25.	45.	100.	130.
DICKINSON	3605.	0.	1600.	405.	1200.	500.	500.	20.	5.	11.	2.	2.	40.
ELLIS	8600.	7500.	300.	500.	200.	0.	100.	35.	0.	10.	11.	14.	84.
ELLSWORTH	1000.	200.	500.	130.	0.	0.	170.	5.	5.	2.	2.	1.	10.
LINCOLN	3800.	0.	3000.	320.	80.	400.	0.	7.	2.	1.	1.	8.	12.
MCPHERSON	17000.	100.	15430.	1470.	0.	0.	0.	178.	36.	9.	97.	36.	179.
MARION	1000.	200.	600.	130.	0.	70.	0.	9.	0.	9.	1.	0.	10.
RICE	11424.	0.	4434.	6480.	510.	0.	0.	100.	7.	3.	15.	75.	80.
RUSH	11400.	225.	10640.	310.	0.	0.	225.	370.	174.	7.	4.	185.	140.
RUSSELL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SALINE	6500.	0.	4000.	1000.	0.	0.	1500.	40.	8.	4.	4.	24.	70.
DIST TOTAL	94329.	10225.	54904.	23105.	2630.	970.	2495.	999.	302.	81.	182.	445.	755.
SOUTH CENTRAL													
BARBER	1010.	0.	0.	0.	500.	300.	210.	10.	5.	0.	5.	0.	21.
COMANCHE	3500.	0.	0.	3300.	200.	0.	0.	30.	10.	0.	10.	10.	30.
EDWARDS	64550.	0.	12900.	48970.	2600.	80.	0.	575.	350.	35.	29.	161.	150.
HARPER	1500.	0.	200.	600.	400.	100.	200.	23.	2.	11.	7.	3.	18.
HARVEY	10600.	0.	5967.	1830.	1600.	700.	503.	116.	12.	29.	46.	29.	97.
KINGMAN	6726.	50.	0.	6356.	80.	240.	0.	54.	11.	40.	2.	1.	51.
KIOWA	23000.	0.	1200.	21800.	0.	0.	0.	184.	56.	55.	18.	55.	106.
PAWNEE	55500.	4000.	30300.	20600.	500.	0.	100.	504.	126.	50.	76.	252.	262.
PRATT	40931.	0.	2380.	35031.	3320.	40.	160.	321.	129.	96.	64.	32.	250.
RENO	10103.	0.	2204.	5203.	2613.	83.	0.	100.	40.	25.	10.	25.	95.
SEDGWICK	11000.	150.	8000.	2500.	100.	200.	50.	180.	72.	63.	9.	36.	85.
STAFFORD	45000.	0.	9000.	32500.	3255.	160.	85.	350.	24.	280.	11.	35.	150.
SUMNER	1500.	0.	1270.	40.	150.	40.	0.	25.	0.	0.	0.	25.	25.
DIST TOTAL	274920.	4200.	73421.	178730.	15318.	1943.	1308.	2472.	837.	684.	287.	664.	1330.

