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G98-1372 Management Recommendations for Blocked-end Furrow Irrigation

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Management Recommendations
for Blocked-end Furrow Irrigation

**Proper blocked-end furrow irrigation management practices can minimize water application,
irrigation costs and the leaching of agri-chemicals below the root zone.**

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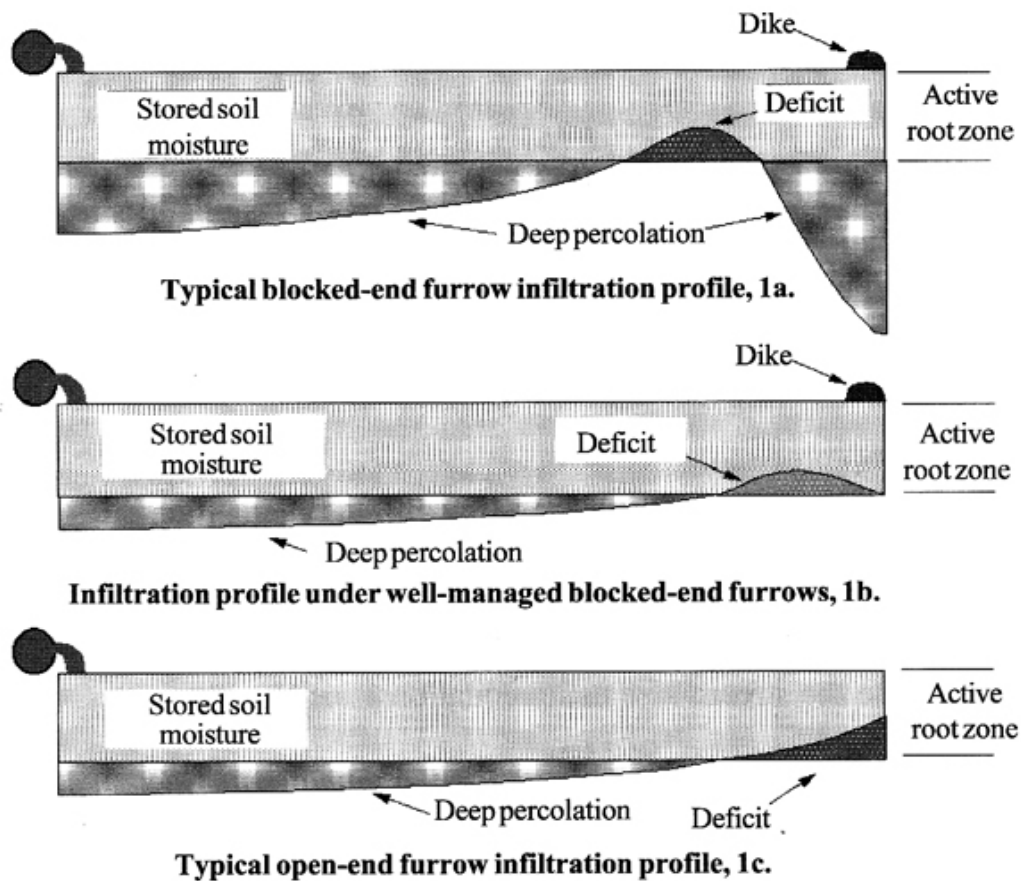*Dean E. Eisenhauer, Professor, Biological Systems Engineering*

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The goal of every irrigator should be to apply the right amount of water uniformly to meet crop needs. To do this, irrigators need to know how much water is applied and where it goes. In other words, they need to know how uniformly the irrigation water infiltrates into the soil profile. Achieving a uniform water application is not easy when using furrow irrigation. However, with a better understanding of how irrigation system management affects water distribution and a willingness to make management changes, the uniformity and efficiency of most systems can be improved. This NebGuide outlines the use of the "cutoff ratio" to improve irrigation management when blocked-end furrows are used.

In Nebraska, diking or blocking the lower end of a field is a common practice on gently sloping (less than 0.01 ft/ft or 1 percent) furrow irrigated ground. This is especially true when a runoff-recovery system is not in place. Nebraska law prohibits irrigation water runoff if the source is groundwater. Blocking furrow ends can result in non-uniform water distribution, agri-chemical leaching and excessive deep percolation at both the upstream and downstream ends of the field. Management practices, soil characteristics and the field slope all impact these problems. *Figure 1 (a)* illustrates a typical blocked-end system water distribution pattern (infiltration profile), *(b)* a well-managed blocked-end system infiltration profile and *(c)* a well-managed open-end or conventional furrow irrigation system infiltration profile.

