Section K

Managing furrow irrigation

The goal of every surface irrigator should be to apply the right amount of water as uniformly as possible to meet the crop needs and minimize leaching of nitrogen from the root zone. Achieving a uniform water application is not easy when using furrow irrigation. To do the job right, irrigators need to take into account how much water is applied and where the water goes (how uniformly water infiltrates the soil profile). With a better understanding of how furrow irrigation management affects water distribution and a willingness to make management changes, furrow irrigation uniformity and efficiency can be improved on almost any field.

Figure K-1. Typical gated pipe furrow irrigation system.

Advance time

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 **advance time** is the number of hours needed for water to reach the lower end of a set. If the advance time is long (i.e., almost as long as the total set time), there may be uneven infiltration along the row and excessive deep percolation at the head of the field (*Figure K-2a*). Shorter, more suitable advance times yield a more uniform infiltration profile along the length of the furrow (*Figure K-2b*).

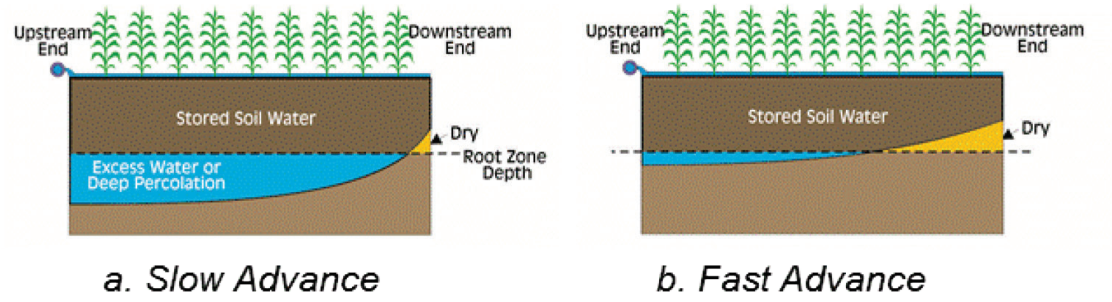

Figure K-2. Soil water infiltration pattern for furrow irrigated fields with slow (a) and fast advance (b) times.

Advance Time is the number of hours needed for water to travel from the delivery point to the lower end of a field.

Set Time is the number of hours water is delivered to the head end of the field.

Stream Size is the water flow rate distributed from each individual gate or siphon tube into an irrigation furrow and is calculated by dividing the water delivery rate (gpm) by the number of gates open.

Set Size is the number of gates or syphon tubes that are actively distributing water to furrows.

Set size and set time

It's easy enough to increase or decrease furrow advance time by changing the number of gates opened. Changing the **set size** has a direct impact, not only on how fast water advances down the field, but more importantly, on the total amount of water applied.

Prior to irrigation, the soil surface conditions should be evaluated and the set size and corresponding **furrow stream size (gpm/furrow)** chosen accordingly. Using a small set size (relatively few gates open) and a long set time may cause excessive runoff. On the other hand, too many furrows running will slow the water's advance rate, resulting in excessive deep percolation, the situation shown in *Figure K-la*. To apply water uniformly and efficiently, surface irrigators must be willing to change both stream size and set time so that water advances down the field rapidly so the depth infiltrated is more uniform from one end of the field to the other (*Figure K-1b*).

Managing runoff

To adequately irrigate the lower end of the field, water must be present at the lower end long enough to get a reasonable amount of water into the root zone. With furrow irrigation this generally means that some runoff is necessary. Nebraska law makes it illegal for water pumped from groundwater to leave the farm. Runoff can be handled in several ways including installation of reuse systems to pump it back to the top of the field, pumping runoff to another field, or blocking the end of the furrow to hold it at the end of the row.

Runoff management greatly affects the amount of water lost to deep percolation, and therefore, the nitrate leaching that results. If irrigation is to be efficient, the time that water takes to get through the field needs to be adjusted according to how the runoff is managed.

