IMPROVING CENTER PIVOT PERFORMANCE TO INCREASE SURFACE WATER SYSTEM EFFICIENCY

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INTRODUCTION

Tests to determine water distribution uniformity under center pivot irrigation in order to improve performance are a single component of The Central Nebraska Public Power & Irrigation District's (CNPPID) multi-faceted effort to advance whole system efficiency. Continuing efforts to improve system components are critical at this time as reduced inflows at Lake McConaughy threaten a continuous water supply. For the reader unfamiliar with the CNPPID surface water system, an overview is included here. Efforts to increase whole system, conveyance lateral and on-farm systems efficiency will be discussed and examples of on-farm center pivot test results are presented.

System Overview

Kingsley Dam closed in 1941, forming the twenty-two mile long Lake McConaughy on its west side. Lake McConaughy is located just to the north of Ogallala in western Nebraska (storage capacity is 1,743,000 acre-feet (AF) at 3265.0 feet above mean sea level) and is the District's primary storage facility on the main-stem of the North Platte River (Figure 1). Storage volume at Lake McConaughy not only serves CNPPID producers but also holds water for other interests. Nebraska Public Power District (NPPD) uses McConaughy water to cool the coal-fired, electric generators at the Gerald Gentleman Station, turn hydroelectric turbines at North Platte and serve its irrigation customers with the water. Storage water from the Glendo Reservoir in Wyoming becomes a part of Lake McConaughy in the fall to serve the five Nebraska canals with Glendo water accounts in the spring and summer months. The US Fish and Wildlife Service (USFWS) maintains and manages a parcel of Lake McConaughy inflows for downstream endangered and threatened species. CNPPID diversions currently provide hydroelectric generation, irrigation water to 113,170.67 acres in Lincoln, Dawson, Gosper, Phelps and Kearney counties and maintain river flows according to the Federal Energy Regulatory Commission (FERC) license requirements.

In addition to Lake McConaughy, the CNPPID system includes four hydroelectric power plants (104 megawatt capacity), a diversion dam directly below the confluence of the North and South Platte Rivers, 26 smaller reservoirs and canyon lakes, a supply canal and three primary irrigation canals that total 587 mi. of conveyance laterals and 1,989 field turnouts.

