USING CPNOZZLE FOR SPRINKLER PACKAGE SELECTION

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INTRODUCTION

Sprinkler irrigation systems and specifically center pivots have been adapted to operate on many different soils, to traverse extremely variable terrain, and to provide water to meet a number of different management objectives. As a buyer, you will be furnished with an array of different sprinkler types, many that are capable of performing adequately. However, you should make a selection based upon accurate field based information, and careful consideration of the interaction among several system design factors. Only then will the system installed meet your expectations.

What flow rate?

When the desire is to replace the peak water use, the flow rate required is virtually the same for all crops. The reason is that although the duration and timing of a specific crop's peak water use rate varies, peak water use rates are quite similar. The system flow rate determines how other factors impact system operation. For example, if the flow rate is greater than necessary, the peak water application rate may cause runoff toward the outer end of the pivot lateral. The system flow rate also determines the size of sprinkler head required at each position of the system and the ability to recover from system downtime.

When estimating the needed system flow rate, there are three important considerations: a) environmental factors; b) estimated system downtime; and d) the soil water holding capacity. The most important environmental considerations are the likelihood of rainfall and the peak ET rate of the crop. NebGuide G89-932 *Minimum Center Pivot Design Capacities in Nebraska* presents a procedure for determination of the minimum net system capacity of center pivots in Nebraska. Estimated crop water use rates, soil water holding capacity and rainfall data from different locations in the Nebraska were evaluated. The analysis identified areas where the system flow rate should be increased to account for lower annual precipitation and greater peak ET rates. Our best estimate is that systems located west of the 20 inch per year annual precipitation line should have greater flow rates.

Table 1 presents the estimated minimum net system capacity required to meet crop demands 90% of the time for regions in Nebraska. The last line in the table provides the system capacity necessary to meet peak water demands 100% of the time. That calculation is based on Equation 1:

$$Q_p = (18.9 \times ET_p \times A \times t_i) / (E_i \times t_f) \qquad \textbf{Equation 1}$$

where:

Q_p = irrigation system flow rate, gpm
18.9 = units conversion constant
ET_p = peak water use rate, in/day
A = irrigated area, acres
t_i = irrigation interval, days
E_i = irrigation efficiency, decimal
t_f = irrigation time per event, days

Table 1. Minimum net system capacities to meet crop water demands 90% of the time for the major soil texture classifications and regions in Nebraska[1].

Soil Texture	Available Water Capacity (in/ft)	Region 1	Region 2
Loam, silt loam or very fine sandy loam	2.5	3.85	4.62
Sandy clay loam, loam	2.0	4.13	4.89
Silty clay loam, clay loam, fine sandy loam	2.0	4.24	5.07
Silty clay	1.6	4.36	5.13
Clay, sandy loam	1.4	4.48	5.19
Loamy sand	1.1	4.83	5.42
Fine sand	1.0	4.95	5.89
Peak ET		**5.65**	**6.60**

[1] Data taken from von Bernuth, et al. 1984 and NebGuide G89-932 *Minimum Center Pivot Design Capacities in Nebraska*.

The values in Table 1 need to be adjusted for system down time and the water application efficiency of the center pivot. Down time can result for regularly scheduled maintenance, load control, system failure, or labor restrictions (manager takes Sunday's off). The down time experienced due to system failure depends on the current age of the components and how frequently the system is checked. Operators with a shutdown phone alarm will have immediate knowledge when the system shuts down while others may not be aware that the system is down for 8 hours or more. For each 12 hours of down time, the system flow rate must be increased by 8%.

Once the net capacity has been adjusted for down time, the gross flow rate required is determined by dividing by the estimated water application efficiency. The system water application efficiency depends on the sprinkler package (sprinkler type and position). Some potential water application efficiencies are provided in Table 2. They are listed as potential efficiencies since they assume that runoff does not occur. Thus, the field conditions will determine what the actual efficiency will be. Selecting the package with the most efficient potential water application efficiency is a place to start, and the use of the CPNOZZLE computer program will help identify choices that should be avoided due to runoff concerns.

Table 2. Estimated water application efficiencies for different sprinkler packages.

Sprinkler/ Nozzle Type	Potential Application Efficiency
High Pressure Impact	80-85
Low Pressure Impact	82-85
Low Pressure Spray (on top of pipeline)	85-88
Low Pressure Spray (truss rod height)	87-92
Low Pressure Spray (3-7ft off the ground)	90-95
Low Pressure Spray (LEPA bubble mode)	95-98

Field data collection

The Soil Survey provides one source of estimates for average water infiltration rates, field slopes and soil water holding capacities. Figure 1 shows a copy of a quarter section located in Pierce county. A planimeter was used to determine the surface area of each mapping unit and create a table like that shown in Table 3. Look up the soil intake family, average field slope, infiltration rate and the soil water holding capacity information on each mapping unit and record them in the table. Be sure to include areas where soil moving has taken place.

