Furrow Irrigation

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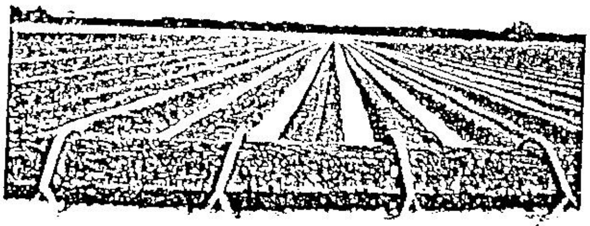
Furrow Irrigation

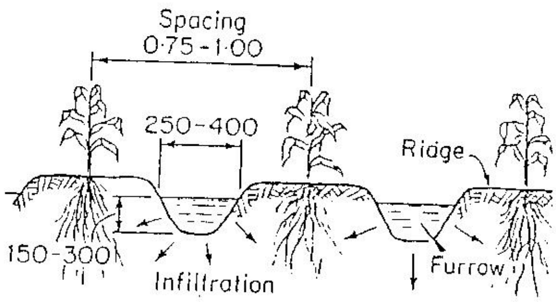
(Design and Evaluation)

1. Introduction

Furrow irrigation is the most widely used method for irrigating row crops. It is also the most misunderstood of all the irrigation methods. Water no longer flows over the entire soil surface but is confined to small channels (furrows) between the crop rows. It is gradually absorbed into the bottom and sides of the furrow to wet the soil (Figure 1).



(a) General view



(b) Cross-section

Figure 1 Furrow Irrigation

Furrow irrigation can be adapted to suit a wide range of row crops, soils and farming practices. However, it is important to use the right shape of furrow, spacing and length and good water management for the method to work well.

2. Size and Shape

The shape of furrows is important to the adequacy and efficiency of furrow irrigation. Furrows are usually V-shaped. The width varies from 250-400 mm and the depth from 150-300 mm (Figure 1 (b). It depends on stream size, soil type and crops.

2.1 Stream Size

Each furrow is like a small channel and must be large enough to carry water without damaging the furrows. Furrow stream sizes are usually between 0.2 and 3.0 l/s. The larger the stream size used, the larger must be the furrow channel.

Furrow stream size is one of the important factors effecting application efficiency. To apply water uniformly throughout the furrow length, the advance time has to be short in order to reduce the opportunity time differences. The size of stream must be as large as the furrow can take. However the erosion must not take place. As a rule of thump, the advance time should be 1/4 of the required opportunity time. For example, if the depth of water applied is 80 mm., the application time is 4 hour. The advance time to the tail end of furrow is 1 hour.

Soil erosion is one of the problems limiting the stream size. The erosion is a function of flow velocity or the size of stream and land slope. The recommended maximum non-erosive slope of furrow can be calculated from Equation 1.

$$Q = \frac{0.6}{S} \qquad \text{.............................} \qquad (1)$$

Where Q = Maximum non-erosive discharge in lps.

S = Furrow slope in %

2.2 Soil Type

On clay soils water infiltrates very slowly and so wide shallow furrows are sometimes needed to increase the soil area through which water can be absorbed more rapidly (Figure 2 a). If the furrow is too narrow water will flow too quickly down the furrows before sufficient water has had time to infiltrate. In extreme cases the crop may not germinate near the top of the furrow because of a lack of water.

On sandy soils water infiltrates more rapidly than on clay soils and the problem is to try and reduce infiltration so that water will flow quickly along the furrow. For this reason narrow, deep furrows are used to reduce the soil area through which water can be absorbed (Figure 2 b).

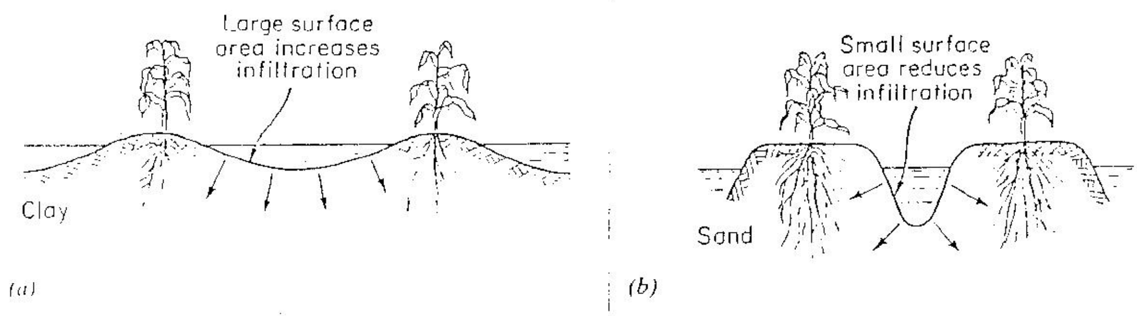


Figure 2 Furrow Shapes (a) On clay soil (b) On sandy soil

2.3 Crops

When seeds are sown or small plants are transplanted it is important that all the soil in the ridge is thoroughly wetted. This is best done by using shallow furrows. As the root system grows, furrows can be cut deeper to improve infiltration and increase the furrow discharge capacity.

For winter and early spring crops, the side slopes of ridges are sometimes changed to increase the soil exposure to the sun and so warm up the soil more quickly (Figure 3).

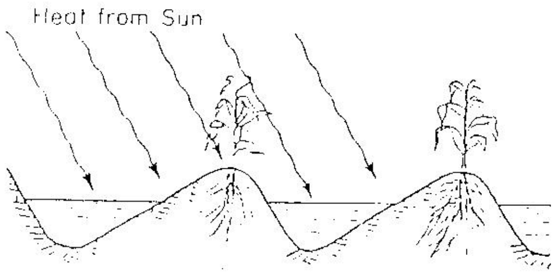


Figure 3   Side Slope Changed to Warm Up soil More Quickly

3. Furrow Spacing

The spacing between furrows depends on water movement in the soil, crops and cultivation practice.

3.1 Water Movement in the Soil

This is the most important from an irrigation point of view. Water moves sideways (laterally) from furrows as well as infiltrating downwards (Figure 4). It will also move upwards to wet the top of the ridges by a process called capilary action. Furrows must be spaced, so that all the soil reservoir is properly wetted and this depends on the soil type.

On sandy soils the lateral moverment of water is usually small and so furrows need to be close together (0.5 m). On clay soils there is much more lateral wetting and furrow spacing can be 1.2 m or more. If the furrow spacing is too wide there will be a dry area in between the furrows and the crop may not get enough water.

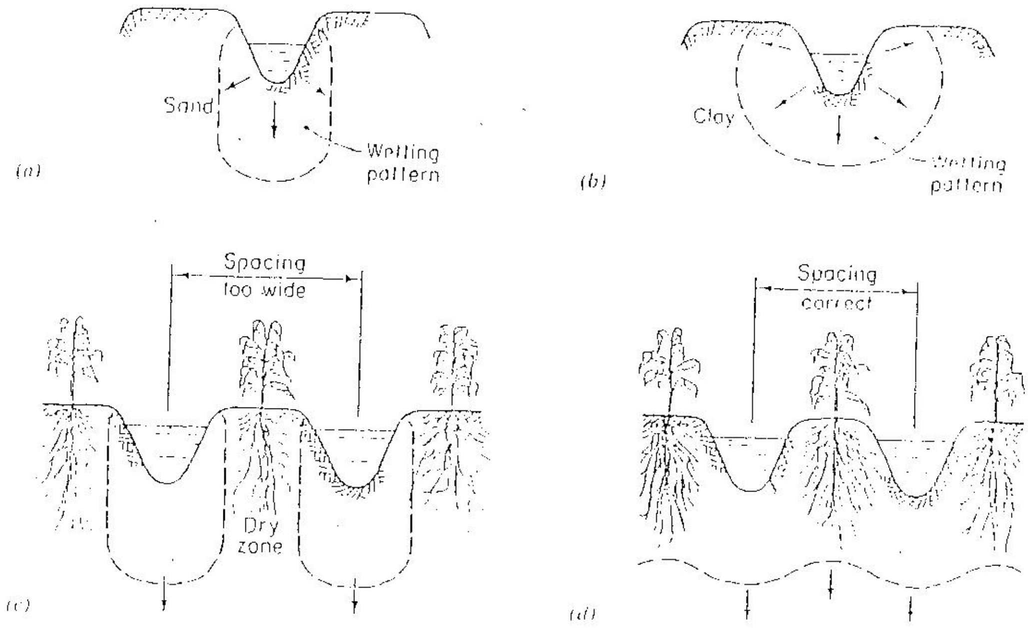


Figure 4 Furrow Spacing (a) Sandy soil (b) Clay soil (c) Spacing too wide (d) Right spacing.

3.2 Crop

Row crops are normally spaced 0.75-1.0 m apart for the convenience of planting, cultivating and harvesting. Some crops, such as vegetables can be planted in double rows. The ridge is then made much wider than for single planting and is often called a bed.

