IRRIGATION MANAGEMENT SERIES

Sprinkler Package Effects on Runoff

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Farmers are used to managing many variables. They have to choose from many crop varieties, herbicides, insecticides, fertilizers, and tillage methods. They must determine the proper rate and timing of irrigation applications while dealing with changing weather, varying soils and fluctuating markets.

Many long-term decisions, such as selecting a sprinkler package for a center-pivot system, are more complicated now since industry has developed many options. These options can make possible very efficient irrigation systems, but also can be a wasteful and costly choice if used under the wrong conditions. Low pressure sprinkler packages have become popular since low pressure requirements can minimize pumping costs.

While many properly designed and operated sprinkler packages have high application efficiencies, there has been a trend to place nozzles closer to the ground, which is often below the top of the crop canopy, especially for corn. This height adjustment is made in an attempt to minimize and/or eliminate droplet evaporation, drift losses, and canopy evaporation.

Reducing the pressure and lowering the discharge point, however, has a distinct disadvantage in that this reduces the wetted diameter and increases the instantaneous application rate. The application rate for most low pressure systems greatly exceeds the soil intake rate and, unless sufficient surface storage is available to hold the water in place until infiltration occurs, water movement will occur. Water movement within the field and water movement off the field as runoff both reduce irrigation application uniformity and efficiency.

Irrigators have several irrigation strategy options to prevent runoff, beginning with the design and selection of nozzle packages. Run-off potential is reduced using nozzles that have larger wetted throw diameters, higher pressure to increase wetted diameter, higher

Table 1. Example Printout from CPNOZZLE's Potential Runoff Analysis

Percent Potential Runoff

0.1 NRCS Intake Family

System Length, feet	Wetted Radius, feet	Surface Storage, inches	900 gpm	1000 gpm	1100 gpm
128	30	0.5	0.0%	0.0%	0.0%
256	30	0.5	0.0%	0.0%	0.0%
384	30	0.5	0.0%	0.0%	0.0%
512	30	0.5	0.0%	0.0%	0.0%
640	30	0.5	0.0%	0.0%	0.9%
768	30	0.5	0.6%	2.4%	3.9%
896	30	0.5	3.2%	4.9%	6.3%
1024	30	0.5	5.3%	6.9%	8.3%
1152	30	0.5	7.1%	8.6%	10.0%
1280	30	0.5	8.6%	10.2%	11.5%
Weighted Average Potential Runoff			3.4%	4.5%	5.6%
Hour per revolution			59	53	49

1.0 in application amount, 1280 feet system length mounting location of the nozzle, and decreased flow per unit irrigated area.

However, there are limitations. Decreasing irrigation capacity, for example, raises the risk of crop water stress and yield loss if irrigation capacity falls too much below seasonal peak crop water use rates, especially on low water holding capacity soils. Decreasing application depth requires more frequent applications, so increased canopy and soil surface evaporation losses occur, which reduces the irrigation efficiency.

Once a nozzle package is installed, several management practices might be altered to reduce run-off; such as 1) decreasing application depth, and 2) increasing surface storage using appropriate residue and tillage management systems.

However, heavy dependence on surface storage of water can also be a problem if tillage and residue management programs fail due to large rainfall events or cannot be placed due to weather conditions and decreases in surface water storage capacity due to natural deterioration and breakdown of residues during the course of the growing season. It is very important to design the nozzle packages appropriately for the field conditions so that runoff potential is minimal.

There are many types of nozzles which can be mounted in a variety of positions, with or without regulators, and using one of several splash pad options. Mixing and matching these options means hundreds of nozzle package options are available. Runoff control should be given priority consideration when establishing the nozzle package selection criteria. While evaporation and drift losses are often a major concern of irrigators, runoff can result in much greater irrigation water losses if the nozzle package is poorly matched to soil and irrigation capacity conditions.

Runoff control should be a major design criteria when selecting a nozzle package. Prediction of runoff for various conditions can help an irrigator select an appropriate center pivot nozzle package. The following graphs represent predicted runoff volumes for various operating and field conditions using CPNOZZLE.

