FURROW IRRIGATION INFILTRATION AND EVALUATION

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FURROW INFILTRATION

Introduction

The most important factor to consider in furrow irrigation is the ability of the soil to absorb irrigation water. The rate and the amount of water the soil will absorb is important in designing irrigation systems. Through "Operation Fuel" the SCS received a flowing furrow infiltrometer from the Mississippi Soil and Water Commission to help develop information about how different soils respond to furrow irrigation methods.

Methods and Procedures

The furrow infiltrometer consists of two major sections, an equipment section and a field section. The equipment section consists of a 300-gallon storage tank for water supply, a supply pump to deliver water to the furrow, a flow regulating valve to control the flow rate, in-line flow meters to measure the amount of water delivered to the furrow and returned to the storage tank, an AC generator to power an electric sump pump and other equipment mounted on a portable trailer. The field section consists of an inflow sump box with a stage recorder to measure water into the furrow, an outflow sump box with a stage recorder to measure water out of the furrow, a sump pump to return excess water to the supply tank, and various hoses.

After initial setup and calibration, the infiltrometer was used to evaluate infiltration characteristics of a soil that was commonly irrigated using furrow methods.

The steps for a typical run are as follows:

1. Select site and mark off 30 feet of furrow.
2. Fill supply tank and move to site.
3. Position upper sump in head of furrow.
4. Bury lower sump in end of furrow.
5. Layout supply hoses.
6. Fill hoses and sump boxes with water.
7. Mount and zero stage recorders on sump boxes.
8. Install sump pump in lower sump box.
9. Set valves and begin run.
10. Run evaluation for approximately 3 hours.
11. Close valves and allow lower sump to return water stored on the surface into the supply tank.
12. Remove equipment and analyze data.

Results

The results of evaluations on two sites on the Dubbs series (Fine-silty, mixed, thermic Typic Hapludalfs) are as follows. Site E2 was a field in continuous cotton. The soil had a moderately strong surface crust and many small cracks. During the infiltration test, water entered the soil and moved laterally through these small cracks into adjacent furrows. Indications were that the soil cracks extended to the depth of the plow pan approximately 12-14 inches in depth. These cracks qualitatively affected the results of the infiltration test. The quantitative effect was unknown.

The soil profile was described as follows:

- 0 to 6 inches, brown silt loam, weak fine granular structure, very friable.
- 6 to 14 inches, brown silt loam with dark yellowish brown mottles, weak fine subangular blocky structure, firm.
- 14 to 19 inches, dark yellowish brown silt loam with yellowish brown mottles, weak medium subangular blocky structure, friable.
- 19 to 39 inches, yellowish brown very fine sandy loam with dark yellowish brown mottles, weak medium subangular blocky structure, friable.
- 39 to 50 inches, yellowish brown fine sandy loam with pale brown mottles, weak medium subangular blocky structure, friable.

Soil samples were taken before irrigation for moisture, bulk density and textural analysis. The results are shown in Table 3. The results of the infiltration test are shown in Table 1.

Table 1
Cumulative Infiltration
Site E2

time (minutes)	infiltration (inches)
30	2.76
40	3.06
50	3.28
60	3.37
70	3.45
80	3.52
90	3.56

Using the infiltration data listed in Table 1, a linear regression was calculated and the resulting line has the equation:

$$F=0.919\,t^{.312} \qquad r^2 = 0.919$$

where F is the infiltration in inches and t is the opportunity time in minutes.

Site E3 was also in continuous cotton. The soil had a moderate surface crust with a few small cracks extending only a few millimeters into the soil. The quantitative effect on the infiltration was unknown.

The soil profile was described as follows:

- 0 to 18 inches, dark brown silt loam, weak fine granular structure, friable.
- 18 to 24 inches, dark brown silt loam with dark yellowish brown mottles, weak medium subangular blocky structure, firm.
- 24 to 34 inches, dark brown silty clay loam with dark yellowish brown and dark grayish brown mottles, weak medium subangular blocky structure, firm.
- 34 to 48 inches, dark grayish brown silty clay loam with brown and dark yellowish brown mottles, weak subangular blocky structure, firm.

Prior to water being applied, soil samples were taken for moisture, bulk density and textural analysis. The results are shown in Table 3. Results of the infiltration test are shown in Table 2.

Table 2
Cumulative Infiltration
Site E3

time (minutes)	infiltration (inches)
10	1.28
20	1.67
30	1.68
40	1.59
50	1.53
60	1.55
70	1.56
80	1.60
90	1.65
100	1.68
110	1.71
120	1.76
130	1.82
140	1.88
150	1.92
160	2.00
170	2.08
180	2.17

Using the infiltration data in Table 4, a linear regression was calculated and the resulting line has the equation:

$$F = 0.938\,t^{.129} \qquad r^2 = 0.664$$

where F is the infiltration in inches and t is the opportunity time in minutes.