3.3 Cultivation practice

On many farms the equipment available for cultivation and harvesting may also determine furrow spacing. The same row widths are often chosen for different crops and soils so that the same implements can be used throughout. However, it is important that the width chosen will ensure sufficient wetting of all the soils on the farm.

4. Furrow Length

The choice of furrow length depends on the following factors: soil type, stream size, irrigation depth, field size and shape, slope and farming practice.

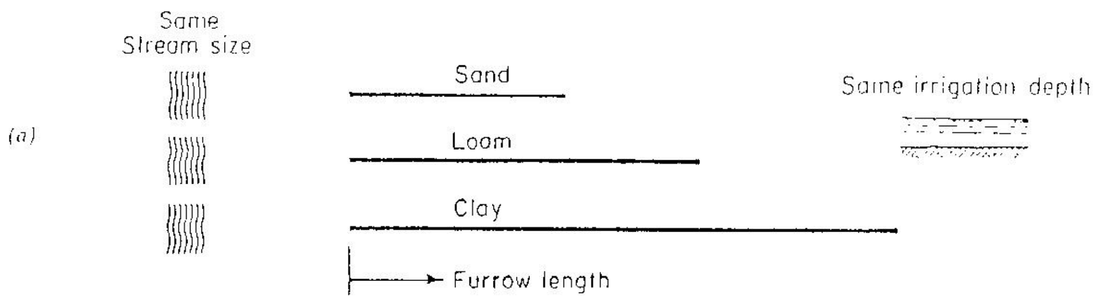
4.1 Soil Type, Stream Size, Irrigation Depth and Slope

These factors are the most important in determining what length furrows can be as shown in Figure 5.

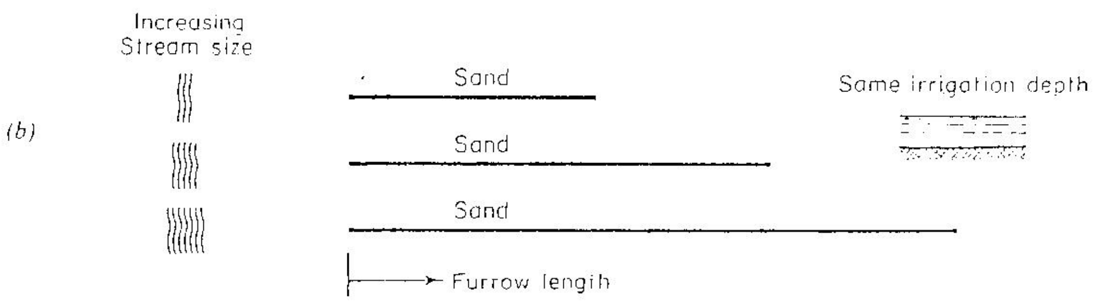
The effect of soil type is shown in Figure 5 (a). When irrigating sandy soils water infiltrates rapidly. This mean that furrows must be short (100 m or less) for water to flow quickly along to the far end even when quite large stream sizes are available. If the furrow was too long for the stream size, too much water would be lost in deep percolation near the farm channel.

On clay soils water infiltrates more slowly and so furrows can be longer than on sands (up to 800 m or more) even when only small stream sizes are available. If the furrows are not long enough for the stream size, excessive run-off can occur. This is because water cannot be ponded in furrows as it can in basins and so water must be left flowing until sufficient has been absorbed into the soil.

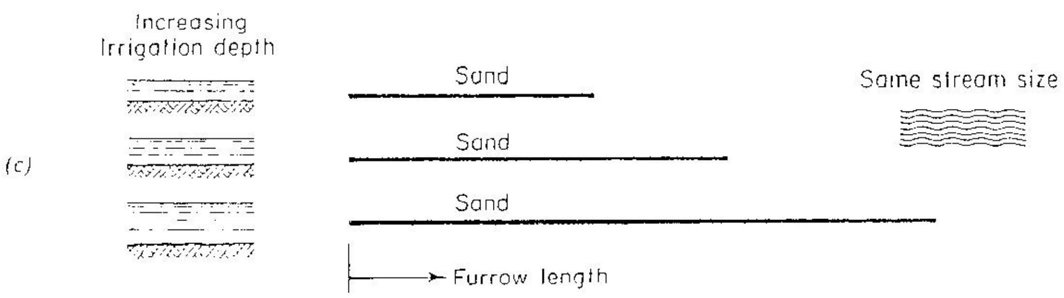
As in Figure 5(b) furrows can be longer on the same soil when a larger stream size is available. This is because water will advance more rapidly down the furrows when the flow is increased. However, there is a limit to the size of stream that can be used because of the risk of soil erosion. (max 3.0 l/s).



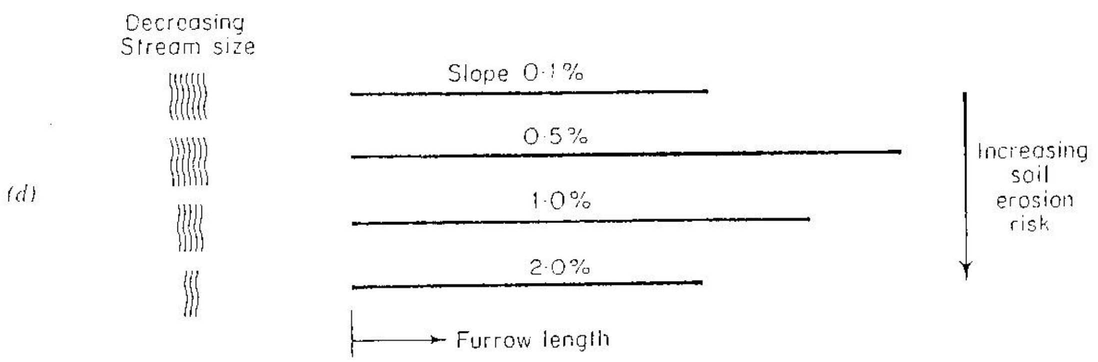
(a) Furrow can be longer on clay soils than on sands



(b) Furrows can be longer when larger stream sizes are used



(c) Furrows can be longer when larger irrigation depths are applied.



(d) Furrows are usually shorter on steeper sloping land to prevent erosion.

Figure 5 Factors Effecting Furrow Length

Applying larger irrigation depths (Figure 5 c) also means that furrows can be longer because there is more time available to spread the flow down the furrows.

When furrows are used on steeper sloping land (up to 0.3 %) they can usually be longer. This is because water moves more rapidly down the furrow as the slope increases. However on sloping land there is always the risk of soil erosion. As the land becomes steeper than 0.3 %, smaller stream sizes are used to prevent erosion occuring. This means that shorter furrow lengths must be used (Figure 5 d).

As in the case of basins and borders there are no simple ways to calculate the best furrow length for different conditions. It is again usual to rely on local experience or the experience of others (Table 1).

Table 1 Suggested Furrow Lengths (m)

Slope (%)	Maximum Stream size (l/s)	Clay		Loam			Sand		
		Average irrigation depth (mm)							
		75	150	50	100	150	50	75	100
0.05	3.0	300	400	120	270	400	60	90	150
0.1	3.0	340	440	180	340	440	90	120	190
0.2	2.5	370	470	220	370	470	120	190	250
0.3	2.0	400	500	280	400	500	150	220	280
0.5	1.2	400	500	280	370	470	120	190	250
1.0	0.6	280	400	250	300	370	90	150	220
1.5	0.5	250	340	220	280	340	80	120	190
2.0	0.3	220	270	180	250	300	60	90	150

For example using Table 1 on a clay soil with a slope of 0.1 % the maximum stream size is 3.0 l/s and the best length of furrow is 340 m for an irrigation depth of 75 mm. If the application depth was increased to 150 mm the furrow length could also be increased to 440 m.

4.2 Field Size and Shape

This may be a practical limit to the length of furrows. In small fields furrows may be as long as the field. Larger fields may be divided into two or more equal lengths as in the case of border (Figure 6). This makes it easier to deliver the same amount of water to each furrow.