CPNOZZLE is a computer program developed by the University of Nebraska Northeast Research and Extension Center in Concord, Nebraska, to estimate potential runoff for center-pivot irrigation nozzle packages.

CPNOZZLE Potential Runoff Analysis.

The potential runoff for a given system uses information about the system length, the surface storage value or the field slope, the radius-of-throw of the sprinkler nozzles, the application depth, the system output (capacity), and the Natural Resources Conservation Service (NRCS) Soil Intake Family. The input variables are discussed as follows:

System Length. The system length for the following series of runoff charts was held constant at a common length of 1,280 feet. The application rate must increase to keep the same application depth with distance from the center pivot point, since the proportion of the field covered by each additional unit of length increases. For example, approximately two-thirds of the area of a field lies outside the mid-point of a center pivot lateral. The output runoff estimates shown in the figures are the weighted average for the entire system. However the highest runoff potential is usually at the outer end of the center pivot where the application rates are the highest.

Surface Storage. The available surface storage choices on CPNOZZLE are 0.0, 0.1, 0.3, and 0.5 inches which coincide with field slopes of >5 percent, 3-5 percent, l-3 percent, and 0-l percent, respectively. The 0.0 inch surface storage (>5 percent field slope) has been omitted for the purpose of limiting the number of figures.

Application Amount. The initial application amount was 1.0 inch. Depending on the percentage of runoff predicted with the initial application amount, another run was conducted using either a 0.75- or a 1.5-inch application amount. If the predicted runoff percentage with the 1.0-inch application amount was excessive, then the lower application amount was used to generate a new series of runoff curves. However, if the initial runoff percentage was low, another series of curves using a 1.5-inch application amount were developed. Runoff, for the purposes of this bulletin, was defined as excessive when the weighted average was greater than 5 percent. However, when selecting a sprinkler package, the preferred package design should be for no runoff. Unacceptable levels of runoff can occur at the outer edge even with a low overall weighted average.

NRCS Soil Intake Family. The available soil intake families are 0.1, 0.3, 0.5, 1.0, 1.5, and 2.0. Again, to limit the number of figures, the 1.5 and 2.0 soil intake families have been omitted since their percentage of runoff is low for most of the different system configurations. Figures are provided for the 0.1, 0.3, 0.5, and 1.0 soil intake families.

RESULTS

The runoff analyses are shown for the standard length pivot in Figures 1 through 19 and are organized first by the soil intake family, and then by surface storage value.

NRCS Soil Intake Family 0.1. Figures 1 through 6 illustrate the data obtained for the 0.1 soil intake family. Figure 1 shows results for the low surface storage value of 0.1 inch. The only potential runoff values for this surface storage value that are close to acceptable occur at the low system capacity value and the high radius-of throw value. Since predicted runoff was excessive, the results for an application amount of 0.75 inches are shown in Figure 2. Reducing application depth did increase the number of capacity and radius-of-throw options, but generally the only values close to acceptable are for low capacity and high radius-of-throw systems. For this combination of soil intake family and surface storage, the options for package selection and system design are minimal.

If surface storage is 0.3, then several package options, shown in Figure 3, with large wetted radius may be possible for medium to low system capacities. By reducing the application amount to 0.75 inch, shown in Figure 4, a system using a radius-of-throw of 30 feet or greater will have an acceptable runoff percentage for most system capacities. A system using a radius-of-throw of 20 feet will have an

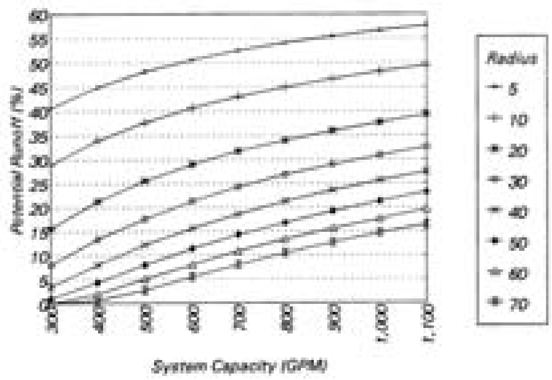

Figure 1. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.1 in.; App. Amt. – 1.0 in.; Intake Family – 0.1; System Length – 1,280ft.

