

ON-FARM IRRIGATION SYSTEM MANAGEMENT

FURROW IRRIGATION SYSTEMS

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INTRODUCTION

In another section you saw the importance of planning for the primary water supply. Assuming that you have the water supply committed, the next step is to use it. The goal is effective, efficient irrigations.

- Effective irrigations produce the desired crop response.
- Efficient irrigations make the best use of available water.

Effective, efficient irrigations are the result of knowing **WHEN** to irrigate, **HOW MUCH** to irrigate, and **HOW** to irrigate.

WHEN to irrigate is an agronomic decision, based on how you want the crop to develop.

HOW MUCH to irrigate is the Soil Moisture Deficit, SMD, in the current effective root zone. You must know how much water is needed to take the soil back to field capacity.

HOW to irrigate is not just knowing how to set a siphon tube or hook up a sprinkler pump. Knowing **HOW** to irrigate is knowing how to apply water evenly (a high distribution uniformity) with control of the total application (a high irrigation efficiency).

This section will look at three aspects of furrow irrigation systems . . .

1. The important operational characteristics of each system will be described
2. How to apply water evenly (and get good distribution uniformity) with each system will be explained.
3. How to control the total amount of water applied (and get good irrigation efficiency) with each system will be explained.

The two measures of irrigation performance are distribution uniformity (DU) and irrigation efficiency (IE). DU is a measure of how evenly water is applied. You must be able to apply water evenly before you can have high efficiencies. IE is a measure of how much applied water ends up in the effective root zone available for crop use (or is beneficial in maintaining a salt balance).

With furrows there are three aspects to good DU, down-row uniformity, cross-row uniformity, and general soils variability.

- Good down-row uniformity is the result of getting water to the end of a furrow quickly. Recommendations are that water should get to the end of a furrow in 1/3 to 1/2 the set time for medium loams and 1/4 to 1/3 with coarse soils. For very heavy, cracking clays, up to 2/3 of the set time may be okay.
- Cross-row uniformity is a problem of differential compaction of the furrows

by tractor traffic. The infiltration rates are changed thus, some furrows take water faster than others. You may want to irrigate the field in two sets, one in the wheel-rows, one in the off-rows.

- You can't do much about general soils variability. Surge irrigation may be helpful to get water across a field that is streaked badly.

Tailwater reuse systems are highly recommended. They make it easy to manage the fast advance needed for high down-row uniformity.

Preplanning an irrigation is always a good practice. Know the soil moisture depletion and then compare how much water is to be delivered (the furrow flow rate times the set time divided by the furrow area).

DISTRIBUTION UNIFORMITY AND IRRIGATION EFFICIENCY

Distribution uniformity, DU, is a measure of how evenly water infiltrates across a field. If twice as much water infiltrates in one part of the field as in another, that is bad DU. DU's are expressed as a percentage. 100 percent DU is impossible but means that the same amount of water was infiltrated all across the field.

HOW to irrigate also means controlling the total amount of water applied. Irrigation efficiency, IE, is a measure of how much water allocated to a field ends up in the effective root zone, available for crop use. ("Allocated" water is all water delivered except surface runoff that is used on another field.) Irrigation efficiencies are also expressed as a percent.

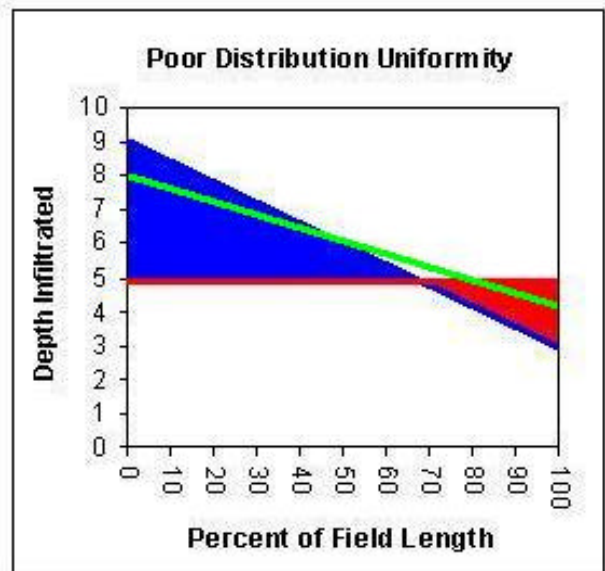
A 100 percent IE would mean that all water that was delivered to a field and was not

saved runoff, soaked into the soil and stayed in the effective root zone.