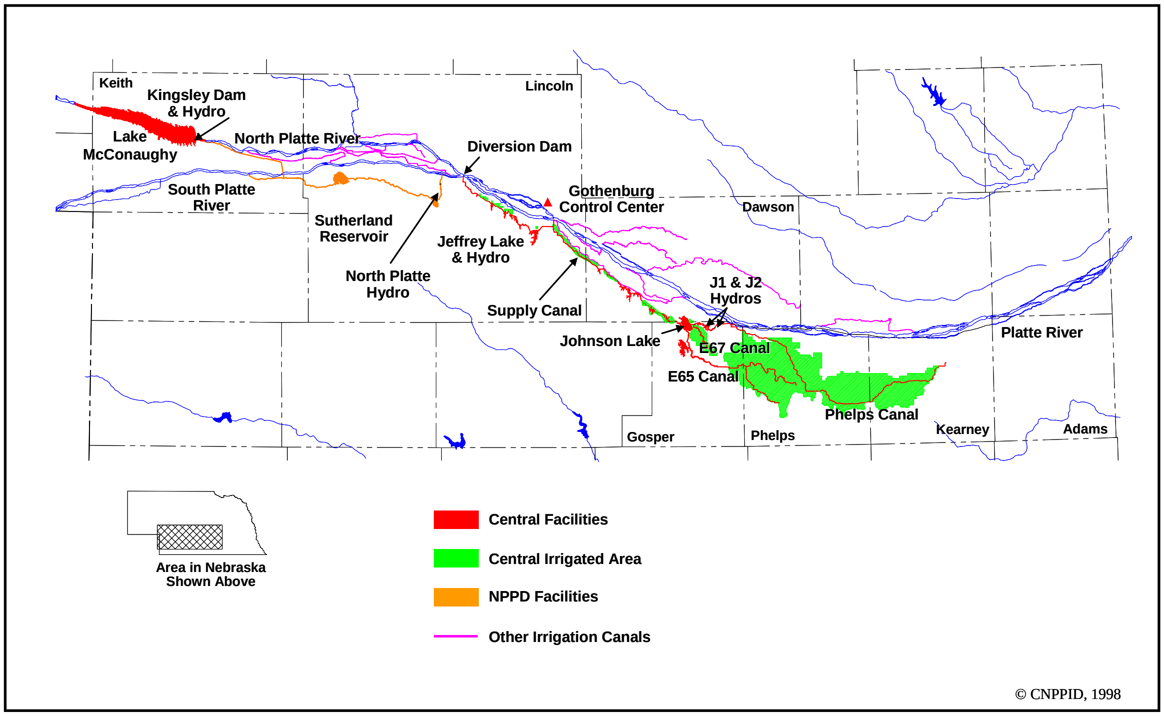

Figure 1. The CNPPID system.

INCREASING WHOLE SYSTEM EFFICIENCY

The goal of whole system efficiency is to provide a continuous, reliable storage water supply where the ratio of irrigation use to water diverted at the headgates is high. Basin parameters are key inputs to the annual Operations Plan, developed by CNPPID engineers in cooperation with other users and approved by the fifteen member Board of Directors. Water supply and releases to and from Lake McConaughy are projected and mass balance calculations applied to keep the system sustainable and provide water for all downstream beneficial uses. Releases are necessarily higher in wet conditions and held to minimum flows when water in the basin is in short supply.

Due to the current historic low inflows to Lake McConaughy, surface elevation is 51 foot below full pool with 585,800 AF of stored water or roughly a third of total capacity. This level is up 9.6 feet from the September low following the 2003 irrigation season (Figure 2). An emergency conservation mode of operations has limited all but essential use within the District since 2002, however, the current low inflows are not meeting minimum demand and a system water balance has not been achieved (Figure 3).

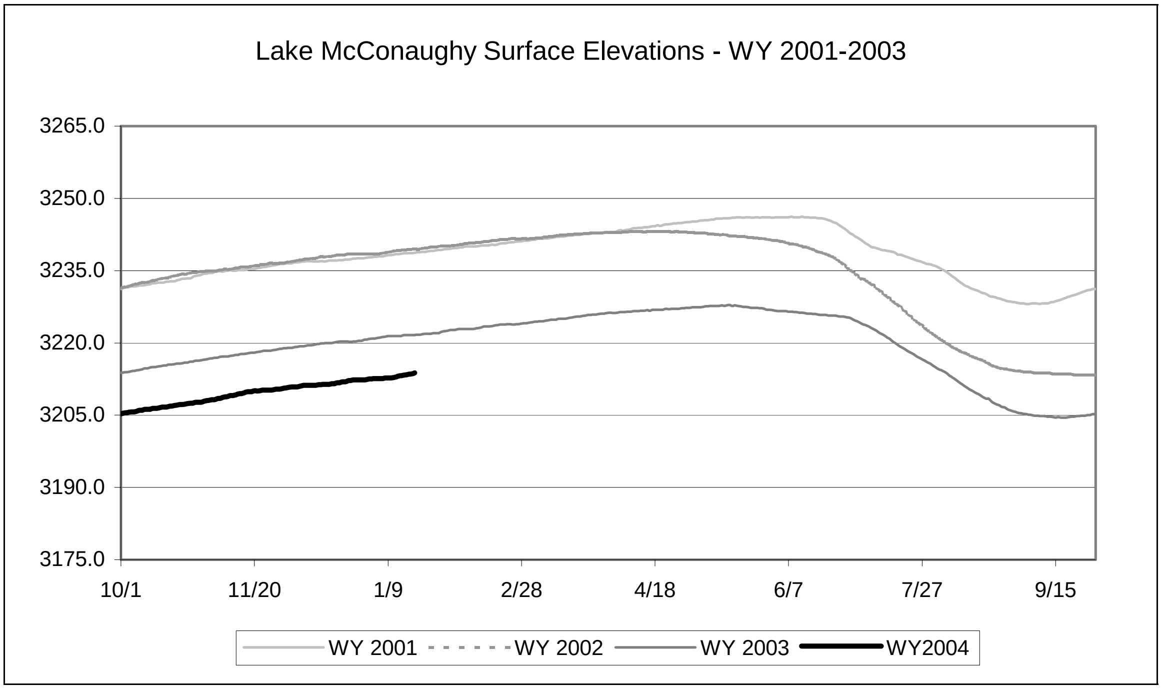

Figure 2. Lake McConaughy Surface Elevations Water Years (WY) 2001-2004.

