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Irrigation in Brookings County: The Economics of Reduced Pressure Irrigation

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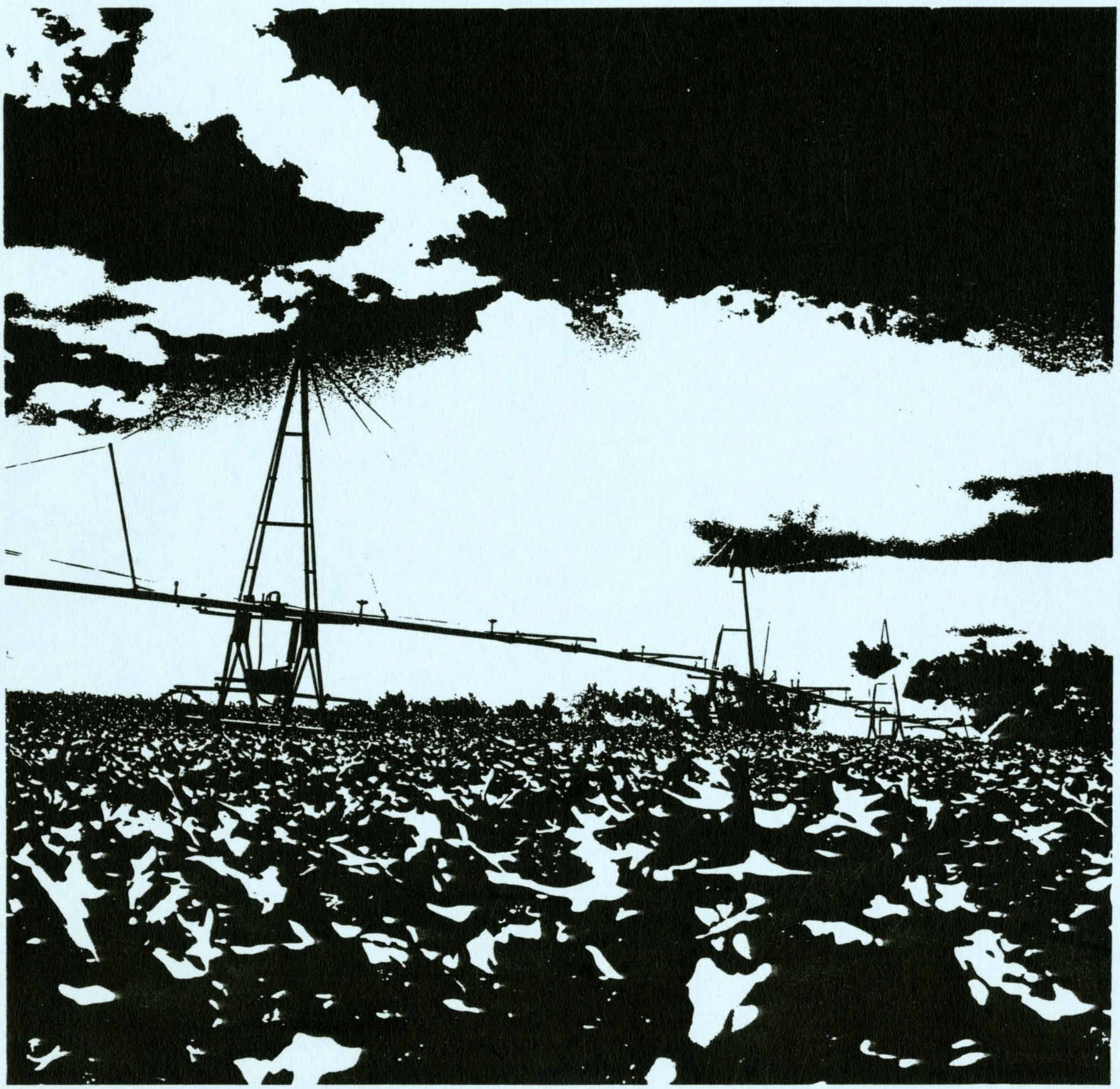

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THE ECONOMICS OF REDUCED PRESSURE IRRIGATION

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Donald C. Taylor
November 13, 1984

SUMMARY AND CONCLUSIONS

This bulletin focuses on a recently developed irrigation technology -- reduced pressure water distribution. The amount of energy required, and hence the dollar expenditure for fuel, to pump water under reduced pressure is less than that required with traditional high pressure systems. The sharp energy price rises of the 1970s provided incentive for the development and use of the new technology.

With water distributed under reduced rather than high pressure, the span of water coverage perpendicular to a center pivot arm is reduced. The water application rate with reduced pressure is, therefore, greater. Unless soil textures are relatively coarse and field topographies are relatively level, the amount of water runoff may be greater with reduced pressure water distribution. The potential for added runoff and less even water infiltration associated with reduced pressure irrigation may result in low pressure irrigators having lower yields.

In 1980, about 5% of South Dakota's center pivot irrigated area was estimated to involve low pressure water distribution. Several low pressure systems were introduced in Brookings County during 1980 and 1981. The basic dataset used in this study reflects the 1982 experiences of Brookings County irrigators in using electrically powered center pivot systems operating with "low" [less than 45 pounds per square inch (psi)], "medium" (between 45 and 65 psi), and "high" (more than 65 psi) water distribution pressure.

The two principal questions explored in the bulletin are the following:

- What is the maximum that an irrigator can afford to pay to convert a center pivot system from high to reduced pressure; and

- How much less would the expected yields under reduced pressure have to be for a farmer to be well advised to purchase an irrigation system with high rather than reduced water distribution pressure?

Certain preliminary steps were required before these questions could be directly dealt with. The principal findings emerging from the study are the following.

<u>There is no statistically significant relationship between corn grain yield and center pivot operating pressure in Brookings County</u>.

The corn grain yield with "high" pressure water distribution is 1.4 bu per acre higher than that with "low" pressure, based on 1982 data. This difference is not statistically significant, however. The production function analysis also shows no statistically significant relationship between corn grain yield and center pivot operating pressure.

The study shows that reduced pressure center pivots in Brookings County are placed on fields with relatively coarse soils and flat topographies. The failure for corn grain yields to be less with reduced pressure could reflect the rather favorable environment under which the reduced pressure systems are being used.

A possible confounding factor, however, is the much above-average precipitation during the 1982 irrigation season. Since use of the irrigation systems studied was only about 40% of normal in 1982, a full opportunity for the impact of reduced center pivot operating pressure on corn grain yield was not realized during the period of study.

<u>The results of the study show that irrigators in Brookings County can expect to realize an annual energy saving with reduced pressure irrigation of $8 to $12 per acre, or $1,040 to $1,560 per center pivot</u>.

The extent of prospective energy savings with reduced pressure depends on several factors. The most important factors, and the values for these factors assumed in the analysis, are as follows:

- "Low" and "high" water distribution pressures of 30 and 75 psi, respectively;

- The height which water is lifted from the water source to the center pivot arm (54 feet);

- Seven to 10 inches of pumped irrigation water;

- Water discharge (689 gallons per minute);

- An electric demand charge of $17.50 per horsepower and a variable energy cost of $0.06 per kilowatthour;

- Pumping and irrigation efficiencies of 75 and 80%, respectively; and

- 130 acres irrigated per center pivot.

Given the technical and economic environment facing "average" farmers in Brookings County in the early 1980s, investing in new irrigation systems does not appear to be profitable.

A whole-farm linear programming analysis with 1982 price and yield relationships shows the use of already-owned irrigation systems to be profitable. The renting of additional irrigated land is also profitable. But the purchase of a new irrigation system to place on a quarter-section of dryland is not. (The model takes account of the estimated average benefit of irrigation over time, but does not take into account the special value of irrigation during periods of unusual drought.)

Above-average irrigators can usually expect to obtain above-average yields. The results of the analysis show that yields would have to be at least 23 to 27% higher than "average" for the purchase of an irrigation system to be economically justified.

The results of the study show that an irrigator could afford to pay between $4,900 and $7,355 to convert a system from "high" (75 psi) to "low" (30 psi) pressure.

The amount that can be profitably spent to convert an irrigation system from high to reduced pressure depends on the prospective annual energy saving, which in this case is assumed to be between $8 per acre ($1,040 per center pivot) and $12 per acre ($1,560 per center pivot). Additional factors influencing the break-even expenditure for converting a system from high to low pressure are the interest rate for discounting the future income stream and the number of years within which the income stream is realized (or within which a loan to finance the conversion must be repaid). In this analysis, 14.5% interest and an 8 year pay-back period are assumed.

The results of the study show that a potential center pivot investor could expect to earn greater profit from a "low" (30 psi) than a "high" (75 psi) pressure system as long as the yield reduction (if any) with the reduced water pressure is no more than 4%.

The purchase cost of a low pressure system (center pivot machine, pump, electrical connections) is usually quite similar to that for a high pressure system. In Brookings County in 1982, the difference was only 1.5% (more for the low pressure unit). The energy cost to operate an appropriately sized and managed reduced pressure system, as noted above, is less than that for a high pressure system.