A 50 percent IE means that only half of the water that was delivered and not saved runoff, soaked into the ground and stayed in the effective root zone. The other half was deep percolation or tailwater that was not saved for reuse.

Again, distribution uniformity is a measure of how evenly irrigation water soaks into the soil. Irrigation efficiency is a measure of how much water that is applied to a field, and does not become saved tailwater, ends up in the effective root zone.

There are two relationships between DU and IE, explained in figures below. In the figures, the thick red line depicts the depth of the actual soil moisture deficit at irrigation. The blue line depicts the actual depth of irrigation at various points in the field. The blue area depicts deep percolation. The red area depicts under irrigation. The green line shows the infiltration of water with a 75% DU rather than the blue line with a 62% DU, when both applied the same average depth of water.



You must have good Distribution Uniformity before good Irrigation Efficiency. The figures above show that without good DU you will either cause excessive deep percolation (the blue area) or underirrigate part of your field (the red area). Note that if you could have applied about 0.5" less, with the improved DU, and still have less deep percolation, less underirrigation and a higher efficiency. Underirrigation may result in a higher IE, but it is not an effective way of growing.

There are two important relationships between DU and IE. The first was demonstrated above. You need to have good DU before you can have good IE. You have to be able to apply water evenly before you can apply it efficiently. But good distribution uniformity is no guarantee of good irrigation efficiency. As seen in the figure above, a good DU allows a good IE, but you still must control the total amount applied.

Sprinkler and drip systems usually provide good DU. However, they are not automatically efficient. You could have a 100 percent DU, that is, apply the same amount of water all over the field, but apply twice as much water as needed, all over the field.

FURROW IRRIGATION SYSTEMS

An important characteristic of furrow systems is that the amount of water soaking into the soil during an irrigation is dependent on two factors, the "infiltration rate" of the soil and the "opportunity time" at any point in the field. Opportunity time is the time that water is on the soil surface soaking in, the time that the soil has the "opportunity" to infiltrate water.

The soil's infiltration rate is a measure of how fast water is soaking into the soil. Infiltration rates are described in terms of "inches per hour". An infiltration rate of 1 inch/hour

means that if you ponded a one-inch depth of water on a soil with that IR, it would take 1 hour for it to soak in completely. Infiltration rates change constantly during an irrigation.

Remembering the [relationship between DU and IE](http://www.waterright.org/site2/advisories/duie.asp) (<http://www.waterright.org/site2/advisories/duie.asp>), you have to get good DU first. With furrow irrigation systems, there are three factors to consider for achieving high distribution uniformities . . .

- Down-row uniformity is a measure of uniformity from the top to the bottom of any one furrow. If 8 inches of water soaks in at the top of the furrow and only 4 inches at the bottom, that is bad down-row uniformity. Given a homogenous soil (no streaking), down-row uniformity depends on the difference in opportunity time from the top to the bottom of the furrow. [Land leveling](#) is very important to achieving high down-row uniformity.
- Cross-row uniformity is a measure of uniformity between adjacent furrows. Extending the example of down-row uniformity, assume that the next furrow soaked in six inches of water at the top and only three inches at the bottom. That would be bad down-row uniformity AND bad cross-row uniformity (as the first furrow infiltrated eight and four inches top to bottom). Cross-row uniformity depends on the difference in opportunity times between furrows and also the different infiltration rates in furrows due to tractor traffic.
- General soils variability is a measure of uniformity due to different soil types in the field. Some fields are laid out over old stream channels or are just naturally variable. Thus, just due to the different soils and their different infiltration rates, different amounts of

water will soak in to different parts of the field.

INFILTRATION RATES AND DOWN-ROW UNIFORMITY

When you turn water into the top of the furrow, it takes time to reach the bottom of the furrow. (This is in contrast to sprinkler systems where you turn the valve on and the entire lateral is spraying water almost immediately.) When you turn water off in a furrow, it is essentially gone immediately. (Obviously, if you are blocking your furrow ends, this must be modified somewhat.)

The time that it takes for water to run off of a furrow is usually very small in relation to the total set time (for example 15 minutes out of a 24 hour set). Thus, we just say water is gone immediately after it is turned off. (Blocking furrows will increase the opportunity time at the bottom of a furrow.

Blocking may or may not increase DU depending on the increase in opportunity time and length of furrow affected. Blocking does not usually increase DU as much as other techniques discussed further on. For example, you are running a 24 hour set. It takes 16 hours for water to run from the top of the furrow to the bottom. Thus, the opportunity time at the top of the furrow is 24 hours- at the bottom, only 8 hours.

