OVERVIEW OF NEW DEVELOPMENTS IN SPRINKLER IRRIGATION

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INTRODUCTION

The Central Great Plains changed significantly with the advent of center pivot irrigation systems. Many airline passengers have been fascinated with the large circles that dot the terrain. Some have puzzled as to what the circles can be. However, we all know that this large scale development, which began approximately 30 years ago, has changed many of our life styles. The ability to irrigate sandy soils and rough terrain has made it possible to irrigate many acres which previously were nonirrigable. The development was not limited to new areas but many surface irrigated fields were converted to center pivot systems. The ability to substitute energy and machines for labor was very attractive. It allowed more efficient irrigated farming with little or no increase in labor requirements.

CENTER PIVOT CHARACTERISTICS

The advent of center pivots came with different manufacturers providing machines with many different colors, drive towers, and structure designs. Many of the first systems had problems with miring down and erosion in the wheel tracks. This is not near the problem today because of the larger floatation tires. Wheel tracks are sometimes graveled or elevated and compacted for improved tire travel. Most of the current systems now use electric motors for powering each drive tower and rubber tires that minimize the traction problem.

Irrigation Uniformity

The uniformity of applying water with center pivots is generally evaluated using catch cans to measure the depth of water parallel with the lateral. Mathematical models were also written to evaluate the uniformity of the large self propelled irrigation machines. It was quickly shown that with proper design and installation, uniform irrigations are possible with center pivots. Note, I said with proper installation. When properly designed systems are not installed according to design their uniformity is usually reduced.

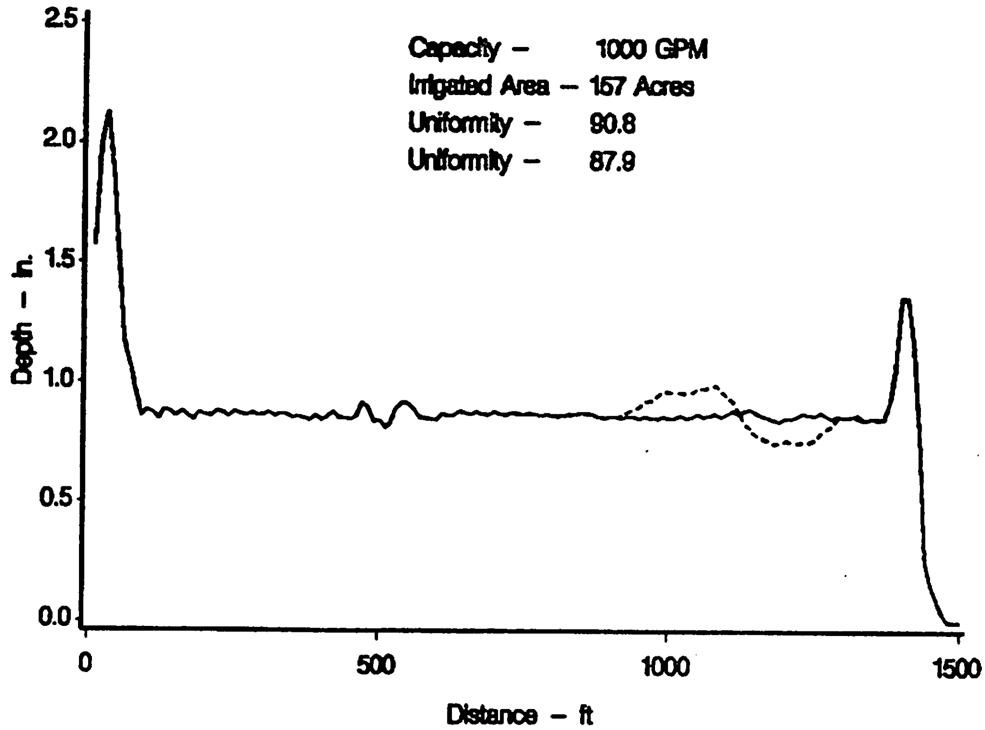

Figure 1 Typical center pivot as designed (CU = 90.8) and with 10 sprinkler heads incorrectly installed shown as dashed (CU = 87.9).

Figure 1 is an example of a computer simulation to evaluate the application uniformity of a center pivot. The information needed for this program is the pump and well characteristics, the sprinkler size, model and location on the lateral. Most of the current sprinkler nozzles packages are now selected with computer programs to provide uniform irrigations. The dashed line in Figure 1 demonstrates what can happen if the sprinklers are not installed as designed. In this case the 5 heads between towers 6 and 7 were exchanged with those between towers 7 and 8. The uniformity only drops by 3 percent but you can certainly observe the change in application depths just beyond 1000 feet.