If yields are no different with low than high pressure water distribution, an irrigation investor is usually well-advised to purchase a low pressure system. If yields are less with low pressure, however, the trade-off between reduced yield (and the very slightly higher purchase cost in this analysis) and energy savings from the low pressure system needs to be determined. With the assumptions in this analysis, the break-even yield reduction is 4%. With different prospective energy savings, of course, the break-even point would be different.

One high priority issue for research emerging from this study concerns the determination of prospective yield reductions that can be expected in environments not ideally suited for reduced pressure irrigation. Of particular interest would be the estimation of prospective yield reductions with soil groups having different water infiltration rates and fields having different slopes. With such parameters, potential irrigators could make better decisions on whether reduced pressure units would be in their best economic interest.

THE ECONOMICS OF REDUCED PRESSURE IRRIGATION

by Donald C. Taylor

INTRODUCTION

The sharp energy price increases of the early 1970s provided economic incentive to irrigation equipment manufacturers to develop energy-saving irrigation technologies. One such technology involves reduced pressure center pivot water distribution.[1] Low pressure systems involve distribution pressures of 35 to 40 pounds per square inch (psi) or less, whereas traditional systems commonly involve 65 psi or more.[2]

About a fifth of the area in the United States irrigated with center pivots in 1980 involved low pressure water distribution (Table 1).[3] Rates of low pressure adoption in states with major center pivot acreages vary widely. Georgia ranks first, with 70% of its center pivot area involving low pressure systems. States in the 30 to 40% range are Colorado, New Mexico, and Kansas.

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[1]For an analysis of this and 9 other energy-saving irrigation technologies, see Battelle (1982a, 1982b, and 1983).

[2]The water distribution pressures for irrigation sprinkler systems are not bimodal as the commonly used "high" and "low" pressure terms would seem to denote. Rather, the actual pressures range across a wide continuum. When the terms high and low (reduced) pressure are used without quotation marks in this bulletin, they are not intended to represent specific, well-defined pressures. When "high" and "low" are in quotation marks, they represent either (a) the "high" (more than 65 psi) and "low" (less than 45 psi) pressure categories for which some of the survey data are reported or (b) the assumed "high" (75 psi) and "low" (30 psi) pressures used in the energy-saving and investment analyses.

[3]Buckingham (1980, 10) indicates manufacturers of center pivots report that 40 to 80% of their sales in 1980 involved low pressure units.

In 1980, about 5% of South Dakota's center pivot irrigated area was estimated to involve low pressure systems. In this bulletin, the economics of the early adoption of reduced pressure irrigation in South Dakota are examined.

The reduced pressure technology and its general expected impacts on costs and yields are first described. The actual cost and yield experience in Brookings County in 1982 with reduced pressure water distribution are then presented. Emerging from the analysis are insights on the economics of converting center pivot systems from high to reduced pressure and investing in new high versus reduced pressure systems.

TABLE 1. ESTIMATED LOW-PRESSURE CENTER PIVOT IRRIGATED AREA, UNITED STATES, 1980

State	Total center pivot irrigated area ('000 acres)	Low-pressure irrigated area ('000 acres)	Low-pressure as a percent of total center pivot irrigated area
States with over 200,000 acres of center pivot irrigation			
Georgia	510	357	70.0
Colorado	600	240	40.0
New Mexico	225	74	32.9
Kansas	988	293	30.0
Minnesota	297	45	15.2
Texas	570	86	15.1
Nebraska	2,356	236	10.0
South Dakota	226	11	4.9
Washington	389	4	1.0
Sub-total	6,161	1,346	21.9
Other states	1,590	190	12.0
U.S. Total	7,751	1,536	19.8

Source: Sloggett (1982, 33)

REDUCED PRESSURE TECHNOLOGY

The primary thrust for developing the technology for reduced pressure irrigation water distribution took place in the mid to late 1970s. The principal innovations were controlled droplet type impact sprinkler heads and low pressure spray nozzles that enabled the relatively uniform application of water even at substantially reduced distribution pressures (Skinner and Harrison, 1981). Center pivot operating pressures as low as 20 psi are common with sprinkler and spray nozzle water application.[1]

Investment and fuel energy costs

The initial investment for reduced pressure irrigation systems is not greatly different from that for traditional high pressure systems. Additional sprinklers or spray nozzles are required for low pressure water distribution. Electric booster pumps for end guns to cover field areas beyond the end point of center pivot arms and base-flow water regulators to overcome pressure fluctuations when center pivots move over rolling ground may also be required.[2] Counterbalanced against these potentially greater expenditures for reduced pressure systems, however, are reduced costs for smaller pumps and motors (Marek, et al., 1983).

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[1]Lyle and Bordovsky, at Texas A&M University, are developing a low energy precision application (LEPA) system that involves pressures of less than 10 psi (Lyle and Bordovsky, 1980 and 1982; White, 1984). With the LEPA system, water is distributed through drop tubes and orifice-controlled emitters rather than sprayed into the air.

[2]Variations in pressure caused by elevation differences in an irrigated field are more critical for low pressure systems because such variations are large relative to a system's operating pressure.

The fuel energy cost to distribute irrigation water under reduced pressure is less. This is true because fuel costs are directly proportional to the "total dynamic head" involved in an irrigation system. The "total dynamic head" depends on three factors:

- The "lift" or total vertical distance that water must move from its source (well, stream, or lake) to the center pivot arm;

- "Friction" which represents the loss of pressure resulting from water flowing through pipes[1] and fittings; and

- The pressure at which water is distributed through the sprinkler heads or spray nozzles (Curtis, 1979).[2]

"Head" is usually expressed in terms of "feet of water." It represents the pressure created by the weight of a column of water of a specific height in feet. "Lift" and "friction" are usually expressed directly in terms of feet. Since a head of 2.31 feet of water creates a pressure of 1.0 lb, multiplying pressure (measured in "pounds per square inch") by 2.31 enables the expression of pressure also in "feet of water."

If the "lift" is relatively great, the proportional impact of reduced water distribution pressure on fuel energy costs is relatively small. The converse is also true. The key factor determining the economic benefit of a potential investment in reduced pressure irrigation, however, is the absolute (not the relative) drop in "total dynamic head" resulting from reduced pressure water distribution.

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[1]Pipe friction losses depend on the length of pipe, the nature of piping material, the diameter of the pipe, and the rate of flow through the pipe.

[2]The power to energize auxiliary center pivot equipment (e.g., the center pivot drive unit, booster pumps, base-flow water regulators) also contributes to the "total dynamic head" for a system.

For electrically powered center pivots, the reduction in energy costs with reduced pressure shows itself in two forms. Once-per-season demand charges are usually less, since the horsepower requirement on which these charges are based is less with reduced pressure systems.[1] Second, the kilowatt hour variable cost is less because of the reduced flow of power required to pump water under reduced pressure (Jacobs and Brosz, 1980).

If pump assemblies and motors are appropriately adapted to reduced pressure sprinkler and spray nozzle packages, the costs of energizing the reduced pressure irrigation systems can certainly be expected to be less (Sheffield, 1984a). Whether investing in a reduced pressure system is economic, however, depends on whether reductions in yield are associated with reduced pressure water distribution.

Possible yield reductions

Possible yield reductions arise with reduced pressure irrigation because of potentially greater water runoff and/or non-uniform water infiltration in irrigated fields.[2] Underlying these possible problems are certain technical features of reduced pressure water distribution. These features are first placed in the perspective of the water distribution pattern for any center pivot system.

Figure 1 shows a center pivot irrigation circle. The circle is arbitrarily divided into four concentric bands -- each comprised of equal geographic areas. Center pivot systems are designed so that the volume of water discharged from the center pivot arm within each concentric band is the same. Thus, the amount of water discharged per foot of center pivot arm increases with distance along the arm (i.e., from A to B).

The greater intensity of water discharge along the arm is accomplished through the use of successively more narrowly spaced and larger sized sprinkler heads and spray nozzles along the arm. The rate of movement of the arm in each succeeding concentric band is greater. As a result, the irrigation water application rate[1] in the outer band is several times greater than that in the inner band.

Figure 2 shows the span of water distribution for a center pivot system. Under high pressure, the distance of water coverage perpendicular to the center pivot arm is relatively great. With reduced pressure, the span of coverage is less [i.e., the wetted area at a particular point in time (ACBDA) is less]. Unless the discharge of water is reduced (which is seldom done), the rate of water application with reduced pressure is greater. This accentuates the inherent problem of higher water application rates as one moves toward the periphery of center pivot irrigation circles.

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[1]Demand charges are usually based on the actual HP used in pumping water, rather than on the name plate HP. If name plate HP is the basis, the motor on a system converted from high to low pressure would have to be changed in order for a reduction in the demand charge to be realized.

[2]The potentially greater water runoff with reduced pressure irrigation can also lead to the accumulation of water in the tracks through which pass the wheels supporting the center pivot towers. If so, the wheels may become bogged down, with a result that the normal rotation of the center pivot arm is interrupted.

