SPRINKLER DESIGN & UNIFORMITY CONSIDERATION OVERVIEW

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INTRODUCTION

Irrigation has developed dramatically across the Central Plains during the last half of a century. There were few lands irrigated before the 1950s. Since then the area has developed extensive amounts of land (figure 1). As of the 1997 US Census the amount of irrigated land in several counties in the Central Great Plains exceeded 200,000 acres/county. Many counties in the three state area exceed 100,000 acres/county. The High Plains Aquifer (Ogallala Aquifer) is the primary source of water for most of these lands. In fact, there is little irrigation in areas of the Central Plains when the aquifer is not present.

Today center pivots are the primary source of irrigation in the region. The migration from surface and other forms of sprinkler irrigation has been ongoing for several years and results from several situations. First, mechanized sprinkler irrigation systems require substantially less labor than other methods of irrigation that were previously used. In many cases the availability of labor has constrained producers and pivots were a welcomed development. Pivots also have the potential to be very efficient. This has become more necessary as groundwater supplies have dwindled in some areas and/or regulations have been developed to restrict the amount of water applied to crops or limited the amount of land that could be irrigated.

Since pivots constitute the vast majority of the sprinkler irrigated land in the Central Great Plains this discussion of sprinkler design will focus solely on their design. The design of pivots involves the following steps:

1. Layout the system on the land to be irrigated and gather relevant information about soils, slopes, crops and water supplies.
2. Determine the water supply rate (system capacity) needed to satisfy crop water requirements.
3. Select the type of sprinkler package that will be used, and then determine the size and location of the sprinkler devices to be used on the center pivot.

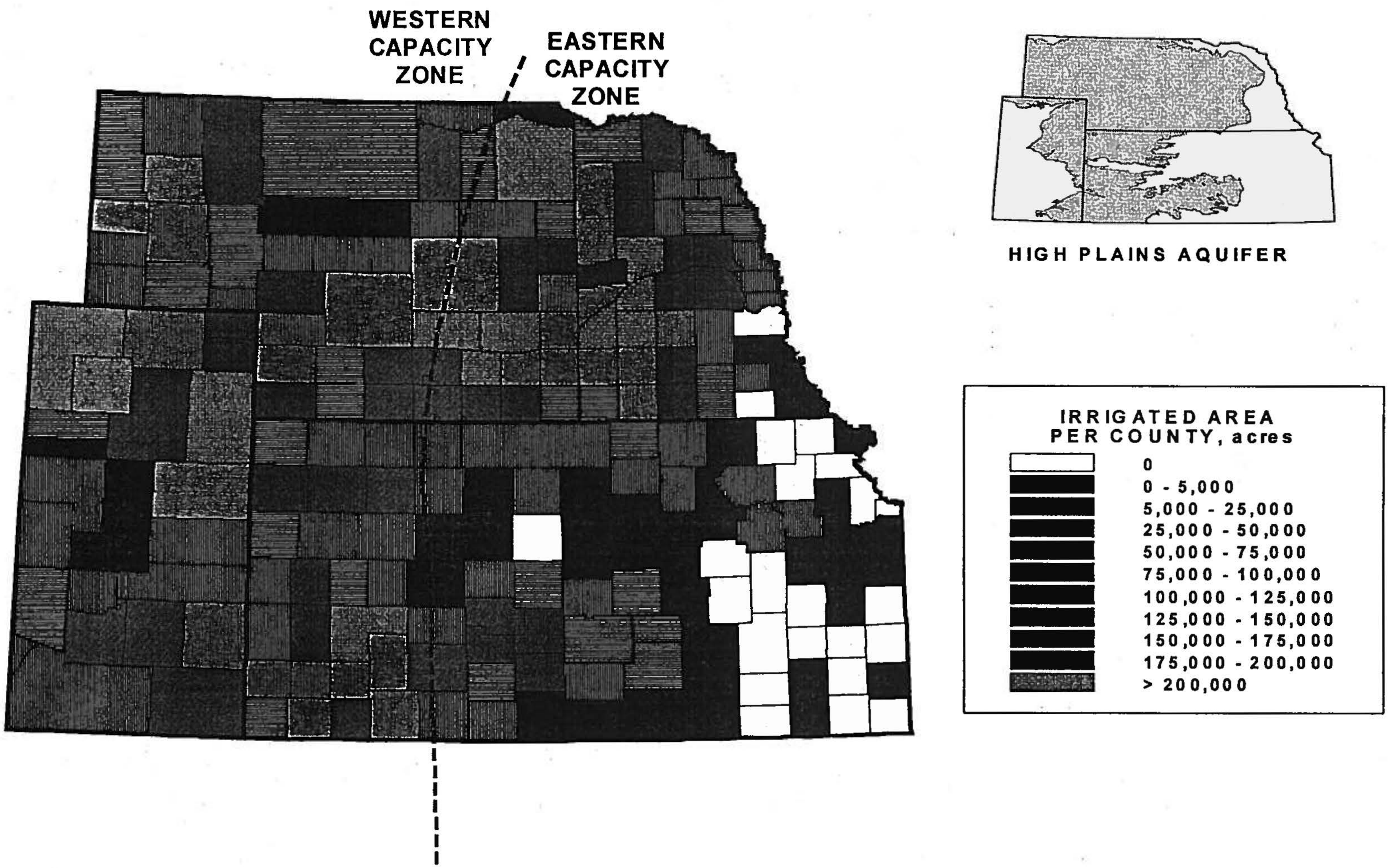

Figure 1. Density of irrigation in counties in the Central Plains States and the alignment with the High Plains Aquifer.