Incorrect heads were installed for a distance of 300 feet. In this span two 100 foot increments resulted with applications either increased or decreased by 12%. Thus, 10% of the field would be either over irrigated or under irrigated by 12% for each irrigation. These problems are easy to correct but must be detected. It is not obvious just by observing an irrigation. A catch can test or computer simulation of the physical inventory could detect the problem.

The irrigation uniformity for both systems was near 90 which is generally considered acceptable for sprinkler irrigation systems. The characteristics of center pivot systems is that they can be designed with very high uniformities. The large spike of application at the outer end results from the application of the end gun. The uniformity is in the high 90's if this area were neglected. Center pivot systems do however have a problem of high application rates that exceed the intake rate on many soils. The application rates are directly related to the type of sprinkler heads installed on the systems.

Sprinkler Heads

The first center pivots were installed with high pressure (50- 70 psi) impact sprinklers. They were evenly spaced with the sprinkler discharge increasing with distance from the pivot. The problem of many center pivots is surface runoff caused by the high application rates at the outer end of the system. The big drops from these sprinklers would compact the soil and reduce the intake rate to less than the application rate. The surface runoff would decrease the uniformity of the resulting irrigation and either leave dry spots or require excess irrigation to apply sufficient water to all points in the field.

Center pivot systems are now available with many different sprinkler head sizes and spacings. Many systems were converted to medium pressure (35-50 psi) impact heads to reduce the energy requirements and provide smaller drops to reduce the surface sealing. Many of these systems use variable spaced heads with closer spacings as the distance increases from the pivot. Sprinkler discharge from the individual heads have less variation with the decreased spacing, thus compensating for the increased discharge required per unit length as the distance from the pivot increases. The reduced pressure saves 45 feet of head required by the pumping plant. A further reduction is possible with spray heads that can operate at 20 psi, thus saving an additional 45 feet of head. Some systems are now being converted to LEPA heads that operate at 6 to 10 psi.

Surface Runoff

The conversion of systems to low pressure sprays or LEPA heads may not be the correct decision for all systems. Even though the pumping costs can be reduced per volume of water pumped, this is not the only consideration in selecting the system for any particular field. Surface runoff can become a very significant problem as the operating pressure is decreased. The application rate increases as the pressure decreases. As the water is applied through sprinklers with smaller and smaller pattern radii, the application rate must increase to apply sufficient water to satisfy crop demand. Figure 2 illustrates the typical application rate from systems with the high, medium, and low pressure heads. Superimposed on this figure is the intake rate of a typical soil. The area between the intake rate and the application rate curves is potential surface runoff. Sufficient surface storage must be available to hold this volume of water or surface movement and erosion can occur.

