AE-91 (Revised)

Selecting a Sprinkler Irrigation System

Tom Scherer
Extension Agricultural Engineer

The four basic methods of irrigation are: subsurface irrigation ("subirrigation," which uses tile drain lines), surface or gravity irrigation, trickle irrigation (also called drip irrigation) and sprinkler irrigation. Of the acres currently irrigated in North Dakota, more than 80 percent use some type of sprinkler system. Statewide, the center pivot is the most popular sprinkler system.

If the sprinkler system is for a *new* installation, two important tasks must be performed prior to purchasing the system. First, you must check the county soil survey maps to make sure the soils in the field can be irrigated. Second, you must have a readily available source of water near the field and a **water permit issued by the State Water Commission** for that water. The water source must be of sufficient quantity and quality for successful irrigation. Extension publication AE-92, "Planning to Irrigate ... A Checklist," provides more information on what is required to begin irrigating.

A sprinkler "throws" water through the air to simulate rainfall, whereas the other three irrigation methods apply water directly to the soil, either on or below the surface. A sprinkler system can be composed of one sprinkler or many. When many sprinklers are used, they are attached to a pipeline at a predetermined spacing to achieve a uniform application amount. When selecting a sprinkler system, the most important *physical* parameters to consider are:

1. The shape and size (acres) of the field.
2. The topography of the field. Does the field have many hills with steep slopes?
3. The amount of time and labor required to operate the system. How much time and labor do you have available?

The center pivot system is very adaptable but doesn't fit very well on irregularly shaped fields; long, narrow fields; and fields that contain some type of obstruction (trees, farmsteads, etc.). In these situations, other sprinkler systems may be used more effectively.

Sprinkler System Capacity

The sprinkler system capacity is the flow rate needed to irrigate an area adequately and is expressed in gallons per minute per acre (gpm/acre). The system capacity is dependent on the:

1. Peak crop water requirements during the growing season
2. Effective crop rooting depth
3. Texture and infiltration rate of the soil
4. The available water-holding capacity of the soil
5. If the water source is a one or more wells, the well or wells' pumping capacity
6. The State Water Commission permitted pumping rate

Table 1 shows the system capacity needed for the most commonly irrigated crops in North Dakota and various soil textures. To use this table, you must determine the dominant soil texture in the field and what type of crops will be grown (the crop rotation), then determine the appropriate system capacity.

For example, if you plan a rotation of potatoes, corn and alfalfa on loamy sand, you can determine from Table 1 that potatoes require 7 gpm/acre, corn 5.9 gpm/acre and alfalfa 5.6 gpm/acre. You would select a design system capacity for the crop requiring the largest amount, in this case the potatoes at 7 gpm/acre. If you install a center pivot system covering 130 acres, you would need about 910 gpm for proper design. However, what you need for proper design and what a well will produce is frequently different. As a general rule, under full-season irrigation, you need a minimum flow rate of 6 gpm/acre

(Continued on back page)

Table 1. System capacity in gallons per minute per acre (gpm/acre) for different soil textures needed to supply sufficient water for each crop in nine out of 10 years. An application efficiency of 80 percent and a 50 percent depletion of available soil water were used for the calculations.

Crop	Root Zone Depth (ft)	Coarse Sand and Gravel	Sand	Loamy Sand	Sandy Loam	Fine Sandy Loam	Loam and Silt Loam
Potatoes**	2.0	8.2	7.5	7.0	6.4	6.1	5.7
Dry Beans	2.0	7.9	7.1	6.4	6.1	5.7	5.4
Soybeans	2.0	7.9	7.1	6.4	6.1	5.7	5.4
Corn	3.0	7.3	6.6	5.9	5.5	5.3	4.9
Sugarbeets	3.0	7.3	6.6	5.9	5.5	5.3	4.9
Small Grains	3.0	7.3	6.6	5.9	5.5	5.3	4.9
Alfalfa	4.0	6.8	5.9	5.6	5.1	5.0	4.5

**Adjusted for 40 percent depletion of available water.

NDSU Extension Service
North Dakota State University
Fargo, North Dakota 58105
JANUARY 2010

What It Looks Like

Brief Description

Center Pivot

This self-propelled sprinkler system rotates around the pivot point and has the lowest labor requirements of the systems considered. It is constructed using a span of pipe connected to moveable towers. It will irrigate approximately 132 acres out of a square quarter section. Center pivot systems are either electric or oil-drive and can handle slopes up to 15 percent. Sprinkler packages are available for low to high operating pressures (25 to 80 pounds per square inch, or psi, at the pivot point). Sprinklers can be mounted on top of the spans or on drop-tubes, which put them closer to the crop. The water application amount is controlled by the speed of rotation. Center pivots are adaptable for any height crop and are particularly suited to lighter soils. They are generally not recommended for heavy soils with low infiltration rates.