SYSTEM PLANNING AND LAYOUT

The first step in the design of any irrigation systems is the layout of the system for the land that is available. The layout should consider the size of the field, the types of soils in the field, slopes in the field (especially at the outer edges of the field) and any impediments to the rotation of the center pivot lateral. An example is shown in figure 2 for the layout of a pivot where a sizeable portion of the field consists of silt loam soil and other portions of a sandy loam soil. We will see later that these conditions will affect the discharge (gallons per minute, gpm) that will be required and the potential for runoff from the sprinkler packages that are installed on the pivot. The setting in figure 2 contains a farmstead in one corner of the field that will restrict the complete rotation of the pivot. At this point the decision needs to be made regarding the length of the pivot lateral. It would be possible to shorten the lateral so the pivot could make a complete revolution, the pivot point could be moved to the southeast to allow the pivot to make a complete revolution, or the pivot could operate only over a portion of the field in what is often referred to as a windshield wiping pattern. Additionally modifications could possibly be made to the farmstead to allow for complete revolution. Any of these decisions could be correct; however, the decision must be made and the consequences of the layout in the design and operation of the pivot must be considered. Once the operation of the pivot has been determined, the amount of land irrigated with the pivot should be determined. The actual irrigated area is important for water supply and water rights as well as for farm management. The layout should also consist of the location of other important physical features such as the location of the well or other water supply system, location of electrical lines, etc. It is best to develop the layout to a known scale so that the length of pipe, electrical wire and other factors can be determined. Photographs available from the USDA Field Service Office are often an excellent base map for the system layout. If features in the field could interfere with the rotation of the center pivot, i.e., items such as an already installed well, it is desirable to draw the paths of each tower in the field to determine if special lengths of spans will be required for the pivot lateral. Of course actual measurement in the field will be necessary to provide the accuracy needed for final design and installation.

It is essential to consult with the appropriate governmental entity early in the design process to determine the types of permits required before developing water resources. Of course, most of the surface water supplies in the Central Plains have long sense been appropriated and it is very unlikely that additional irrigation development will be possible based on surface water. Limitations on the use of groundwater are also expanding rapidly across portions of the region and each state, and in some cases smaller political divisions such as Natural Resource Districts or Water Conservation Districts, have unique procedures for development of water resources. You should have a clear understanding of these constraints as the design is developed.

SYSTEM CAPACITY

The next step in the design is the determination of the amount of water that should be supplied to the irrigated land. We refer to this quantity of water as the system capacity and it is usually expressed in gallons per minute (gpm) or gallons per minute per acre of irrigated land (gpm/acre). The capacity should be large enough to satisfy crop water requirements during the peak water use periods of the year. However, excessively large capacities can lead to runoff with center pivots and overly large capacities often contribute to poor irrigation water management. The variation of installation cost for a reasonable range of system capacity is usually small and generally cost variations do not play a major role in the design. In many locations in the Central Plains the water supply capacity is limited by the ability of the aquifer to provide water to a well or by the delivery capacity of the surface water purveyor.

The system capacity is based on the types of crops to be grown, the soils

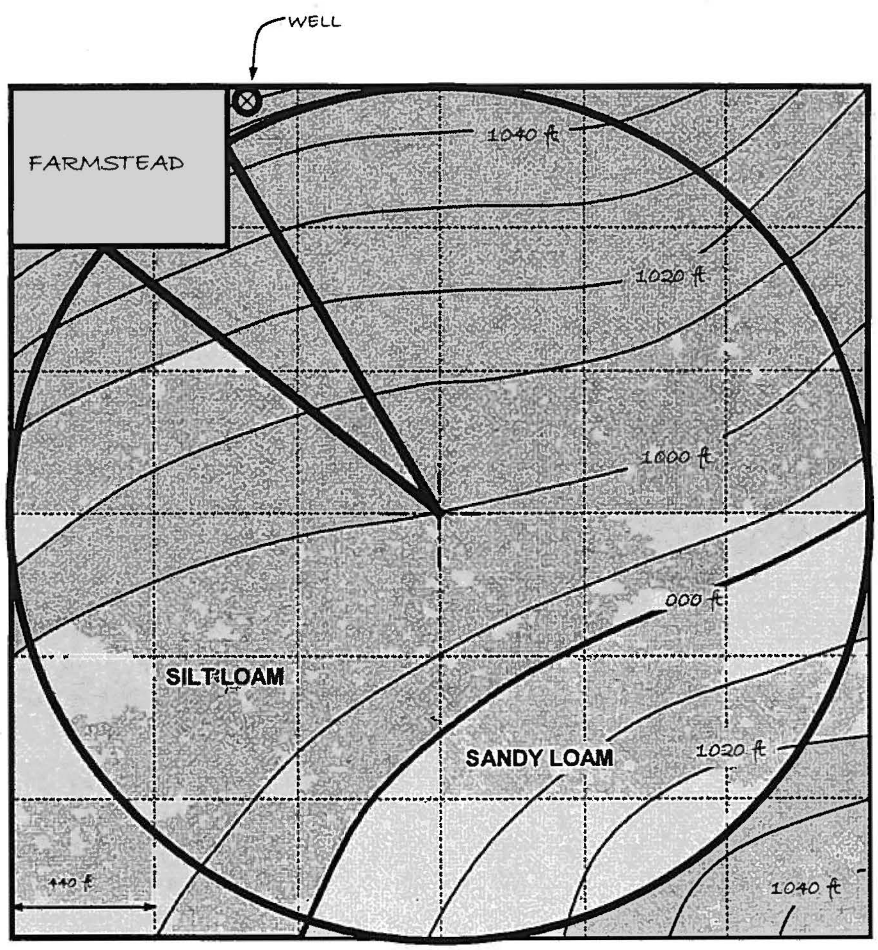

Figure 2. Illustration of a layout map needed for center pivot design.

present in the field, the amount of risk that the irrigator is willing to accept and the anticipated application efficiency of irrigation system. In the Northern Central Plains the primary irrigated crop has traditionally been, and continues to be, corn. Corn generally uses water at near the maximum rate during the middle of the summer and therefore provides a good estimate of the system capacity that would be needed for other crops as well. Guides have been developed for the Northern Central Plains for the required system capacity. The results in figure 3 is based on analysis of a series of years for different soil types (von Bernuth, et al., 1983). The method relies on the allowable depletion of soil water before irrigating. The allowable depletion is computed as:

$$Ad = Rd \times TAW \times MAD \qquad \textbf{(1)}$$

where Ad is the allowable depletion in inches, Rd is the root depth in feet, TAW is the total available water holding capacity of the soil (inches/foot) and MAD is the management allowed depletion expressed as a decimal fraction. The total available water holding capacity of the soil is generally determined based on the soil texture. Typical values are given in table 1.