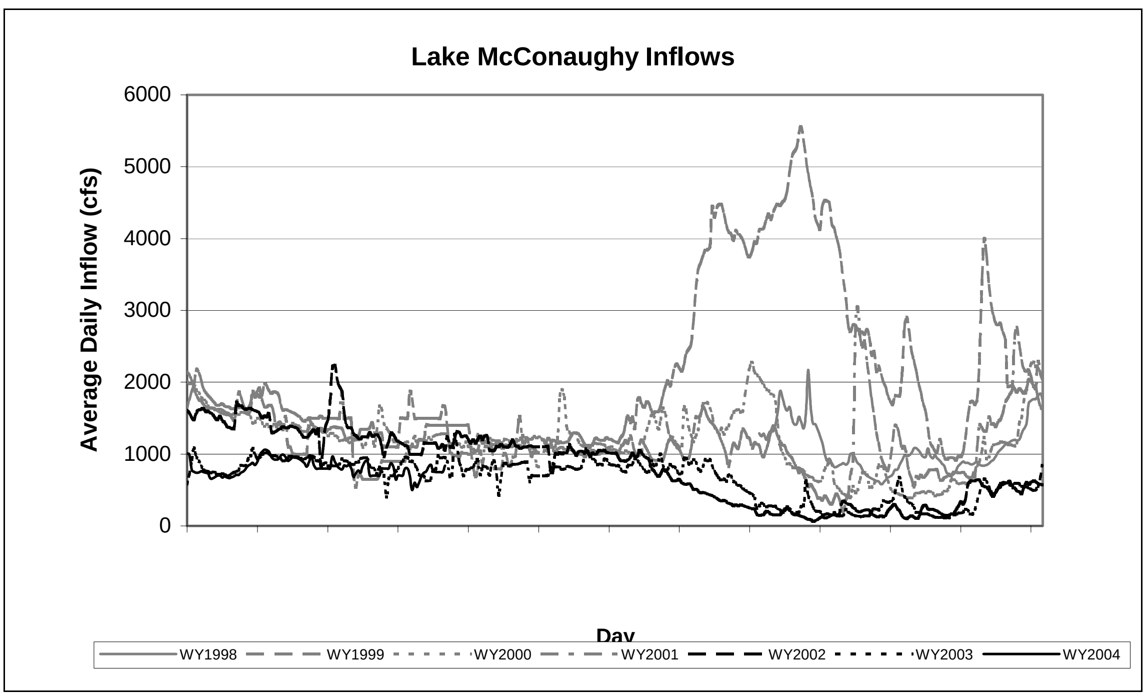

Figure 3. Lake McConaughy inflows, Water Years 1998 – 2004.

New measures have been taken in recent years to increase whole system efficiency and although they may seem small, storage water savings appears to be substantial. A series of automated rain gauges installed along the supply and irrigation canals allows operators at the Gothenburg Control Center to track location and intensity of summer storm events in real time and reduce the response time needed to shut down releases from McConaughy to compensate. Also the smaller, downstream lakes are being drawn down further in August to meet the irrigation demand, saving system water by reducing the additional conveyance losses from Lake McConaughy.

INCREASING CONVEYANCE LATERAL EFFICIENCY

Seepage and evaporation are an inherent part of running water through earthen canals. The evaporation portion is somewhat significant in the reservoirs (near 3 ft. annually at full pool in Lake McConaughy) and of little significance in the canals as the canal banks help attenuate the wind speed across the water surface and stream width is small.

Canal seepage losses recharge groundwater supply, which can be pumped to the surface again, or they become part of return flow to both the Platte and Republican Rivers. However, seepage losses require CNPPID to divert additional water at the headgates to meet that demand. Hydraulic conductivity of the canal beds varies by soil type. Within a same soil type, cut sections tend to have a better retention rate than fill sections.

Efficiency efforts to reduce seepage demand or improve the ratio of AF delivered/diverted include pipeline installations and membrane, concrete and polymer linings. One hundred and thirty-one miles of pipeline and another 13 linear miles of membrane or concrete liners have replaced earthen laterals since the District was formed (Figure 4). Membrane linings include full linings where losses are limited to evaporation and partial linings installed below the canal bed. An estimated 60% reduction in losses occurs with partial linings.