Deep wheel tracks can be a problem on some soils; however, a number of management methods are available to control this problem. Electric-drive pivots are the most popular due to flexibility of operation. Computerized control panels allow the operator to specify speed changes at any place in the field, reverse the pivot, turn on auxiliary pumps at a specified time and use many other features.

Center Pivot With Corner Attachment

Corner attachment systems that allow irrigation of most of the corner areas missed by a conventional center pivot system are available. Depending on the method of corner irrigation, pivot systems with corner attachments will irrigate 145 to 154 acres out of a 160-acre quarter section. The most common method of corner irrigation has an additional span, complete with a tower attached to the end of the center pivot system main line, which swings out in the corners. As it swings out, sprinklers are turned on to irrigate the corners. A buried wire, global positioning system unit or mechanical switch controls the movement of the corner span.

Another type of corner system uses several end-guns mounted on the end of the center pivot system main line. The end-guns are activated in sequence from smallest to largest and back again as the machine moves past the corners. A corner span generally costs about half as much as the rest of the pivot, thereby increasing the capital cost per acre on a square 160 acres. However, if the field is rectangular, the corner span can be extended on one or both ends, thereby increasing the amount of irrigated acreage from 170 to 185 acres. High-value crops and/or high land value, as well as scarcity of irrigable land, are necessary to justify additional costs for more than a "plain" center pivot.

Linear Move

The linear move (sometimes called a lateral move) irrigation system is built the same way as a center pivot; that is, with moving towers and spans of pipe connecting the towers. The main difference is that all the towers move at the same speed and in the same direction. Water is pumped into one of the ends or into the center. Water can be supplied to the linear move either through a canal or by dragging a supply hose that is connected to a main line or by connecting and disconnecting from hydrants as the linear moves down the field.

To gain acreage and make the transition from one side of the field to the other, some linear move systems pivot at the end of the field. Due to the lateral movement, powering a linear with electricity is difficult. Usually, a diesel motor with a generator is mounted on the main drive tower and supplies the power needed to operate the irrigation system. The primary advantage of the linear move is that it can irrigate rectangular fields up to a mile in length and a half mile wide. Due to the high capital investment, linear moves are used on high-value crops such as potatoes, vegetables and turf.

Traveling Big Gun

The traveling big gun system uses a large-capacity nozzle (¾ to 2 inches in diameter) and high pressure (90 to 125 psi) to throw water out over the crop (175- to 350-foot radius) as it is pulled through an alley in the field. Traveling big guns come in two main configurations: hard-hose or flexible-hose feed. With the hard-hose system, a hard polyethylene hose is wrapped on a reel mounted on a trailer. The trailer is anchored at the end or center of the field. The gun is connected to the end of the hose and is pulled to the trailer. The gun is pulled across the field by the hose wrapping up on the reel. With the flexible-hose system, the gun is mounted on a four-wheel cart. Water is supplied to the gun by a flexible hose from the main line. A winch cable on the cart pulls the cart through the field. The cable is anchored at the end of the field. Most traveling big gun systems have their own power unit and cable winch mounted directly on the machine. The power unit may be an internal combustion engine or a water drive.

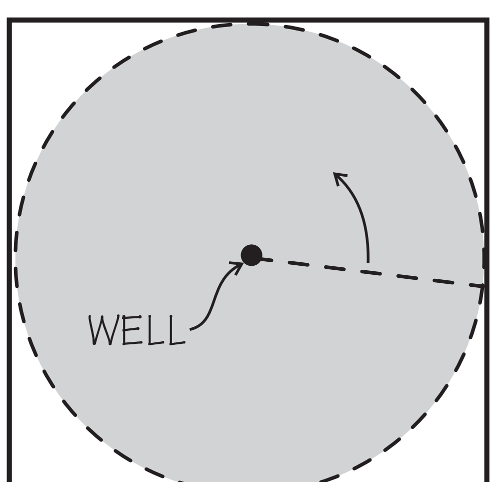
Particularly adaptable to various crop heights, variable travel speeds, odd-shaped fields and rough terrain, the big gun requires a moderate initial investment, more labor and higher operating pressures than center pivots and linear moves. One 1,320-foot-long (quarter mile) set usually covers eight to 10 acres, but many variations using different water quantities and operating pressures are available. Irrigated cropland is sacrificed because the alley is generally two rows wide. Most big gun systems are used on a maximum of 80 to 100 acres per gun.