More water will soak in at the head of the furrow than at the bottom. Having a large difference in opportunity time from top to bottom of a furrow doesn't necessarily mean that there will be a large difference in total water soaked in at the top versus the bottom.

As you saw in the ["Soil, Water and Plant"](#) section, infiltration rates decrease with time. Thus, 12 hours of opportunity time doesn't mean twice as much water soaked in as for 6

hours of opportunity time. But the rate of decrease is different for different soils. The table below gives example depths of water infiltrated with 12 hours and 24 hours of soaking time in different soils.

You can see that the difference in infiltration will be greatest for the coarse soil in the table below:

SOIL <u>TYPE</u>	12 hrs <u>SOAKING</u>	24 hrs <u>SOAKING</u>
Coarse	3.0"	5.5"
Medium	2.5"	4.0"
Fine	2.0"	3.0"

Note also that the depth infiltrated in 24 hours IS NOT twice as much as that infiltrated in 12 hours. This is because infiltration rates generally decrease with time. Soils do not soak in water at a constant rate at all times during an irrigation.

It is important to see that the infiltration rate of the coarse soil does not decrease as fast as the finer soils. In the example table there was 2.5 inches more water soaked in over 24 hours in the coarse soil, but only 1 inch more in the fine soil.

Thus, a coarse soil will give the greatest difference in depth infiltrated for a given difference in opportunity time. This means that you need to get water to the end of a furrow faster in a coarse soil than in a fine soil.

In summary, we know that there is a built-in problem with down-row uniformity in furrows due to the fact you can't get water on the full furrow immediately. But we also just saw that there is not a direct relationship between the time water is soaking into the furrow at any one point and the amount that soaks in. So . . .

GENERALLY, THE FASTER YOU RUN WATER DOWN A FURROW, THE BETTER YOUR DOWN-ROW DISTRIBUTION UNIFORMITY..

ADVANCE RATIOS AND DOWN-ROW UNIFORMITY

Because set times differ for each irrigation it is easier to describe (and recommend) how fast water gets to the bottom of a furrow in terms of an ADVANCE RATIO. Advance ratios can be defined two ways.

One way is to view the advance ratio as the ratio of the time it takes to get water to the bottom of a furrow to the total set time. Thus, if it took 8 hours out of a 24-hour set to get water to the end of a furrow, the advance ratio would be 1/3 (8/24). If it took 12 hours out of the 24-hour set, the advance ratio would be 1/2 (12/24).

The other way, and the one that will be used in this handbook is to define advance ratios as the total set time divided by the time of advance. Thus, for a 24 hour set and an eight hour advance time, the advance ratio is three. For a 24 hour set and a six hour advance time, the advance ratio is 4.

The higher the advance ratio, the faster the advance. An advance ratio of from 3 to 4 is recommended in coarse soils (with an advance ratio of 4 used only with the coarsest soils). Water should get to the end of a furrow in about 1/4 to 1/3 of the total set time with coarse soils.

Remember that infiltration rates in coarse soils do not slow as fast as in fine soils. Thus, you need to cover the furrow faster to get good distribution uniformity. For example, if you were planning a 24-hour set on a coarse sandy loam you should get the water to the

end of the furrow in 6 to 8 hours. This would be 1/4 to 1/3 of the total 24.

For finer soils, an advance ratio of from 2 to 3 is recommended. That is, you should get water to the end of the furrow in about 1/3 to 1/2 of the total set time with fine soils. For example, if you were planning a 24-hour set on a fine clay loam you should get the water to the end of the furrow in 8 to 12 hours (1/3 to 1/2 of the total 24 hours).

Some options for getting water to the bottom of a furrow faster and achieving acceptable advance ratios are . . .

- Using larger stream sizes (keeping in mind erosion).
- Reducing the length of the furrow (this could be a permanent change or temporary). Some growers will use gated or flexible PVC pipe laid across the middle of the furrow for the preirrigation only).
- Using [torpedoes](#) (weighted 6-10 inch diameter pipes dragged in the furrow after cultivators) to break up clods and leave a smooth open channel to allow faster water flow.
- Driving tractors so the wheels are in the uncompacted rows (lowers the soil infiltration rates thus, providing faster water flow).
- [Other practices to firm furrows.](#) (<http://www.ianr.unl.edu/pubs/irrigation/g1340.htm>)
- Using ["surge" irrigation techniques](#)" (<http://www.ianr.unl.edu/pubs/irrigation/nf176.htm>), alternate wet/dry cycles during irrigation of any one furrow.