In 2003 an anionic polyacrylamide (PAM) solution was sprayed along 233 miles of earthen or open laterals to slow seepage with only limited success. More study will be done with this product to determine its use in the system.

Additional reduction of losses have been achieved by: automation of check gates that keep canal head steady, and use of the Target Operations Curve (TOC) at Elwood Reservoir. The fill and release schedule at Elwood Reservoir in Gosper County closely follows the TOC developed by an engineering group for CNPPID. By incorporating the TOC into the Operations Plan, surface elevation of the reservoir is lower for part of the year, water needs are adequately met and losses to seepage have been reduced by an average of 5000 AF annually.

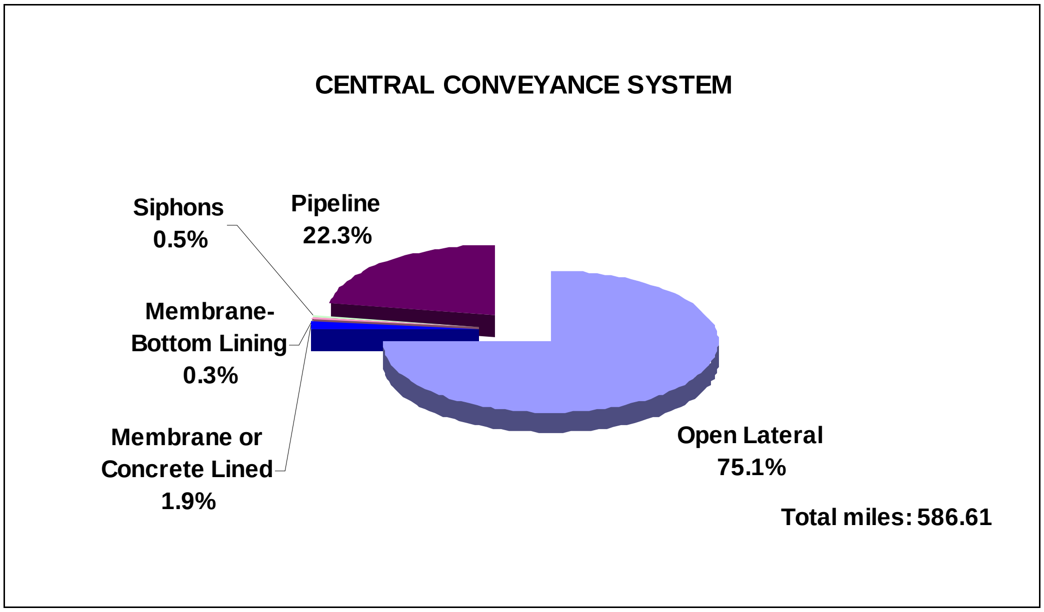

Figure 4. CNPPID system conveyance.

INCREASING ON-FARM EFFICIENCY

The 2003 on-farm systems, shown with associated acres in Figure 5, include flood (USFWS wetland areas), siphon tubes, gated pipe; with and without associated reuse pits and/or surge valves, three sub-surface drip (SDI) demonstration sites and center pivots.