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[1]"Rate" of water application concerns the amount of water applied per unit of time. "Depth" of water application concerns the amount of water applied to a given land area.

FIGURE 1. A SKETCH SHOWING THE DIVISION OF A CENTER PIVOT IRRIGATED AREA INTO FOUR EQUAL SUBAREAS

Legend:

A = center pivot machine
AB = center pivot arm
BGFB = circumference of irrigated field area (i.e., center pivot irrigation circle)

Special features:

1. The area comprising each concentric circle is the same.

2. The length of the center pivot arm in each successive concentric circle is less, i.e., EB < DE < CD < AC.

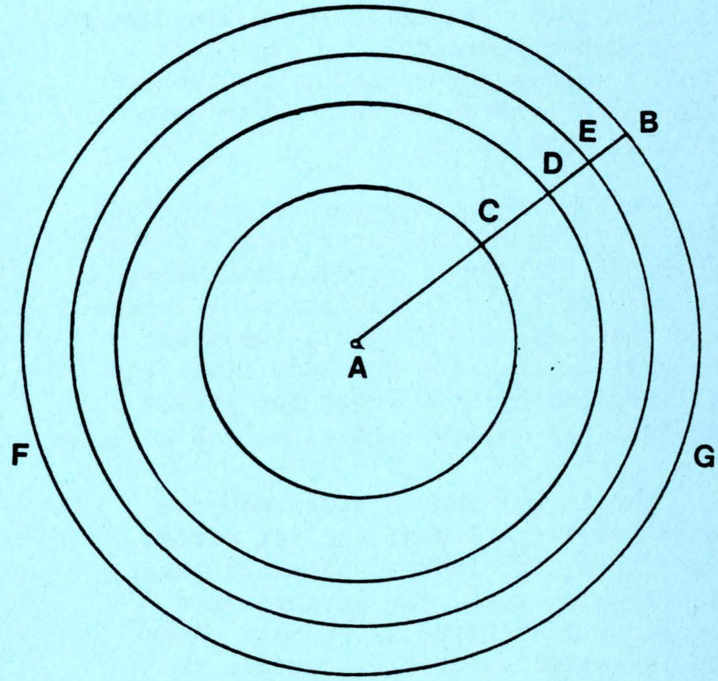
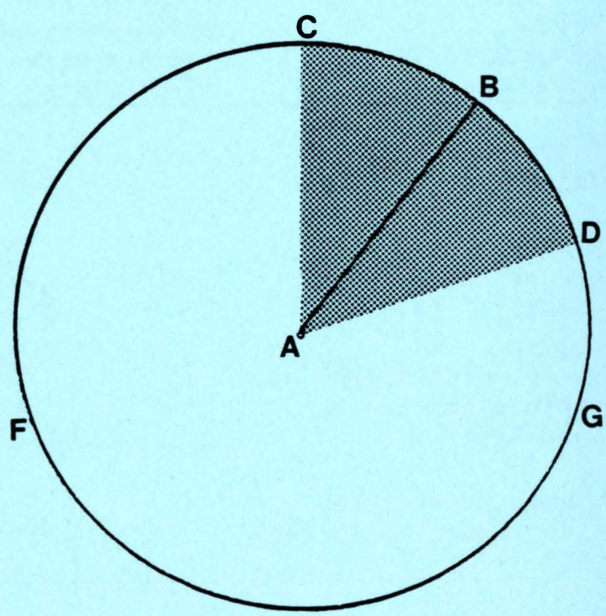


FIGURE 2. A SKETCH SHOWING THE SPAN OF WATER DISTRIBUTION FOR A CENTER PIVOT SYSTEM

Legend:

A, AB, BGFB = the same as in Figure 1

ACBDA = wetted area at a particular point in time



Some illustrative data are provided in Table 2. With water distributed at 20 psi rather than 75 psi, the area wetted under a center pivot at any point in time is only about a fourth as much. This implies a four times greater water application rate. With high pressures, a fairly common application rate is 1 inch per hour. Under low pressure, about 4 inches per hour could be expected. This -- equivalent to about one inch of rain in 15 minutes -- is a rapid rate of water application.

Whether reduced pressure irrigation results in increased water runoff depends on the rate of water application versus the rate of water infiltration or intake into the soil. In general, the finer the soil texture and the less level the soil topography, the lower the infiltration rate (Gilley, et al., 1982).

The larger nozzle sizes and reduced pulverization of the jet stream associated with reduced pressure water distribution result in larger water droplet sizes (Battelle, 1983). When the larger water droplets impact the soil, the tendency for surface crusting increases, thereby accentuating possible inherent problems of inadequate infiltration associated with finer soil textures and steeper topographies. The potential thereby increases, not only for greater water runoff, but also for greater soil erosion (Gilley and Mielke, 1980).[1]

The second source of possible yield reductions with reduced pressure water distribution arises from possible less uniform infiltration of water within an irrigated field. The underlying cause for this problem is added possible water runoff from one place to another within an irrigation circle. If this happens, high spots may be "under-irrigated" and low spots "over-irrigated."[2]

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[1]Research at the Center for Irrigation Technology at California State University, Fresno shows a counterbalancing feature of larger water droplet sizes, namely, a reported 2 to 10% reduction in water evaporation and wind-drift losses (Renn, 1984).

[2]For a study of the economics of irrigation with non-uniform infiltration, see Feinerman, et al. (1983).

TABLE 2. THE APPROXIMATE AREA WATERED UNDER A 1320 FEET LENGTH CENTER PIVOT SYSTEM WITH END GUNS, HIGH VERSUS LOW PRESSURE

	High pressure	Low pressure
Type of water delivery system	Constant spacing impact sprinklers, larger orifice sizes to end of pipeline	Spray nozzles with 360° pattern and small mist application
No. of sprinklers or nozzles	40	150 - 400
Normal operating pressure at the pivot (psi)	75	20
Diameter of wetted area at the terminal end of the pivot arm (ft)	130-140	30-40
Approximate area wetted (ACBDA in Figure 2) (acres)	4.1	1.1

Source: Sheffield (1984a)

In summary, the initial investment costs for reduced pressure systems usually do not differ greatly from those for high pressure systems. Operating costs for appropriately suited reduced pressure water distribution, however, are less.

If irrigated fields involve coarse textured soils and flat topographies, yields with reduced pressure water distribution are expected to be comparable to those under traditional high pressures. In such circumstances, the purchase of new irrigation systems with reduced pressure water distribution is economically advantageous. Whether converting an existing high pressure system to reduced pressure water distribution would be economic, however, requires study. The cost of making the conversion would need to be compared with the reduction in cost for energizing a reduced pressure system.

To the extent that irrigated fields involve finely textured soils and/or sloping topographies, yields under reduced pressure center pivots can be expected to be less.[1] In such circumstances, the economics of investing in a new reduced pressure system would depend on the extent of expected yield reduction versus the expected energy saving from the reduced pressure irrigation.

These are the two main economic issues explored in this bulletin. In capsule form, they are as follows:

- What is the maximum that an irrigator can afford to pay to convert a system from high to reduced pressure; and

- How much less would the expected yields under reduced pressure water distribution have to be for a farmer to be well advised to purchase an irrigation system with high rather than reduced water distribution pressure?

[1]This statement assumes "everything else the same." DeBoer and Beck (1983) show that reduced tillage practices can help overcome added water runoff that otherwise would result from reduced pressure water distribution.

CENTER PIVOT IRRIGATION IN SOUTH DAKOTA

Historical changes[1]

In 1970, less than 10% of the irrigation systems serving South Dakota's privately developed irrigated land involved center pivot machines. By 1981, the percentage grew to 64 (Table 3). The Irrigation Survey (1982) shows 69% of all the state's systems in 1982 to be center pivots. The percentage is roughly the same in North Dakota, and about double that in 3rd and 4th ranking Kansas and Nebraska in the 10-state Great Plains Region.

The decade of the 1970s saw not only a major shift to center pivot irrigation, but also a major shift to electricity for energizing South Dakota's irrigation systems. For privately developed irrigated land, the proportion of area served by electrically powered systems increased from about 1/3rd in 1970 to about 3/4ths in 1981 (Table 3). In 1982, 4/5ths of the state's total irrigation power units are reported to have been electrically powered (Irrigation Survey, 1982).

The trends toward electrically powered center pivot irrigation in the Big Sioux River Basin (one of five river basins east of the Missouri) during the 1970s were even stronger than for those in the state as a whole. For example, 69% of the Big Sioux River Basin's privately developed irrigation in 1981 involved center pivots and 89% of its total irrigated area involved electrically powered systems (Table 3).

[1]For reports on irrigation development in South Dakota during the 1970s, see Taylor (1983 and 1984a).

Brookings County, the field site for the research reported in this bulletin, rests within the Big Sioux drainage area. Between 1969 and 1982, the irrigated area in Brookings County increased by more than 16 times (U.S.D.C., 1972, 1984). This is about double the rate of expansion in irrigation in the Big Sioux River Basin, and well over triple the rate of expansion in the State as a whole (D.W.N.R., 1970 and 1981).