There may or may not be objections to using any of the above options. But recognize that without an acceptable advance ratio, you will not achieve high down-row distribution

uniformity. And without high DU, you cannot achieve a high irrigation efficiency.

RUNOFF REUSE SYSTEMS

The faster you get water to the end of a furrow, the faster you are going to have to deal with tailwater. This is not to say that tailwater is bad. The potential for significant tailwater in furrows is a natural result of achieving acceptable advance ratios.

Options for dealing with tailwater are . . .

- Letting the tailwater runoff your farm, which is not allowed in Westlands.
- Blocking the ends of the furrows.
- Cutting back furrow streams as they reach the end of the furrow so as to just keep the furrow wet.
- Installing a [tailwater return \(reuse, recycle\) system](#) to gather and use the tailwater.

Whenever a stream is cutback, the excess flow must be used in another furrow. With constant cutbacks, many sets may be running at once, complicating the irrigation management.

Tailwater systems lead to simpler management of furrows than cutback streams. Tailwater return systems require some land set aside for a sump and the cost of a pump and return pipeline/ditch.

Important decisions for tailwater systems include sump size and where to put it, pump size, return piping size and placement, and power source. You should also have a fair idea of the amount of tailwater to expect and how you plan to use it. Pump sizing is important. If the pump is too small in relation to the sump size and expected tailwater flows, you run the risk of not keeping up with the

incoming tailwater. If it is too large, you run the risk of excessive cycling.

Tailwater systems that reuse tailwater immediately (without going through a regulating reservoir) will almost always run into the cycling problem. Thus, you are almost forced to use either gated pipe or sprinklers for the return flow.

Sufficient screening of the tailwater must be in place to prevent blockage of the gates or sprinklers by field trash. If your farm is not laid out in a single block or you are leasing separate fields, a small, temporary sump may be useful. A trailer-mounted diesel or PTO-powered pump can be used to supply either one or two sprinkler lines or aluminum (or possibly flexible PVC) gated-pipe.

Sump placement affects another important decision, what to do with the tailwater. You should not pump tailwater back into the same set that produced it if you have an alternative use. When you pump tailwater directly back into the set that produced it you do not get the full use of the power used by the pump. The infiltration rate of the soil has decreased and you get into a constant recycling situation.

A small sump can be used at the bottom of a field pumping back to a large reservoir at the top of the farm. This will allow a gravity supply to the farm. If the farm is contiguous, one or more large sumps can be placed at the low side of the farm and used only to irrigate the fields adjacent to the sumps. If you are designing a multi-field tailwater system, it may help to consult a qualified agricultural engineer.

CROSS-ROW UNIFORMITY

The compaction caused by tractor/implement wheels causes different infiltration rates in adjacent furrows. Thus, not only do you have

to deal with the built-in problems with down-row uniformity, but also the furrow-to-furrow differences due to different compactions, the cross-row uniformity. There are three types of strategy for dealing with the differences in infiltration rates between wheel and non-wheel rows.

1. You could use the irrigation labor to manually check depths infiltrated/advance ratios in each furrow, changing stream sizes and moving water as it became necessary. This can be time-consuming and requires excellent irrigators.
2. You could try to even up the compaction in the furrows by running an empty tractor in the "off" rows. In doing this, make sure you run the tractor with enough moisture in the soil to achieve the compaction desired. This can be a risky strategy as you may reduce infiltration rates so low that you cannot get enough water into the soil.
3. Or, you could run water in two passes across the field. The first sets (with smaller streams and longer set times due to the lower infiltration rates) could be in the wheel rows. The second time through water would be run in the non-wheel rows (with larger stream sizes and shorter set times because of the higher infiltration rates). Obviously, this doubles some of the labor requirements but makes the management of any set much easier.

Again, what strategy you use depends on your situation.

GENERAL SOILS VARIABILITY

"Streaked" fields (fields with different types of soils running through them) are always

tough to manage for irrigation efficiency and uniform crop development. If the streaking is bad enough and the economics warrant, many growers will just use sprinklers.

If the streaking is well-defined and is primarily down the rows, you may be able to adjust the stream-sizes and set timing as you change sets across the different soils. Thus, one set might be in the lighter streak, with larger stream-sizes and shorter set times, while the next set would be in the heavier streak, with a smaller stream-size and a longer set time.