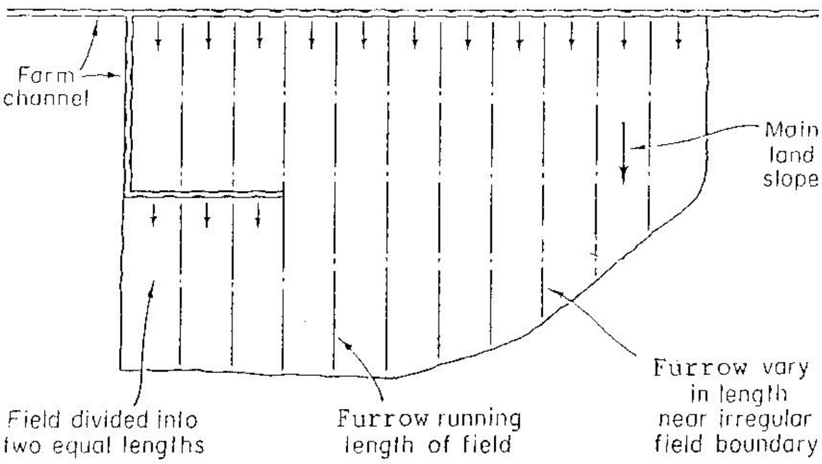


Figure 6- Effec of field size and shape on length of furrow

4.3 Farming Practice

From a farming point of view furrows should be as long as possible. Fewer farm channels and drains are needed, less land is taken up by the channels and it is easier to mechanise. Short furrows require a lot of attention because the flow must be changed frequently from one furrow to the next.

The use of tractors on the farm can also affect furrow lengths. Furrows are often compacted by tractors tyres and this can reduce soil infiltration rates. This can be of benefit on sandy soils as furrow lengths can be increased without extra percolation loss. However, all the furrows would need similar compaction otherwise water would advance at different rates.

5. Slope

Ideally furrows should have a uniform slope. A minimum slope of 0.05 % is needed to ensure that water will flow down the furrow and any excess water can be drained.

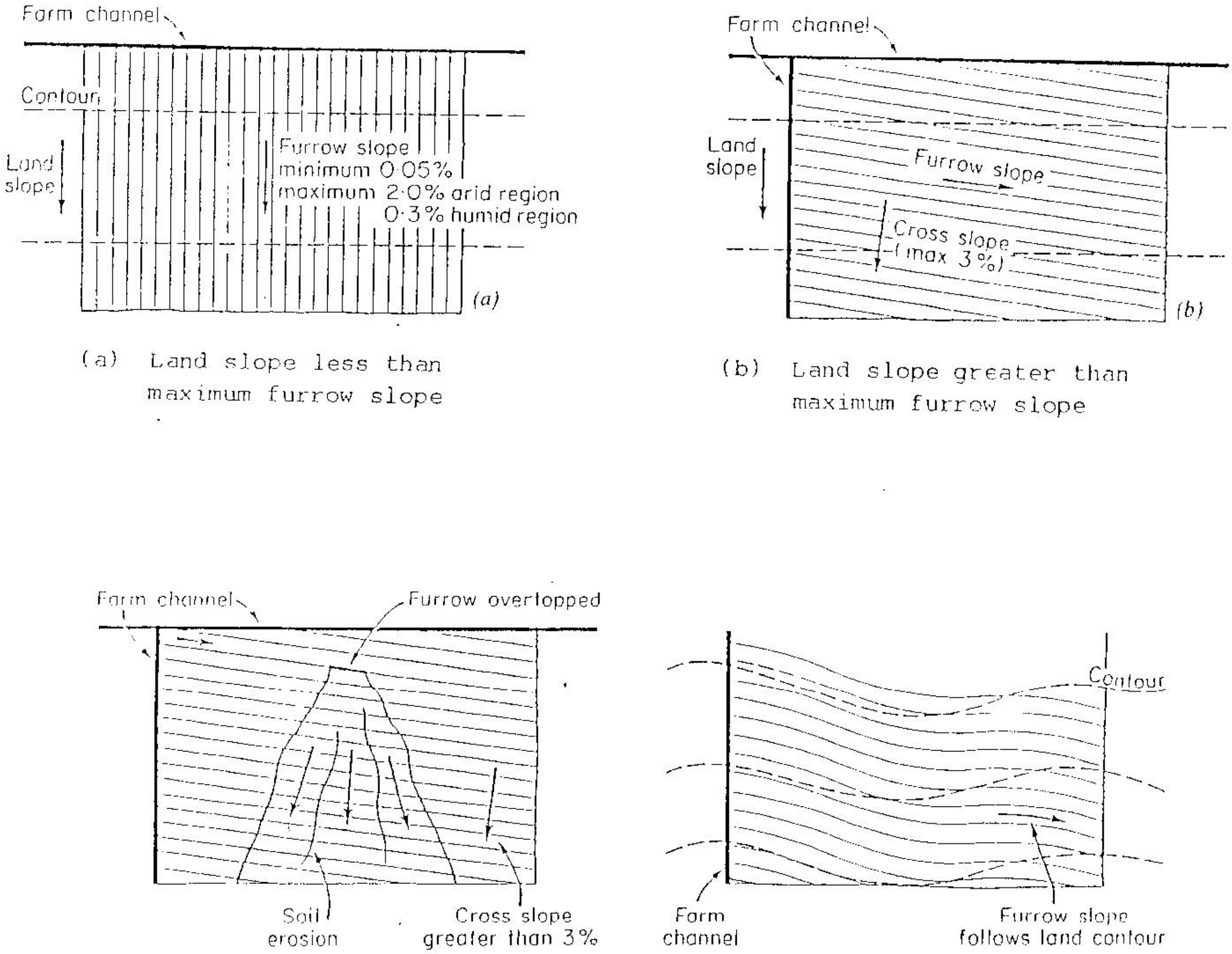
The maximum slope depends on the risk of soil erosion. This is more critical in furrows than in borders because the flow is confined in a small channel and so it can erode the soil more easily. In arid regions the maximum furrow slope is 2.0 %. In more humid regions where there is a risk of intensive rainfall the maximum slope is 0.3 %.

The maximum allowable slope is usually related to a non-erosive stream size (Table 1). This is the maximum stream size that will not cause any erosion in the furrow. Furrows on slopes of 0.05 % and 0.1 % could safely carry flows greater than 3 l/s from an erosion point of view. In practice however, this would be beyond the capacity of most furrows and overtopping would occur.

When it is practicable, furrows should be straight and parallel to the edge of the field and aligned down the main land slope. If the land slope is too steep furrows can be aligned across the main slope to reduce the furrow slope (Figure 7). However the land slope should be less than 3 % to avoid any risk of serious soil erosion. If the cross slope was greater than this and a furrow near the top of the field overtopped it could seriously damage the field and wash away the topsoil. Great skill needed to irrigate in these conditions.

On undulating land furrows are sometimes set out along the land contours. They are called contour furrows. Cultivating and irrigating furrows in this way again requires great skill. This should not be done on sandy soils or on clay soils which tend to crack.

Some furrows are used on level ground but this is usually when irrigating heavy clay soils with low infiltration rates.



(a) Land slope less than maximum furrow slope

(b) Land slope greater than maximum furrow slope

(c) Erosion risk when cross slope is too steep

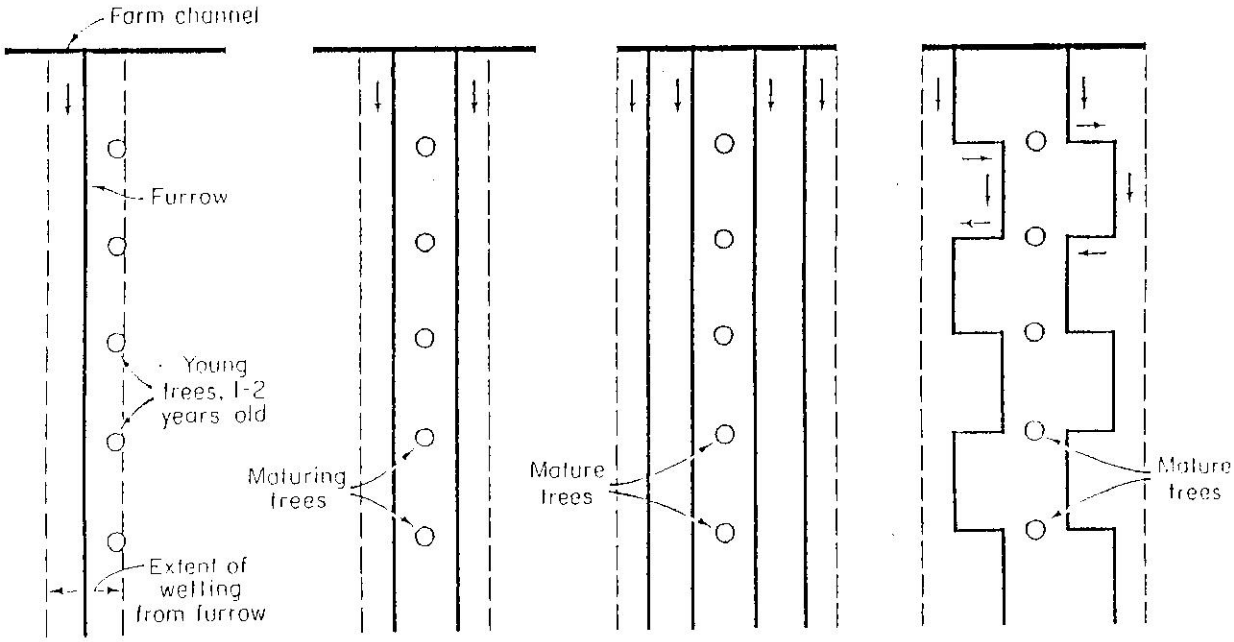
(d) Furrow on undulating land

Figure 7 Furrow Alignment on Sloping Land

6. Crops

Most row crops such as vegetables, cotton, sugar beet and potatoes are irrigated by furrow methods. The crops are usually planted on raised beds or ridges with furrows spaced between them.