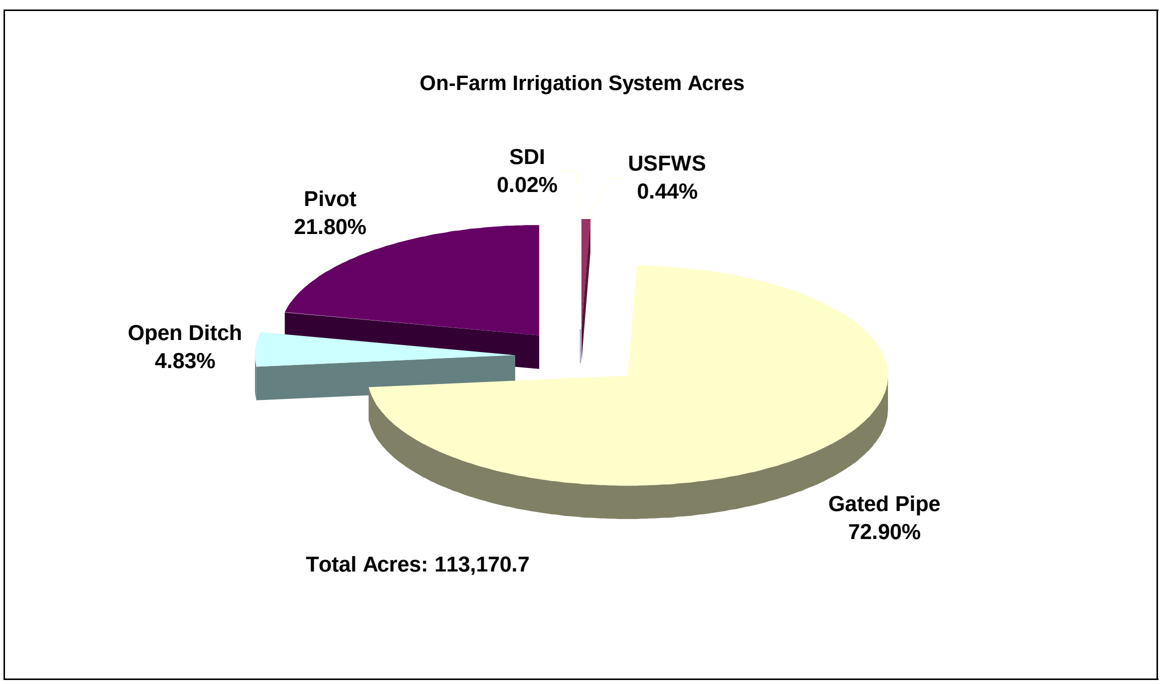

Figure 5. On-farm irrigation system acres served by CNPPID in 2003.

CNPPID has encouraged on-farm conservation efforts for many years through cost-share assistance. Up to $1,500 in material and labor costs is available at each turnout to accommodate an upgrade to a new water conservation practice. An additional conservation policy was implemented in 2001 with the introduction of the Pivot Incentive Policy.

This policy provides a cash incentive to producers to install a center pivot and is designed to offset some of the start-up costs associated with the change. The Pivot Incentive Policy represents a significant financial commitment to water conservation; incentive payments for the 68 new pivots added since 2002 total $194,046.31. Two hundred-six pivots served District acres in 2003 (Figure 6) and 26-29 installations, most replacing gated pipe, are slated for the 2004 season.

CNPPID has experienced a significant upswing in the number of center pivots replacing open ditch or siphon tube systems at the field level. Labor availability and labor cost are most probably the driving force of the increase, however, the potential benefit to water supply without yield reductions are of interest to both CNPPID and its producers.

Pivots coming on-line are normally designed and installed by local dealership staff using manufacturer's software packages and the CNPPID flow rate options to the field. Necessarily, the District's interest is not design but function of these systems following installation.