Efficiencies of fields that are streaked across the furrows may be improved by using "surge irrigation". Surge acts to reduce infiltration rates very rapidly. Depending on the mix of Usoils, this rapid decrease may result in infiltration rates that are close to equal across the soil streaks. The surge irrigation technique consists of several cycles of wetting and drying the furrow during an irrigation. The goal is to rapidly decrease the soil infiltration rates by sealing over the soil surface and allow faster water advance.

Many growers will recognize the surging technique. One common name for it was "bumping" water. The major operational problem with surging is the labor involved in creating the wet/dry cycles. Modern surge techniques may involve six or more cycles in an irrigation. That means labor has to start/stop water six times in each furrow during an irrigation.

Irrigation equipment manufacturers have created specialized surge irrigation valves for use with gated pipe that can do this automatically. They consist of a familiar looking TEE-fitting for gated pipe with a timer-controlled, automatic butterfly valve inside. The butterfly can be set to direct all the water to one side or the other of the TEE.

Or, it can be set to split the flow to both sides. Some of these valves are quite elaborate with solar-powered controllers that will automatically operate the valve to surge water down one side of the valve or the other.

A common management technique is to install the valve in the field with a set of gated pipe running from each side. The valve is first set to first direct all water to the gates on one side of the valve, then the other on a varying time schedule. Then, for the last part of the irrigation, water is directed to both sides.

An example would be to force 30 gpm streams down the furrows during the cycling portion of the irrigation. The first cycle might be 2 hours on-2 hours off, then 4 hours on-4 hours off, then 6 hours on-6 hours off. During the last portion of the irrigation, after the furrow has been completely wetted, the TEE valve is set to split the water evenly so that 15 gpm streams are used. The switch from 30 to 15 gpm provides an automatic cutback stream.

Surge has not been shown to be effective in all cases. A lot depends on the type of soil and its reaction to wet/dry cycling. If the wheel/non-wheel row situation results in very uneven advance rates without surge, you should try the surge technique in alternate rows first.

Some tests have shown surge to worsen an uneven advance situation in adjacent furrows because the infiltration rates in the uncompacted row are reduced much less than those in the compacted rows.

IRRIGATION EFFICIENCY WITH FURROWS

With good advance ratios and strategies for handling cross-row variances and soil streaking you get good DU. But what about

controlling the total amount of water applied? Since the soil's infiltration rate can be very hard to predict, controlling the total infiltration can be very difficult.

It is important to react to the results of the first set. When irrigating, usually the top of the root zone will become almost saturated. The depth of soil to where water has reached during an irrigation is called the "wetting front". As the irrigation is stopped, the water in the saturated zone will drain downwards (remember that soil will not hold water above its field capacity).

A [soil probe](#) can be used to judge where the wetting front is during an irrigation as it can only be pushed into soil with a significant water content.

You should stop irrigating before the wetting front reaches the total root zone depth you are trying to wet. If you are trying to irrigate to 4 feet, change sets when the wetting front hits about 2.5 - 3 feet. This is because the excess water in the 2.5-3 feet will redistribute into the full 4 foot soil profile.

Come back in one or two days and use the probe again to see how far down water redistributed. With experience you will know how far down the wetting front must be to soak the desired root zone depth.

Also, using the [probe](#) at the top, middle, and bottom of the furrow one to two days after an irrigation can give you an idea of the distribution uniformity. If the DU was high, the probe will go in to about the same depth at all points in the different furrows. If the probe goes in to a depth of five feet at the top of the furrow and only two feet at the bottom, you know that something didn't go right.

PREPLANNING AN IRRIGATION

There should be some [preplanning to a furrow irrigation](http://www.wateright.org/site2/advvisories/furrow.asp) (<http://www.wateright.org/site2/advvisories/furrow.asp>). You will have to react to the first set but it is a good idea to know what the limits of the irrigation might be. A recommended approach to a furrow irrigation is . . .

1. Determine the Soil Moisture Deficit. The fastest, cheapest, and most flexible way to do this is with a soil sampler and the [feel method](#) in the "Soil-Water-Plant Relationships" section.
2. Use the following equation to estimate the gross depth applied . . .

(1) GROSS APPLIED =
GPM x HOURS x 96.3 / AREA
where:

GROSS APPLIED is the inches of water applied to the AREA

GPM is the furrow flow in gallons per minute

HOURS is the total set time in hours

AREA is the area covered by the GPM in square feet and if wetting each furrow, AREA = furrow spacing x furrow length If wetting every other furrow, AREA = 2 x furrow spacing x furrow length.

3. Subtract the percentage of GROSS APPLIED you think you can recover in surface runoff. That is, determine how much water that you apply will runoff the field and be used. Then, subtract this from the depth applied. Use the following equation . . .