Most of the center pivots purchased in Brookings County during the 1970s involved traditional high pressure water distribution. With the development of energy saving reduced pressure irrigation technology, however, Brookings County irrigators began in 1980 to purchase reduced pressure center pivot machines.

The basic purpose for initiating the research reported in this bulletin was to obtain farm-level data on the performance of reduced pressure center pivot systems in Brookings County. To do this, a field survey of irrigators in the county was undertaken in 1982. The survey was limited to irrigators producing corn grain (by far the dominant irrigated crop in Brookings County) under center pivots energized by electricity.

In this report, attention is given to the economics of reduced pressure irrigation. See Taylor (1984b) for a detailed description of the surveyed farms and a report on the economics of producing irrigated corn grain.

Brookings County center pivots

In Brookings County in 1982, 85 farmers are reported to have had irrigated land (U.S.D.C., 1984). The 1982 survey involved 37 of these irrigators, or somewhat less than half of them.

The selection of the 37 irrigators in the study was based on preliminary information provided by irrigation equipment dealers in the county. Because of a primary interest in the research in reduced pressure irrigation, disproportionately large fractions of reduced pressure irrigators were selected for inclusion in the study.

In particular, all irrigators reported as having "low" pressure units were selected. Two-thirds of the irrigators having "medium" pressure systems and 1/5th of those having only "high" pressure systems were also selected -- in a random manner. Thus, the sample of center pivots on which the research is based has randomized components. On the other hand, it cannot be viewed to represent fully all the

TABLE 3. TYPE OF IRRIGATION SYSTEMS AND ENERGY SOURCES, PRIVATELY DEVELOPED IRRIGATION, BIG SIOUX RIVER BASIN AND SOUTH DAKOTA, 1970 AND 1981

Irrigation feature	Big Sioux River Basin		South Dakota	
	1970	1981	1970	1981
Center pivot systems				
Total number	8	292	58	1,756
As a percentage of all systems	9.8	69.0	7.7	63.9
Area irrigated with electrically powered systems				
Acreage	5,415	58,203	31,974	316,484
As a percentage of the total irrigated area	67.6	89.0	34.7	74.3

Source: D.W.N.R. (1970, 1981)

county's electrically powered center pivots, or the county's complete population of irrigation systems.

In this section, characteristics of the 57 center pivots operated by the 37 surveyed irrigators are described. In the following sections, the results of the economic analysis of reduced pressure irrigation are presented.

The operating pressure at the center pivot for the 57 units studied averaged 53 psi and ranged from 22 to 86 psi (Figure 3).[1] About equal numbers of systems involved pressures of less than 45 psi, 45-65 psi, and more than 65 psi. These three ranges characterize the "low", "medium", and "high" pressure categories created for use in the study.

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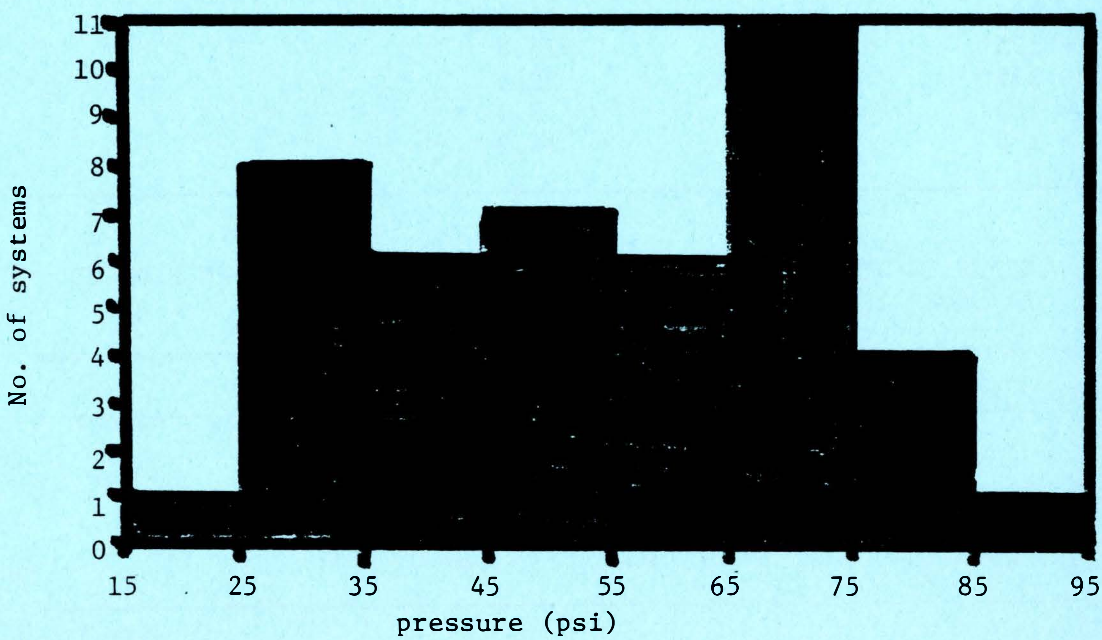
[1]Tests of irrigation pumping plant efficiencies were performed by an SDSU Extension agricultural engineer on 24 of the study center pivots. One component of the tests was measurement of system water distribution pressure. The operating pressures of 16 other systems were "estimated" by the Extension specialist. For 10 other center pivots, the irrigator respondents provided information on water distribution pressures. On 7 center pivots, no information on actual operating pressures was available.

The "high" pressure systems were first placed in use by the irrigator respondents much earlier than the "low" pressure systems (Figure 4). For example, only 25% of the "high" pressure systems studied were first placed in use in 1980 or later. Slightly over 50% of the "medium" pressure systems were, and 94% of the "low" pressure systems were.

About 3/4ths of the study center pivots involve either 7 or 8 towers and pivot arms ranging in length from 1,225 to 1,325 feet. The shortest pivot arm is 750 feet and the longest is 1,944 feet. Eight of the 57 systems have corner extender units, and 8 of the systems were towed from one irrigation site to another in 1982. Forty-eight of the 57 study center pivots have injectometers for applying plant protection chemicals and fertilizer.

The acreage irrigated per center pivot in 1982 averaged 132 and ranged from 50 to 304 (Table 4). About 1/3rd of the systems involve 126 to 135 acres -- which is the maximum area in a quarter-section that can be irrigated if no corner extender unit is used. Although only 20% of the center pivot arms are shorter than 1,225 feet, 45% of the center pivots provided irrigation water for 125 acres or less in 1982.

FIGURE 3. CENTER PIVOT WATER DISTRIBUTION PRESSURE, REDUCED PRESSURE IRRIGATION STUDY, BROOKINGS COUNTY, 1982



All of the respondents use groundwater rather than surface water. The depth to well water after drawdown for them averages 42 and ranges from 10 to 145 (Table 5). These pumping depths are considerably less than the 120 feet estimated average for the state (Sloggett, 1982).

FIGURE 4. YEAR WHEN CENTER PIVOT SYSTEMS WERE FIRST USED BY THE IRRIGATOR RESPONDENTS, REDUCED PRESSURE IRRIGATION STUDY, BY OPERATING PRESSURE CATEGORY, BROOKINGS COUNTY, 1975-1982