As with any irrigation system, infiltration below the active crop root zone results in deep percolation and the potential leaching of agri-chemicals that may eventually contribute to groundwater pollution. When using a blocked-end furrow irrigation system, percolation below the active root zone can occur at any point in the field. Excessively long application (set) times, large stream sizes (stream size is the amount of water flowing into an individual furrow), low infiltration rates or any combination of these can cause excessive ponding at the downstream end of diked fields. It is not uncommon to find water ponded 1 foot deep just upstream of the dike. With the slopes commonly seen in blocked-end furrow systems, this ponded water may extend upstream of the dike as much as 500 feet. The deep percolation associated with blocked-end furrow irrigation raises

concerns regarding the contribution of these systems to excessive levels of nitrate and other agri-chemicals in groundwater. Effective irrigation management techniques along with the proper timing of agri-chemical applications will help minimize potential groundwater contamination.

Typical blocked-end furrow infiltration profile, 1a.

Infiltration profile under well-managed blocked-end furrows, 1b.

Typical open-end furrow infiltration profile, 1c.

Figure 1. Infiltration profiles under blocked-end and conventional furrow irrigation.

Evaluating and Changing Practices

The correct amount of water to apply at each irrigation depends on many factors, including the amount of soil water used by the plants between irrigations, the water holding capacity of the soil and crop root depth. Efficient irrigation is achieved by almost filling the crop root zone with each irrigation. In general, apply water when the crop has used about one-half of the available water in the active root zone. If possible, leave storage room in the soil water reservoir for 0.5 to 1.0 inches of rainfall. One way to do this is to irrigate every-other furrow, leaving one furrow dry and providing room for rainfall storage. NebGuide G97-1338, *Managing Furrow Irrigation Systems* discusses every-other furrow irrigation in more detail. The first irrigation often occurs when roots have penetrated about 18 to 24 inches. For the first irrigation, a small or light application will refill the active root zone. In Nebraska, off-season precipitation usually replenishes the soil profile below this depth and additional moisture is not needed for early plant development. Usually, on medium-textured soils, 1.5 to 2.0 inches of water is all that is necessary to replenish the soil moisture in the top 18 to 24 inches.

To evaluate irrigation practices, estimate the gross depth and uniformity of application. The gross depth of water applied can be figured by first calculating the size of the stream flowing into each furrow. Divide the pump discharge (in gallons per minute, gpm) by the number of furrows flowing to determine the individual stream size (gpm per furrow):

$$Stream\ size = \frac{Pump\ discharge\ (gpm)}{Number\ of\ furrows\ flowing} \quad (1)$$

Note: this calculation is only accurate if leaks in the delivery system are minimal. A key to good management is to maintain pipes and ditches to minimize leaks or seepage. Once the furrow stream size is known, the average gross depth of water applied over the field area (inches of water) can be calculated using:

$$Gross\ depth\ (inches) = \frac{1,155 \times Stream\ size\ (gpm) \times Time\ water\ applied\ (hours)}{Furrow\ length\ (ft) \times Watered\ furrow\ spacing\ (inches)} \quad (2)$$

For example, consider the following situation:

Pump producing 960 gpm
Set size (number of furrows flowing) = 100
Water is applied for 12 hours
Rows are 1,320 feet long
Watered furrow spacing is 30 inches

Calculate the stream size using equation 1 as:

$$Stream\ size = \frac{960\ gpm}{100\ furrows} = 9.6\ gpm\ per\ furrow$$

Calculate the gross depth applied using equation 2 as:

$$Gross\ depth\ (inches) = \frac{1,155 \times 9.6\ gpm \times 12\ hours}{1,320 \times 30\ inches} = 3.4\ inches$$

Having this kind of information about your irrigation system will help you to make better management decisions and improve overall irrigation performance. To avoid completely refilling a fully developed root zone on sandy-textured soils, the gross application amounts should not exceed 1.5 to 2 inches, and should not exceed 2.5 to 3 inches on medium- to fine-textured soils.

Applying the appropriate average application over the field area does not, however, guarantee efficient irrigation. Water must also be uniformly applied from the upstream to the downstream end of the field (*Figures 1b and 1c*). Crop yields can be reduced on both ends of the field if excessive deep percolation occurs. Set time and stream size are perhaps the most "manageable" irrigation parameters, and those that accommodate the field conditions will improve irrigation efficiency and water distribution uniformity.

Set Time and Stream Size

The appropriate combination of set time and stream size depends on a field's slope, intake rate and length of run. The combination of set size (stream size) and set time must be balanced to achieve efficient, uniform irrigation and to limit deep percolation. Having too many gates open (small stream size) slows the advance rate of the water. Using too long a set time can result in significant ponding upstream of the dike. Any combination of set time and stream size resulting in excessive deep percolation should be avoided.

The *cutoff ratio* is a management parameter that helps irrigators determine the proper set-size set-time balance and evaluate system performance. It is the ratio of the time required for water to advance to the end of the field to the total set time:

$$Cutoff\ ratio = \frac{Average\ advance\ time}{Set\ time} \quad (3)$$

Average advance time is the average time it takes for water in the furrows being irrigated to move from the top to the bottom of the field.