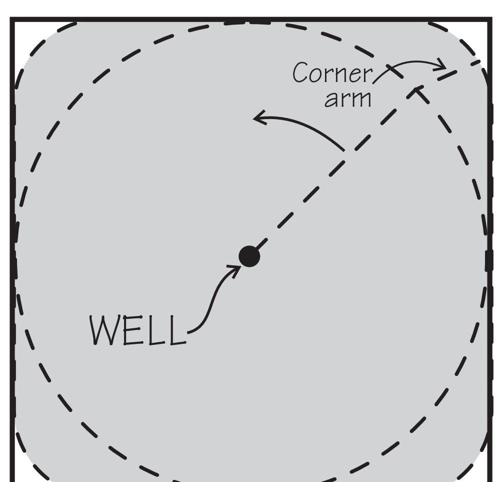
Side Roll

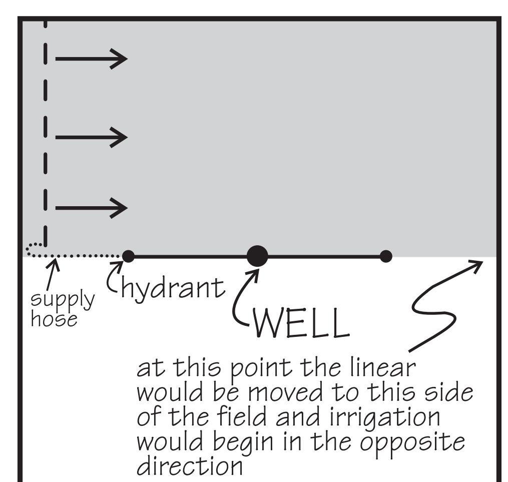
The side roll (sometimes called a wheel roll) system, as shown, consists of a lateral, usually a quarter mile long, mounted on 4- to 10-foot-diameter wheels with the pipe acting as an axle. Common pipe diameters are 4 and 5 inches. The side roll irrigates an area from 60 to 90 feet wide. When the desired amount of water has been applied to this set area, a gasoline engine at the center is used to move the side roll to the next set. The sprinklers generally are mounted on weighted, swiveling connectors so that no matter where the side roll is stopped, the sprinklers always will be right side up. This type of system is not recommended for slopes greater than 5 percent and should be used mainly on flat ground. When not being used, side rolls are subject to damage from high winds.

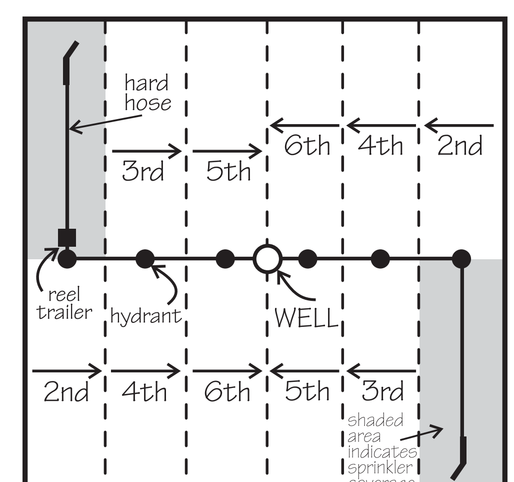
Side roll systems also are adapted only to low-growing crops; have medium labor requirements, moderate initial investment, medium operating pressure (50 psi at inlet) and generally rectangular field requirements; and each lateral is capable of irrigating a maximum of 40 acres. The side roll is better adapted to heavier soils than a continuous moving system. Special wheels must be purchased for moving this system from field to field without disassembly. One variation of the side roll system has trail lines with up to three additional sprinklers on 60-foot spacing. This reduces the number of sets required to irrigate a particular field.

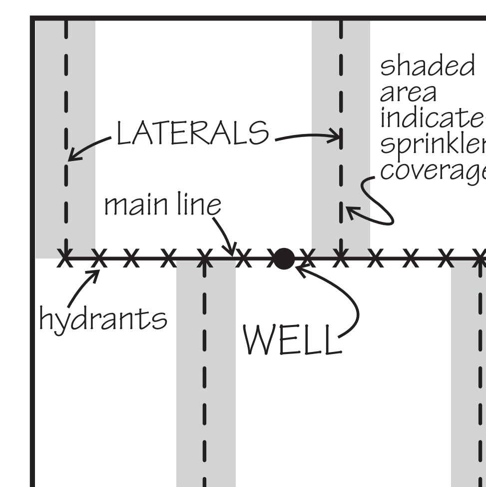
Sample 160 Acre Layout











(Continued from front page)

because most of the soils irrigated in North Dakota are loamy sands or sandy loams. A lesser flow rate can be used but more intensive water management will be required.