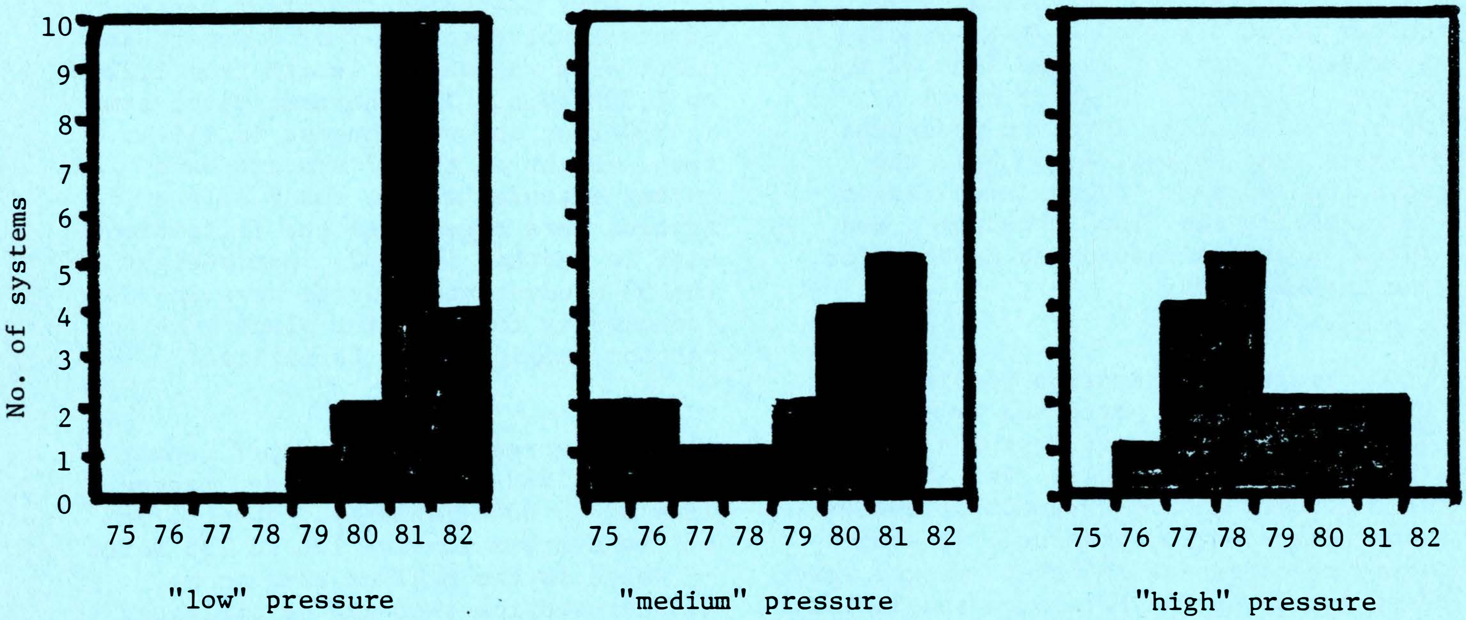


TABLE 4. ACRES IRRIGATED PER CENTER PIVOT, REDUCED PRESSURE IRRIGATION STUDY, BROOKINGS COUNTY, 1982

Acreage category	Frequency of response (%)
< 100	17.9
100 - 125	26.8
126 - 135	32.1
136 - 165	8.9
> 165	14.3

TABLE 5. DEPTH TO WELL WATER AFTER DRAWDOWN, CENTER PIVOTS IN REDUCED PRESSURE IRRIGATION STUDY, BROOKINGS COUNTY, 1982

Depth category (feet)	Frequency of response (%)
< 20	15.0
20 - 40	35.0
41 - 60	35.0
> 60	15.0

The water discharge for the center pivots in 1982 averaged 689 gallons per minute (gpm) and ranged from 300 to 990 gpm. The pumping efficiencies averaged 67% and ranged from 52 to 89%. These are slightly lower than those reported by DeBoer and Jennings (1979) for 33 electrically powered irrigation pumping plants in eastern South Dakota in 1976. Finally, the energy requirement for the center pivots during the 1982 irrigation season averaged 17,200 kilowatt hours (kwh) per center pivot and ranged from 1,710 to 64,690 kwh.

IN-FIELD IMPACTS OF REDUCED PRESSURE IRRIGATION

Yields

The relationship between corn grain yields and water distribution pressure is examined via cross tabulations and production function estimations. Because factors other than water distribution pressure are known to influence yield, attention is given in the analysis to the other factors as well.

The mean corn grain yield for the "low" pressure center pivots is 1.4 bu per acre less than that for the "high" pressure center pivots (Table 6). The differences in yield among pressure group categories, however, are not statistically significant (0.10 level).

Other factors of production may conceivably have been more favorable for the "low" pressure center pivots. If so, these more favorable conditions could have compensated for possible adverse yield impacts of reduced water pressure. To explore this possibility, cross tabulated data on several yield-determining inputs were examined.

Mean fertilizer levels, seeding rates, and irrigation applications[1] for corn grain under the center pivots are not significantly different among the three water pressure categories (Table 7). The mean date of planting for the "low" pressure center pivots in 1982, on the other hand, is significantly earlier than that for the "high" pressure center pivots. Further, none of the "low" pressure center pivots are placed on fields with slopes exceeding 1% (Table 8). Reduced tillage practices, which can help overcome added runoff that otherwise might accompany reduced pressure irrigation, were followed under 60% of the "low" pressure center pivots and under no more than 44% of either the "medium" or "high" pressure center pivots.

[1]The mean irrigation application for the sample of 3.9 inches is roughly 40% of normal. It is low because of unusually great precipitation during the 1982 irrigation season. The fact that irrigation applications were limited reduced the possibility of being able to observe the impact of varying water pressures on corn grain yield.

TABLE 6. MEAN CORN GRAIN YIELDS, BY WATER DISTRIBUTION PRESSURE CATEGORY, REDUCED PRESSURE IRRIGATION STUDY, BROOKINGS COUNTY, 1982

Water pressure category	Mean pressure (psi)	Mean yield (bu per acre)[a]
"Low"	32.0	122.5
"Medium"	55.2	123.1
"High"	75.7	123.9
Total sample	54.3	123.2

[a]The differences in yield among pressure group categories are not significant at the 0.10 level.

Being able to segregate the impact of water distribution pressure on yield from the impacts of these other potentially disturbing variables, therefore, became important in the analysis. This was done through the estimation of production functions in which corn grain yield was regressed against a series of variables, including the following:[1]

[1]Data on these variables were obtained from two interviews with survey respondents, rainfall gauge and electric meter readings for the various center pivots, soil moisture tests, and the interpretation of map-based soils information.

- Center pivot operating pressure (psi);

- Rainfall and irrigation, separately and combined, seasonal totals and by phase within the growing season (inches);

- Soil moisture at the time of corn pollination (%);

- Fertilizer nutrient applications [lb per acre of each of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O)];

- Time of planting and seeding rate ('000 kernels per acre);

- Reduced or conventional tillage practices;

TABLE 7. CORN GRAIN PRODUCTION INPUT DATA, BY WATER DISTRIBUTION ON PRESSURE CATEGORY, REDUCED PRESSURE IRRIGATION STUDY, BROOKINGS COUNTY, 1982[a]

Water pressure category	Mean fertilizer application (lb per acre) Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Planting characteristics: Mean date of planting	Mean seeding rate ('000 kernals per acre)	Mean irrigation application (inches)
"Low"	145.7	49.1	34.2	May 13	27.4	3.77
"Medium"	147.4	46.3	33.5	May 17	26.1	4.30
"High"	135.6	44.6	25.9	May 18	26.2	3.53
Total sample	142.9	46.7	31.2	May 16	26.6	3.87

[a]Only for one variable in the table are the differences in mean values among pressure group categories significant at the 0.10 level. This variable is planting date -- which is significantly earlier for the low than high pressure center pivots.

TABLE 8. WITHIN-FIELD SLOPES AND TILLAGE PRACTICES, FIELDS IRRIGATED BY CENTER PIVOTS, BY WATER DISTRIBUTION PRESSURE CATEGORY, REDUCED PRESSURE IRRIGATION STUDY, BROOKINGS COUNTY, 1982

Water pressure category	Percentage of farmers with: Within-field slopes of 1% or less	Reduced tillage land preparation
"Low"	100.0	60.0
"Medium"	71.4	35.7
"High"	73.3	43.7
Total sample	81.6	46.5

- Soil corn yield productivity rating (%);

- Available water capacity of the soil (%); and

- The irrigated acres operated by the study respondents.

The coefficients on each yield-determining input in the estimated production functions reflect the impact on yield associated with each input, with all other inputs held constant at their mean levels of usage. This statistical feature of the estimations enables the segregation of the impact on yields (if any) of the individual yield-determining variables which is not possible with the cross tabulation analysis.

A total of 20 production functions -- involving linear additive and log linear forms and different combinations of the yield-determining variables -- was estimated. For the complete results, see Taylor (1984b). Selected findings follow.

Three of the variables were found to be consistently related to yield -- nitrogen, planting date, and available water capacity. For each additional pound of elemental nitrogen applied at the margin, approximately 0.15 to 0.25 bu per acre of additional corn grain was produced. For each day earlier in planting, the yield was approximately 0.8 to 1.0 bu per acre higher. For each additional percentage point of available water capacity, yield was 2 to 3% less (thereby reflecting an inherent responsiveness of the soils to irrigation).

Less stable (statistically consistent) relationships between several variables and corn grain yield were shown in the production function results. Those of most direct interest to the reduced pressure study involve the soil moisture, rainfall, and irrigation variables.

There is some evidence that higher moisture levels during the pollination period deterred from the achievement of higher yields. One extenuating circumstance was near twice normal precipitation at the time of pollination. During the vegetative and maturation periods and for the total growing season, on the other hand, there is some evidence that rainfall and irrigation applications were directly related to higher yields.

The failure for more consistently positive rainfall and irrigation-yield relationships to emerge in the production function analysis is undoubtedly the result of above-average precipitation during the year under study. At certain times during the growing season, rainfall in all likelihood exceeded the evapotranspiration needs of the crop. Related to this, irrigation levels were unusually low. The atypically small range of observations on the irrigation variables reduced the chances of being able to identify statistically stable relationships between irrigation levels and yield.

The production function results show no statistically significant relationships between corn grain yield and either (1) the reduced tillage variable or (2) the center pivot operating pressure variable. These results are undoubtedly associated with the rather favorable environment under which the reduced pressure systems are being used. The extent to which the atypically low irrigation levels precluded observation of any possible negative impact of reduced pressure on corn grain yield is not known.