(2) NET APPLIED = (1 - SAVEDRO / 100) x GROSS APPLIED

where:

NET APPLIED is the net depth of water infiltrated in the furrow in inches

SAVED RO is the percentage of GROSS APPLIED that you think will be saved as surface runoff

GROSS APPLIED is the gross applied as previously calculated

4. Ask yourself, "With the GPM (furrow stream size) planned, will I get an acceptable ADVANCE RATIO". (That is, are you going to get water to the end of the furrow in an acceptably short time?) If not, change a factor in the irrigation and go back to step 2.
5. Then, determine the POTENTIAL IRRIGATION EFFICIENCY . . .

(3) POTENTIAL IE =
100 x IN ROOT / NET APPLIED
where:

POTENTIAL IE is the best irrigation efficiency you could hope for. This assumes that all NET APPLIED remains in the effective root zone

IN ROOT is water infiltrated that remains in the effective root zone in inches.

If NET APPLIED is greater than the soil moisture deficit at irrigation, then IN ROOT = SMD

NET APPLIED is the net applied previously calculated

6. If the POTENTIAL IE is below 75 percent, see if you can change a parameter in the irrigation. You would like to see 75 percent or above. Furrow irrigations have been measured at 90 percent IE when using fast advance ratios and tailwater reuse systems. Options are . . .

- o Try another combination of GPM and HOURS (faster flow for fewer hours).
- o Consider every-other row irrigation if the situation warrants (this will double the AREA).
- o Consider surge irrigation, compaction, use of torpedoes, shorter furrows or some other method to achieve an acceptable advance ratio with a lower GPM.
- o If not in place, consider installation of a tailwater return system or use of cutback streams (see below for calculating GROSS APPLIED with cutback streams). Sometimes there is nothing you can do. Putting on very low applications with furrows, especially on steeper grades, is hard to do efficiently.

As an example of preplanning, assume the following . . .

- 1320 foot furrow on 3.3 foot spacing.
- Soil moisture deficit at irrigation of 3.5 inches.
- A planned 24 hour set.
- A planned 20 gpm furrow stream.
- Desired advance ratio of 2 (furrow advance in 12 hours out of the total 24 hour set).

- Every furrow wet.

Remember, an important assumption is that the planned 20 gpm furrow stream will give you the 2 advance ratio.

Using equation (1) the GROSS APPLIED is

$$\text{GROSS APPLIED} = \text{GPM} \times \text{HOURS} \times 96.3 / \text{AREA}$$

$$\text{GROSS APPLIED} = 20 \times 24 \times 96.3 / (3.3 \times 1320)$$

$$\text{GROSS APPLIED} = 10.5 \text{ inches}$$

Estimate that you will save 30 percent of this as runoff.

Using equation (2) to calculate the NET APPLIED . . .

$$\text{NET APPLIED} = (1 - \text{SAVED RO}/100) \times \text{GROSS APPLIED}$$

$$\text{NET APPLIED} = (1 - 30/100) \times 10.5$$

$$\text{NET APPLIED} = 7.4 \text{ inches}$$

Using equation (3), the POTENTIAL IE is . . .

$$\text{POTENTIAL IE} = 100 \times \text{IN ROOT} / (\text{NET APPLIED})$$

$$\text{POTENTIAL IE} = 100 \times 3.5 / 7.4$$

$$\text{POTENTIAL IE} = 47 \text{ percent}$$

Note that the soil moisture depletion is 3.5 inches. Thus, 3.5 inches is the most you could infiltrate into the effective root zone. The rest is going into deep percolation or runoff that is not saved.

47 percent is not good potential IE.

You should be trying for a minimum 70 percent.

The first change considered is to use a larger furrow stream with a shorter set time. Assume that a 30 gpm stream will get out in 6 hours of a 12 hour set.

Now from equation (1) . . .
$$\text{GROSS APPLIED} = 30 \times 12 \times 96.3 / (3.3 \times 1320)$$

$$\text{GROSS APPLIED} = 8.0 \text{ inches}$$

and from equation (2) . . .
$$\text{NET APPLIED} = (1 - \text{SAVED RO}/100) \times (\text{GROSS APPLIED})$$

$$\text{NET APPLIED} = (1 - 30/100) \times 8$$

$$\text{NET APPLIED} = 5.6 \text{ inches}$$

and from equation (3) . . .

$$\text{POTENTIAL IE} = 100 \times \text{IN ROOT} / \text{NET APPLIED}$$

$$\text{POTENTIAL IE} = 100 \times 3.5 / 5.6$$

$$\text{POTENTIAL IE} = 63 \text{ percent}$$

This is still not good IE.