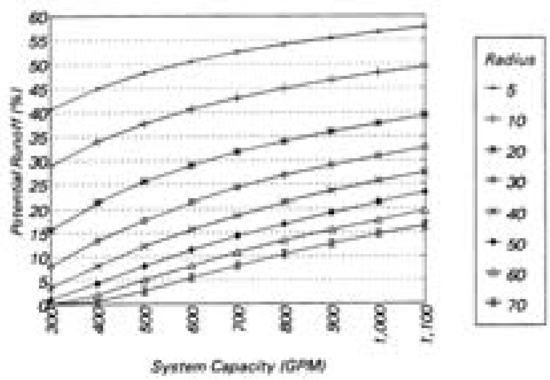

Figure 2. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – .1 in.; App. Amt. – 0.75 in.; Intake Family – 0.1; System Length – 1,280 ft.

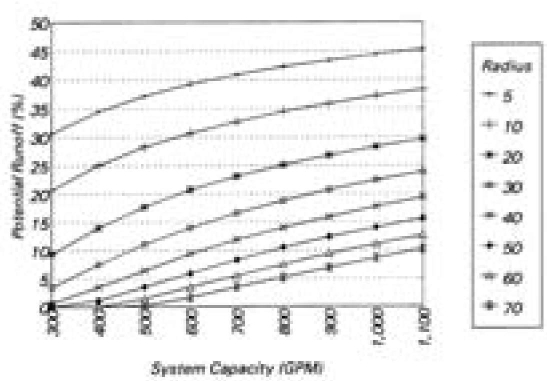

Figure 3. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.3 in.; App. Amt. – 1.0 in.; Intake Family – 0.1; System Length – 1,280 ft.

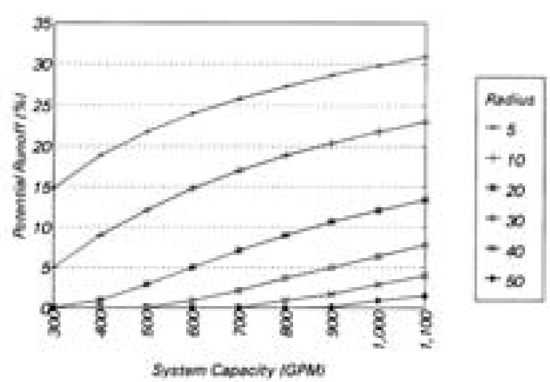

Figure 4. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.3 in.; App. Amt. – 0.75 in.; Intake Family – 0.1; System Length – 1,280 ft

acceptable runoff percentage for system capacities at or below 600 GPM. System capacity would have to be limited to use most low radius-of-throw nozzles. Low radius-of-throw values of 5 and 10 feet are unacceptable for this combination of surface storage and soil intake family.

Increasing to a high surface storage value of 0.5 inches and looking at the 1.0 inch application amount, Figure 5 shows that the radius-of-throws of 30 feet or greater have acceptable runoff percentages. The 20-foot radius- of-throw has acceptable runoff percentages for system capacities of 700 GPM or less. The 5- and 10-foot radius-of-throws have largely unacceptable runoff values. Since a fair number of wetted diameter options in Figure 5 were identified, the application amount was increased to 1.5 inches. However, Figure 6 shows that this management option would only have acceptable runoff percentages occur at very limited system capacities and high radius-of-throws.

Figures 1 through 6 generally indicate that for the soil intake family of 0.1, the high radius-of-throw (high pressure) systems would minimize runoff potential and therefore would be required to have efficient irrigation. High pressure systems would be the best choice when selecting packages and designing systems for fields with this soil intake family.