Energy Use

The electric energy payment per center pivot for irrigation in 1982 averaged $1,800 and ranged from $390 to 4,330.

On a per acre basis, the mean energy cost for the total sample is $15.43 (Table 9). The mean energy cost per acre irrigated for the "high" pressure center pivots is about $2.50 higher than that for the "low" pressure center pivots, but the difference is not statistically significant. The energy cost per acre-inch of irrigation water pumped also does not differ significantly among the water pressure categories.

To more precisely estimate the impact of center pivot operating pressures on energy costs, some linear additive regressions were estimated.[1] Different combinations of the following variables were regressed against the cost per acre for electricity to pump the irrigation water, with the center pivot system the unit of analysis:

- Center pivot operating pressure;

- Feet of lift;

- The distance between the groundwater well source and the center pivot machine;

- The length of the center pivot arm;

- The acre-inches of irrigation water pumped; and

- The horsepower rating of the irrigation pump.

The statistical properties of the estimated regressions are not particularly robust.[1] The coefficients on the water pressure variable, however, are always positive in sign and are significant at the 0.16 level. The coefficients most often range in magnitude from 0.07 to 0.10, which implies an energy cost with "high" (75 psi) pressure center pivots that is roughly $3.15 to $4.50 per acre more than with "low" (30 psi) pressure center pivots.

These measured energy cost differences for reduced pressure irrigation in Brookings County in 1982 are less than would be expected if irrigation applications had been more nearly normal during the growing season. The AGNET-PUMP "irrigation system cost analysis" program (Thompson, 1984) was, therefore, used to estimated the difference in energy costs with more typical levels

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[1]The philosophical basis underlying the conduct of this analysis is that human behavior and managerial decisions influence the in-field technical performance of irrigation systems.

[1]The overall F-ratios for the final eight regressions are significant at the 0.10 level. The R^2's range from 31 to 54%, and the coefficients on two to four independent variables in the individual regressions differ significantly from zero.

TABLE 9. IRRIGATION ENERGY COSTS, CORN GRAIN PRODUCTION, BY WATER DISTRIBUTION PRESSURE CATEGORY, REDUCED PRESSURE IRRIGATION STUDY, BROOKINGS COUNTY, 1982[a]

Water pressure category	Mean dollars per acre irrigated	Mean dollars per acre-inch of irrigation water
"Low"	13.30	5.42
"Medium"	15.42	4.01
"High"	15.79	6.12
Total sample	14.84	5.18

[a]The mean energy costs for both criteria in the table do not differ significantly among water pressure categories (0.10 level).

of irrigation applied to corn, alfalfa, and soybeans. The irrigation levels assumed for the three crops -- 9.4, 8.8, and 7.7 acre-inches, respectively -- are the mean levels applied for these crops in the Sioux River Basin between 1969 and 1981 (D.W.N.R., annual).

Additional assumptions in the AGNET system operating cost analysis include the following:

- "Low" and "high" pressures of 30 and 75 psi, respectively;

- 54 feet of lift;[1]

- 689 gallons per minute water discharge;

- Pumping and irrigation efficiencies of 75 and 80%, respectively;

- An electricity demand charge of $17.50 per horsepower and a variable energy cost of $0.06 per kwh; and

- 130 acres irrigated per center pivot.

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[1]This is based on the average 42 foot depth to well water drawdown determined in the 1982 irrigation survey and an assumed 12 foot elevation of a center pivot arm from ground level.

The energy cost for pumping comprises about 57% of the total center pivot operating costs for "low" pressure units and 70% for "high" pressure units (Table 10). The variable kwh cost is 84% greater with "high" than "low" pressure irrigation, and the annual electric demand charge is 67% greater. The (a) repair and maintenance and (b) center pivot operating costs, as determined in the AGNET analysis, are identical or nearly so for the "high" and "low" pressure systems.

The estimated annual irrigation system operating costs are $11.79 per acre higher for "high" than "low" pressure corn. The absolute cost differentials for alfalfa and soybeans -- $11.30 and $10.41 per acre, respectively -- are slightly less because of smaller irrigation applications for these crops. In relative terms, however, the irrigation system operating costs with "low" pressure are 31% less than with "high" pressure for all three crops.

For purpose of comparison, data on energy savings with reduced pressure irrigation reported in the literature are indicated in Table 11. Because the amount of prospective energy savings from reduced pressure water distribution depends on a variety of factors, infor-

TABLE 10. ANNUAL IRRIGATION SYSTEM OPERATING COSTS, "LOW" (30 PSI) VERSUS "HIGH" (75 PSI) PRESSURE WATER DISTRIBUTION, REDUCED PRESSURE IRRIGATION STUDY, IRRIGATED CORN, ALFALFA, AND SOYBEANS[a]

	Corn		Alfalfa		Soybeans	
Cost item	"Low" pressure	"High" pressure	"Low" pressure	"High" pressure	"Low" pressure	"High" pressure
Energy cost for pumping						
Annual demand charge	$ 788	$1,313	$ 788	$1,313	$ 788	$1,313
Variable kwh cost	1,161	2,139	1,087	2,003	951	1,752
Sub-total	(1,949)	(3,452)	(1,875)	(3,316)	(1,739)	(3,065)
Repair & maintenance costs						
Center pivot system	728	728	681	681	596	596
Power unit	274	304	258	286	228	255
Sub-total	(1,002)	(1,032)	(939)	(967)	(824)	(851)
Center pivot operation costs						
Labor	325	325	325	325	325	325
Energy for electric motors on towers	162	162	152	152	133	133
Sub-total	(487)	(487)	(477)	(477)	(458)	(458)
Total						
For the center pivot system	$3,438	$4,971	$3,291	$4,760	$3,021	$4,374
Per acre irrigated	26.45	38.24	25.32	36.62	23.24	33.65

Source: These data were generated through use of the AGNET-PUMP "irrigation system cost analysis" program.

[a]The seasonal irrigation applications involve 9.4, 8.8, and 7.7 acre-inches for corn, alfalfa, and soybeans, respectively.

mation is provided on assumptions as reported in the respective references.

The findings reported in the 11 publications -- when interpreted relative to the irrigation pumping environment in Brookings County -- lend general support to the empirical results from this study. Together, they suggest that irrigators in Brookings County might expect to realize annual savings of $8 to $12 per acre, or about $1,040 to $1,560 per center pivot, from using "low" (about 30 psi) rather than "high" (75 psi) pressure water distribution.[1]

[1]Thirteen of the 37 respondents in the 1982 survey had had experience with both high and reduced pressure systems. Their views about reduced pressure irrigation are as follows. Eleven of the 13 believed they were realizing energy savings with reduced pressure irrigation. Over 90% of the respondents reported that they did not believe that reduced pressure water distribution resulted in each of reduced yields, more water runoff, more soil erosion, more irrigation water applied, more time spent in supervising irrigation water applications, and greater problems with center pivot maintenance and repairs.

ECONOMICS OF INVESTMENT DECISIONS

Decisions on whether to adopt reduced pressure irrigation arise in two situations: current irrigators who are considering whether to convert their systems from high to reduced pressure and prospective center pivot system purchasers who are considering whether to select high or reduced pressure units. In this section, the focus is first on the conversion possibility and then on the new purchase possibility.

Converting systems from "high" to "low" pressure

Consistent with the findings in Brookings County in 1982, the yield associated with "low" pressure irrigation is assumed in this analysis to be no less than that with "high" pressure irrigation. The decision on whether it could be profitable to convert a system from "high" to "low" pressure, then, depends on the cost of converting the system relative to the prospective savings in energy from pumping water under the reduced pressure.

TABLE 11. ENERGY SAVINGS FROM REDUCED PRESSURE IRRIGATION REPORTED IN THE LITERATURE[a]

Literature source	Energy Savings: Dollars per acre	Energy Savings: Percentage	Underlying assumptions in the analysis: Pressure differential (psi)	Irrigation application (inches)	Feet of lift	Pump efficiency (%)	Irrigation efficiency (%)	Electric Charge: Demand ($ per HP)	Electric Charge: Per kwh (cents)
Pretzer, 1981	7.74	33	40	24	100	-	-	-	5
Sheffield, 1984b	7.85	44	40	-	-	-	-	-	6
Jacobs and Brosz, 1980	8.28	28	40	24	150	68	-	12	3
Gilley and Supalla, 1982	8.30	-	43	9.75	26	-	70	-	-
Jones, et al., (ND)	11.50	-	30	-	-	-	-	-	3
Curtis, 1979	-	28(47)	45	8	100(20)	70	-	-	-
Marek, et al., 1983	-	33	30	20	250	-	-	-	-
Mahoney and Erickson, 1984	-	30 to 40	50	-	-	-	-	-	-
Gilley and Mielke, 1980	-	48	45	-	54	-	-	-	-
Erickson and Lazarus (in IA, 1981)	-	60	60	14	-	-	-	-	-

[a]Dashes in the table reflect data items for which no information is provided in the respective references. In addition to the references reported in the table, Battelle (1982a) reports general energy savings for reduced pressure center pivot systems for 17 states that range from $8.83 to $57.71 per acre. The savings most commonly are in the range of $14 to $28 per acre.