A sprinkler system must be designed to apply water uniformly without runoff or erosion. **The application rate of the sprinkler system must be matched to the intake rate of the most restrictive soil in the field.** If the application rate exceeds the soil intake rate, the water will run off the field or relocate within the field, resulting in over- and underwatered areas. Using tillage that improves surface storage, such as deep cultivation or making basins, will help control runoff. The intake rate of the soils in your field can be found in the county soil survey available at your local Natural Resources Conservation Service or Extension office.

Selecting the Most Appropriate Sprinkler System

Five of the most common sprinkler systems in use in North Dakota are compared in this publication using the following criteria:

1. A square 160-acre field
2. A 100-foot-deep well near the center of the field
3. An adequate water supply for any sprinkler system
4. Suitable soils for the system application rate

Table 2 shows the costs of irrigation development using the criteria stated above. The costs shown are averages; actual costs for most farms will vary depending on the distance from the water source to the field, whether the sprinkler system is new or used, options selected and the type of financing package. Take care to ensure that the cash flow generated is sufficient to cover payments on the irrigation investment.

Table 2. Comparative cost of new sprinkler irrigation systems (square 160-acre field, 100-foot-deep well in middle of property). Assumes three-phase electric power lines run along the edge of the field.

	Center Pivot	Pivot w/Corner[1]	Linear Move[2]	Big Gun	Side Roll
CAPITAL COSTS:					
Number of Systems Required	1	1	1	2	4
Acres Irrigated (in 160)	128	152	158	158	158
Required Flow Rate (GPM)	768	912	948	948	948
Irrigation System Cost	$65,000.00	$95,000.00	$114,000.00	$63,000.00	$64,000.00
Well, Pump, Motor	$27,000.00	$30,000.00	$30,000.00	$35,000.00	$32,000.00
Pipe, Meter, Valves	$4,500.00	$4,500.00	$11,000.00	$20,000.00	$23,000.00
Electric Panel and 1,400 ft of Wire	$10,000.00	$10,000.00	$10,000.00	$10,000.00	$10,000.00
TOTAL CAPITAL COST	$106,500.00	$139,500.00	$165,000.00	$128,000.00	$129,000.00
CAPITAL COST PER ACRE	$832.03	$917.76	$1,044.30	$810.13	$816.46
ANNUAL OWNERSHIP COST (per acre)					
Depreciation on System (25 year life, straight line depreciation)	$20.31	$25.00	$28.86	$15.95	$16.20
Depreciation on Well, Pump, Motor and Pipe (25 year life, straight line depreciation)	$12.97	$11.71	$12.91	$16.46	$16.46
Interest on Investment (6% rate averaged over 25 years)	$24.96	$27.53	$31.33	$24.30	$24.49
Insurance ($0.50/$100 of capital investment)	$4.16	$4.59	$5.22	$4.05	$4.08
TOTAL ANNUAL OWNERSHIP COST	$62.40	$68.83	$78.32	$60.76	$61.23
OPERATING COSTS (per acre)					
Power (electric)[3]	$18.90	$19.02	$19.84	$29.34	$20.94
Labor (@ $15.00/hr)	$10.00	$10.00	$15.00	$30.00	$35.00
Maintenance (1.5% new cost)	$12.48	$13.77	$15.66	$12.15	$12.25
TOTAL ANNUAL OPERATING COST	$41.38	$42.79	$50.51	$71.49	$68.19
OPERATING AND OWNERSHIP COST	**$103.78**	**$111.62**	**$128.83**	**$132.25**	**$129.42**
Annual Cash Cost of Ownership	$70.50	$74.91	$87.06	$99.85	$96.77
Kilowatts Hours (KWH) of Energy (pumping energy plus tower motor energy on pivot and linear)	33.69	42.44	46.95	74.74	50.17
Pressure at Well (psi)	40	40	45	100	60

[1] Buried wire guidance. For GPS guidance system, add $12,000
[2] Guidance uses a furrow-sensing wheel. For GPS guidance system, add $20,000
[3] Based on an off-peak electric rate of 6 cents per kilowatt-hour (kwh); annual meter charge of $600 and 900 hours of pump operation per growing season

For more information on this and other topics, see: www.ag.ndsu.edu

1500-9-94, 2M-9-98, 1M-8-05, 500-1-10