Orchards and vineyards can also be irrigated with furrows. When the trees are young a single furrow may be enough to wet the root zone. As they grow, more furrows can be placed down between the tree rows (Fig. 8).



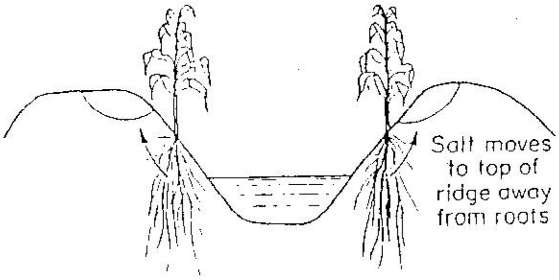
(a) Number of furrows increased as trees grow larger

(b) Zigzag furrows used to improve spread of water

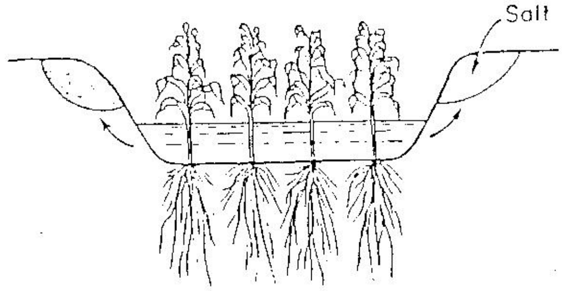
Figure 8 Using Furrow Irrigation in Orchards

Sometimes special furrow layouts are used such as zig-zag patterns to improve the spread of water in the soil. An advantage of furrows is that not all the soil surface is wetted and so there is good access in the orchard even during irrigation

When saline water is used for irrigation crops which are sensitive to salinity are usually planted on the side of the ridge and not on the top (Figure 9). This is because salt which is not leached down into the soil usually accumulates on the ridge top. In arid regions where irrigation water is limited plants are often grown in the furrow. This helps plants to obtain as much water as possible and keeps them well away from any salinity.



(a) Crop planted on side of furrow



(b) Crop planted in bed of furrow

Figure 9 Using Furrow Irrigation With Saline Water

7. Irrigating Furrows

When irrigating furrows, water is supplied to each furrow from the farm channel using siphons or spiles. Several furrows can be irrigated at the same time depending on the discharge available in the farm channel. The stream size must be large enough for the flow to advance quickly down the furrow. This will ensure a reasonably uniform irrigation.

Some water will always be lost in deep percolation but this will be quite small if the right stream size is used.

Run-off can be a major problem. Even on well-managed furrows, run-off can be as much as 30 % of the inflow. For this reason it is important to provide a shallow drain at the end of the field (sometimes called a tail drain) to remove this excess water. On many farms this is not fully understand and drains are not provided. This can result in water logging which may damage sensitive crops. There are several ways in which irrigators can reduce run-off losses.

One way is to allow some water to pond at the end of a furrow and to back up into adjacent furrows. Any water which does not infiltrate within 24 hours must be drained before any damage is done to the crop.

Another way is to reduce the stream size and relax the quarter time rule. This is a common practice on clay soils where deep percolation losses will be small even if the advance only reaches the end of the furrow in half the contact time (T/2).

A third method is to reduce the stream size once the flow has reached the end of the furrow. This is called the cut-back method. The stream size is usually cut back (or reduced) once or twice during an irrigation as shown in Figure 10.

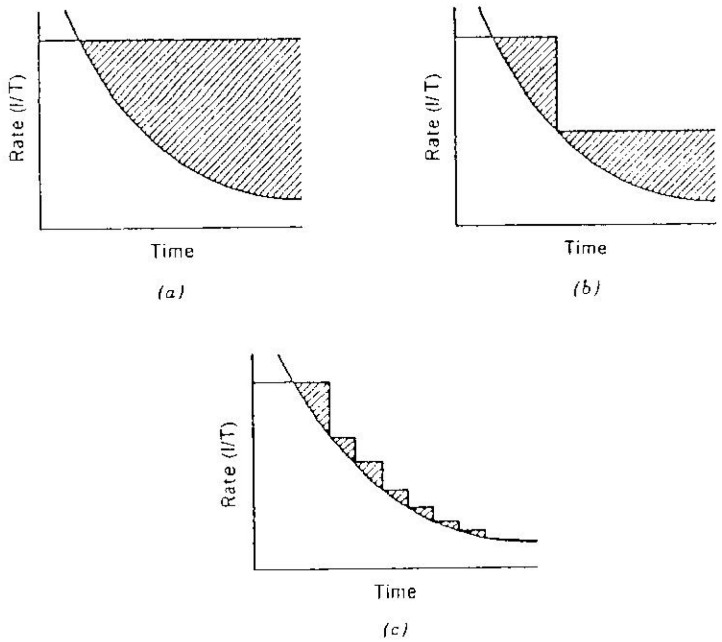


Figure 10 Relationships between inflow rate (to the field) and time with and without cutback irrigation. The cross-hatched areas are the amount of runoff from the field. (*a*) No cutback. (*b*) One cutback. (*c*) Several cutbacks.

On some well organised schemes run-off water is collected in storage ponds and pumped through a pipeline back into the irrigation system (Figure 11). This must only be done with great caution because run-off water may become mixed with saline drainage water and this can result in damage to crops. As a general rule drainage water is best left alone unless the irrigator is sure it is safe to use.

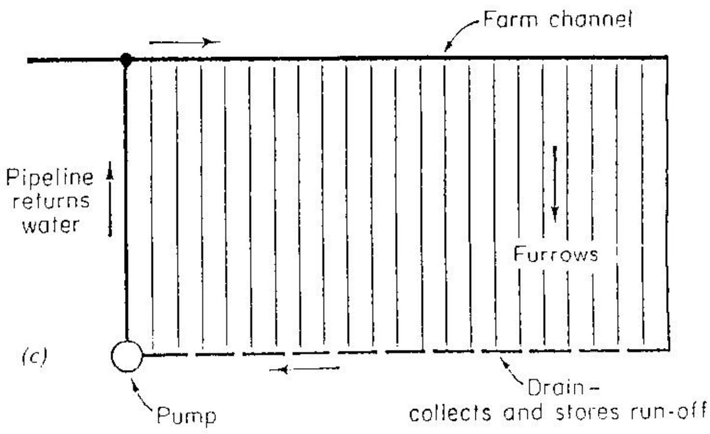


Figure 11 A Return Flow System

All of these practices can greatly improve furrow irrigation efficiency but they can be very difficult to put into practice. Usually irrigators have enough problems just trying to irrigate without the extra problem of coping with run-off. A great deal also depends on the irrigation system and on the skill of the irrigator for these practices to work well.

8. Alternate Furrow Irrigation

This method is very useful when there is a water shortage. A limited amount of water can be spread over a large area so that all the crops obtain some water.

The practice involves irrigating every second (alternate) furrow in a field instead of irrigating every furrow (Figure 12). For example, if a crop is normally irrigated every 10 days, alternate furrow irrigation would mean irrigating furrows 1, 3, 5 and 7 on day 5 and furrows 2, 4 and 6 on day 10. The crop receives some water every 5 days instead of a large amount every 10 days. This is usually better for the crop.