Table 1. Total water holding capacity of soils.

Soil Texture	Total Available Water Holding Capacity (inch/ft.)(TAW)
Loam, and silt loam and very fine sandy loam with silt loam subsoil	2.5
Sandy clay loam, loam, and silt loam and very fine sandy loam with silty clay subsoil	2
Silty clay loam, clay loam, and fine sandy loam	2
Silty clay	1.6
Clay, sandy loam	1.4
Loamy sand	1.1
Fine sands	1

The management allowed depletion is often take as 0.4 to 0.5 and the root depth can usually be estimated to be 4 feet for the actively managed root zone for corn unless there are subsoil impediment to root development.

The net system capacity that is required to maintain soil water content above the allowable depletion is shown in figure 3. The net system capacity is the supply rate that is required if the irrigation system was available to operate at anytime the system is needed and if the irrigation system and manager were able to perfectively apply the water at 100 percent efficiency.

An example will help illustrate the use of figure 3. If corn was to be irrigated in western Nebraska (see figure 1) on a sandy loam soil and the management allowed depletion was specified as 0.5, then allowable depletion would be:

$$Ad = Rd \times TAW \times Rd = 4.0 \times 1.4 \times 0.5 = 2.8 \text{ inches} \quad \textbf{(2)}$$

Using figure 3, the net system capacity would be approximately 5.3 gpm/acre. Thus, if 125 acres were irrigated the net system supply would have to be approximately 660 gpm. The net system capacity computed in figure 3 represents the amount that would be needed to avoid crop water stress 9 out of 10 years. With this capacity there may be some years, such as 2002, where more capacity would be desirable. However, we generally recommend designing for the 90 % probability.

The net system capacity is adjusted for the fraction of the downtime for the irrigation system and the application efficiency of the system. Downtime, expressed a decimal fraction, is the amount of time that the system is inoperable. Reasons for downtime could be for system maintenance, equipment breakdowns and electrical load management/control. For example, if you have

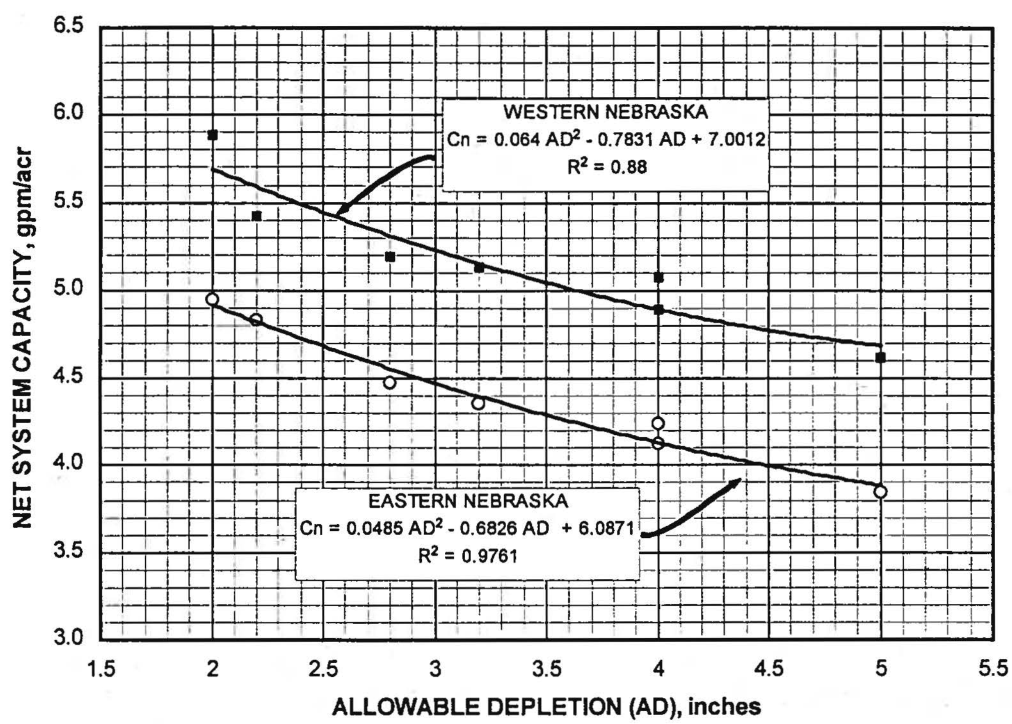

Figure 3. Net system capacity required for center pivots in western and eastern Nebraska.

electrical load management one day per week then the downtime would be 1/7 = 0.14, i.e. 14%.

The application efficiency is used to describe the fraction of the water applied to the field that is stored in the root zone for future crop water use. Water that is applied to the field can evaporate as droplets while in the air, as droplets on the crop canopy or as water that leaves the soil surface and enters the atmosphere (figure 4). A small amount of water from center pivots may drift from the intended point of application and arrive downstream either in the same field or in adjacent tracts. Usually the amount of water that drifts from the field is quite small. Some water that is applied to the field may runoff the intended point of application. Runoff water may actually leave the irrigated field or it may accumulate in low lying areas within the field. When the water accumulates in low spots the excess infiltration at that point may percolate through the root zone and be lost to future crop use. If center pivots are properly designed and managed, the systems can be very efficient. Application efficiencies for center pivots often range from 85% for impact sprinkler packages to values in the 90% range for systems that apply water nearer the surface of the crop. Other manuscripts in the proceedings provide more defendable values for the application efficiency for specific types of sprinkler packages and also discuss the management practices required to achieve the design efficiency.