To convert a system from high to low pressure inevitably requires the replacement of high pressure impact sprinklers with a larger number of reduced pressure sprinklers and/or spray nozzles. Sheffield (1984b) writes that, depending on circumstances, the costs for replacing sprinklers can amount to $1,000 to $10,500 per quarter-section center pivot.

To enable a full 130 acre circle to be irrigated under reduced pressure requires a booster pump to energize the end gun(s). The cost for an electric booster pump package can be expected to be in the range of $1,500 to $2,500 (Sheffield, 1984b).

If the elevation varies from place to place within an irrigation circle, base-flow regulators or flow-valves may be required to achieve uniform water distribution along the center pivot arm. Reduced pressure irrigation is more vulnerable to such elevation differences because elevation-induced pressure variations are large relative to the operating pressure of reduced pressure systems. Depending on the number and type of flow-control services, their installed cost can vary from $400 to $800 (Sheffield, 1984b).

In converting an irrigation system from high to reduced pressure, changes in the system's pumping plant are also required. The pump column has to be pulled and -- depending on the extent of pressure reduction -- rather extensive changes to the pump bowls and impellers may be needed. To enable a reduction in energy costs usually requires the replacement of the power unit with a smaller electric motor. The net cost for changes to the pumping unit -- determined by the extensiveness of changes required and the trade-in value of the used power unit[1] -- can amount to $1,000 or more.

In summary, Sheffield (1984b, 14) concludes that "the entire cost to convert an existing high pressure system to a lower pressure system ... can easily run from $5,000 to $15,000." Preliminary experience indicates that the lower end of the range is probably more pertinent in Brookings County.[1]

[1]The trade-in value of used pump bowls and impellers is very little.

With this as background, the prospective economics of converting an irrigation system from "high" (75 psi) to "low" (30 psi) pressure in Brookings County are examined. For purpose of analysis, the prospective energy saving from reduced pressure irrigation is assumed to be in the range of $8 to $12 per acre. For a center pivot irrigating 130 acres, the associated annual energy savings would be between $1,040 and $1,560 per system.

The present value of a uniform series of annual incomes -- as assumed for energy savings in this case -- is determined by the formula,

$$PV = AI \left[\frac{1-(1+i)^{-n}}{i}\right], \text{ where}$$

PV = present value;

AI = the annual value of income in the uniform series;

i = the rate of interest; and

n = years over which the annual flow of income is realized.

Assuming an interest rate of 14.5% and an 8 year period of amortization, the present value of an $8 per acre or $1,040 annual stream of energy savings is $4,900. At $12 per acre ($1,560 per center pivot), the present value of the energy savings is $7,355.[2]

[1]One irrigation dealer in Brookings indicates that $3,500 has covered the cost of several recent "high" to "low" pressure conversions.

[2] The 8 year period of amortization is based on a rather common 8 year "lease-purchase" period for new irrigation systems in Brookings County. Physically, however, the life of the

These are the potential break-even expenditures for converting an existing "high" (75 psi) pressure irrigation system to "low" (30 psi) pressure. Their interpretation is illustrated as follows. If the expected energy saving from reduced pressure in a particular situation is $8 per acre and the other assumptions apply, making the conversion would appear to be profitable at any cost less than $4,900. With different assumptions on energy savings, the pay-back period, and/or the interest rate, the break-even expenditure points will be different. By using the formula with the appropriate assumed values, the break-even expenditure points for any assumed situation can be determined.[1]

Purchasing "High" or "Low" Pressure Irrigation Systems

In this section, the economics of investing in new irrigation systems are examined. The purchase of an irrigation system can usually be expected to impact the overall organization of a farm. A whole-farm perspective is, therefore, adopted in the analysis. The organizational nature and profitability of a typical farm in Brookings County are determined in the analysis with various assumptions concerning the possible purchase of irrigation systems.

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converted system might more likely be in the area of 15 years. For an equity financed conversion -- with an "economic pay-back period" of 15 years -- the present values of the $8 and 12 per acre based income streams are $6,540 and $9,810, respectively.

[1]The key assumptions underlying the prospective annual energy savings, as indicated above, are the price of electricity, the feet of lift, the acre-inches of irrigation water applied, the pumping and irrigation efficiencies, and the acres irrigated under a center pivot. To determine the prospective energy savings with values for these variables different from those assumed in this study, the AGNET-PUMP "irrigation system cost analysis program" can be used.

For detailed information on the nature of the typical farm and the basic linear programming model developed to analyze the farm, see Kiendl and Taylor (1984). In that analysis, two different levels were assumed for each of initial net operating capital, interest rate, and commodity price level. In this analysis, only one level for each of the three is assumed, namely, $27,500 initial operating capital; 14.5 and 15% interest rates on long-term and operating credit, respectively; and 10 year average projected prices. Further, in this analysis a single-period rather than polyperiod linear programming model is used.

As indicated above, the costs of new high and low pressure center pivot systems are not generally expected to differ much. Purchase price information for Brookings County in 1982 is consistent with this (Table 12). The price of a new low pressure system -- $43,145 -- is only 1.5% more than that for a high pressure system. The additional $1,500 expense for reduced pressure sprinklers (spray nozzles) is not quite counterbalanced by the 14% higher expense for the high pressure electrical system.

The typical Brookings County farm examined in this analysis has the following acreages of owned land: dryland 287, irrigated 130, and pasture 62. Provision is made in the model for the purchase of land and irrigation systems that can be placed on owned or rented quarter-sections of dryland. In addition, land can be rented, with maximum rented acreages as follows: dryland 324, irrigated 130, and pasture 86.

Irrigated crops included in the model are corn, alfalfa, and soybeans. Dryland counterparts of these crops, plus oats, are also in the model. Livestock enterprises are hog farrowing and finishing, hog finishing, steer and heifer fattening, and dairy milk production. For the input-output coefficients for these crop and livestock enterprises, see Kiendl and Taylor (1984).

The most profitable farm organization plan with 10 year average projected prices and assumed "low" pressure irrigation is termed the baseline solution. The baseline solution involves a hog-soybean cash grain farm with enough irrigated corn to raise and feed out the hogs produced on it (Table 13, Column 3). The maximum permitted acreages of dryland and irrigated alfalfa are also raised, with the income from the sale of alfalfa representing 9% of the total value added on the farm.

The total dryland and irrigated acreages in the baseline solution are 493 and 191, respectively. Renting 234 acres of dryland and 61 acres of irrigated land is profitable. With the baseline conditions, however, purchasing an irrigation system to place on dryland is not profitable.

The conditions reflected in the crop and livestock budgets reflect a typical, average level of farm management. Different farmers, of course, differ in their managerial abilities. To explore the economics of an above-average manager possibly investing in a new irrigation system, the yields on the irrigated crops were adjusted up until the purchase of a "low" pressure center pivot to irrigate 130 acres just became profitable.[1]

The "low" pressure break-even yield increase is 23%. In other words, if a farmer could reasonably expect to obtain irrigated yields 23% above those reflected in the baseline conditions (Table 14), it would be profitable for him to invest in a "low" pressure irrigation system.[2]

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[1]The costs of producing the irrigated crops were not adjusted up in

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this yield-increasing analysis. Although above-average managers can be expected to achieve above-average efficiency, it is probably unrealistic for them to achieve yield increases of 20 to 25% without incurring some additional cost. The actual yield increments needed to justify the purchase of irrigation systems may be somewhat larger than those reported below. The main point of the analysis in this section, however, is not so much the break-even yield increase level for each of "low" and "high" pressure irrigation as it is the difference between the break-even yield increases for "low" versus "high" pressure systems.

[2]An alternate means of viewing the requirement for irrigation to become profitable is in terms of a necessary price increase rather than a necessary yield increase. The baseline prices and 23% higher prices for the crops are as follows: corn $2.35 and $2.89 per bu, oats $1.37 and $1.69 per bu, soybeans $5.98 and $7.36 per bu, and alfalfa $46.39 and $57.06 per ton.

TABLE 12. THE PURCHASE PRICE OF NEW HIGH AND LOW PRESSURE CENTER PIVOT SYSTEMS, BROOKINGS COUNTY, 1982

Cost Item	High Pressure	Low Pressure
Center pivot sprinkler	$27,500	$29,000
Electrical system		
Motor	3,650	3,450
Connecting service	2,633	2,033
Switches	680	627
Sub-Total	(6,963)	(6,110)
Well construction & materials	5,385	5,385
Pump	2,650	2,650
Total	$42,498	$43,145

Source: AGNET-PUMP "irrigation system cost analysis" program, with some modifications determined in consultation with irrigation equipment dealers in Brookings.