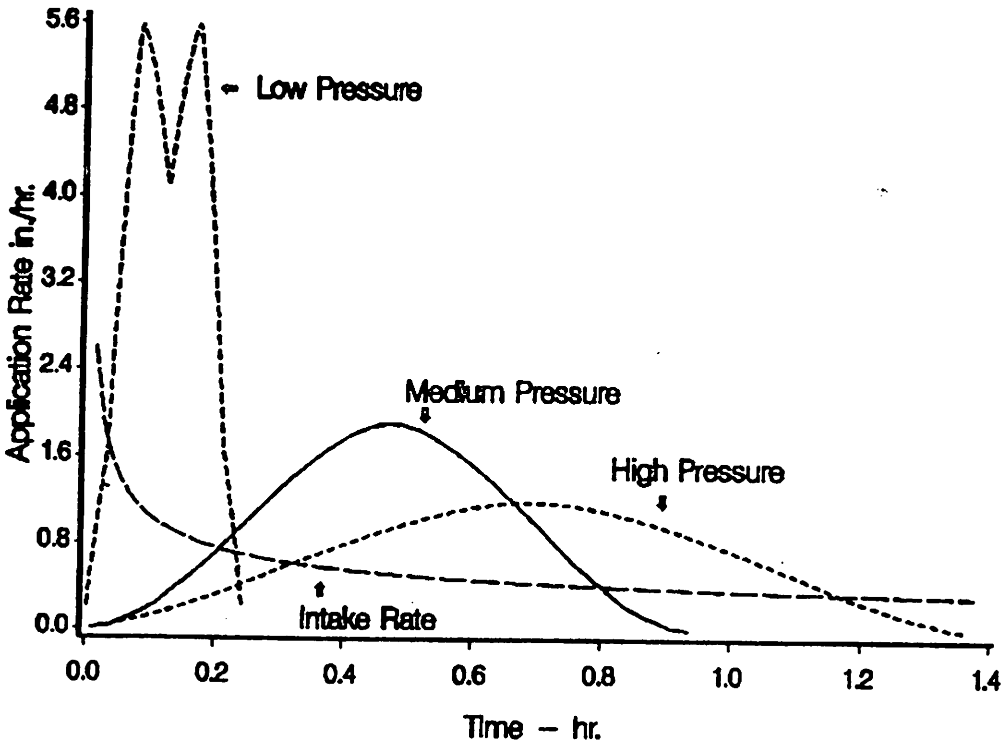

Figure 2 Application rate curves at a radius of 1000 feet for a center pivot system applying 0.86 inches in a 60 hour/revolution with three different pressure sprinkler heads. A typical intake rate curve is included to demonstrate potential runoff.

Increasing the intake rate is one way to compensate for the increased application rate. By chiseling and maintaining a surface mulch the intake rates can be maintained or increased. It is also possible to create small pits or check dams in the furrow for increasing surface storage and preventing applied water from moving on the surface. The application depth can be decreased by increasing the speed of travel of the center pivot, thus decreasing the volume of water available for runoff. However, this may also decrease the penetration of the water into the root zone for use by the crop. Texture or particle size and soil structure also affect the intake rate characteristics of the soil. Another significant parameter affecting the potential runoff is the slope. A field that is flat will have less surface movement and surface runoff than a field with more slope.

Surface runoff is not observed on many fields, only because we don't look very close. A significant amount of relocation can take place under the pivot even though only a small amount of water may runoff outside of the field boundaries. Twenty years ago, we measured 20% runoff or relocation under a high pressure system on slopes of 1 to 3% near Yuma. With the LEPA system Buchleiter observed 30 to 50% runoff on slope of 3 to 10%, respectively. This movement reduces the uniformity for an irrigation. It may be necessary to apply extra water to compensate for this nonuniformity. There are other presentations that will discuss runoff in more detail.

Energy Consumption and Costs

Decreased pumping cost is the main benefit of converting to lower pressure sprinkler heads. The following example will illustrate the magnitudes of reduced costs as a function of pumping lift and center pivot pressure. Table I tabulates the water horsepower required to pressurize the water for a typical center pivot system with various depths to the water table. The horsepower is reduced by 19, 11, and 12 hp. for each increment of reduction from high pressure to medium pressure, from medium pressure to low pressure, and from low pressure to LEPA, respectively. The greatest reduction is from the high pressure to medium pressure.

Table I
The water horsepower required for supplying 850 gpm to a center pivot irrigating 126 acres. The pumping plant efficiency is assumed to be 65%.

	Pivot pressure (psi)			
Dynamic Lift(feet)	90 (high)	65 (med.)	50 (low)	35 (LEPA)
50	85	66	55	43
100	102	83	71	60
150	118	99	88	76
200	135	116	104	93
250	151	132	121	109
300	168	149	137	126
400	201	182	170	159
500	234	215	203	192

The actual cost of these various operating conditions are shown in Table II. The pumping plant is assumed to supply 24 inches with a center pivot system operating at an 85% irrigation efficiency. It is obvious that the costs are the greatest for the deeper lifts. If the water requirements were less than the assumed 24 inches or the electric cost per KWH were different the costs could be adjusted by direct proportion. For example if only 12 inches were required the costs would all be 1/2 of the tabulated costs. However if electric costs were $0.10 the costs would all be doubled.

Table II
Calculated pumping costs for applying 24 inches of net irrigation at 85% efficiency and electricity costing $0.05 per KWH.

	Pivot Pressure (psi)			
	90	65	50	35
Dynamic Lift(feet)	(high)	(med.)	(low)	(LEPA)
50	$2860	$2220	$1830	$1450
100	$3410	$2770	$2390	$2000
150	$3970	$3330	$2940	$2560
200	$4520	$3880	$3500	$3110
250	$5070	$4430	$4050	$3670
300	$5630	$4990	$4600	$4220
400	$6740	$6100	$5710	$5330
500	$7840	$7200	$6820	$6440

These costs are an economic indicator of the benefit for converting to lower pressure systems. The cost is reduced by $400 for each increment of change in the pivot pressure to the next lower pressure sprinkler head. However, the assumed irrigation efficiency of 85% can be affected significantly by the operation and management of the systems. The factors that can influence the costs are pumping plant efficiency, soil water evaporation, surface runoff, over irrigation and seasonal water requirements.