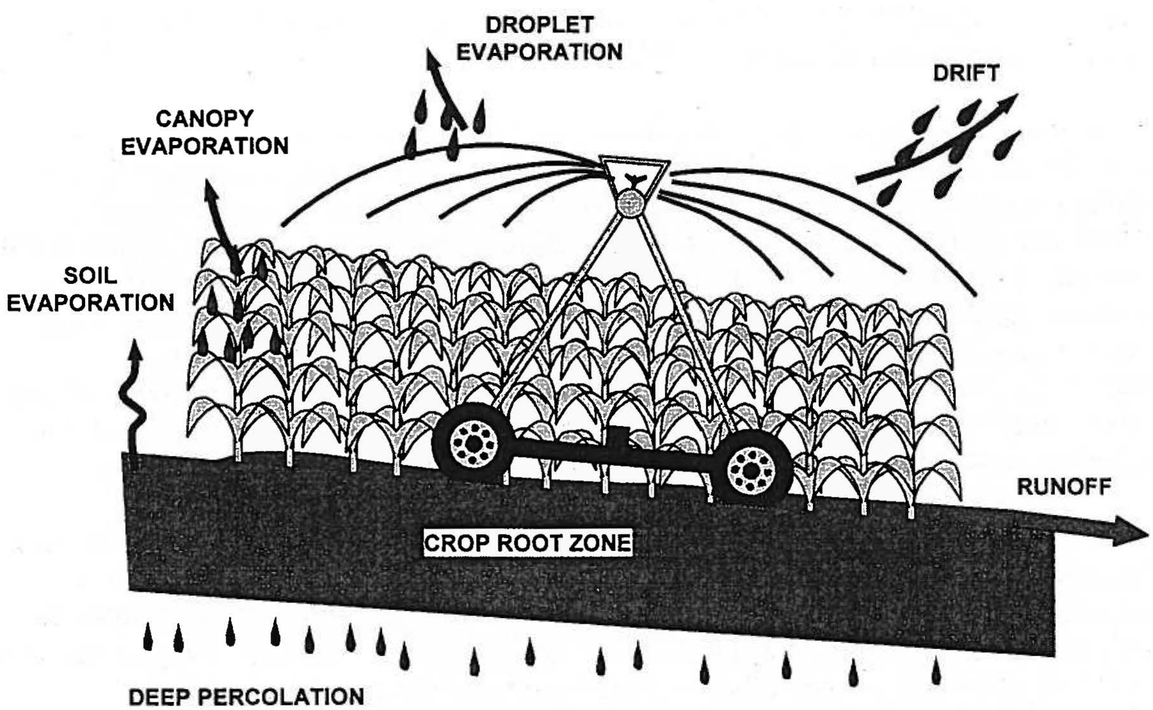

Figure 4. Diagram of processes that affect the application efficiency of center pivot irrigation systems.

The actual, gross, capacity that is required from the water supply must be large enough to overcome losses of water during application and to account for the downtime. The gross system capacity that is required is computed based on:

$$Cg = \frac{Cn}{Ea \times (1 - Dt)} \quad \textbf{(3)}$$

where, Cg is the gross capacity in gpm/acre, Cn is the net system capacity in gpm/acre, Ea is the application efficiency expressed as a decimal fraction (i.e., between 0 and 1) and Dt is the downtime expressed as a decimal fraction.

For example, if an application efficiency of 85% was used and there was one day of downtime per week the gross system capacity for the previous example would be:

$$Cg = \frac{Cn}{Ea\,(1 - Dt)} = \frac{5.3\text{gpm / acre}}{0.85\,(1.0 - 0.14)} = 7.25\text{gpm / acre} \quad \textbf{(4)}$$

When the gross capacity is used with the 125 acre field that was used in the previous example we see that a system flow rate of approximately 900 gpm would be required. If the procedure was repeated for a silt loam soil the capacity would need to be about 800 gpm to maintain soil water levels above the allowable depletion 90% of the time when one day per week is lost to downtime and the application efficiency is 85%.

The results shown in figure 3 are based on analysis of results for Nebraska conditions. Heermann, et al. (1974) conducted a similar study using a slightly different way to compute the probability of exceeding the allowable depletion. Their results were based on climatic conditions for Akron, Colorado. While there are slight differences in the resulting curves, the results for western Nebraska can be used for eastern Colorado. The results would be expected to be to apply for Northwest Kansas as conditions are similar to Central and Western Nebraska. The procedures for the system capacity methods presented here are also described in the NebGuide by Kranz, et al. (1989). The NebGuide can be located on the internet at http://www.ianr.unl.edu/pubs/irrigation/g932.htm.

The capacities determined in this procedure are ideal and unfortunately at many locations in the Central Plains the aquifer is not good enough to provide the capacity calculated in this procedure. In those cases the irrigator must choose among several undesirable alternatives. One choice is to accept a higher level of risk that soil water levels will drop below the targeted allowable depletion. Perhaps the capacity that is available will only meet the requirements in 8 of 10 years rather than the design probability of 90%. The irrigator may choose to avoid load management programs that would cause the system to be off 14% of the time. Ultimately, the irrigator may be faced with accepting either suppressed crop yields in some years and/or reducing the amount of land irrigated. The irrigator may also choose a crop rotation that will shift the peak water use period of part of the field to allow the pivot to meet each peak use on a portion of the field. In almost all cases the irrigator will want to adopt an irrigation strategy that will develop and maintain a full soil profile just prior to the peak use periods of the year. Selection among these alternatives depends on individual choices and producer conditions and it is not possible to provide a general recommendation.

It has been our experience that excess capacity often leads to inefficient irrigation. With center pivots this occurs in two ways. First, if the capacity is much larger than the crop water requirements then the machine needs to be idle for a period of the weak. However, if the irrigator does not adopt effective irrigation scheduling methods the temptation is to "let the pivot run". This leads to excessive applications and often leaching of nitrate-nitrogen. The second problem with excessive capacity is that the application rate with center pivots increases directly with the system capacity and the potential for runoff is larger for high system capacities.