NRCS Soil Intake Family 0.3. Figures 7 through 12 show predicted runoff for 0.3 soil intake family soils. Figure 7 shows that for the low surface storage (0.1 inch) only the very high radius-of-throws will provide acceptable potential runoff percentages with high irri-

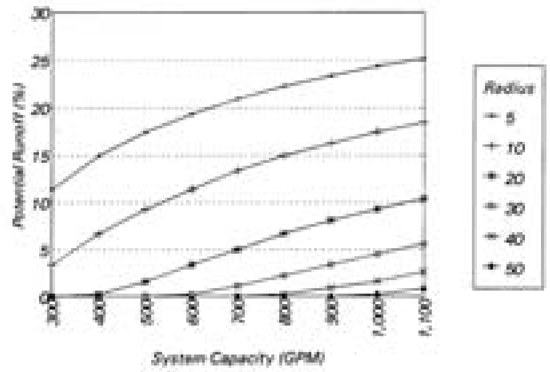

Figure 5. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.5 in.; App. Amt. – 1.0 in.; Intake Family – 0.1; System Length – 1,280 ft.

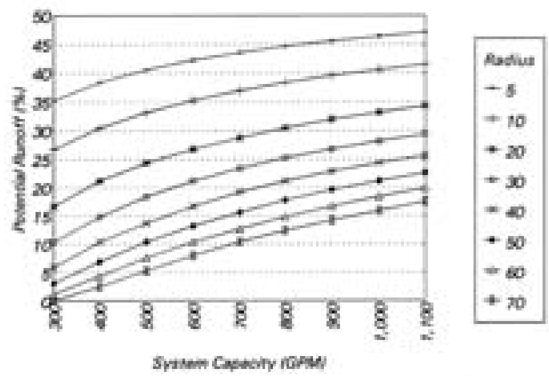

Figure 6. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.5 in.; App. Amt. – 1.5 in.; Intake Family – 0.1; System Length – 1,280 ft.

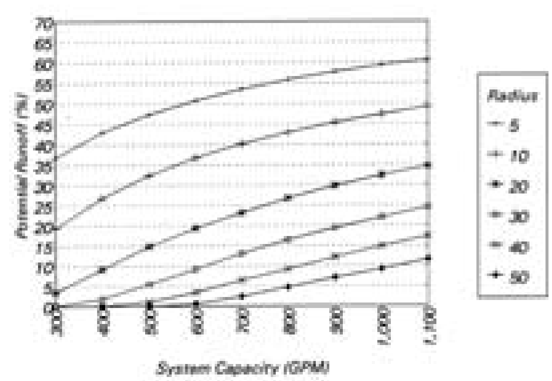

Figure 7. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.1 in.; App. Amt. – 1.0 in.; Intake Family – 0.3; System Length – 1,280ft.

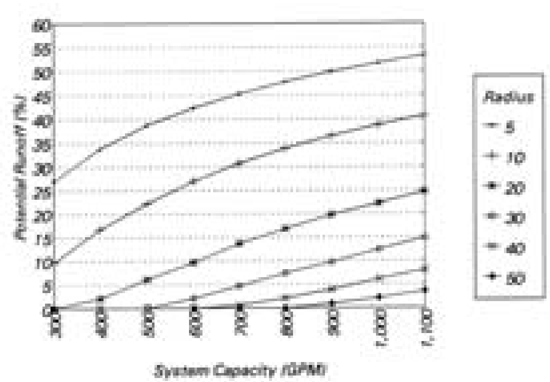

Figure 8. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.1 in.; App. Amt. – .75 in.; Intake Family – 0.3; System Length – 1,280 ft.

gation capacity. The 60- and 70-foot radius-of-throw lines are not shown; however, the 50-foot radius of-throw is acceptable at capacities less than 800 GPM. Thirty- and 40-foot radius-of-throws may have applications with low system capacities.

Figure 8 again illustrates that reducing application depth will allow use of lower pressure systems under more capacity conditions. Figure 9 shows that with medium surface storage (0.3 inch), 30-foot or greater radius of- throws would largely eliminate excessive run-off. Twenty-foot radius-of throws would be limited to capacities of less than 600 GPM. Figure 10 shows results with a 1.5-inch application depth. Figures 11 and 12 show the potential runoff percentages for the high surface storage (0.5 inch) and indicate that, depending on the application amount, smaller radius-of-throws can be used with larger system capacities. Figure 11 shows us that when using an application amount of 1.0 inch on a field with high surface storage, any radius-of-throw above 20 feet can be used with any of the system capacities without worrying about potential runoff. However, with an increase in the application amount, only the lower system capacities (300-800 GPM) and the higher radius of- throws (30 feet or greater) can be used without an unacceptable amount of potential runoff (Figure 12).