DISTRICT AND COUNTY	TOTAL IRRIGATED ACRES	GRAVITY IRR ACRES		SPRINKLER IRRIGATED ACRES					PUMPING ENERGY SOURCE (NO. OF UNITS)				FARMERS IRRIGATING
		OPEN DITCH	GATED PIPE	CENTER PIVOT	TOW LINE SIDE ROLL	BIG GUN	OTHER SPRINKLER	NUMBER OF WELLS	NATURAL GAS	DIESEL FUEL	LP GAS	ELECTRIC POWER	
NORTHEAST													
ATCHINSON	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
BROWN	160.	0.	0.	0.	160.	0.	0.	0.	0.	2.	0.	0.	3.
DONIPHAN	275.	0.	0.	0.	0.	275.	0.	0.	0.	2.	0.	0.	4.
JACKSON	200.	0.	0.	0.	0.	0.	200.	0.	0.	2.	0.	0.	2.
JEFFERSON	1200.	250.	750.	0.	0.	150.	50.	15.	0.	7.	0.	8.	10.
LEAVENWORTH	120.	0.	60.	0.	0.	0.	60.	0.	0.	3.	0.	0.	4.
MARSHALL	1850.	0.	950.	700.	100.	0.	100.	2.	0.	3.	13.	0.	14.
NEMAHA	400.	0.	0.	0.	0.	0.	400.	0.	0.	5.	0.	0.	5.
POTTAWATOMIE	4000.	0.	2000.	1600.	100.	100.	200.	50.	0.	10.	3.	37.	35.
RILEY	1500.	800.	500.	200.	0.	0.	0.	15.	0.	1.	7.	7.	10.
WYANDOTTE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DIST TOTAL	9705.	1050.	4260.	2500.	360.	525.	1010.	82.	0.	35.	23.	52.	87.
EAST CENTRAL													
ANDERSON	100.	0.	0.	0.	0.	50.	50.	0.	0.	2.	0.	0.	2.
CHASE	300.	20.	60.	0.	0.	220.	0.	0.	0.	5.	0.	0.	5.
COFFEY	480.	0.	160.	0.	80.	200.	40.	0.	0.	6.	0.	0.	6.
DOUGLAS	100.	0.	100.	0.	0.	60.	0.	2.	0.	0.	0.	2.	2.
FRANKLIN	1800.	0.	470.	130.	0.	1200.	0.	0.	0.	10.	8.	0.	18.
GEARY	380.	0.	380.	0.	0.	0.	0.	3.	0.	0.	3.	0.	17.
JOHNSON	1120.	0.	0.	320.	0.	200.	600.	0.	0.	6.	7.	7.	20.
LINN	75.	0.	0.	0.	0.	75.	0.	0.	0.	1.	0.	0.	1.
LYON	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MIAMI	90.	0.	0.	0.	0.	90.	0.	0.	0.	0.	1.	0.	1.
MORRIS	250.	100.	0.	0.	0.	150.	0.	0.	2.	0.	0.	0.	2.
OSAGE	115.	0.	0.	0.	0.	115.	0.	0.	0.	2.	2.	0.	4.
SHAWNEE	8560.	0.	7760.	320.	200.	150.	130.	80.	16.	8.	24.	32.	60.
WABAUNSEE	980.	0.	860.	0.	120.	0.	0.	12.	0.	2.	4.	6.	4.
DIST TOTAL	14410.	120.	9790.	770.	400.	2510.	820.	97.	24.	36.	49.	47.	142.
SOUTH CENTRAL													
ALLEN	1050.	1050.	0.	0.	0.	0.	0.	0.	0.	1.	0.	2.	3.
BOURBON	120.	0.	0.	0.	0.	120.	0.	0.	0.	0.	1.	0.	1.
BUTLER	1200.	0.	0.	0.	500.	500.	200.	0.	0.	0.	0.	0.	20.
CHAUTAUQUA	500.	0.	0.	250.	0.	0.	250.	0.	0.	2.	0.	2.	3.
CHEROKEE	1000.	100.	100.	0.	0.	800.	0.	0.	0.	8.	2.	0.	10.
COWLEY	2000.	100.	1900.	0.	0.	0.	0.	1.	2.	2.	1.	1.	10.
CRAWFORD	500.	0.	0.	0.	0.	500.	0.	0.	0.	0.	4.	0.	4.
ELK	150.	0.	0.	0.	0.	150.	0.	0.	0.	0.	2.	0.	2.
GREENWOOD	1000.	0.	200.	0.	0.	800.	0.	2.	0.	2.	2.	4.	7.
LABETTE	500.	0.	0.	0.	0.	350.	150.	0.	0.	3.	3.	0.	6.
MONTGOMERY	1350.	0.	0.	640.	0.	710.	0.	15.	0.	3.	12.	0.	8.
NEOSHO	1200.	0.	0.	200.	0.	1000.	0.	0.	0.	0.	6.	0.	6.
WILSON	720.	0.	0.	0.	220.	500.	0.	0.	0.	2.	7.	0.	9.
WOODSON	250.	250.	0.	0.	0.	0.	0.	0.	1.	0.	0.	4.	5.
DIST TOTAL	11540.	1500.	2200.	1090.	720.	5430.	600.	18.	3.	23.	40.	13.	94.
STATE TOTAL	3033101.	603497.	1644115.	727175.	32603.	14958.	10753.	18689.	11534.	2468.	1683.	3177.	9375.