Reuse System consists of a reuse pit or sump to collect runoff volume and a pump to distribute the runoff water to another portion of an irrigated field.

Systems with reuse system

One way to improve on-farm surface irrigation efficiency is to **reuse** the runoff. Runoff is collected and either diverted to another field, or pumped back to the top of the same field. If runoff is reused, larger furrow stream size can be used to advance water through the field faster. This will provide more uniform infiltration without wasting water.

If the irrigation is to be relatively uniform, how long should it take to get water to the lower end of the field? When runoff is reused, apply the less-than-half rule to obtain uniform application: The average furrow advance time should be less than half of the total set time. For example, if the total set time is 12 hours, the advance time should be 6 hours or slightly less.

For the first irrigation of the season some adjustments are needed. If the irrigator normally uses 12-hour set times, shorter set times should generally be used during the first irrigation to avoid uniformly over-irrigating the whole field. The active root zone is very shallow early in the season. Water storage capacity in this shallow depth is small.

Furthermore, the infiltration rate is highest during the first irrigation, so less time is needed to refill the root zone. The easiest adjustment is to shorten the set time as compared to later irrigations. Turning off the water two hours after runoff begins will result in the advance time being 65% to 75% of the total set time. The less-than-half rule will be easier to follow as the season progresses and advance times are faster as furrows become smoother.

Three-quarter-plus rule is a furrow irrigation management criterion to improve water application efficiency by setting the stream size so that water advances to the end of the furrow in three-fourths of the overall set time.

Systems without reuse system

When no runoff reuse system is available, systems should be managed to minimize runoff losses at the lower end of the field. If there is no reuse system, apply the **three-quarters-plus rule** to estimate the advance time. Water should get to the end of the field in about three-fourths of the total irrigation set time. This rule applies throughout the growing season, both for early season and later irrigations. For example, if you run 12-hour irrigations, your set size should be adjusted so that water reaches the end of the field in an average of nine hours. Although a nine-hour advance time follows the three-quarters-plus rule, a 12-hour set time may still over-irrigate the entire field, resulting in very low efficiency. For the first irrigation of the season when the root zone is shallow, 12-hour sets are likely too long on quarter-mile rows.

Blocking the lower end of the field is one method used to retain water that would otherwise become runoff. If too much water accumulates at the blocked end, nitrate leaching and excessive deep percolation can result (*Figure K-3,* top). If blocked-end furrows are used, apply the three-quarters-plus rule for advance time, as discussed earlier. By properly managing blocked-end furrow irrigation, deep percolation cannot be eliminated, but it can be minimized (*Figure K-3* bottom).

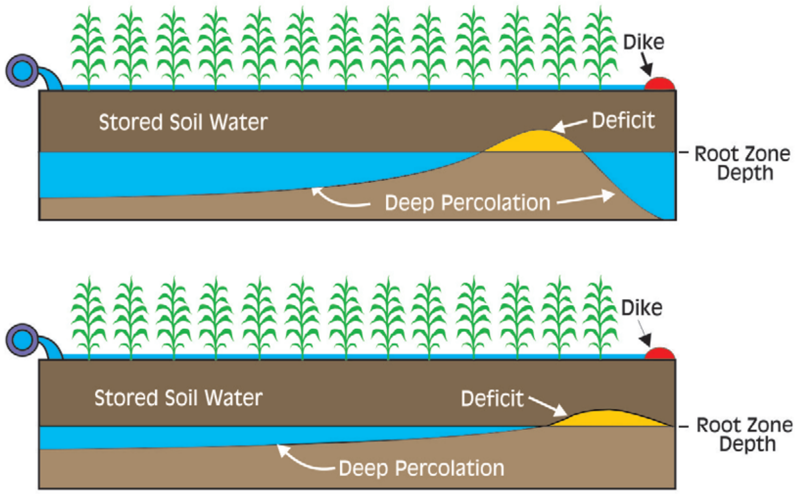

Figure K-3. Infiltration profiles under conventional furrow irrigation with blocked-end furrows (top) and three-quarter-plus advance rule (bottom).