NRCS Soil Intake Family 0.5. Figures 13 through 16 illustrate runoff predictions obtained for the 0.5 soil intake family and show that increasing soil intake properties increases the sprinkler package options even with high capacity. Since high intake soils tend to have

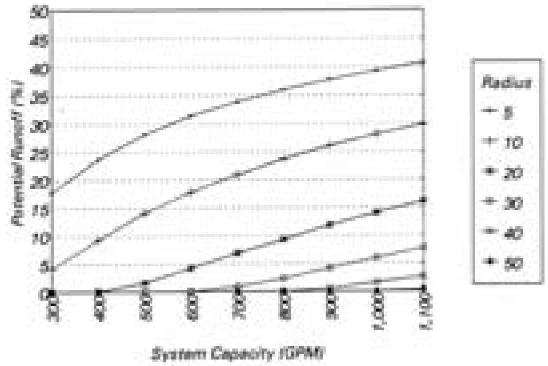

Figure 9. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.3 in.; App. Amt. – 1.0 in.; Intake Family – 0.3; System Length – 1,280 ft.

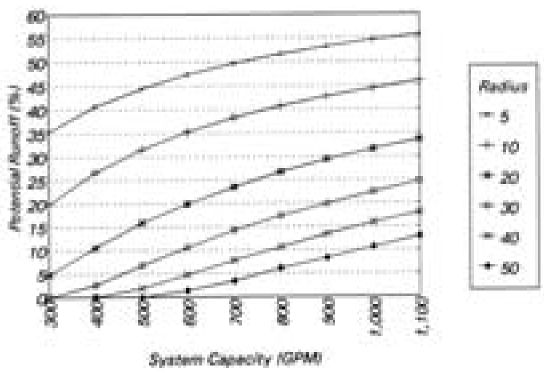

Figure 10. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.3 in.; App. Amt. – 1.5 in.; Intake Family – 0.3; System Length – 1,280 ft.

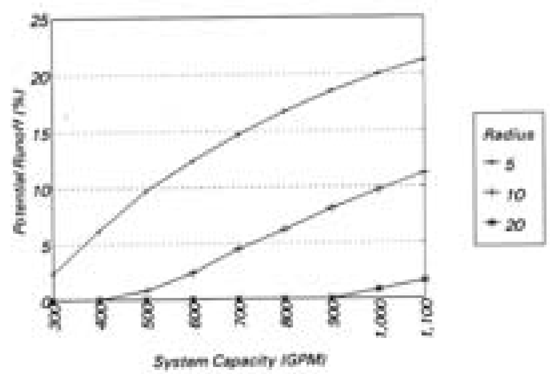

Figure 11. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.5 in.; App. Amt. – 1.0 in.; Intake Family – 0.3; System Length – 1,280 ft

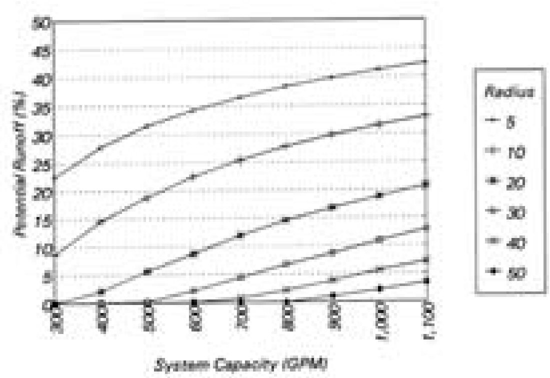

Figure 12. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.5 in.; App. Amt. – 1.5 in.; Intake Family – 0.3;System Length – 1,280 ft.

low holding capacity, high capacity becomes more important. For the high-capacity systems, the wetted radius should be 40 foot or greater (Figure 13). Increasing application depth (Figure 14) would require wetted radius of over 50 feet at very high capacity. Increasing surface storage (Figures 15 and 16) has the same effect as with lower intake family soils in that a smaller wetted radius can be used with additional capacities. Although the 5 and 10 foot radius-of throws still produce generally unacceptable runoff percentages.