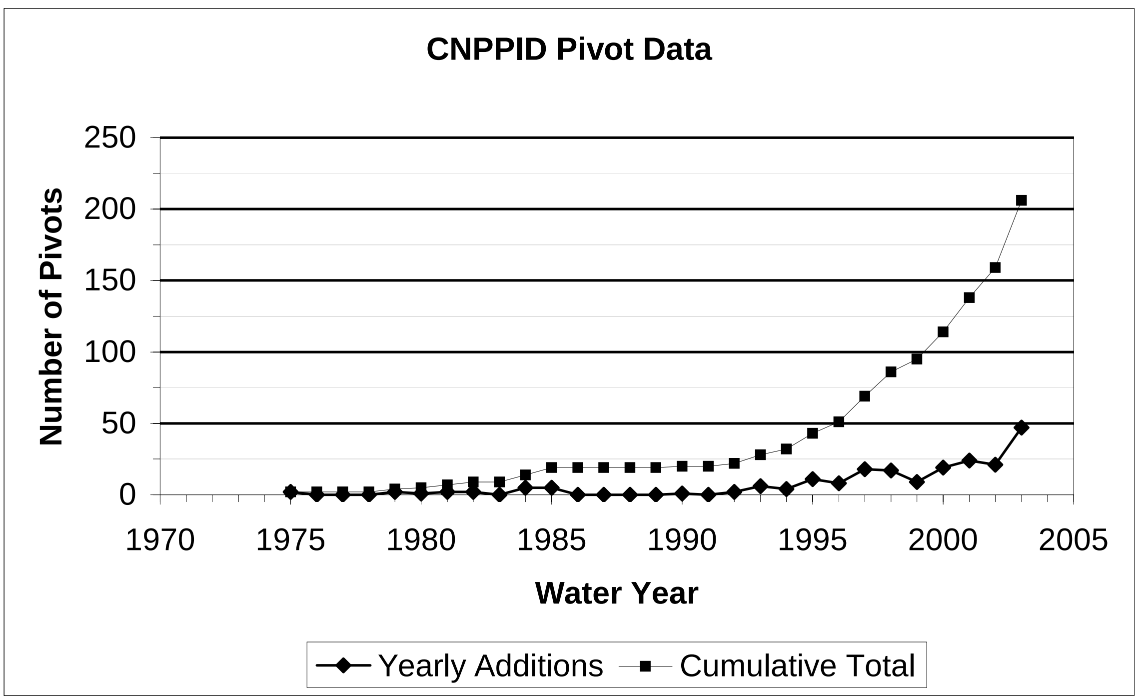

Figure 6. The number of annual additions and cumulative total of center pivot irrigation systems served by the CNPPID District.

On-Farm Center Pivot Testing

A survey of the CNPPID system prior to the 2001 irrigation season revealed that none of the center pivot installations had been field-tested for water distribution uniformity. And so began the effort to assess center pivot installations against the following assumptions:

- Modified Heermann and Hein coefficient of uniformity (CU) is 90 ± 5% after the second tower to the outside edge of the wetted perimeter,
- Sediment load in the water has no effect on CU,
- Number of years pivot has been in service has no effect on CU
- Calibrated table provided by the manufacturer matches actual field application rate.

Surface water use through a pivot presents challenges related to filtering debris, sediment and algae loads. Filtering of surface debris and small fish or benthic organisms is accomplished with 5/32" perforated galvanized steel pipe, 18" or 24" in diameter and in lengths indirectly proportional to canal depth. Any sediment or algae load carried by the water pass through pipe perforations and sprinkler heads and are delivered to the field.

The agricultural engineering standard; ANSI/ASAE S436.1 OCT97: *Test procedure for determining the uniformity of water distribution of center pivot and lateral move irrigation machines equipped with spray or sprinkler nozzles* was used for these tests with one exception. A single line of Irrigage rain collectors (Rogers, et al, 2001) replaces the multiple lines of the catch cans in the standard to improve data collection. Rogers et al., have done extensive testing to verify this substitution. The main outcome of this test, the modified Heermann and Hein coefficient of uniformity (CU), describes variation of the sample data from the mean (average) depth applied at all locations. A value of 100% is an unlikely scenario, however, coefficients near 90% are attainable. Application depths ± 10% of the mean depth applied were accepted as normal, as in the standard.

Test 1ER

Results of this test are shown in Figure 7. Most notably, this producer believed he was applying 0.75 inches of water to his field in a single rotation while actual mean depth of application is 0.41 inches; CU is 78%. The unit is an older model with spray nozzles above the lateral and in this case, sediment appeared to be the problem. No pressure regulators are in place, however, differential elevations at the base of each collector are not correlated with changes in the uniformity pattern. According to field elevations, this test should represent maximum application uniformity in this field.

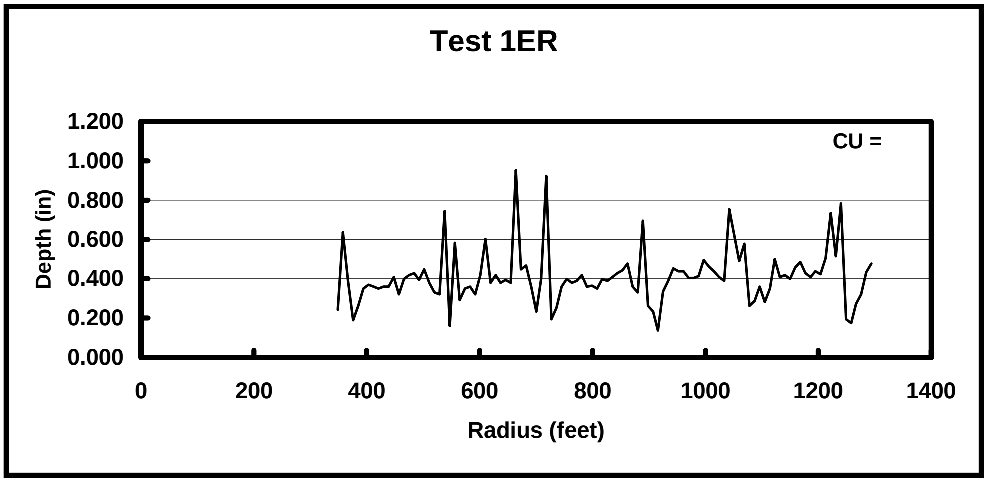

Figure 7. Test results at ER site.