Factors influenced by sprinkler head changes

Potential surface runoff generally increases as the pattern radii decrease because application rates increase (Fig. 3). Unless the cultural practices can modify the intake rate and prevent an increase in surface runoff, additional irrigation amounts will be required to satisfy crop water requirements. Assuming that an additional 20% surface runoff occurred, the additional pumping cost of 20% would be more than the savings in energy except for possibly lifts of less than 100 feet. Careful evaluation of runoff potential must be considered before making any changes.

Another generally claimed advantage for reduced pressure is less wind drift and evaporation during an irrigation. The literature, however, on the subject of evaporation losses does not lead to a single conclusion. Some research indicates that evaporation from smaller drops is higher than that from larger drops. However, the spray nozzles with smaller drops are generally also mounted closer to the soil surface to decrease the time for evaporation to occur. Most estimates would indicate that evaporation losses are less than 5% or about the accuracy of measuring the water applied. Wind drift is a function of the height at which water is discharged and the drop size. Spray systems would tend to have more drift unless they are mounted either beneath the canopy or at least close to the crop or soil surface.

Over irrigation is probably the area that can be influenced most by improved irrigation scheduling and management. Studies have shown that on the average there may be a potential savings of 30%. This is obviously as important as reducing the operating pressure of the system.

IRRIGATION MANAGEMENT

My research has focused on the management or scheduling of center pivots to increase production and reduce costs. Cooperators were able to increase their production when they applied the correct amount of water at the time when the soil could store the water for use by the crop. Several research projects have shown that often as much as 30 percent of the water is applied in excess to that required. Water savings are usually possible in the early and late season. Unless systems are oversized, they must often run almost continuously during the few weeks when the crop is using water at a maximum rate.

It is important to measure the amount of rainfall on each field so that its' contribution can be accounted for properly. A key to proper management is to know the amount of water that is applied with the center pivot and the amount of rainfall on each field. It is recommended to use catch cans to evaluate the amount of water applied and its' uniformity. Computer simulations can also be an effective way to evaluate the center pivot system.

Irrigation Scheduling

A number of different approaches can be used to schedule irrigations for center pivot systems. The measurement of soil water or plant water potential can be used to determine the current need for an irrigation. Tensiometers, gypsum blocks, neutron probes, and soil sampling are methods of measuring soil water to determine the need for an irrigation. A projection of the soil water decrease is needed to forecast the next irrigation date. All of these techniques require a considerable amount of time and some expertise to operate, maintain and interpret the data. Infrared temperature guns are available for measuring the crop temperature directly and algorithms have been developed to schedule irrigations based on air and crop temperature differences. This is a fairly new technique which can measure the development of crop water stress and thus indicate the need or timing of irrigations. It doesn't, however, indicate the amount of water to needed.

Irrigation scheduling programs for personal computers are available and are relatively simple to use. They require that some estimate of reference evapotranspiration (ET_r) be available to maintain a water budget for tracking the soil water status. There are a number of weather stations in the Central Plains that are collecting the necessary data to run a scheduling program. There will be several presentations on irrigation scheduling techniques tomorrow.

A key factor in the scheduling of irrigations is not only a projection of the ET. The rainfall must be measured on each field and the center pivot system must be evaluated as to the amount of water that is applied per irrigation. Errors in either the rainfall or irrigation amount will lead to either over irrigation or under irrigation. Either situation will cause a reduction in the net returns from crop production.

Computer Control of Center Pivots

A system which can greatly assist in the management of center pivots has a computer mounted on the pivot which can communicate by radio to a base station. The management systems provide the ability to control and monitor the operation of center pivots from a central office location. The benefits are the reduced time and vehicle mileage to monitor systems. The computer control can allow a timely starting and stopping of an irrigation. With rain gages mounted at the pivot the rainfall can be telemetered back to the central office and used directly in an irrigation scheduling program. The system also provides the irrigation date and time data to the central office. An irrigation scheduling program can be an integral part of the base station software which can provide immediate irrigation schedules. Weather stations can be installed to automatically report the data to the computer at the base station and the scheduling program can be completely automated. Periodic checks on the soil water status are recommended to assure that the soil water budget is tracking the field conditions which could result from error in the climatic data or rainfall or irrigation amounts. An analysis of historical data collected with this system can be used by management to improve irrigation system performance in the future.

SUMMARY

Center pivots are an effective way to irrigate areas in the Central Plains. There are a number of decisions that must be made when selecting or modifying existing center pivots. I have discussed a few of these and want to emphasize the importance of management and irrigation scheduling. There are a number of presentations that will examine in more detail the problems of runoff, nozzle selection and irrigation scheduling.