Runoff is not always a water loss or a waste. When irrigation water is supplied from a stream by a canal or pipe system or by direct pumping from the stream, runoff from furrow-irrigated fields in the river valleys actually becomes return flow to the river or canal system. The runoff water is available for diversion again downstream. (It may, however, contain increased levels of nutrients and pesticides.) This process of returning and reusing runoff water occurs on a continual basis in the river valleys, making irrigation more efficient across the system as a whole. Furrow stream size and set times must still be managed to achieve uniform irrigation.

Long rows and long set times

Half-mile rows can be irrigated with reasonable uniformity on fine-textured soils with low infiltration rates. However, irrigation can also be very inefficient under such conditions, especially if 24-hour sets are used. When water is on the upper part of the field for 24 hours and on the lower end for only two or three, there will be a substantial difference in infiltration even if infiltration rates are low. In most cases, irrigation is more efficient if a larger furrow stream size is used and set time is cut to 12 hours or if the field is split into two quarter-mile runs. When 24-hour sets are used on medium-textured soils, excess water application is unavoidable along most of the length of the row. On very fine-textured soils, the problem may not be as serious except for the first irrigation of the season.

Every-other-furrow irrigation

When irrigation is required, it may be important to irrigate the entire field as quickly as possible. **Irrigating every other furrow supplies water to one side of each furrow ridge, but the wetting pattern is usually much more than that.** This technique lets the irrigator apply water to more surface area in a given amount of time than does irrigating every furrow. Research indicates that every-other-furrow irrigation results in yields comparable to those achieved when every furrow is irrigated.

With every-other-furrow irrigation, water applications may be reduced by 20 to 30%. Infiltration is not reduced by one-half as compared to irrigating every furrow, because of increased lateral infiltration when watering every other furrow. Lateral water movement in the field can be checked using a soil probe in the dry rows. *Figure K-4* shows the infiltration pattern for different soil textures. On coarser textured soils, the wetting pattern does not move as far laterally as it does on medium- and fine-textured soils. In this case every-other-row irrigation may be effective only on narrower row spacings. An added benefit of irrigating every other furrow is that by applying less water per irrigation, more storage space is available for precipitation after an irrigation event.

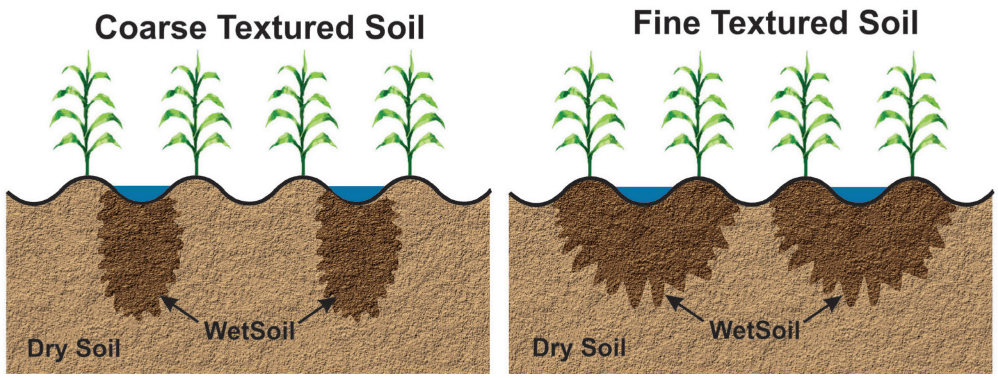

Figure K-4. Every-other irrigated furrow infiltration patterns on coarse and fine textured soils.