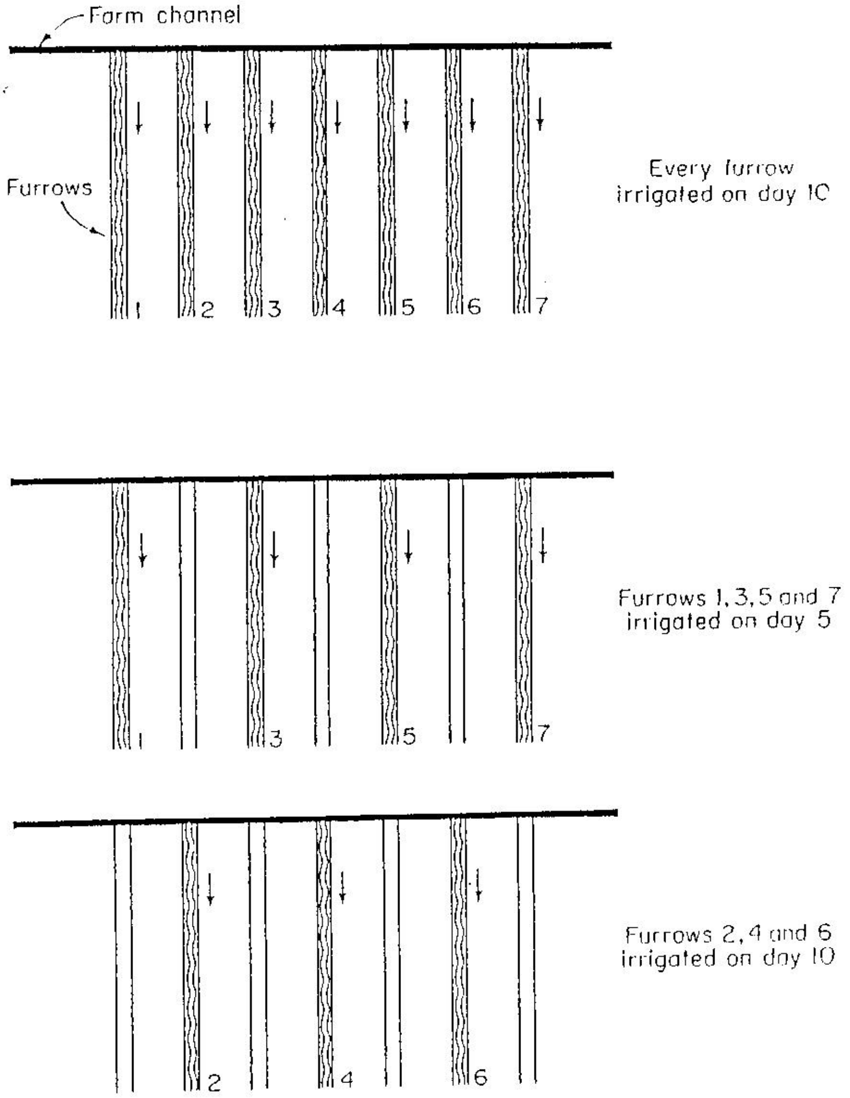


Figure 12 Alternate Furrow Irrigation

When there is a shortage of water the normal interval between irrigations may be increased from 10 to 14 days and this can reduce the crop yield. By using the alternate furrow method all the crop would receive some water every 7 days.

This method is often used to irrigate orchards but water is usually applied to alternate tree rows rather than to alternate furrows. This is called alternate middle irrigation.

9. Common Faults

Although furrow irrigation can be very efficient there are many common irrigation practices which result in poor water distribution and low irrigation efficiency. Some of these are described below.

9.1 Poor Land Preparation

This is very similar to the problem described for border irrigation. Uneven slopes and low areas in a field can result in poor water distribution and water logging. Very small changes in ground level can have significant effects on irrigation efficiency.

All these faults can be corrected by careful land grading.

9.2 Furrows on Clay Soils

On clays infiltration is usually very slow and sometimes there is difficulty in getting enough water to infiltrate into the soil. On sloping land the water may flow too quickly down the furrow with the result that only a small amount of water infiltrates at the head of the furrow causing poor crop growth. This problem can be overcome by using a very small stream size or regrading the land so that the slopes are much flatter. In either case the advance will be slower and more water will infiltrate at the head of the field.

9.3 Different Soil Types Along Furrows

The effect of this is very similar to that for basins and borders. Water distribution will be very uneven. The only solution is to re-align the furrows so that they contain only one soil type.

9.4 Advance Time Too Long

This is usually the result of using a stream size which is too small. It is done for two reasons. Firstly, the irrigation may be to a fixed schedule such as 8 or 12 hours to fit in with other farm work. Secondly, it reduces run-off because water is slow in reaching the end of the furrows (Figure 13). However, this practice greatly increases deep percolation losses. These are not so obvious as run-off which can be easily seen. Only by choosing the right stream size for the soil conditions can losses be reduced.

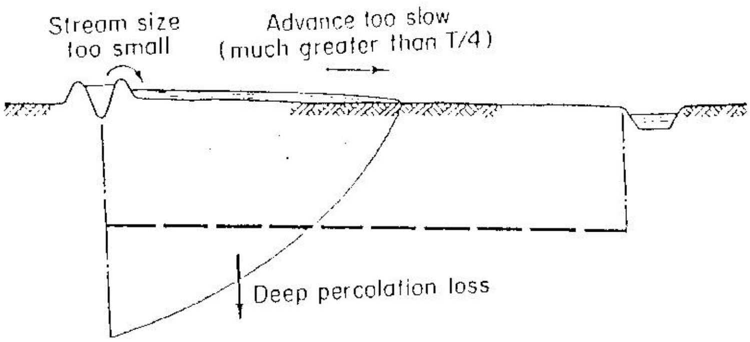


Figure 13 Common Fault-Advance Time Too Long

9.5 Stopping Inflow Too Soon

Even when the right stream size is used, the inflow is sometimes stopped too soon to try and reduce run-off. This results in a poor distribution of water and plants at the ends of furrows do not get enough water (Figure 14). This can be seen very clearly in some crops. The growth is much poorer towards the end of the furrows.

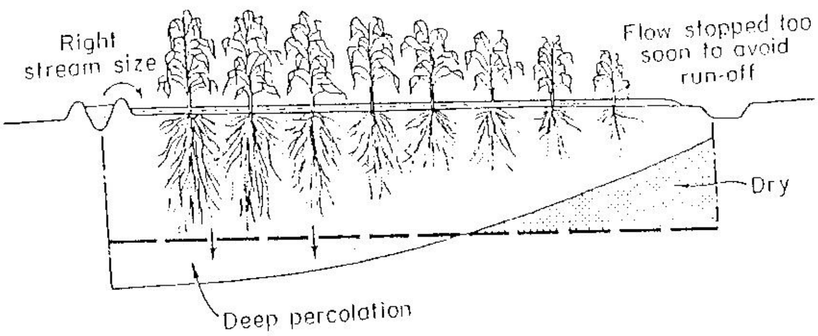


Figure 14 Common Fault-Stopping Inflow Too Soon

9.6 Bunding End cf Furrow

To try and correct the above fault some irrigators bund the ends of furrows to stop all run-off (Figure 15). This improves the infiltration at the far end because water is ponded but there is still

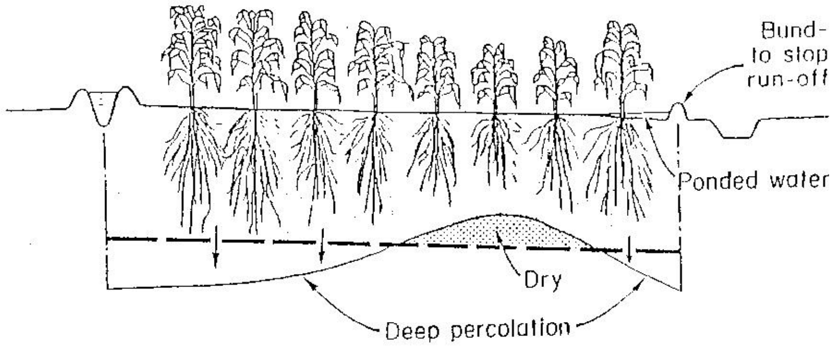


Figure 15 Common Fault-Bunding End of Furrows

not enough irrigation further up the slope. This dry area is often called a hot-spot and is clearly visible in some crcps because of the poor growth.

10. Efficiency

On well managed furrows the irrigation elfficiency can be as high as 90 %. When furrows are not used properly the efficiency can be much lower. The following are guidelines on the effects of poor practice on irrigation efficiency. The figures should be subtracted from 90 %.

Common faults	Subtract
No return flow system	20-40%
Pocr land preparation	10-20%
Different soil types along furrow	5-10%
Advance time too long	10-20%
Stopping inflow too soon	10-20%

11. Furrow Irrigation Evaluation

11.1 Required Data

In furrow irrigation trial, the following information has to be recorded.

1. Size of stream for each furrow, the size of stream in furrow trial should range from very large to very small.

2. Time water advances to each station.

3. Maximum size of stream which may be limited either by size of furrow or by maximum allowable non-erosive discharge.

4. Furrow infiltration rate which may be different from flooding method. The wetted area is less for furrows.

5. Furrow conditions : new or used furrow, soil is compacted or lose.

6. Irrigation depth to fill soil moisture to field capacity or soil moisture deficiency (SMD).

7. Time and rate of runoff.

After all of the required data are available, the effectiveness of trial furrow irrigation is analyzed to determine :

1. Uniformity of application.
2. Application efficiency.
3. Adequacy of irrigation.
4. Effect of stream size change.
5. Effect of furrow length change.
6. Effect of MAD change.

11.2 Equipments

The required equipments for field furrow trial are :

1. A surveying tape.
2. Stakes with a hammer.
3. A watch.
4. 10 x 90 m. cut throat flume.
5. A shovel.
6. A soil core sampler.
7. A recording form.
8. A surveying leveling instrument with staff gauges.