A range of system capacities is generally feasible. I selected a range between a lower limit of approximately 4 gpm/acre and an upper limit of about 8.5 gpm/acre. The system capacity expressed in gpm/acre can be converted to the equivalent daily water supply rate by multiplying by 0.053. The range of system capacities that fall within this recommended range are shown in table 2. The table does not consider the application efficiency and is simply a comparison of the total supply per unit area per day. The values in table 2 should be multiplied by the application efficiency (as a decimal fraction) to convert the supply rates in table 2 to the amount of water that crops could use as evapotranspiration on a daily basis. For example if the producer had a supply of 650 gpm and irrigated 130 acres, then the supply rate would be 0.27 inches/day. If the application efficiency was 90%, this supply rate would be able to meet a daily crop water use of 0.24 inches/day. This water use rate would be exceeded during the peak water use periods of most years and the irrigator would want to have built soil water storage ahead of the peak to mitigate against stress in the peak water use period. In very dry years when rain does not augment the irrigation supply, such as 2002, it is likely that some stress would have occurred even if the crop root zone was full in late June.

I need to stress that building soil water storage ahead of the peak water use period that occurs from the middle of July through the middle of August is generally recommended if the water supply is limiting. I do not recommend "preseason" irrigation that would apply water ahead of planting. Research has shown that these early season applications are usually inefficient. Instead, irrigators may want to replenish depleted soil water to some extent at the end of the previous growing season, while leaving ample room to store spring rains. Then, the soil water reservoir can be replenished in late May and June when the rainfall picture is more clear. Rain will build the reservoir during wet springs and if

Table 2. Depth of water applied per day (inches/day) for combinations of water supply rate and area irrigated. Multiply these gross values by the decimal fraction of the application efficiency to determine the equivalent rate of evapotranspiration that can be sustained.

Water Supply Rate (Q), gpm	Irrigated Area (A), acres												
	80	90	100	110	120	130	140	150	160	180	200	220	240
300	0.20	0.18	0.16	0.14	0.13	0.12	0.11	0.11	0.10	0.09	0.08	0.07	0.07
350	0.23	0.21	0.19	0.17	0.15	0.14	0.13	0.12	0.12	0.10	0.09	0.08	0.08
400	0.27	0.24	0.21	0.19	0.18	0.16	0.15	0.14	0.13	0.12	0.11	0.10	0.09
450	0.30	0.27	0.24	0.22	0.20	0.18	0.17	0.16	0.15	0.13	0.12	0.11	0.10
500	0.33	0.29	0.27	0.24	0.22	0.20	0.19	0.18	0.17	0.15	0.13	0.12	0.11
550	0.36	0.32	0.29	0.27	0.24	0.22	0.21	0.19	0.18	0.16	0.15	0.13	0.12
600	0.40	0.35	0.32	0.29	0.27	0.24	0.23	0.21	0.20	0.18	0.16	0.14	0.13
650	0.43	0.38	0.34	0.31	0.29	0.27	0.25	0.23	0.22	0.19	0.17	0.16	0.14
700	0.46	0.41	0.37	0.34	0.31	0.29	0.27	0.25	0.23	0.21	0.19	0.17	0.15
750	0.50	0.44	0.40	0.36	0.33	0.31	0.28	0.27	0.25	0.22	0.20	0.18	0.17
800	0.53	0.47	0.42	0.39	0.35	0.33	0.30	0.28	0.27	0.24	0.21	0.19	0.18
850	0.56	0.50	0.45	0.41	0.38	0.35	0.32	0.30	0.28	0.25	0.23	0.20	0.19
900	0.60	0.53	0.48	0.43	0.40	0.37	0.34	0.32	0.30	0.27	0.24	0.22	0.20
950	0.63	0.56	0.50	0.46	0.42	0.39	0.36	0.34	0.31	0.28	0.25	0.23	0.21
1000	0.66	0.59	0.53	0.48	0.44	0.41	0.38	0.35	0.33	0.29	0.27	0.24	0.22
1050	0.70	0.62	0.56	0.51	0.46	0.43	0.40	0.37	0.35	0.31	0.28	0.25	0.23
1100	0.73	0.65	0.58	0.53	0.49	0.45	0.42	0.39	0.36	0.32	0.29	0.27	0.24
1150	0.76	0.68	0.61	0.55	0.51	0.47	0.44	0.41	0.38	0.34	0.30	0.28	0.25
1200	0.80	0.71	0.64	0.58	0.53	0.49	0.45	0.42	0.40	0.35	0.32	0.29	0.27
1300	0.86	0.77	0.69	0.63	0.57	0.53	0.49	0.46	0.43	0.38	0.34	0.31	0.29
1400	0.93	0.82	0.74	0.67	0.62	0.57	0.53	0.49	0.46	0.41	0.37	0.34	0.31
1500	0.99	0.88	0.80	0.72	0.66	0.61	0.57	0.53	0.50	0.44	0.40	0.36	0.33
1600	1.06	0.94	0.85	0.77	0.71	0.65	0.61	0.57	0.53	0.47	0.42	0.39	0.35
1700	1.13	1.00	0.90	0.82	0.75	0.69	0.64	0.60	0.56	0.50	0.45	0.41	0.38
1800	1.19	1.06	0.95	0.87	0.80	0.73	0.68	0.64	0.60	0.53	0.48	0.43	0.40

Inches/day = 0.053 GPM / Acres

it is dry then the pivot can be used during the early part of the season when supply exceeds crop demands. This process needs to be initiated early enough to build soil water supplies while dovetailing irrigations will farming operations.

DESIGN OF SPRINKLER PACKAGES

After completion of the system layout and selection of the system capacity, the sprinkler package can be selected for the center pivot. The system layout will provide information for the length of the entire pivot pipeline and the length of each individual span of the pivot. The layout will also provide the total irrigated area and the soil types that are used in selection of the system capacity.

The design of the sprinkler package involves:

- Selection of the type of sprinklers to use (i.e., the sprinkler package) which will also include specification of the nominal operating pressure and the spacing of sprinklers along the pivot pipeline (called the lateral).
- Calculation of the flow rate, or discharge, needed at each sprinkler along the pivot pipeline.
- Determination of the proper nozzle size for each sprinkler.

The selection fo the type of sprinkler package to install involves consideration of the application efficiency, operating costs and installation costs. The sprinkler package affects the amount of water that could potentially run off of the intended point of water application, the amount of water that evaporates in the air or on soil and plant surfaces and to a small degree the amount of drift lost from the field. Other papers in the proceedings focus on the expected efficiency and costs of alternative sprinkler package designs.