Surge irrigation

Surge irrigation (*Figures K-5* and *K-6*) **is the practice of applying water to two set of furrows intermittently in a series of on-off periods, called cycles.** This sequence is repeated several times until the irrigation is completed. The length of time water is applied to a set of gates (the cycle time) is increased automatically by the surge valve. After water has advanced to the end of the field and the advance phase is complete, cycle times are decreased and the "soak phase" (or cutback) begins. Research has documented average reductions in advance time of 30% when using surge valves compared to conventional continuous flow furrow irrigation, especially during the first irrigation event.

Figure K-5. Typical surge valve installation in the Platte Valley of Nebraska.

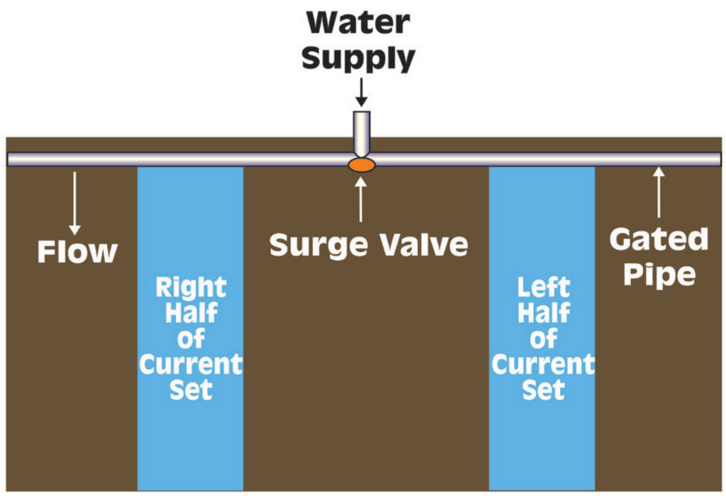

Figure K-6. Typical surge irrigation field layout.

Remember that in Section C we discussed how as the length of infiltration time increased soil infiltration rate decreased. The wetting and drying cycles take advantage of the same reduction in water infiltration rate. Because less water infiltrates in the portion of the furrow that was previously wetted, two things happen. First, there is more water remaining on the surface, which will speed the advance to the end of the field. Second, the reduction in infiltration decreases the amount of deep percolation that will occur at the top end of the field when compared to conventional irrigation practices (*Figure K-7*).

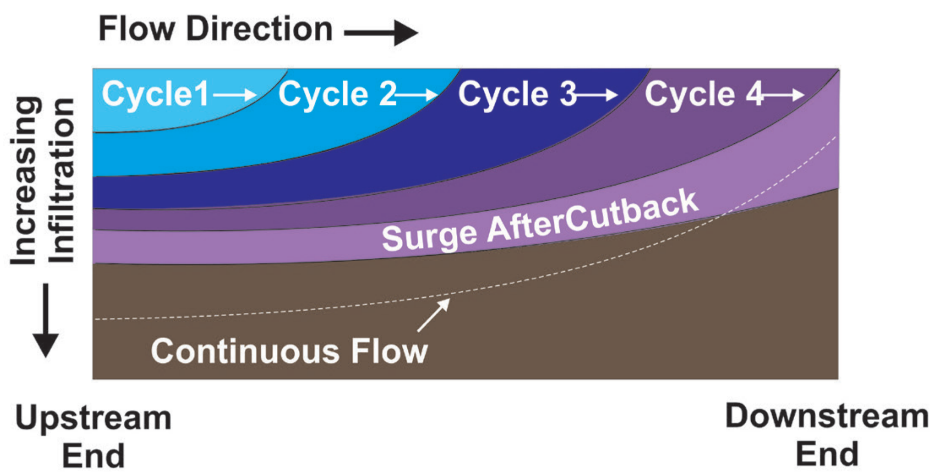

Figure K-7. Comparison of infiltration profiles for surge and continuous flow furrow irrigation systems.

Leaky gates and gaskets

Gated pipe irrigation systems with worn and/or broken gates and gaskets often leak 10 to 30% of the water pumped through them. In Nebraska, some extreme cases of water loss have been observed, where 40 to 60% of the water has leaked out before reaching the set being irrigated. Because some of the water leaving the well head does not reach the desired set, extra water must be pumped to adequately irrigate the crop. Extra water means extra pumping costs. Water losses that result from leaky gates and gaskets decrease irrigation efficiency. Crops cannot use water that never reaches the active root zone.