11.3 Field Evaluation Procedure

A field trial furrow is conducted to determine the necessary data for furrow evaluation. Different stream sizes are tested ranging from a very small to very large. Determine advance rate to each station in furrows. Measure the depth applied at furrow head and different stations in the furrow in order to calculate the water depth infiltrated. The steps of furrow trial are :

1. Select furrows which have uniform slope and shape, can apply water conveniently and are the representatives of other furrows in the area.

2. Set stakes along the furrows at 20-30 m spacing. The first stake should be set a little downstream of the head end to avoid the turbulence in flow measurement.

3. Determine the furrow slope.

4. Install a cut throat flume on the first stake (Station 0) of each test furrow. The second cut throat flume should be installed at 2 stations downstream of the first flume (or at station 2). The last flume is installed at the tail end to measure runoff.

5. Determine soil moisture depletion (SMD) using a soil core sampler set.

6. Apply a constant stream size to each furrow. The size of stream may vary greatly from very small to very large, but for each furrow it is constant. At least 3 furrows should be tested simultaneously. One is for maximum allowable non-erosive stream size calculated by Equation 1, one for intermediate size of stream and the last one for very small stream size. The water should be applied to the adjacent furrows as well to prevent excessive lateral movement of water.

7. Record time when flow is started and the flow rate. The flow rate should be monitored periodically.

8. Record advance time.

9. Record infiltration rate by inflow-outflow method.

10. Observe furrow over-topping and erosion to estimate maximum allowable size of stream. For a new furrow, an erosion may be take place at the very beginning but is stopped after some time. This considers an acceptable size of stream.

11. Record time and rate of runoff at the tail end of furrow periodically.

12. Examine how uniform the water is infiltrated throughout the furrow cross-section.

13. Examine how to improve the effectiveness of furrow.

11.4 Analysis Procedure

The data collected from the furrow trial should be used to construct graphs. The graphs are more useful and convenient for further analysis. The required graphs are :

1. Advance curve

2. Recession curve, for a small furrow the recession curve is assumed constant or a straight horizontal line.

3. Furrow infiltration rate and cumulative infiltration curves.

12. Example of Furrow Irrigation Evaluation

The trial furrow is 350 m long with 0.2 % slope. The soil is sandy loam. Other data are :

- application time 10 hours
- furrow spacing 0.90 m.
- length of furrow for evaluation 200 m.
- root zone depth 1 m.
- soil moisture depletion (SMD) 90 m.
- available moisture 18 % volume
- no. of test furrows 3
- size of stream 0.25, 0.58, 1.12 lps.

The furrow infiltration rates measured by inflow-outflow metod are shown in Table 2 and 3 and are plotted in Figure 16.

The infiltration rate in lps/25 m between station 0 and 2 (50 m apart) can be converted to mm/minute by the following equation.

$$I \text{ (mm/min.)} = \frac{60.I \text{ (lps/L)}}{L.S} \qquad (2)$$

where

I = infiltration rate in mm/min. or lps/L

L = length of measurement in m.

S = furrow spacing in m.

Table 2

Furrow Infiltration Test

Location KU,KPS. Observer VARAWOOT Date 7 JULY 1992

Furrow No. 2 Flow Rate 0.58 lps Shape ◡ Age USED

Slope 0.002 Condition Good Soil Sandy Loam

Time			Sta.A (Inflow)		Sta.B (Outflow)		Intake	
Watch	Diff	Cumu	Head	Flow rate	Head	Flow rate	(8) lps/ 50 m	(9) lps/ 25 m
(1)	(2)	(3)	(4)	(5) lps	(6)	(7) lps		
08:27		0	5.1	0.59	X	X	X	X
33	6	6	4.9	0.57	3.5	0.33	0.25	0.125
38	5	11	5.1	0.59	3.8	0.38	0.20	0.100
49	11	22			4.0	0.40	0.18	0.090
09:03	14	36	4.9	0.57	4.1	0.43	0.15	0.075
20	17	53			4.3	0.45	0.13	0.065
47	27	80			4.3	0.45	0.13	0.065
10:24	37	117	5.1	0.59	4.4	0.48	0.10	0.050
			Avg.	0.58				

First entry made when stream reaches midway between stations A and B
Second entry made a few minutes after stream passes station B.
Subsequent entries made at increasingly longer intervals to obatin at least six entries.

Table 3

Furrow Infiltration Test

Location KU, KPS. Observer VARAWOOT Date 7 JULY 1992

Furrow No. 3 Flow Rate 1.12 lps Shape .... Age USED

Slope 0.002 Condition Good Soil Sandy Loam

Time			Sta.A (Inflow)		Sta.B (Outflow)		Intake	
Watch	Diff	Cumu	Head	Flow rate	Head	Flow rate	(8) lps/25 m	(9) lps/50 m
(1)	(2)	(3)	(4)	(5) lps	(6)	(7) lps		
08:29		0	4.9	1.14				
34	5	5	4.8	1.08	6.0	0.77	0.35	0.175
40	6	11	5.8	1.08	6.5	0.87	0.25	0.125
49	9	20			6.7	0.91	0.21	0.105
09:03	14	34	4.9	1.14	6.8	0.94	0.18	0.090
20	17	51			6.8	0.94	0.18	0.090
47	27	78			6.8	0.98	0.18	0.090
10:24	37	115	4.9	1.14	7.0		0.14	0.070
			Avg.	1.12				

First entry made when stream reaches midway between stations A and B
Second entry made a few minutes after stream passes station B.
Subsequent entries made at increasingly longer intervals to obatin at least six entries.

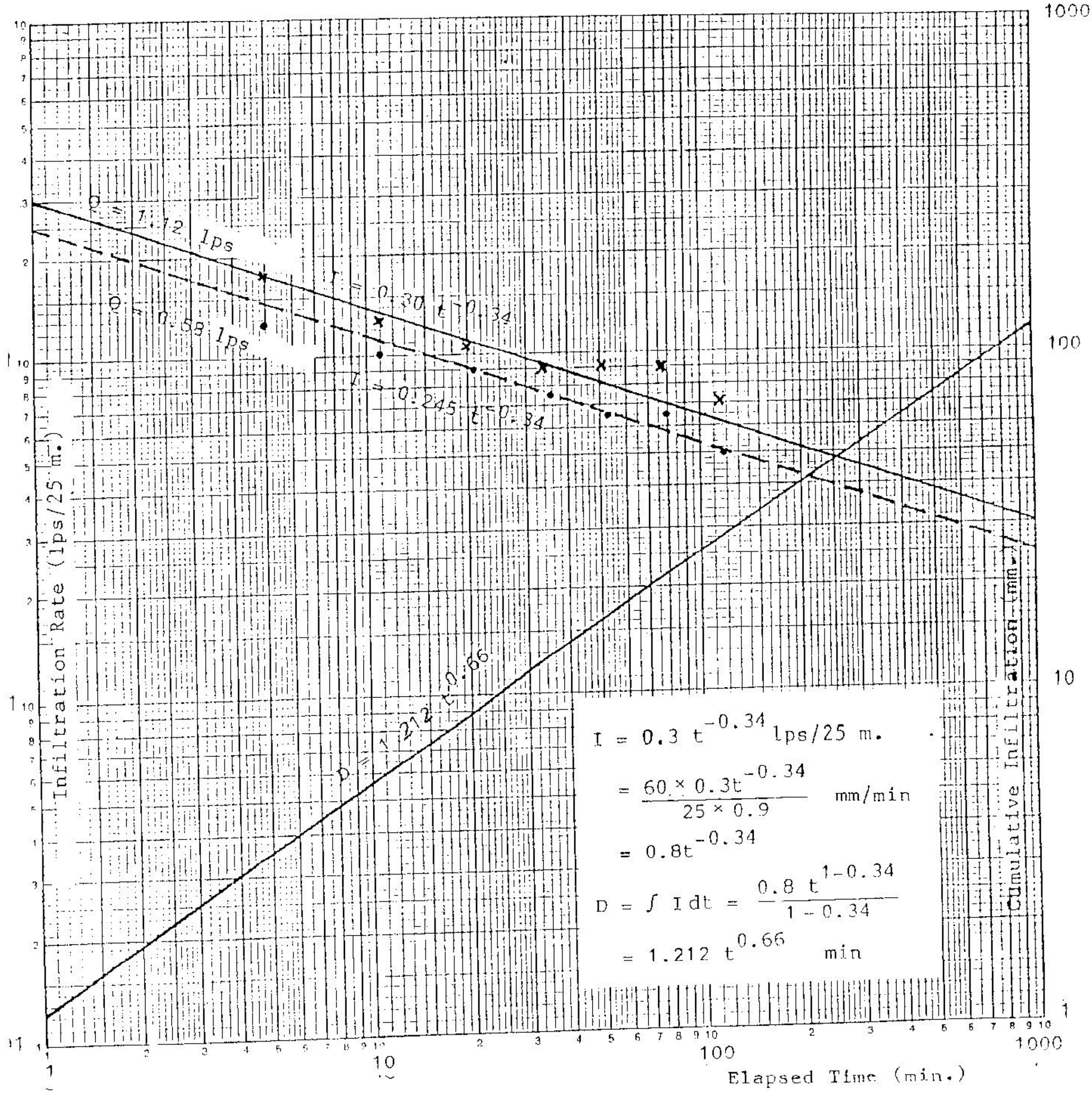


Figure 16 Furrow Infiltration Curves

The advance data are shown in Table 4 and are plotted in Figure 17. It is notes that the advance curves for 0.58 and 1.12 lps are extended to station 13 and 14 (or 325 and 350 m respectively).