Figure 5 shows that the area irrigated by a sprinkler located at the midpoint of the center pivot lateral irrigates less area that a sprinkler located near the end of the lateral. Since more area is irrigated during the same amount of time, the sprinkler near the end of the lateral requires more discharge than the sprinkler closer to the pivot base. The discharge required from a sprinkler depends on the total capacity of the center pivot, the size of the irrigated field (effective radius of the system), the distance from the pivot base to the sprinkler and the spacing between individual sprinklers along the pivot lateral:

$$q = Cg \times R \times S / 6933 \qquad \textbf{(5)}$$

where q is the discharge in gpm for a sprinkler located at a distance of R feet from the pivot base when the gross system capacity is Cg (gpm/acre) and the sprinkler is spaced at a distance of S (feet) from the upstream and downstream sprinklers. For example, if the system capacity was 6 gpm/acre and the sprinkler outlet was located 1300 feet from the pivot base and the spacing of sprinklers was 9 feet, the discharge required for the sprinkler would be 10.1 gpm. Calculations for all sprinklers along the lateral are usually determined with computer programs developed by sprinkler or center pivot manufacturers or suppliers.

If an endgun will be installed on the pivot to pickup some irrigated area, the capacity of the endgun must be determined. The required flow rate from the endgun can be determined from figure 6. Figure 6 shows that the amount of land area irrigated with and endgun reaches a plateau when the radius of the area irrigated with the endgun is about 15% of the length of the pivot lateral. In fact it is difficult to find endguns that throw water this length. A common length of the endgun radius relative to the length of the pivot lateral is about 10% to 12%. In this case the discharge required from the endgun will be about 20% to 25% of the flow rate for the main center pivot system when the endgun is off. For example, if the total flow when the endgun is off is 600 gpm and the radius of the endgun to the pivot lateral is 10%, then the endgun will require about 120 gpm. This is a major quantity of flow and should be considered when the center pivot is matched to the irrigation pump.

After the discharge for sprinklers on the lateral and the discharge from the endgun are determined the pressure distribution along the lateral is computed. With this calculation the pressure at each sprinkler outlet is computed. The effects of pressure regulators are also computed. These computations provide the pressure available at the sprinkler. The pressure is used to determine the size of nozzle required for the respective sprinkler. These computations are very laborious and are done with computer programs. As a result of the computations, the nozzle sizes for each sprinkler outlet are determined.

Installers must be careful to install the proper sprinkler and nozzle at the right location along the pivot lateral. Unfortunately, we still see cases where installation errors results in putting the wrong sprinkler and nozzle at the wrong location along the lateral. The irrigator should insist on a printout of the sprinkler location and nozzle size chart. The irrigator should at least spot check the installation. With the color coding of newer sprinkler nozzles it is fairly easy to walk along the system and compare the design specifications to what was installed.

This description of the design of the sprinkler package shows that once the type of sprinkler package has been selected, the irrigator's job is generally complete. The computation of the spacing of sprinklers, nozzle sizes, pressure regulation, etc. is generally accomplished by sprinkler or pivot manufacturers and/or suppliers. **It is strongly recommended that producers allow these entities develop the specifications for the design and that irrigators follow manufacturer recommendations**. Manufacturers invest large amounts of resources in developing and testing products. They know what their products can

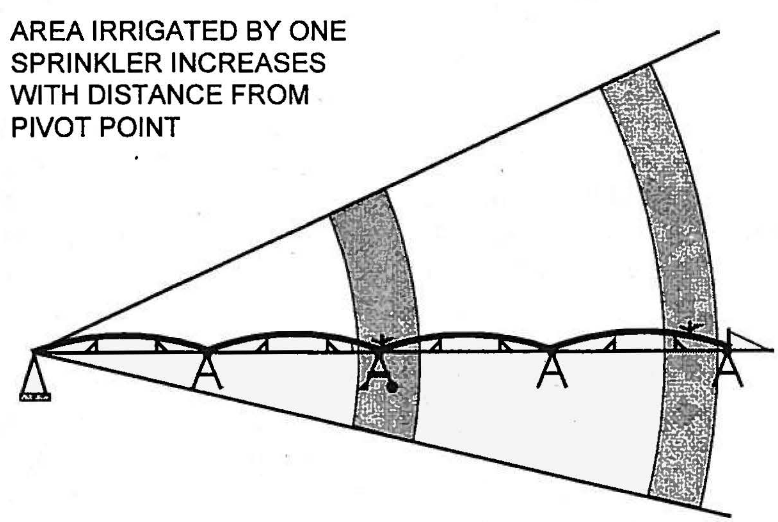

Figure 5. Diagram of area irrigated by a sprinkler located halfway along the pivot lateral and a sprinkler located near the end of the lateral.