Another water management concern about leaky gates and gaskets is excess leaching. Some leaching will generally occur at the upper end of rows under furrow irrigation. However, leaks may worsen the problem by speeding the loss of nitrate during early irrigation events. This can reduce yield at the top of the field. Whether it substantially increases the total nitrate loss for the field depends on how much leakage occurs and how far into the field it runs before it soaks into the soil.

Losses in the delivery system also decrease overall system capacity. This translates into smaller sets. For example, assume a 1,000 gpm well loses 20% (200 gpm) through leaky gates and gaskets. If a furrow stream size of 20 gpm is needed and all 1,000 gpm were available, 50 gates would be flowing. However, with a 200 gpm loss, only 800 gpm are available so only 40 gates can be opened. Smaller sets mean more sets per field. More sets per field mean more time and labor spent changing sets, and more time to get over the field. In this example, a field with 400 furrows would require two additional sets to compensate for the 20% leakage loss. The amount of gate and gasket loss can be checked by using a portable ultrasonic meter to measure flow on the pipeline near the pump and again just upstream of the first gate open on the most distant set from the pump.

Land grading

Land grading benefits irrigators by removing one source of variability in a field. Depressions or reverse grades harm surface irrigation performance by increasing irrigation water advance times. In general, longer advance times mean less uniform and less efficient irrigations. If a field has low spots or reverse grades, water must fill the low spot before advancing past it. Time lost in filling the depression or building up the water level in rows to get over a high spot increases advance time. If the reverse grade is large enough, adjacent furrow ridges may be overtopped before water advances down the furrow. This causes some furrows to be over-irrigated in the middle of the field and under-irrigated on the lower end. The result is excess leaching along part of the row and, possibly, water stress and yield reduction near the end. The area of the field where ponding occurred may also show a yield reduction because of excess leaching, oxygen deprivation in the root system, and/or denitrification.

Reverse grades and low spots can significantly harm surge irrigation performance. During surge irrigation water does not continuously flow down the furrow — it comes in surges. As a result, the furrow stream may never completely fill a depression or accumulate enough water to overtop a reverse grade and the furrow advance will never get past this point, especially in lighter soils.

The land grading process typically requires moving large amounts of soil from one location to another in the field. The equipment used for this process is heavy and even though laser equipment tends to reduce the number of trips across the field, soil compaction is difficult to prevent. Thus, while the land grading process eliminates many factors that reduce water application uniformity, grading creates different levels of compaction, and could expose subsoil that will force the field manager to adjust irrigation management.

Soil compaction

Soil compaction can significantly influence furrow irrigation effectiveness. The best example of this is the obvious difference in irrigation water advance rates between "soft" and "hard" rows. In "hard" furrows, those compacted by machinery traffic, infiltration is slow and advance rates are very quick. Even if the flow in the hard furrow is reduced so that water advances at the same rate as the soft furrow, infiltration in the soft row may still be 50 to 100% more than in the hard furrow (*Figure K-8*).