Another planning option would be to irrigate every-other row with a slightly larger furrow stream than initially planned. Assume that a 25 gpm stream for 24 hours will give you the 2 advance ratio if irrigating every-other row (AREA = 6.6 x 1320).

Now from equation (1) . . .

$$\text{GROSS APPLIED} = 25 \times 24 \times 96.3 / (6.6 \times 1320)$$

$$\text{GROSS APPLIED} = 6.6 \text{ inches}$$

and from equation (2) . . .

$$\text{NET APPLIED} =$$

$$(1 - \text{SAVED RO}/100) \times \text{GROSS APPLIED}$$

$$\text{NET APPLIED} = (1 - 30/100) \times 6.6$$

$$\text{NET APPLIED} = 4.6 \text{ inches}$$

and from equation (3) . . .

$$\text{POTENTIAL IE} = 100 \times \text{IN ROOT} / \text{NET APPLIED}$$

$$\text{POTENTIAL IE} = 100 \times 3.5 / 4.6$$

$$\text{POTENTIAL IE} = 75\%$$

This is acceptable irrigation efficiency.

Again, the key assumptions are that . . .

- 25 gpm will give you an acceptable 2 advance ratio.
- It won't harm the crop to irrigate every other row.
- You can save 30 percent of the applied water as tailwater.

The validity of these assumptions are your responsibility and depend on your experience.

If you were planning to use a cutback stream, the only change in the above calculations comes in the GROSS APPLIED.

Here you must add up the GROSS APPLIED's for each stream size . . .

$$\text{GROSS APPLIED} = ((\text{GPM1} \times \text{HOURS1}) + (\text{GPM2} \times \text{HOURS2})) \times 96.3 / \text{AREA}$$

where:

GROSS APPLIED is the inches of water applied to the AREA GPM1, 2, 3 . . . are the furrow flows in gallons per minute for each cutback HOURS1, 2, 3 . . . are the total time in hours each cutback is run.

AREA is the area covered by the GPM in square feet (if wetting each furrow AREA = spacing x length, if wetting every other furrow

$$\text{AREA} = 2 \times \text{spacing} \times \text{length})$$

For example, assume you were planning a 24 hour furrow irrigation with two cutbacks. The furrows are 1320 feet long on 3.3 foot centers. The irrigation would start at 10 AM with one cutback at 8 PM (just before dark) for a 10 hour initial runtime and the other at 6 AM the next morning (another 10 hours runtime). The initial stream size is 30 gpm with the first cutback to 15 gpm and the third to 7.5 gpm.

GROSS APPLIED is . . .

$$\text{GROSS APPLIED} = ((\text{GPM1} \times \text{HOURS1}) + (\text{GPM2} \times \text{HOURS2}) \dots) \times 96.3 / \text{AREA}$$

$$\text{GROSS APPLIED} = ((30 \times 10) + (15 \times 10) + (7.5 \times 4)) \times 96.3 / (1320 \times 3.3)$$

$$\text{GROSS APPLIED} = 480 \times 96.3 / 4356 = 10.6 \text{ in}$$

As previously discussed, not only to you have to apply water evenly you must be able to control the total amount infiltrated. Most growers like to use 12, 24, or 48 hour sets because they match labor availability. Sometimes however, getting the highest efficiencies requires changing sets at odd times (like 3:00 AM). It is your decision as to if the economics justify using a night irrigator.

IT IS IMPORTANT TO KNOW THAT WESTLANDS WATER DISTRICT WILL

ALLOW YOU TO TURN ON AND OFF AT ANY TIME WITH PROPER NOTICE.

Managing furrow irrigation systems for high irrigation efficiencies is a difficult task at best. What works for one irrigation may not work for the next because the furrow conditions are constantly changing. A used furrow reacts differently from a new furrow, the root zones may be increasing, you may have used well water on one irrigation and canal water on the next, etc.

FURROW SYSTEM EVALUATIONS AND RECOMMENDATIONS

The District's Water Conservation Program has developed a simplified procedure to estimate the [performance of furrow irrigations](#) for those wishing to perform their own evaluations. While this is not a complete, detailed evaluation, it does provide a quick estimate of the system performance. Check with the District to see if a Mobile Lab program is in effect. Many consultants are also available to perform these evaluations.