NRCS Soil Intake Family 1.0. Figure 18 shows that for a high intake soil (1.0 family) a wetted radius of 20 feet or greater can be used for any capacity, even with low surface storage (0.1 inch), and a 10-foot radius package would be possible with limited capacity systems. Increasing surface storage (Figure 18) illustrates a condition where a 10-foot radius has wider applications and the 5-foot radius could be used with limited runoff problems for limited irrigation capacity systems.

Potential Runoff Along the System Length

The weighted average of the potential runoff percentages along the system was used to create the figures. The estimated potential runoff percentages along the length of the system increases with the distance from the pivot point. Figure 19 shows the potential runoff percentages for various distances along a 1,280 foot system using a surface storage value of 0.3 inch, a 1.0 inch application amount, the 0.3 NRCS Surface Intake family, a 30-foot wetted radius, and a 600 GPM system capacity. This corresponds to a data point from Figure

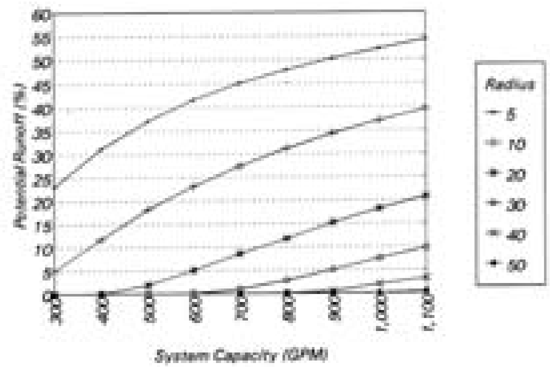

Figure 13. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.1 in.; App. Amt. – 1.0 in.; Intake Family – 0.5;System Length – 1,280ft.

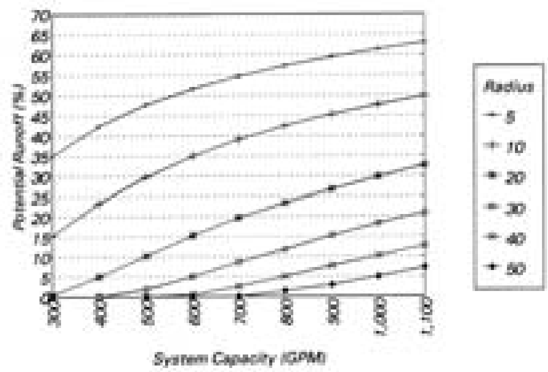

Figure 14. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.1 in.; App. Amt. – 1.5 in.; Intake Family – 0.5; System Length – 1,280ft.

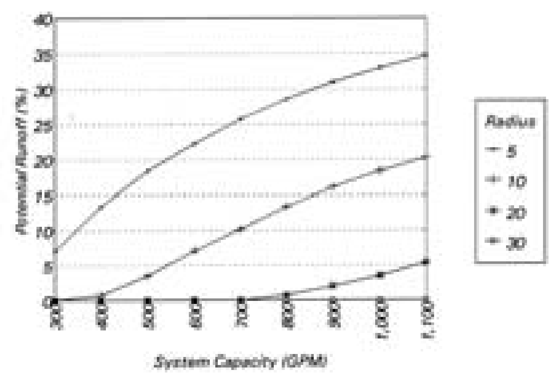

Figure 15. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.3 in.; App. Amt. – 1.0 in.; Intake Family – 0.5; System Length – 1,280 ft.

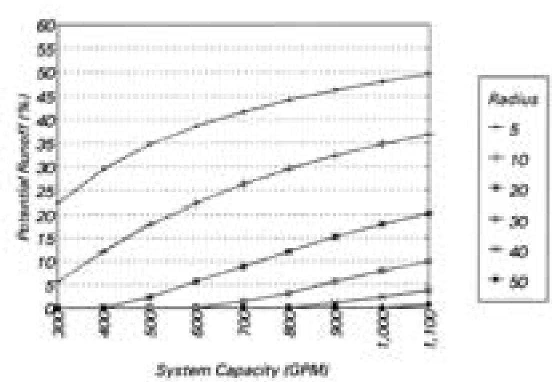

Figure 16. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.3 in.; App. Amt. – 1.5 in.; Intake Family – 0.5; System Length – 1,280 ft.