<u>Tests 2OL</u>

The 1983 impact sprinkler unit has 8, 155 ft. spans, an 86 ft. overhang and a cornering unit. The unit was tested twice, first with the cornering unit fully extended and then folded to the “off” position. In the first test, CU was 80.5% and average application depth was 0.67 inches (Figure 8).

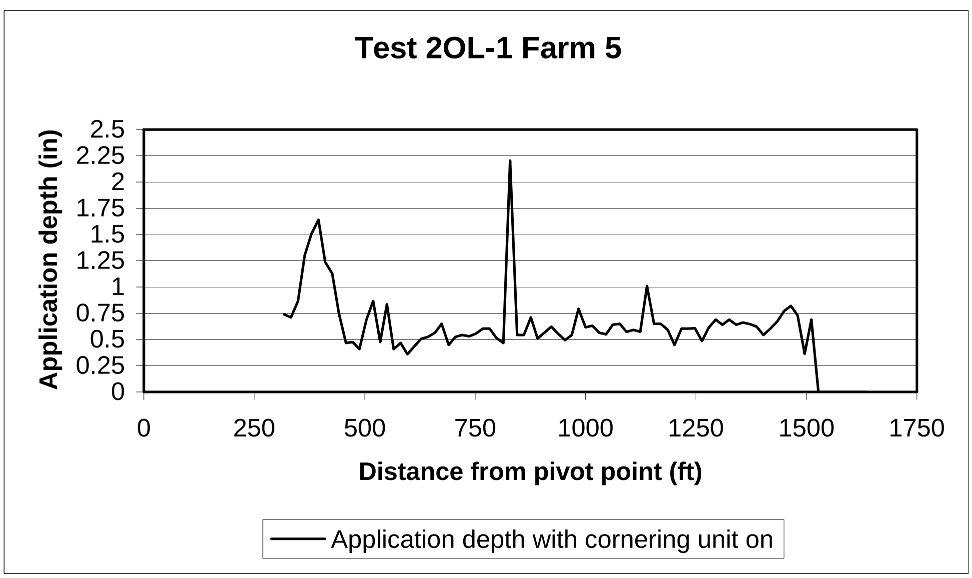

Figure 8. Test 2OL-1.

With the cornering unit folded, CU was 78.9% and average depth applied was 0.90 inches (Figure 9). As shown, a nozzle problem was apparent in the third span and in the folded position, the cornering unit did not shut off completely and depth of application spiked to 2.37 inches. Worn sprinkler heads and a malfunctioning solenoid were the problem here. Also, mean depth of application changed between tests; the producer intended a 0.75-inch application and so the cornering unit needed to be slowed down when fully extended. All problems were easily corrected. Elevations at the base of the collectors were determined again at this site and were not correlated to the uniformity patterns.