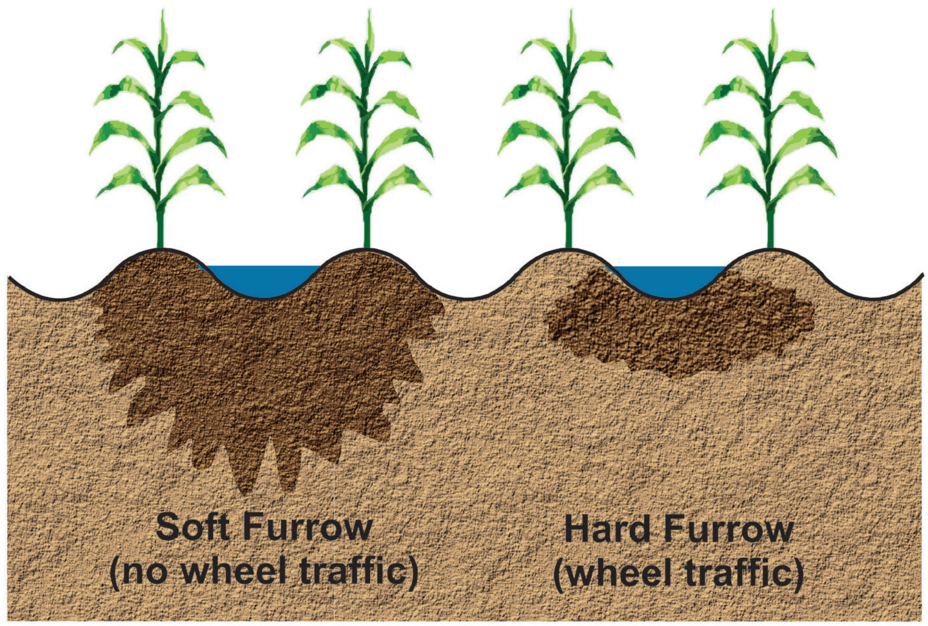

Figure K-8. **Differences in water infiltration patterns under non-wheel track and wheel track furrows.**

This row-to-row difference complicates water management, especially for every-other-row irrigation. It is important to check water penetration after an irrigation to see if the hard rows got wet deep enough. If not, the "dry" furrows and "irrigated" furrows should be alternated from one irrigation event to the next. Watering only soft rows may be one option to avoid the hard row problem. However, this is not an option where dual wheeled equipment is used or where grain carts have compacted rows during harvest. In those cases every other row will not be soft.

In general, extra runoff from hard rows is not a major problem if a reuse system is used.

When no reuse system is in place, the extra runoff increases losses and becomes a headache with blocked-end furrows. More attention should be paid to checking rows and adjusting gates if a large build-up of runoff water behind the end-of-field dike is to be avoided.

Long-term infiltration changes under ridge-till

Many furrow irrigators have switched to ridge-till. It has many advantages in terms of doing field operations in a timely manner and in being able to plant when surface moisture is not optimum. The experience of many producers is that infiltration rates tend to go up after a few years of consistently using the ridge-till system. This has been a great improvement on soils with low infiltration rates where just getting water into the ground had been a problem. However, on soils that had moderate to good infiltration rates before ridge-till, irrigators find that it is becoming more difficult to get water through the field quickly. Some argue that the increase in residue in the furrow greatly retards water flow. That can certainly be a part of the problem. However, there is often another factor that is equally or more important.

After 10 to 12 years of ridge-till, the organic matter increases enough in the top few inches of the soil that the surface opens up and stays more open after the first irrigation. The infiltration rate may increase by 50 to 150% in comparison to a conventional disk-plant system. The increased infiltration slows the advance in the furrow and puts a lot more water in the soil in the upper half of the field.

There is no easy solution to this problem. The most obvious solution (up to a point) is to reduce the number of rows per irrigation set. This increases the gallons per minute per furrow and moves water through the field faster. However, if a smaller set is used, the set time must be shortened, or the entire field will still be over-irrigated. A few farmers have tried row packers. This helps some for the first irrigation, but the packing effect may not carry through the entire season. On some soils, the infiltration rate has become so high that farmers have of necessity switched to center pivots.

More Extension Publications (available at ianrpubs.unl.edu)

G1720, Firming Irrigation Furrows to Improve Irrigation Performance

G1870, Fundamentals of Surge Irrigation

G1338, Managing Furrow Irrigation Systems

G1721, Management Recommendations for Blocked-end Furrow Irrigation

G1868, Surge Irrigation Management

G1869, Surge Irrigation Field Layouts

G1866, Using Polyacrylamide to Reduce Soil Erosion