Begin your analysis by looking at the mapping units with substantial areas. Look for areas with steep slopes (say greater than 7%) and with low infiltration rates (say less than the 0.5 Intake Family). Another factor to look for is soil water holding capacity. If sufficient area is involved, the system may need to be managed according to those areas. You most likely won't select a system to meet soils that comprise less than 10% of the irrigated area. However, field areas with 25 to 50 acres cannot be ignored. Tabulating soil information in this manner will make it easier to make decisions.

When selecting a sprinkler package, take the number of acres in a specific intake family and slope range into account. In Table 3, the 0.3 intake family may not be an issue for sprinkler package selection. However, despite its 0-1% field slope the high water table problems might cause wheel track problems so an attempt should be made to keep the wheel tracks dry which begins to limit the sprinkler package options. Likewise, field areas with field slopes greater than 7% cover more than 40 acres so those areas should be considered carefully. Fortunately

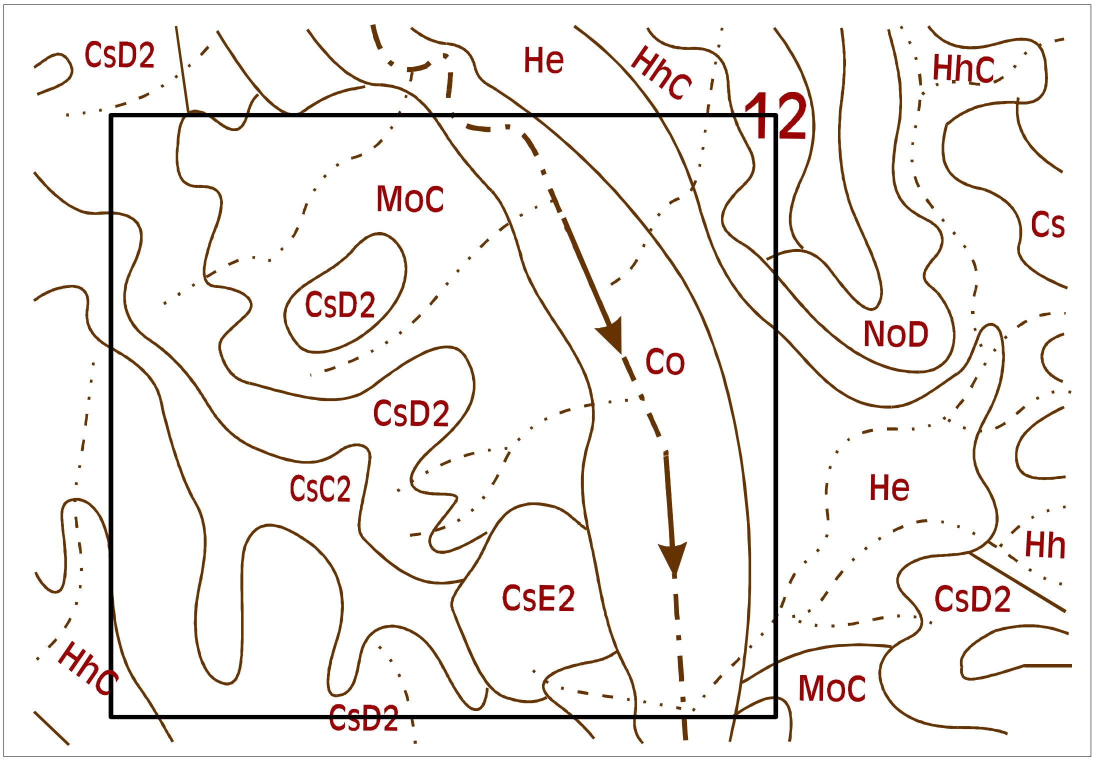

Figure 1. Copy of a soil survey map from Pierce County, NE

the areas with the greatest slope also have soils in the highest Intake Family category. One of the key areas to investigate is located in the middle of the field on the south border since slopes could be steep (CsD2& CsE2) and the steepest areas are close to the outside edge of the irrigated area where water application rates will be highest.

Many sprinkler packages are selected without a field site visit by the designer. Though soil mapping units give some indication of average field conditions, the data is seldom sufficiently accurate to allow a better decision. Therefore, a rough grid topography map (say 200' x 200') will determine if areas mapped as 7 to 11% slopes are closer to 7%.

Finally, the field visit can provide valuable information related to tillage and planting practices. A field farmed on the contour can safely use a sprinkler package that would otherwise generate runoff. Crop residues left on the soil surface absorb much of the impact energy of rainfall and irrigation, thus the soil infiltration rate would be more consistent throughout the season. Soil residues maintain surface storage to prevent runoff. Each of these factors may cause you to make a slightly different decision.

Uniform water application requires that the correct sprinklers be at each position along the pivot lateral, that the pumping plant deliver water at the appropriate pressure and flow rate and that the system is not operated under adverse atmospheric conditions. Another aspect of water application uniformity is the uniformity of infiltration. Water applied to the soil with the precision of a micrometer can be overshadowed by surface runoff problems. Thus, the goal must be to consider how the sprinkler package will match up with the field conditions.