Typical recommendations and expected results for furrow irrigation systems are presented below. Each recommendation is explained in relation to desired distribution uniformity and irrigation efficiency improvements:

- 1. Increase the furrow flow rate - This recommendation would be made if the down-row uniformity was too low. Water is advancing too slow and much more water is infiltrating at the top of the furrow than at the bottom.
- 2. Reduce the set time - The system DU may or may not be good but the sets are too long, producing too much deep percolation.
- 3. Increase the set time - The system DU may or may not be good but the sets are too short and much of the field is underirrigated.
- 4. Change the set configuration - Sometimes it is advantageous to irrigate every other furrow, especially if trying to apply a small depth with a high intake rate soil (refer to the example on pre-planning above). Other times you may need to irrigate every furrow to help infiltrate enough water to satisfy the soil moisture depletion.
- 5. Drag torpedoes in the furrow - This is related to down-row uniformity. Torpedoes will break down clods and leave a smooth path, helping to speed water advance.
- 6. Use socks to reduce erosion - Socks placed over gated pipe outlets act to dissipate energy and prevent erosion at the top of the furrow.
- 7. Tailwater management recommendations - These will change depending on the field, farm configuration, and manager. Note points a. and g. It is always recommended to allow tailwater rather than blocking furrow ends.
- 8. Shorten furrow lengths - This is again related to down-row uniformity. The furrow is so long that there is no furrow flow that will get water to the end sufficiently quick enough. Sometimes it may be best to only temporarily shorten the furrow for the pre and first seasonal irrigations. As the furrow intake rates drop with use, you can go back to the original length. Temporary shortening can be done with aluminum or flexible PVC gated pipe.
- 9. Significant differences in intake rates between wheel and non-wheel rows - This is related to cross-row uniformity. Here we are recommending that you run water first in the wheel rows, then come back and run water in the non-wheel rows. The sets in the wheel rows can be longer with smaller furrow flows (because of the lower intake rates) than in the non-wheel rows.
- 10. Use deeper furrows - This will allow larger stream flows, speeding advance and improving down-row uniformity.

- 11. Use sprinklers rather than furrows - This is usually recommended for a preirrigation when the field is extremely dry and has just been worked up. In this situation it can be hard to control the total application with furrows. Sprinklers provide control over the total application (however be aware of distribution uniformity problems due to wind).
- 12. Use a soil [probe](#) to judge when to stop irrigating - Soil fills to field capacity from the top down (see Figures 5-6a and 6b). During an irrigation, the top of the root zone will nearly saturate. As the irrigation stops, the excess water will redistribute downwards. Using a probe is a good indication of when to change sets.
- 13. Reduce the furrow flow after water has reached the furrow end - cutbacks may be advantageous where very large furrow flows are used to achieve sufficiently quick advance rates. If the cutback was not performed, excessive tailwater would result.
- 14. Improve irrigators mobility - It may be, especially if irrigating both wheel and non-wheel rows in the same set, that the irrigators need to adjust furrow flows continually. They may need to go back and forth between the top and bottom of the field many times to ensure uniform applications.
- 15. Improve overall farm coordination - The irrigation program needs to be meshed efficiently with the pest control/fertility/cultural operations programs.
- 16. Use surge flow - Surge flow can help in very high intake rate soils, long furrows, or fields that are streaked across the rows.
- 17. There is a large difference in how the day sets are managed from the night sets (if the night sets are "managed" at all) - This may only mean making them the same length. But there may be cutbacks being made during the day and not at night.
- 18. There are specific soil problems in the field - This could be a sand streak, saline portions, or even a weed outbreak. Something is reducing distribution uniformity.
- 19. Supply Variations - Depending on how water is distributed on the farm, irrigations in other fields may be changing the total flow to the field. Thus, the irrigator may set 20 gpm per furrow at the start, only to see it dip to 15 as flow is diverted to some other field.
- 20. Communicate - Get everyone together so that all understand the current problems and the strategy for correcting them.

Further reading, [FAO Irrigation Methods, IWTM 5](#) (<http://www.fao.org/docrep/S8684E/s8684e00.htm>), NRCS [Irrigation Water Management](#), (<ftp://ftp-nhq.sc.egov.usda.gov/NHQ/pub/outgoing/jbernard/CED-Directives/neh-2of2/neh15/neh-15.htm>) National Engineering Handbook. See the following link for information of [selecting an irrigation method](#) --a large download--(<http://www.wcc.nrcs.usda.gov/nrcsirrig/irrig-handbooks-part652-chapter5.html>) from the NRCS National Engineering Handbook, Part 652.