1975 KANSAS IRRIGATION SURVEY

DISTRICT	TOTAL IRRIGATED ACRES	GRAVITY IRR ACRES		SPRINKLER IRRIGATED ACRES				PUMPING ENERGY SOURCE (NO. OF UNITS)					FARMERS IRRIGATING
		OPEN DITCH	GATED PIPE	CENTER PIVOT	TOW LINE SIDE ROLL	BIG GUN	OTHER SPRINKLER	NUMBER OF WELLS	NATURAL GAS	DIESEL FUEL	LP GAS	ELECTRIC POWER	
NORTHWEST	409417.	4608.	291696.	104368.	7670.	795.	880.	3005.	1433.	504.	504.	564.	1498.
WEST CENTRAL	454000.	84660.	340520.	26740.	1655.	305.	100.	3278.	2307.	275.	139.	557.	1178.
SOUTHWEST	1633594.	440140.	834164.	356990.	1500.	540.	260.	7921.	6531.	554.	182.	654.	3264.
NORTH CENTRAL	131186.	5674.	32760.	32882.	2350.	1940.	3280.	817.	97.	276.	277.	181.	1027.
CENTRAL	94329.	10225.	54904.	23105.	2630.	570.	2495.	999.	302.	81.	182.	445.	755.
SOUTH CENTRAL	274920.	4200.	73421.	178730.	15318.	1943.	1308.	2472.	837.	684.	287.	664.	1330.
NORTHEAST	9705.	1050.	4260.	2500.	360.	525.	1010.	82.	0.	35.	23.	52.	87.
EAST CENTRAL	14410.	120.	5790.	770.	400.	2510.	820.	97.	24.	36.	49.	47.	142.
SOUTH CENTRAL	11540.	1500.	2200.	1090.	720.	5430.	600.	18.	3.	23.	40.	13.	94.
STATE TOTAL	3033101.	603497.	1644115.	727175.	32603.	14958.	10753.	18689.	11534.	2468.	1683.	3177.	9375.

ENERGY USE IN IRRIGATION IN KANSAS: A COMPUTER SIMULATION

by

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B.A., Bethel College, 1976

AN ABSTRACT OF A MASTER'S THESIS

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requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

ABSTRACT

Irrigation is an energy intensive activity, using approximately 40 per cent of the total energy consumed in crop production in Kansas while being practiced on only 11 per cent of the total crop acreage. The amount of energy used in irrigation is desired when planning energy policy, and when looking at energy alternatives. The amount of energy savings due to various practices helps establish the credibility of these practices.

A computer program was developed that estimated the amount of natural gas, diesel fuel, LP gas, and electricity used by irrigation pumping on a county by county basis in Kansas. The following data for each county were incorporated into the program: irrigated acreages of nine crops, water requirements of these crops, the breakdown (number per county) and pressure requirements of distribution types (center pivot, gated pipe, open ditch, traveling big gun, tow line and side roll, and other sprinkler), the breakdown of fuel sources, the static water level, the drawdown, the overall pumping efficiencies of the four different types of fuel sources, and the irrigation efficiencies of gravity and sprinkler systems.

The United States Geological Survey well records for 24 western Kansas counties were obtained. The average depth to water by county was calculated and plotted versus the years 1950 (1940 for southwest Kansas), 1966, 1973, 1974, 1975, 1976, and 1977. The data given by these records were also used in estimating the pumping depths in western Kansas.

Energy use estimates were made for 1975, the most current year that sufficient data were available for. Statewide estimates were graphed on a monthly basis for 1975. Yearly statewide usage was calculated at 4,182,900 acre-feet of water, and 26,727 x 10^9 BTU; 84 per cent of which was natural gas usage, 8 per cent diesel fuel usage, 5 per cent LP gas usage, and 3 per cent electrical usage.

Investigating the effect of the declining water table on energy use showed the energy use would have been approximately 6 per cent lower in 1975 had the water table always remained stable. Calculations showed approximately 23 per cent of the water and energy used in 1975 could have been saved by improving the gravity irrigation efficiency from 60 per cent to 85 per cent, and an additional 20 per cent of the energy could have been saved by bringing pumping plants up to Nebraska standards for efficiency. The energy use was estimated at 35,563 x 10^9 BTU should all acres irrigable in 1975 be irrigated, while all other data remained at the 1975 level. The additional energy and water requirements due to a "dry" year were calculated. All case studies made calculations on a county by county basis.

Additional calculations which could be made by hand were referred to. A guide to using the program was provided should more current data become available or should it be desireable to run additional case studies.