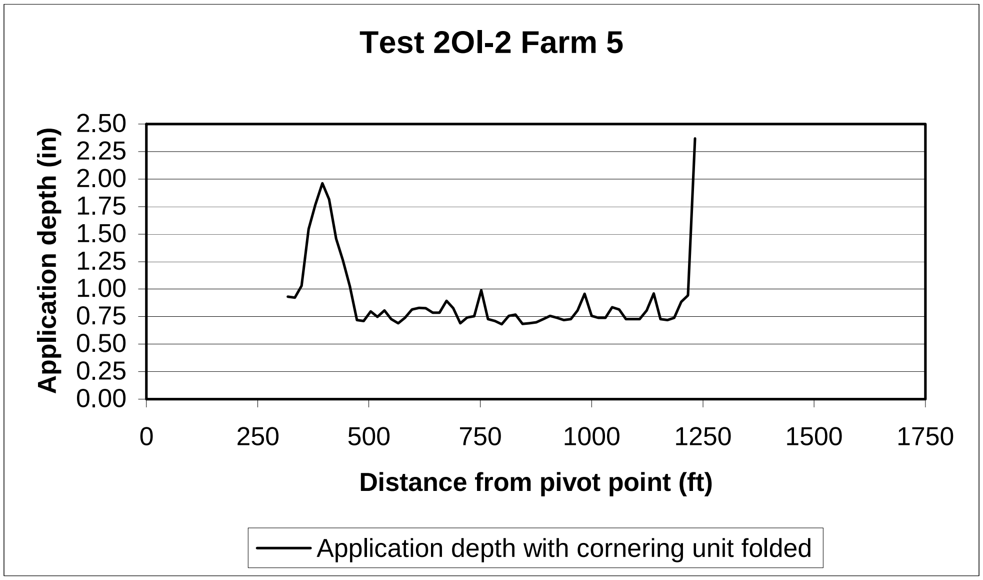

Figure 9. Test 2OI-2.

Test 3EK

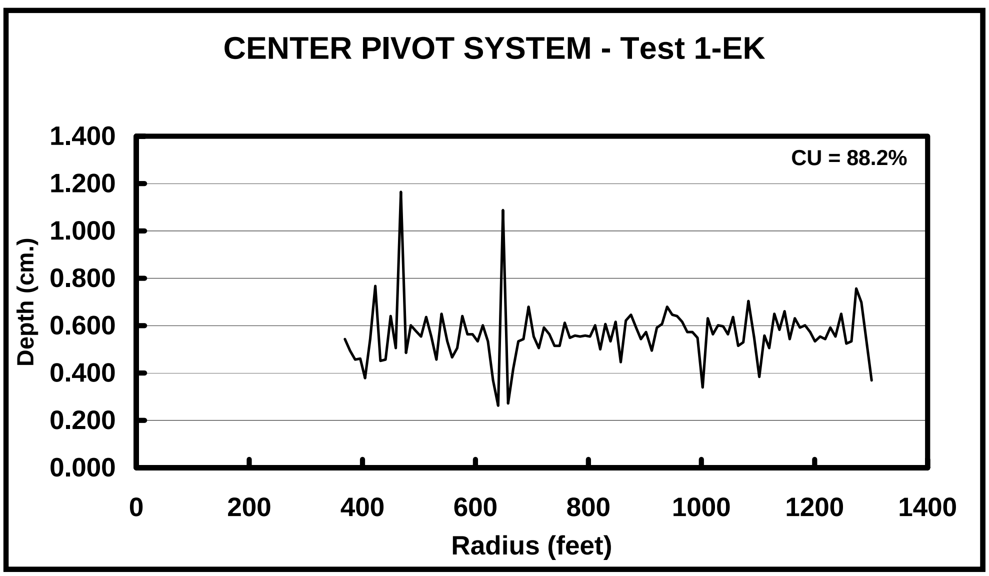

Figure 10. Test 3EK

The pivot in Test 3EK was in its second year of service, a low-pressure system with drops and spray heads. CU is high and the mean application depth of 0.56 inches is just short of the expected 0.60 inches, however, there is room for improvement. The graph clearly shows what happens when sprinkler heads use too much water; neighboring heads are shorted. If the deficit irrigation is not mitigated by rainfall a yield loss would be expected here. Irrigage spacing was 9 feet.

None of the pivots tested to date are without a problem area and each problem found has been easily addressed. Additional field observations not shown here have shown drought conditions can exist under a pivot that is not operating properly and yield losses occur.

The studies completed to date suggest that continuing pivot testing in the system would be useful. CU's near 90% are attainable and although we have formed no opinion on age being a factor in CU we do believe that sediment load in the water can affect CU if it accumulates in sprinkler heads.

Timing of these tests is troublesome in south-central Nebraska as wind speeds higher than the standard allows (11 mph) prevails when corn height does not interfere with data collection. Test conditions in the District are best in July and August, on the soybean side of the corn/soybean crop rotation.

REFERENCES

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Rogers, Danny H., G.A. Clark, M.A. Alam. 2001. Field Scale Evaluation of Center Pivot Systems. Central Plains Irrigation Short Course & Exposition Proceedings. 112-125.