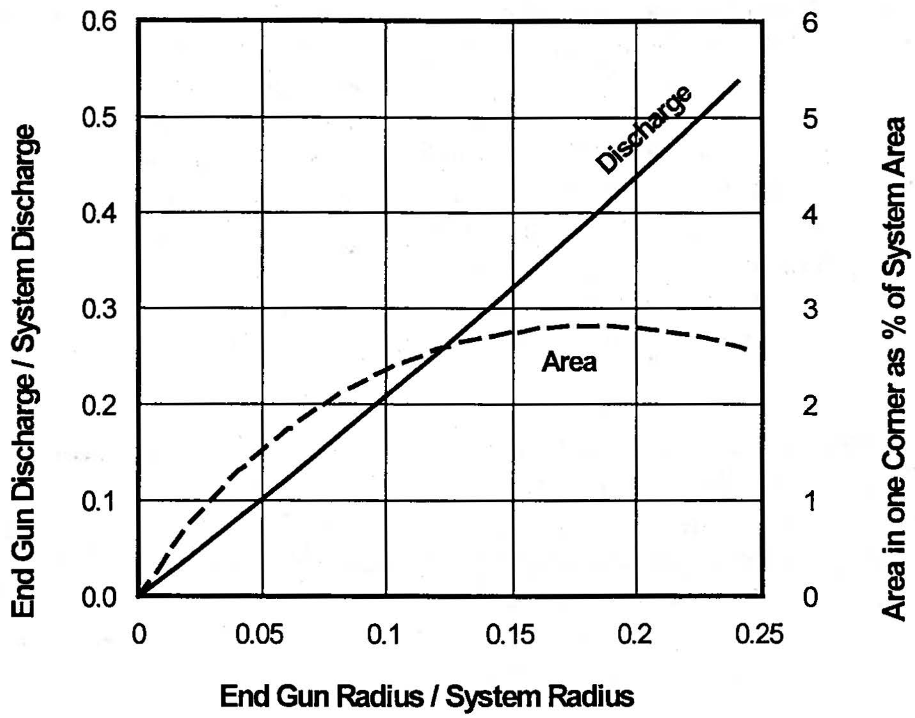

Figure 6. Relationship of the radius of the area irrigated with an endgun to the area irrigated and the discharge required from the endgun.

do and have developed recommendations of how their products should be used.

How do irrigators or dealers modify manufacturers' recommendations? The main variations that occur involve the spacing of devices along the pivot lateral and the height above the ground that devices are installed. Assuming that the discharge from individual sprinklers is correctly computed from the sprinkler supplier or pivot manufacturer, the variations of sprinkler height and spacing primary affect the uniformity of water application.

IRRIGATION UNIFORMITY

Sprinkler irrigation systems are designed to apply water so that plants have equal access to water. It is not possible to perfectly achieve this goal, but center pivots can be designed to very uniformly apply the desired application. The key to achieving the desired uniformity is to provide the adequate overlap of water application patterns between successive sprinklers. The overlap of sprinkler patterns is illustrated in figure 7. The top portion of the diagram shows that about four or five sprinklers along a pivot lateral apply some water to a point on the ground. This pattern is more typical of impact sprinklers and rotating pad sprinklers that have large wetted radii. Sprinklers with stationary spray pad devices may result in fewer sprinklers applying water at a point; however, there still must be adequate overlapping of adjacent sprinkler patterns to achieve uniformity. The only time that overlapping of sprinkler patterns is not needed is when the sprinkler devices are placed close enough together so that equal plant access to water is ensured. This generally occurs with sprinkler packages for low energy precise application (LEPA) system and sprinkler packages that placed in the crop canopy. In each case the spacing of sprinklers along the lateral must be small enough to ensure uniformity. This results in more expensive installation costs. Some growers or dealers try to stretch the spacing to minimize expenses. This generally results in reduced uniformity which reduces application efficiency or crop yield.

Why is overlap necessary? Sprinklers apply water in a circular pattern and the depth of water applied varies along a radial line from the center of the sprinkler to the edge of the wetted radius. The distribution of water along this radial line is referred to as the single-leg distribution of water. Some examples of single-leg distributions for different types of sprinklers are shown in figure 8. The triangular and elliptical patterns are often found with impact sprinklers and the patterns with one or two peaks are common of rotating pad sprinkler devices.

To determine the uniformity of application these single-leg distributions must be overlapped for upstream and downstream sprinklers. This procedure requires accurate information from the sprinkler manufacturers on the distribution of water for their devices at different pressures, nozzle sizes and heights above the soil-crop surface. Computer programs are available to compute the uniformity of distribution. Manufacturers have also measured the performance of their equipment. Either of these processes can be used to develop a sprinkler design that provides acceptable uniformity. It is very unlikely that acceptable uniformity can be achieved without such analyses. Growers and dealers should always stay within the design specifications developed by the sprinkler and center pivot manufacturers.

The height of the sprinkler device above the soil-crop surface also affects the uniformity because water is not thrown as far when sprinklers are close to the surface (figure 9). This reduces overlap and may require closer spacing of sprinklers. When sprinklers are placed in the crop canopy the wetted radius is reduced considerably and the uniformity will be greatly reduced unless devices are placed closer together. In many cases devices should be spaced at a distance that is twice the row spacing of the crops.

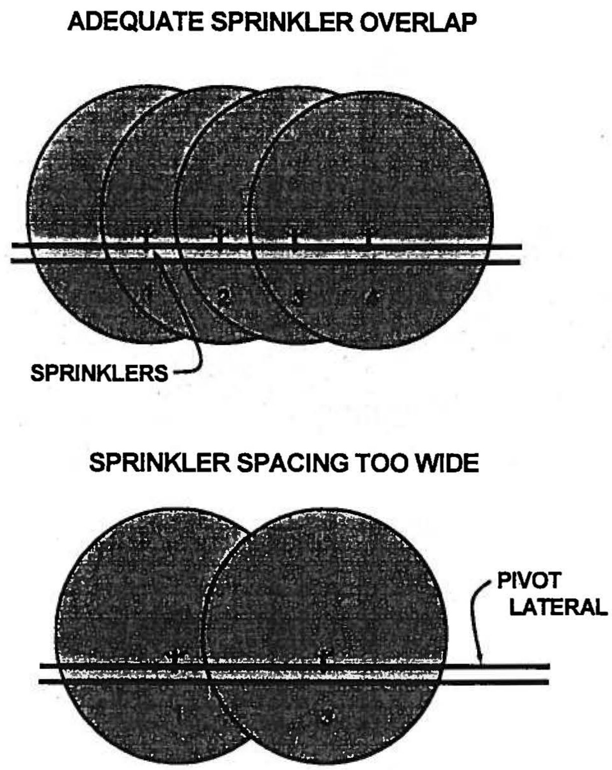

Figure 7. Illustration of the proper amount of overlap with sprinklers and how the patterns would look with inadequate overlapping of adjacent sprinklers.