The most profitable "low" pressure farm organization plan with the 23% higher yield has slightly fewer cropped acres than the baseline solution does (Table 13, Column 4). The area irrigated is more than twice as great. The main impact on enterprise returns is a 40% increase in soybeans cash grain sales.

The "high" pressure break-even yield increase is 27% (Table 14). The

TABLE 13. MOST PROFITABLE FARM ORGANIZATIONAL PLAN WITH "LOW" PRESSURE IRRIGATION, BASELINE YIELDS VERSUS 23% HIGHER IRRIGATED YIELDS, REDUCED PRESSURE IRRIGATION STUDY

Selected characteristics of the most profitable farm organizational plan	Unit	Value for characteristics: Baseline yields	Value for characteristics: 23% higher yields
(1)	(2)	(3)	(4)
Irrigation system purchased	cen. piv.	0	1.0
Cropland rented			
Irrigated	acre	60.8	130.0
Dryland	acre	234.3	137.5
Total	acre	(295.1)	(267.5)
Cropland use			
Irrigated corn	acre	90.8	73.4
Irrigated alfalfa	acre	30.0	30.0
Irrigated soybeans	acre	70.0	286.6
Total irrigated land	acre	(190.8)	(390.0)
Dryland corn	acre	0	0
Dryland alfalfa	acre	90.0	90.0
Dryland soybeans	acre	403.3	176.5
Total dryland	acre	(493.3)	(266.5)
Total cropland	acre	684.1	656.5
Livestock			
Hog farrowing and finishing	sow	62.7	46.7
Finishing market hogs	pig	2.6	30.0
Gross value added[a]			
Market hogs	$	75,672	76,181
Sale of corn grain	$	0	0
Sale of soybeans	$	79,454	111,931
Sale of alfalfa	$	15,513	16,996
Total	$	(170,639)	(205,108)

[a]The gross value added for the hog enterprise is the gross receipts from the sale of market hogs minus the value of home produced corn fed to the hogs. The gross value added for the crop enterprises is simply the gross receipts from crop sales.

most profitable farm organization plan is almost identical with that for the "low" pressure 23% yield increase situation. This outcome suggests that a potential center pivot investor could expect to earn greater profit from a "low" (30 psi) than a "high" (75 psi) pressure system as long as the yield reduction (if any) with the reduced water pressure is no greater than 4%.

TABLE 14. IRRIGATED CROP YIELDS ASSUMED IN THE BASELINE SOLUTION AND REQUIRED IN ORDER FOR THE PURCHASE OF CENTER PIVOT SYSTEMS TO BE ECONOMIC, REDUCED PRESSURE IRRIGATION STUDY

Crop	Unit	Yield per acre assumed in the baseline solution[a]	Yield per acre required for the purchase of a:[b] "Low" pressure system	"High" pressure system
Corn	bushel	130.0	158.6	163.8
Soybeans	bushel	40.0	48.8	50.4
Alfalfa	ton	4.5	5.49	5.67

[a]These irrigated yields are based on Taylor and Shane (1983) and a 1982 sample survey of irrigated farms in Brookings County. The dryland yields assumed in the analysis -- reflecting a 5 year average as reported by S.D.C.L.R.S. (annual) -- are 69 bushels per acre of corn, 26 bushels per acre of soybeans, and 2.5 ton per acre of alfalfa.

[b]The percentage yield increases for the four situations are 23 and 27, respectively.

REFERENCES CITED

Battelle, 1982a. Potential cost savings from investments in energy-conserving irrigation systems. Richland, Washington: Pacific Northwest Laboratory, operated for the US Dept of Energy by Battelle Memorial Inst, PNL-3930, UC-95f.

_______. 1982b. Energy savings potential from energy-conserving irrigation systems. Richland, Washington: Pacific Northwest Laboratory, operated for the US Dept of Energy by Battelle Memorial Inst, PNL-3958, UC-95f.

_______. 1983. Technical descriptions of ten irrigation technologies for conserving energy. Richland, Washington: Pacific Northwest Laboratory, operated for the US Dept of Energy by Batelle Memorial Inst, PNL-4529, UC-95f.

Buckingham, Frank. 1980. Cutting pressure may be the answer. Irrigation Age, Feb.

Curtis, Larry M. 1979. Potential energy savings with low pressure center pivot systems. Auburn: Alabama Univ CES, C ANR-13.

DeBoer, Darrell W. and Dwayne L. Beck. 1983. Field evaluation of reduced pressure sprinklers. Paper presented at the Summer Meetings of the American Soc of Agri Eng, Bozeman, Mont.

_______ and Bruce A. Jennings. 1979. Energy efficiencies of electric irrigation pumping plants. Proc SD Acad Sci, LVIII:17-20.

DWNR, Annual. Irrigation questionnaire data summaries. Pierre: Office of Water Rights, SD Dept of Water and Natural Resources, 1969-1981 mimeo.

Feinerman, E., J. Letey and H.J. Vaux, Jr. 1983. The economics of irrigation with nonuniform infiltration. Water Resources Research, XIX (6):1410-1414.

Gilley, James R. and Lloyd N. Mielke. 1980. Conserving energy with low-pressure center pivots. J of the Irr and Drain Div, Proc of the Amer Soc of Civ Engr, CVI 1R1:49-59.

_______, Lloyd N. Mielke and Wallace W. Wilhelm. 1982. Water and energy conservation using center pivot irrigation and reduced tillage practices. Lincoln: Univ of Nebraska, WRC, Proj Compl Rep B-048-NEB.

_______ and Raymond J. Supalla. 1982. Economic analysis of energy saving practices in irrigation. Paper presented at the Summer Meetings of the American Soc of Agri Engr, Madison, Wis.

I.A. 1981. Low pressure system halves power cost. Irrigation Age, Mar.

Irrigation Survey. 1982. Published by the Irrigation Journal, Brentwood Publication, Elmgrove, Wis.

Jacobs, James J. and Donald Brosz. 1980. Converting center pivots to low pressure: can you afford it? Laramie: Univ of Wyoming AES B-707.

Jones, Ken, Delbert Schwab, Sam Harp and Dudley Barefoot, ND. Sprinkler operating pressure and energy use. Stillwater: Oklahoma State Univ CES, Energy Event No. 401.

Kiendl, Paul and Donald C. Taylor. 1984. Impacts of credit and commodity price levels on the organization and growth of an irrigated farm firm. Brookings: SD AES Bul in press.

Lyle, William M. and James P. Bordovsky. 1980. New irrigation system design for maximizing irrigation efficiency and increasing rainfall utilization. College Station: Texas Water Res Inst TR-105.

_______ and James P. Bordovsky. 1982. LEPA irrigation system evaluation. St. Joseph, Missouri: American Soc of Agric Eng, ASAE Paper No. 82-2536.

Mahoney, Rosemary K. and Duane E. Erickson. 1984. Irrigate for less in Illinois, Illinois Irrigation Newsletter, VI (4):1-5.

Marek, Thomas H., Daniel J. Undersander and R. Nolan Clark. 1983. Efficiency investigations of high and low pressure center pivot irrigation systems. Amarillo: Texas A&M Univ Agric Res and Ext Cen Tech Rep No 32.

Pretzer, Don D. 1981. Center pivot irrigated corn. Manhattan: Kansas State Univ CES MF-585.

Renn, Linda. 1984. Low pressure conversions add up to energy savings. Irrigation Age, May.

SDCLRS, Annual. South Dakota Agricultural Statistics. Sioux Falls: SD Crop and Live Rep Ser, published annually in May, 1975 through 1984.

Sheffield, Les. 1984a. Here's what to consider in going from high to low pressure. Irrigation Age, Mar.

_______. 1984b. Here's a look at costs involved in going from high to low pressure. Irrigation Age, Apr.

Skinner, Robert E. and Kerry A. Harrison. 1981. Save energy with low pressure center pivot systems. Athens: Univ of Georgia CES Cir 731.

Sloggett, Gordon. 1982. Energy and U.S. Agriculture, irrigation pumping, 1974-80. Washington, D.C.: Nat Res Econ Div, Econ Res Serv, USDA Agric Econ Rep 495.

Taylor, Donald C. 1983. The 1970s: A decade of growth in South Dakota irrigation. Brookings: SDSU Econ Dept Res Rep 83-4.

_______. 1984a. Regional shifts during the 1970s: South Dakota irrigation. Brookings: SD AES Cir 243.

_______. 1984b. An economic study of irrigated corn grain production in Brookings County. Brookings: SD AES Tech Bul in press.

_______ and Richard C. Shane. 1983. The impact of rising energy prices on crop production: Brookings and Turner Counties. Brookings: SD AES Bul 684.

Thompson, Tom. 1984. PUMP irrigation system cost analysis program. Lincoln, Neb : AGNET Computing Network.

USDC, 1972 and 1984. U.S. Census of Agriculture, South Dakota. Washington, D.C.: Bur of the Census, US Dept of Comm, Gov't Printing Off, for Census Years 1969 and 1982, prelim.

White, John. 1984. LEPA experiments convincing to texas cotton and sugar beet growers. Irrigation Age, June/July.

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