Table 3. Summary of soil characteristics for each mapping unit in a quarter section of land in Pierce County, NE.[1]

Mapping Unit	Drainage Group	Soil Water Holding Capacity (in/ft)	Field Slope (%)	NRCS Intake Family	Land Area (Acres)
Co	Moderately Slow High Water Table	2.4	0-1	0.3	42.1
He	Well	2.4	0-1	1.0	23.9
CsC2	Well	2.4	1-7	1.0	11.0
HhC	Well	2.4	1-7	1.0	36.8
MoC	Well	2.3	1-7	0.5	5.3
CsD2	Well	2.4	7-11	1.0	28.0
NoD	Well	2.4	7-11	1.0	1.8
CsE2	Well	2.4	11-17	1.0	11.1

[1] Data taken from Pierce County Soil Survey

The zero runoff goal requires that the sprinkler package be carefully matched to the field conditions and to the operator's management scheme. Too often the desire to reduce pumping costs clouds over selecting the appropriate sprinkler package. An attempt should be made to select sprinkler packages that do not result in runoff. This requires that the water application pattern of the sprinkler be compared to the soil infiltration rate. If an accurate estimate of soil surface storage is available from field measurements, it should be included in the analysis.

Estimating Runoff

A computer program CPNOZZLE, based on research conducted across the country provides an opportunity to develop a rough estimate of how well suited the water application characteristics are to a field's soils and slopes. The program is also useful in predicting how much the design criteria should be changed to eliminate a potential runoff problem. For example, if the normal operation of applying 1.25 inches of water per revolution produces runoff, the program can be used to determine a water application depth that produces no runoff. If you are in the process of retrofitting the an old system with a new sprinkler package, the program can be used to select an appropriate system flow rate and sprinkler wetted radius.

The **CPNOZZLE** program has been converted to run in the Windows environment using the Visual Basic software. The new version incorporates the use of the Green and Ampt infiltration rate estimation procedure in addition to the NRCS Intake Family curves. The Green and Ampt procedure uses soil physical properties such as the percent sand, silt, and clay, saturated hydraulic conductivity, and porosity to estimate parameters needed to calculate infiltrated depth. Listed in Table 4 are the parameters for major soil texture categories and the estimated weighted potential runoff for a 1.3 inch application depth delivered by a 1320 foot system, with a flow rate of 1000 gpm and a sprinkler wetted diameter of 48 feet.

The program still includes the NRCS Intake Family method of estimating the weighted potential runoff. Using the same system components as used for the Green and Ampt equation, the NRCS Intake Family procedure was used to estimate the weighted potential runoff from sprinklers with wetted diameters of 30 and 48 feet. These results are presented in Table 5. Note that the 0.1 Intake Family is aligned with soils with high clay percentages, the 0.3 Intake Family with soils in the loam/silt loam categories, and the 1.0 with the sandy loam or loamy sand categories. It is clear that the use of the Green and Ampt equation allows a much broader range of soil textures to be evaluated.

Table 4. Green and Ampt parameters[1] and calculated weighted potential runoff.

Soil Type	Percent Sand	Percent Silt	Percent Clay	Saturated Hydraulic Conductivity (cm/hr)	Wetting Front Suction Head (cm)	Sat. Soil Water Content (cm^3/cm^3)	Initial Soil Water Content	Weighted Potential Runoff[2] (%)
Sa	90	3	7	11.0	3.0	0.42	0.08	O
LSa	85	6	9	8.0	7.0	0.40	0.11	3.8
SaL	66	21	13	6.0	12.0	0.41	0.15	4.6
L	43	39	18	2.7	18.0	0.43	0.20	26
SiL	20	64	16	0.8	35.0	0.49	0.24	45.8
SaCL	59	13	28	1.2	19.0	0.33	0.21	55.0
CL	32	34	34	0.9	21.0	0.39	0.30	55.9
SiCL	13	63	34	0.9	30.0	0.43	0.29	62.6
SaC	51	7	42	0.7	20.0	0.32	0.28	70.2
SiC	10	45	45	0.7	20.0	0.42	0.32	70.2
C	27	23	50	0.6	26.0	0.39	0.33	70.2

1 Values taken from the Handbook of Hydrology by Maidment, 1992.
2 Weight potential runoff for a center pivot with a system length=1320 feet; flow rate=1000 gpm; sprinkler wetted diameter=48 feet; application depth=1.3 inches.

Table 5. Weighted potential runoff estimated using the NRCS Intake Family procedure for systems with sprinkler package wetted diameters of 30 and 48 feet.

	Weighted Potential Runoff			
Intake Family Number	Wetted Diameter = 30		Wetted Diameter = 48	
	800 gpm	1000 gpm	800 gpm	1000 gpm
0.1	64	67	58	61
0.3	49	53	37	43
0.5	34	40	20	23
1.0	11	19	1	5
1.5	2	8	0	0
2.0	0	2	0	0
3.0	0	0	0	0

SUMMARY

Center pivot buyers have a vast array of sprinkler packages to choose from. Selecting the most appropriate sprinkler package for an individual field should be based upon collection of accurate field based information for soils, slopes, and cropping practices. The final selection should not be based on energy costs alone. Rather the system should first apply water uniformly without generating runoff. The "**CPNOZZLE**" computer program presents an opportunity to perform some 'what if?' sorts of analysis prior to making a sprinkler package purchase.

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