In actual evaluation, all three test furrows have to be analyzed to determine the best size of stream. However, in this example, only 1.12 lps-test furrow is analyzed for the distribution uniformity (DU), application efficiency (E_a) and adequacy of irrigation.

(1) Calculation of Distribution Uniformity (DU)

$$DU = 100 \frac{\bar{D}_{LQ}}{\bar{D}} \% \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where

$\bar{D}_{LQ}$ = average low quarter depth infiltrated

$\bar{D}$ = average depth infiltrated

Assume that the recession takes place immediately throughout the whole furrow length after the flow is stopped. For 1.12 lps.-test furrow, the opportunity time and depth infiltrated for the 200 m test furrow are shown below :

Station* (i)	$Taad_i$ (min.) (Figure 17)	To_i (min.)	D_i (mm.) (Figure 16)
0	0	600	82.6
1	5	595	82.2
2	10	590	81.7
3	17	583	81.1
4	26	574	80.2
5	36	564	79.3
6	48	552	78.2
7	59	541	77.2
8	72	528	75.9

* (1 station = 25 m.)

Table 4

Water Advance and Recession Data for Furrow Irrigation

1. Location KU,KPS., Observer VARAWOOT, Date 7 JULY 1992
2. Crop Condition Good, Furrow condition Good
3. Furrow spacing 0.90 m, slope 0.2 %
4. Irrigation: duration 7, frequency 7
5. A: advance B: advance C: advance D:
Stream 0.25 lps 0.58 lps 1.12 lps

A: Time – min. Watch	A: Diff.	A: Cumu.	A: Station	B: Time – min. Watch	B: Diff.	B: Cumu.	B: Station	C: Time – min. Watch	C: Diff.	C: Cumu.	C: Station	D: Time – min. Watch	D: Diff.	D: Cumu.	D: Station
08:22		0	0	08:24		0	0	08:27		0	0				
39	17	17	1	31	7	7	1	32	5	5	1				
09:05	26	43	2	39	8	15	2	37	5	10	2				
39	34	77	3	50	11	26	3	44	7	17	3				
10:22	43	120	4	09:03	13	39	4	53	9	26	4				
				22	19	58	5	09:03	10	36	5				
				46	24	82	6	15	12	48	6				
				10:03	17	99	6.5	09:22	7	55	6.5				

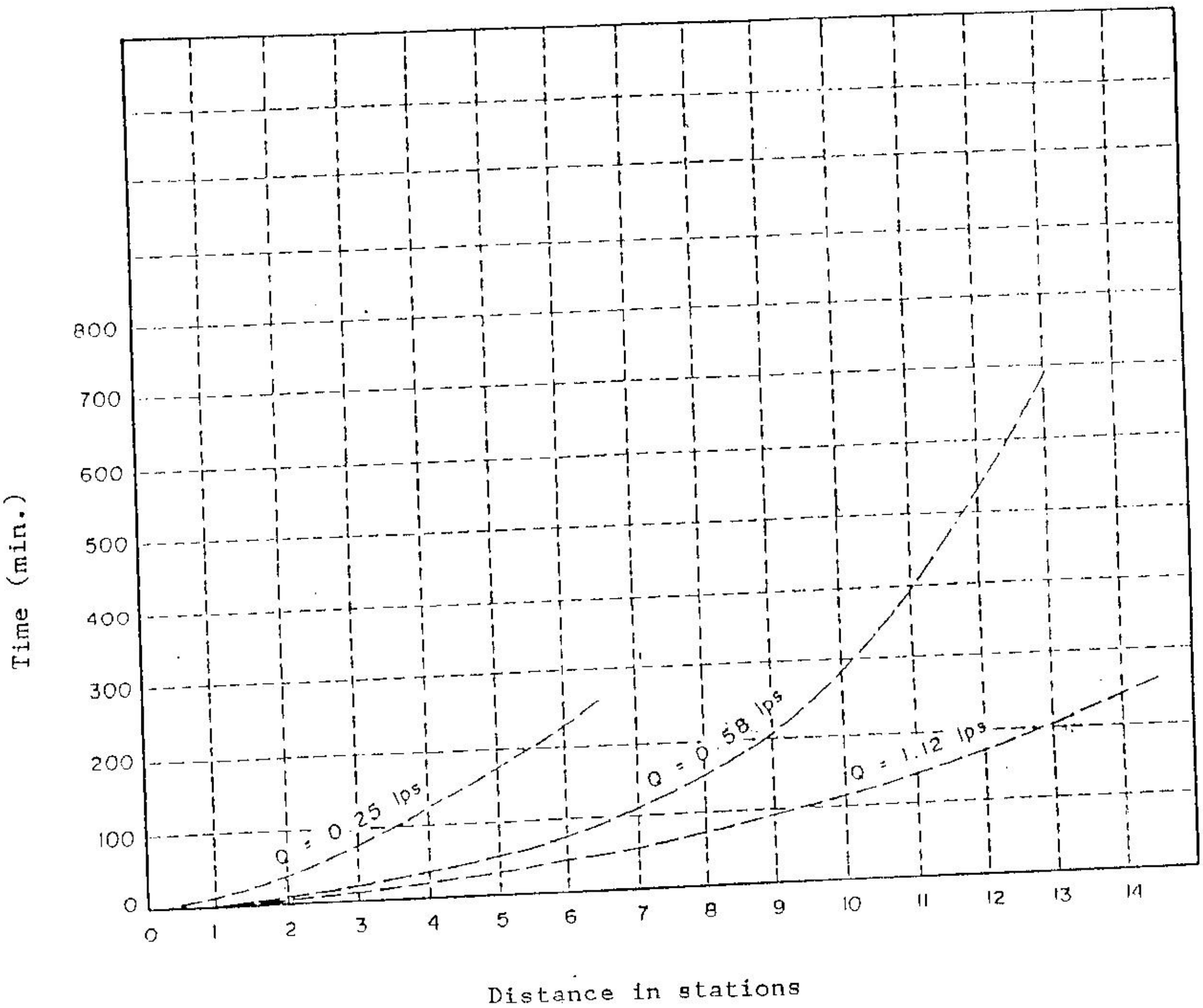


Figure 17 Advance Curves of Furrows

$$\bar{D} = \frac{(\frac{82.6}{2} + 82.2 + \ldots + 77.2 + \frac{75.9}{2})}{8}$$

$$= 79.9 \text{ mm.}$$

$$\bar{D}_{LQ} = \frac{(\frac{78.2}{2} + 77.2 + \frac{75.9}{2})}{2}$$

$$= 77.1 \text{ mm.}$$

$$DU = 100 \times \frac{77.1}{79.9} = 96.5 \%$$

(2) <u>Calculation of Application Efficiency</u> (E_a)

$$E_a = \frac{V_{RZ}}{V_T} \times 100 \% \quad \ldots\ldots\ldots\ldots \quad (4)$$

where

V_{RZ} = volume or depth stored in root zone

V_T = volume or depth applied

The SMD = 90 mm. indicates under irrigation of the whole furrow length. In this case,

$$V_{RZ} = \bar{D} = 79.9 \text{ mm.}$$

$$V_T = \frac{QT}{A}$$

$$= \frac{1.12 \times 10 \times 3600}{200 \times 0.9}$$

$$= 224 \text{ mm.}$$

$$E_a = \frac{79.9}{224} \times 100 = 35.7 \%$$

(3) <u>Determine Adequacy of Irrigation</u>

For under irrigation case, storage efficiency (E_s) is used to measure adequacy of irrigation

$$E_s = 100 \frac{V_{RZ}}{SMD} \% \quad \ldots\ldots\ldots\ldots \quad (5)$$

$$= 100 \times \frac{79.9}{90} = 88.8 \%$$

(4) Calculation of Irrigation Water Losses

Runoff Losses (RO)

$$RO = V_T - V_{RZ}$$

$$= 224 - 79.9 = 144.1 \text{ mm.}$$

$$= \frac{141.1}{224} \times 100 = 64.3 \%$$

(5) Summary of The Furrow Trial Evaluation

For 1.12 lps-test furrow, the results are :

DU = 96.5 % .... Good

E_a = 35.7 % .... Too Low

RO = 64.3 % .... Too High

(Because the size of stream 1.12 lps is too high. Recommend Cut Back technique)

E_s = 88.8 % .... Under Irrigate

To complete irrigation, the application time should be increased, which can be calculated as follow :

SMD = 90 mm.

$$T_o \text{ (at tail end)} = \left(\frac{90}{1.212}\right)^{1/0.66}$$

$$= 683 \text{ min.}$$

$$T_a \text{ (application time)} = T_o + T_{adv.}$$

$$= 683 + 72 = 755 \text{ min.}$$

$$\text{Advance Ratio} = \frac{T_{adv.}}{T_o} = \frac{72}{683} = \frac{1}{9.5}$$

The advance ratio (1/9.5) indicates water advance too fast. The size of stream should be decreased in such away that the advance ratio is $\frac{1}{4}$.

$$\frac{T_{adv}}{T_o} = \frac{1}{4}$$

$$T_{adv} = \frac{683}{4} = 170 \text{ min.}$$

From the advance curve in Figure 17, the suitable stream size is 0.58 lps, or the furrow length is increased from 200 m to 300 m.