Table I. Recommended cutoff ratios for blocked-end furrow irrigation systems.				
General slope description	*Slope percent*	*Clayey soils*	*Loamy soils*	*Sandy soils*
Low	0.1	0.95	0.85	0.70
Moderate	0.5	0.90	0.80	0.65
Steep	1.0	0.85	0.75	0.60

For blocked-end furrow irrigation systems, choosing the appropriate cutoff ratio depends on soil factors and field slope. *Table I* lists the target cutoff ratios for a number of soil/field slope combinations. For a specific field situation and irrigation set time, use the cutoff ratio to determine a desired average advance time. For example: on a loamy soil with average slope of about 1 percent and a set time of 12 hours, the desired average advance time should be about 9 hours (9 hrs = 0.75 x 12 hrs). If the current advance time is longer than the desired advance time, the easiest way to change it is to alter the furrow stream size (change the number of furrows flowing in each set). This will affect the cutoff ratio and the uniformity of water application. Keep this in mind: decreasing set size without altering set time will increase the gross application.

When selecting the furrow stream size, consider furrow erosion. In general, the maximum non-erosive stream size decreases as furrow slope increases. Estimate the maximum non-erosive stream size for a field by dividing 12.5 by the field's average percent slope:

$$Non\text{-}erosive\ stream\ size \square \frac{12.5}{Average\ field\ slope\ (percent)} \quad (4)$$

As a rule of thumb, your selected furrow stream size should be less than or equal to the result of equation 4, but still large enough to obtain relatively uniform water application. Another limit on furrow stream size is that most furrows cannot transport more than about 50 gpm without overtopping. Very small stream sizes may limit infiltration too severely and should also be avoided.

With the proper cutoff ratio and gross application, you can achieve uniform water application and minimize deep percolation. Experiment with different combinations of furrow stream size and set time to determine the optimum settings for a particular irrigation in a particular field. The best combination is the one that moves water to the end of the furrow within the requirements of the cutoff ratio, is less than the maximum non-erosive stream size and results in gross applications that are not excessive.

To demonstrate the use of equations 1 through 4 and the cut off ratio concept, consider an example where the first irrigation of the year has the following conditions:

Soil = Loam	Pump discharge = 1,000 gpm
Furrow length = 1,320 feet	Set size = 80 gates flowing
Set time = 24 hours	Observed average advance time = 21 hours
Watered furrow spacing = 60 inches (*every-other furrow irrigated*)	Average field slope = 0.5 percent

First calculate the observed cutoff ratio, furrow stream size and gross application:

$$Cutoff\ ratio = \frac{21\ hours}{24\ hours} = 0.88$$

$$Stream\ size = \frac{1,000\ gpm}{80\ furrows} = 12.5\ gpm\ per\ furrow$$

$$Gross\ depth\ (inches) = \frac{1,155\ x\ 12.5\ gpm\ x\ 24\ hours}{1,320\ ft\ x\ 60\ inches}\ \ 4.4\ inches$$

These calculations indicate two items to evaluate. First, the gross water application (4.4 inches) is quite excessive on a medium-textured soil. One way to decrease the gross application is to reduce the set time. Second, according to *Table I*, the cutoff ratio is too high and should be reduced (from 0.88 to 0.80). Increasing the furrow inflow rate or stream size is one way to do this. To improve the cutoff ratio and increase irrigation uniformity, increase the rate at which water advances through the field. Decreasing the set size (opening fewer gates per set) increases the furrow stream size and more quickly moves water down the field.

Referring to the calculations shown in *Table II*:

- Using the *Desired cutoff ratio* of 0.80 (*Table I*).
- We determine a *New advance time* of about 10 hours.
  Note: The set time has been decreased from 24 hours to 12 hours.
- We find the *Advance time ratio* by dividing the *New advance time* by the *Original advance time* yields a value of about 0.5.
- Having found the *Advance time ratio*, and knowing our soil texture, we can enter *Figure 2* and find the corresponding *Furrow ratio*. The *Furrow ratio* is the *New number of gates* to be opened divided by the original number of gates opened. In this example, the *Furrow ratio* is 0.65.
- The *New number of gates* to open is 52.

In this example, reducing the gross water application was also a goal. In order to obtain a real reduction in gross application, the ratio of original set time to new set time (24 hours ÷ 12 hours = 2) must be greater than the ratio of original number of gates opened to the new number of gates opened (80 gates ÷ 52 gates = 1.54).