9. The potential runoff percentage for these conditions is approximately 5 percent. Figure 19 shows that actual runoff percentage values begin increasing at 768 feet from the pivot point and is estimated to be over 12 percent at the outer edge. This illustrates that while the series of figures using the weighted average runoff are useful as guidelines, they do not fully represent all considerations associated with managing runoff. Runoff control problems are generally at the outer edge of the system and estimating the magnitude at this point would require a full analysis. This analysis also assumes uniform field conditions, therefore fields with slope or soil changes are not adequately covered by a single analysis.

Summary

CPNOZZLE, a computer software program that estimates irrigation runoff, was used to develop a series of runoff charts. Surface storage, soil intake, application depth, wetted radius and system capacity were the variables used for runoff predictions. As expected, tight soils with little surface storage have high runoff potential, even if system capacity is limited. For these soils, nozzle package and capacity options are limited. Options on nozzle packages and irrigation capacity increase with increasing soil intake and surface storage. Results show, however, situations where runoff could be a problem and can exist under any nozzle package. Results presented are also for the average weighted runoff for the entire system. Unacceptable runoff amounts may occur at the outer edges of the system even if the over-all average is low. The model also assumes uniform field conditions. Final design and package selections must consider individual field characteristics.

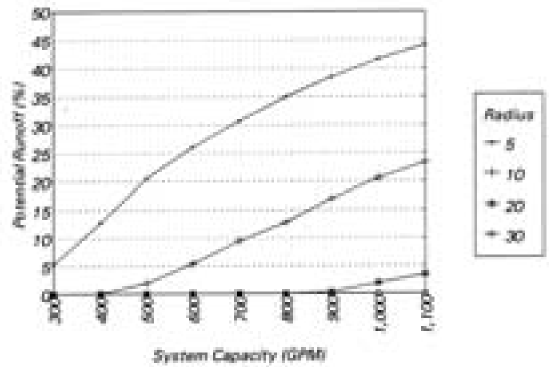

Figure 17. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.1 in.; App. Amt. – 1.0 in.; Intake Family – 1.0; System Length – 1,280 ft.

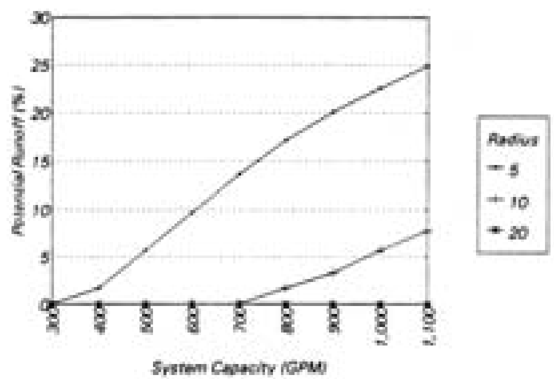

Figure 18. Predicted Irrigation Runoff Potential for Various System Capacities and Wetted Radius. Storage – 0.3 in.; App. Amt. – 1.0 in.; Intake Family – 1.0; System Length – 1,280 ft.

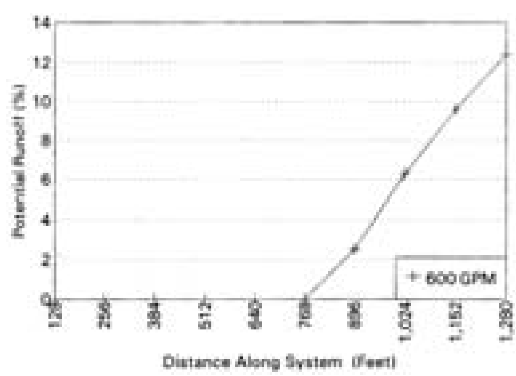

Figure 19. Predicted Irrigation Runoff Potential for Various Distances Along the System. Storage – 0.3 in.; App. Amt. – 1.0 in.; Intake Family – 0.3; Wetted Radius – 20 ft.

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