(6) Try Furrow Length of 300 m.

$$T_a = T_o + T_{adv.}$$

$$= 683 + 170 = 853 \text{ min.}$$

From Figure 16 and 17, the opportunity time and infiltrated depth can be calculated as follow :

Station (i)	$Tadv_i$(min.) (Figure 17)	To_i (min.)	D_i(mm.) (Figure 16)
0	0	853	104.2
1	5	848	103.8
2	10	843	103.4
3	17	836	102.8
4	26	827	102.1
5	36	817	101.3
6	48	805	100.3
7	59	794	99.4
8	72	781	98.3
9	90	763	96.8
10	110	743	95.1
11	140	713	92.6
12	170	683	90.0

$$\bar{D} = \frac{(\frac{104.2}{2} + 103.8 + \ldots + 92.6 + \frac{90}{2})}{12}$$

$$= 99.4 \text{ mm.}$$

$$\bar{D}_{LQ} = \frac{(\frac{98.3}{2} + 96.8 + \ldots + 92.6 + \frac{90}{2})}{4}$$

$$= 94.7 \text{ mm.}$$

$$DU = \frac{94.7}{99.4} \times 100 = 95.3\ \%$$

$$V_T = \frac{1.12 \times 853 \times 60}{300 \times 0.9}$$

$$= 212.3 \text{ mm.}$$

$$E_a = \frac{V_{RZ}}{V_T} \times 100$$

$$= \frac{90}{212.3} \times 100 = 42.4\ \%$$

$$E_s = 100\ \%$$

$$DP = \bar{D} - V_{RZ}$$

$$= 99.4 - 90 = 9.4 \text{ mm.}$$

$$DP = \frac{9.4}{212.3} \times 100 = 4.4\ \%$$

$$RO = V_T - V_{RZ} - DP$$

$$= 212.3 - 90 - 9.4 = 112.9 \text{ mm.}$$

$$RO = \frac{112.9}{212.3} \times 100 = 53\ \%$$ ...... Too High

Cut back is recommended to reduce runoff.

(7) Increase Application Efficiency Using Cut Back

Furrow Length = 300 m.

Q = 1.12 lps.

From Figure 16,

$$I = 0.3\ t^{-0.34} \text{ lps/25 m.}$$

One cut back at 180 min.

Station (i)	$Tadv_i$ (min.)	To_i (min.)	I_i (lps/25 m.)
0	0	180	0.0513
1	5	175	0.0518
2	10	170	0.0523
3	17	163	0.0531
4	26	154	0.0541
5	36	144	0.0554
6	48	132	0.0570
7	59	121	0.0587
8	72	108	0.0611
9	90	90	0.0650
10	110	70	0.0708
11	140	40	0.0856
12	170	10	0.1371

$$\bar{I}_1 = \left(\frac{0.0513}{2} + 0.0518 + \ldots + 0.0856 + \frac{0.1371}{2}\right)$$

$$= 0.7591 \text{ lps.}$$

$$V_T = \frac{[1.12 \times 180 + 0.7591 \times (853 - 180)] \times 60}{300 \times 0.9}$$

$$= 158.33 \text{ mm.}$$

$$E_a = \frac{90}{158.3} \times 100 = 56.8 \%$$

Second cut back at 360 min.

Similarly

$$\bar{I}_2 = 0.52 \text{ lps.}$$

$$V_T = \frac{[1.12 \times 180 + 0.7591 \times 180 + 0.52 \ (853 - 360)] \times 60}{300 \times 0.9}$$

$$= 132.1 \text{ mm.}$$

$$E_a = \frac{90}{132.1} \times 100 = 68.1 \%$$

Third cut back at 540 min.

$$\bar{I}_3 = 0.44 \quad lps.$$

$$V_T = \frac{[2.399 \times 180 + 0.44\ (853 - 540)]\ 60}{300 \times 0.9}$$

$$= 126.6 \quad mm.$$

$$E_a = \frac{90}{126.6} \times 100 = 71\ \%$$

(8) Use Reuse System

If the reuse system is used the application efficiency may increase to 95.3 %

Field Practice

Field Evaluation of Furrow Irrigation

1. Purpose

The efficiency of furrow irrigation depends on the selection of shape, size and length of furrow suitable to types of soil, water application rate, irrigation water depth applied and slope. The objectives of the furrow field evaluation is to determine how good the design and management of the furrow are under field conditions. How good are the indices of uniformity efficiency and adequacy in such a way that the evaluation results can be used to improve quality of furrow irrigation.

2. Required Equipements

1. A leveling surveying instrument.
2. A surveying tape.
3. A watch.
4. 12 stakes of 60 cm long per furrow with a hammer.
5. 3 cut throat flumes of 10 x 90 cm per furrow.
6. A shovel.
7. A bucket.
8. A water leveling indicator.
9. A soil core sampler with 5 sets of 1 + 3 + 1 cm thick rings.
10. 12 of 2" diameter siphon tubes.
11. A form for recording infiltration rate by inflow-outflow method.
12. A form for recording flow through cut-throat flume.
13. A form for recording advance and recession.

3. Field Evaluation Procedure

1. Choose 3 representative furrows.
2. Set stakes at 25 m. intervals. The first stake must be located at least 3 m. from the head of furrow to make sure that the measured stream size is accurate enough.
3. Measure furrow shape and spacing.
4. Measure furrow slope.
5. Install the first flume at stake 0.
6. Install the second flume at a distance of 2 stations downstream of the first.
7. Determine soil moisture content, bulk density, water contents at field capacity and permament wilting point using a soil core sampler. Take a least 3 samples.
8. Apply 3 uniform stream sizes namely 100 %, 60 % and 20 % of maximum non erosion discharge (Q max.)

   $$Qmax = \frac{0.6}{S} \text{ lps.}$$

   when S = furrow slops, %

   Apply water to the adjacent furrows to prevent over lateral movement.
9. Record time when flow was started and the size of stream. The stream size should be frequently checked.
10. Record time when water advances to each station.
11. Record time when runoff was started and rate of runoff.

4. Analysis Procedure

4.1 Preliminary Analysis

1. Determine infiltration rate and cumulative infiltration curves and formula.

2. Determine advance and recession curves.

3. Determine soil moisture depletion.

4.2 <u>Analysis of Effectiveness of Water Application</u>

1. Uniformity

2. Efficiency

3. Adequacy

4.3 <u>Analysis for Improving Effectiveness</u>

1. Changing Q

2. Changing L

3. Changing SMD

4. Use of cut-back

5. <u>Recommendations</u>

Furrow Infiltration Test

Location .... Observer .... Date ....

Furrow No. .... Flow Rate .... Shape........... Age ....

Slope .... Condition .... Soil................

Time			Sta.A (Inflow)		Sta.B (Outflow)		Intake	
Watch	Diff.	Cumu.	Head	Flow rate	Head	Flow rate	(8) lps/ 50 m	(9) lps/ 25 m
(1)	(2)	(3)	(4)	(5) lps	(6)	(7) lps		
					X	X	X	X

First entry made when stream reaches midway between stations A, and B. Second entry made a few minutes after stream passes station B. Subsequent entries made at increasingly longer intervals to obatin at least six entries.

Water Advance and Recession Data for Furrow Irrigation

1. Location ______, Observer ______, Date ______
2. Crop Condition ______, Furrow condition ______
3. Furrow spacing ______ m, slope ______ %
4. Irrigation: duration ______, frequency ______
5. A: ______ B: ______ C: ______ D: ______
   Stream ______

Time _ min.			Station	Time _ min.			Station	Time _ min.			Station	Time _ min.			Station
Watch	Diff.	Cumu.		Watch	Diff.	Cumu.		Watch	Diff.	Cumu.		Watch	Diff.	Cumu.	