Table II. Example showing how set time and cutoff ratio are used to improve the performance of a furrow irrigated set.			
Parameter	Calculation method	Our example	Your example
Desired cutoff ratio	Table I	0.80	
New advance time	Desired cutoff ratio x New set time	0.80 x 12 = 9.6 hrs	
Advance time ratio	New advance time ÷ Old advance time	10 ÷ 21 = 0.48	
Furrow ratio	Figure 2	0.65	
New number of gates	Old number of gates x furrow ratio	80 x 0.65 = 52 gates	
New stream size	Equation 1	1,000 ÷ 52 = 19.2 gpm	
New gross application	Equation 2	(1,155 x 19.2 x 12) ÷ (1,320 x 60) = 3.4 in	

The results in *Table II* indicate furrow stream size was increased from 12.5 gpm to 19.2 gpm per furrow, and gross water application depth was decreased from 4.4 inches to 3.4 inches. For loamy soils, a 3.4 inch application is not unreasonably large and represents a 23 percent reduction when compared to the original conditions. Further, the new stream size of 19.2 gpm is non-erosive given the 0.5 percent field slope (19.2 gpm □ 12.5 , 0.5 percent). In this example, we have demonstrated: 1) how to improve the uniformity of irrigation by using the cutoff ratio; and 2) how to reduce the gross depth of application by reducing the irrigation set time proportionately more than the reduction in set size.
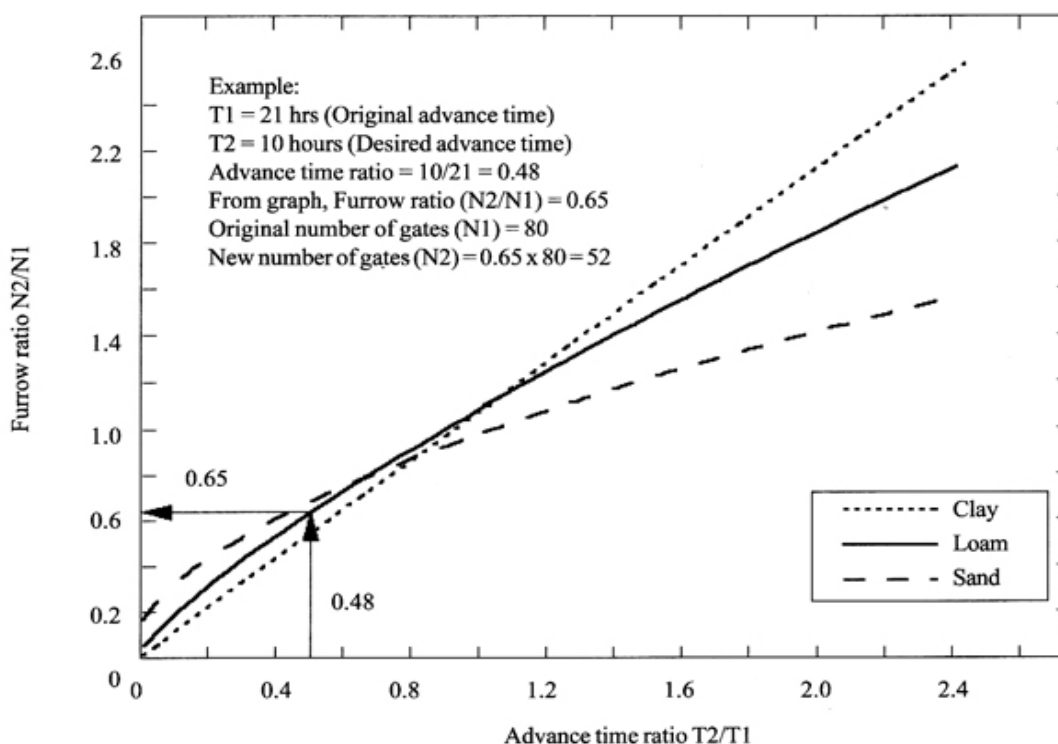
Figure 2. Graph for determining proper set size.

Summary

Regardless of whether you dike or block the ends of your furrows, or if you irrigate using every or every-other furrow, soil texture, slope and surface conditions (whether the furrow is smooth or rough, wet or dry) all influence how quickly water advances down the furrow. The speed of advance is directly related to how uniformly irrigation water is distributed within the soil profile. The soil infiltration rate is also affected by soil surface conditions. If the soil was recently tilled and the surface is loose, the infiltration rate may be very high. On the other hand, if heavy rains, water flowing over the surface or a furrow-packing implement have packed the soil, the infiltration rate may be reduced. Infiltration rates vary from one irrigation to the next and from season to season. To optimize irrigation performance, soil surface conditions should be evaluated prior to all irrigations and the set size and corresponding stream size chosen accordingly. The Cutoff ratio has been designed as a tool to assist you in making set time and stream size irrigation management decisions. Visit your local Cooperative Extension office for the latest printed and computer-based aids using the cutoff ratio concept.

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