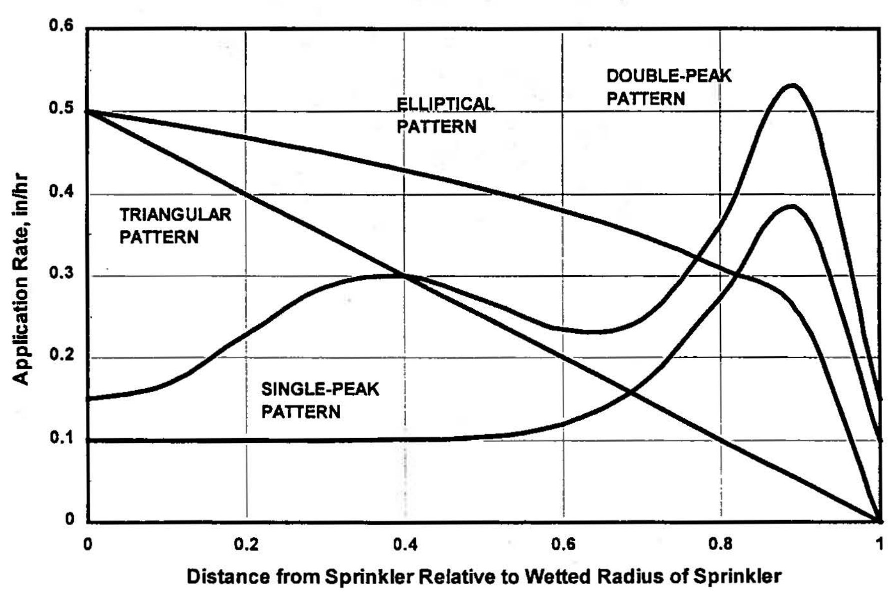

Figure 8. Single-leg distributions commonly found for individual sprinklers.

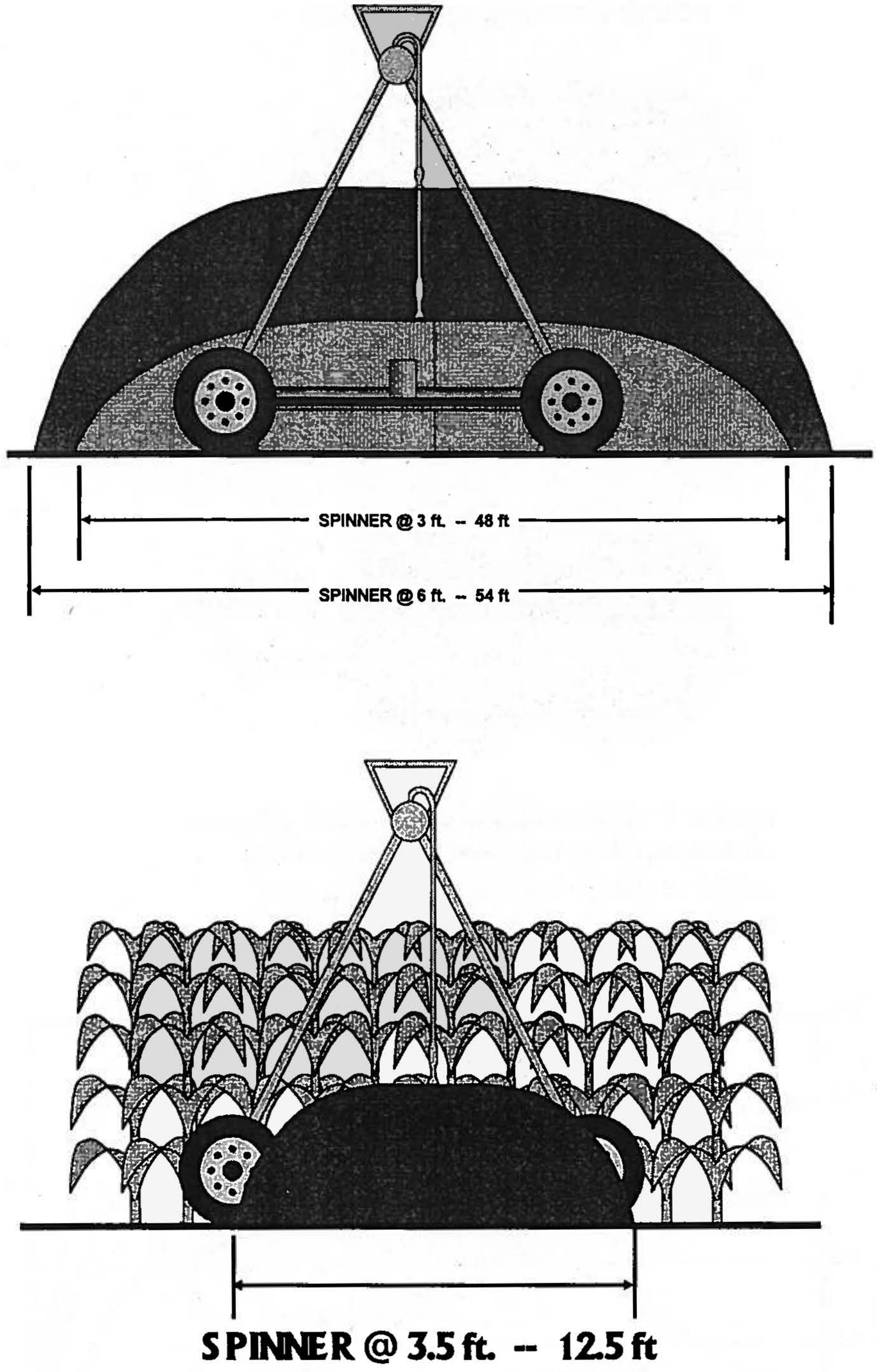

Figure 9. Illustration of the effect of height of nozzle placement and placement in the crop canopy on the wetted radius of a rotating pad sprinkler device.

SUMMARY

This paper presents general considerations for the design of center pivot irrigation systems. Other papers in the proceedings provide details about many of the topics discussed here. The design of a sprinkler system involves the layout of the system on the proposed tract of land, determination of the system capacity required to meet crops water requirements while considering downtime and application inefficiency, and computation of the discharge required for sprinklers along the center pivot lateral. Several decisions must be made during the process. The effect of these decisions on the uniformity of water application and ultimately the efficiency of application should be considered. Center pivots have the ability to apply water very efficiently; however, to attain this potential it is necessary to adhere to manufacturer's guidelines and to combine good design with effective irrigation scheduling and management.

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