Table 3
Soil Physical Characteristics

site #	depth (in)	bulk density (g/cc)	water content % wt	water content % vol	sand %	silt %	clay %
e2	2	1.40	8.3	11.7	25	59	16
e2	6	1.68	12.8	21.4	22	60	18
e2	10	1.50	15.4	23.1	22	57	21
e2	14	1.44	14.7	21.1	25	58	17
e2	18	1.43	13.7	19.6	27	57	16
e3	2	1.33	9.8	13.0	24	54	22
e3	6	1.36	14.4	19.6	20	55	25
e3	10	1.61	10.1	16.3	20	55	25
e3	14	1.58	16.0	25.3	21	52	27
e3	18	1.51	19.3	29.1	na	na	na

na = not available

Conclusions

It should be noted that these data are for one site and should not be used for broad interpretation. However, interpretations may be possible as more data are gathered on different sites, using these methods.

The traveling furrow infiltration data were collected over relatively short time spans (1-3 hours) compared to actual furrow irrigation times (12-24 hours). However the infiltration rates were similar to those previously determined using a ring infiltrometer. To improve the accuracy of measurement and simulation of furrow infiltration under field conditions, the traveling furrow infiltrometer procedure will be modified for the next irrigation season. The equipment will be placed in a field in two different arrangements.

In the first arrangement instead of using the trailer water supply, the inflow from an actual furrow gate will be measured using the furrow evaluation inflow box. The sump box will be set 200' down the row. The sump pump will then pump the water into the furrow to continue the irrigation of the furrow. A flume will be used to measure the runoff from the furrow. In this case the infiltration will be measured over 200' of furrow for the entire irrigation set time. In the second arrangement the equipment will be used in the same manner as this past year. In both situations a ring infiltrometer will also be set up nearby to give additional information.

FURROW EVALUATION

Introduction

In conjunction with the acquisition of soil infiltration rates from the traveling furrow infiltration trailer, furrow evaluations are made on actual field applications to determine the actual performance characteristics of the system. After an evaluation is made, changes in management (furrow stream size, set time lengths, furrow length changes, etc.) can be recommended to improve the irrigation efficiency.

Methods and Procedures

The system evaluated had rows of 1320' with a slope of .2'/100' in the evaluation area. A furrow inflow box was installed in the ground next to the gated pipe to measure the inflow stream size. Spaced at 330' intervals, data recorders with float switches were installed in the furrow to measure the time required for water to reach the station and the time required for the water to recede from that point. These times give the opportunity time for infiltration for the first four stations and the last station shows how long tailwater was leaving the field. The actual runoff volume was not recorded this past season but flumes will be used this next season to record runoff volumes from individual furrows.

Results

The flow rate into the furrow was measured to be 11.6 gpm (average) for a total of 19.2 hours. This represented an application of 4.97" of water for that furrow. The opportunity time and intake at each point in the furrow for the 19-hour set time are shown in Table 4. Intake was calculated using the furrow infiltration equation developed from the flowing furrow infiltrometer data on site E3.

With an application of 4.97" and an average intake of 2.39", the application efficiency was 48%. This means 2.58" of irrigation water ran off. The pattern efficiency (how well the water was distributed down the furrow) was 95%. The intake rate of the soil prevents larger applications from being made. With an application of 2.39" a farmer will have to irrigate every 8 to 12 days.

It appears that a shorter inflow time would accomplish nearly the same results. The intake rates of the soils drops sharply after the initial infiltration so that long opportunity times are not required. This also indicates that allowing tailwater to runoff for long time to irrigate the lower end of the field is also unnecessary. Therefore a analysis was done on determining what would happen if the irrigation time was cut to only 12 hours rather than the 19 plus hours. These results are shown in Table 4. Opportunity time is the amount of time water is infiltrating at any given point along a furrow (recession time minus advance time). Intake is the depth of water absorbed by a soil at a selected point along the furrow.

Table 4
Furrow Evaluation Results

Station	19 hr set time*		12 hr set time**	
ft	Opportunity time minutes	Intake inches	Opportunity time minutes	Intake inches
0	1154	2.44	720	2.30
330	1134	2.44	700	2.29
660	1099	2.43	665	2.27
990	1014	2.40	580	2.23
1320	640	2.26	206	1.95

* actual set time used
** recommended set time

The application for a 12-hour irrigation was 3.07". The average intake was 2.21". While reducing pumping from 19 to 12 hours, the intake only dropped from 2.39" to 2.21". The application efficiency increases to 72% while the pattern efficiency drops slightly to 88%. The effect of reducing irrigation set times on infiltration and runoff is shown graphically in Figure 1. The well was pumping 2250 gpm from a depth of 47 feet and consuming 2.95 gal of fuel per hour, the reduction in water pumped would be 7 million gallons. It would take 12 hours per set with approximately 200 rows being done per set. For a 160 acre field 8 sets would be required. The current system would take 154 hours to complete the irrigation. The new system would require only 96 hours to complete the irrigation with only a .18" reduction in the water applied (which is only one day's use). The resultant fuel savings would be 171 gallons of diesel each time the field would be irrigated (normally 3 to 4 times per season). Additional savings would be obtained through decreased engine hours per season lengthening engine life.

Conclusions

The furrow evaluation when combined with soils intake data allows for the planning of an irrigation system that achieves the greatest possible efficiency. The soils intake data alone allow for planning a system, but only a furrow evaluation can determine factors such as rate of advance and recession times. Furrow evaluations will provide needed information for the computer design of irrigation systems in the future without the need for field evaluations.

Acknowledgments

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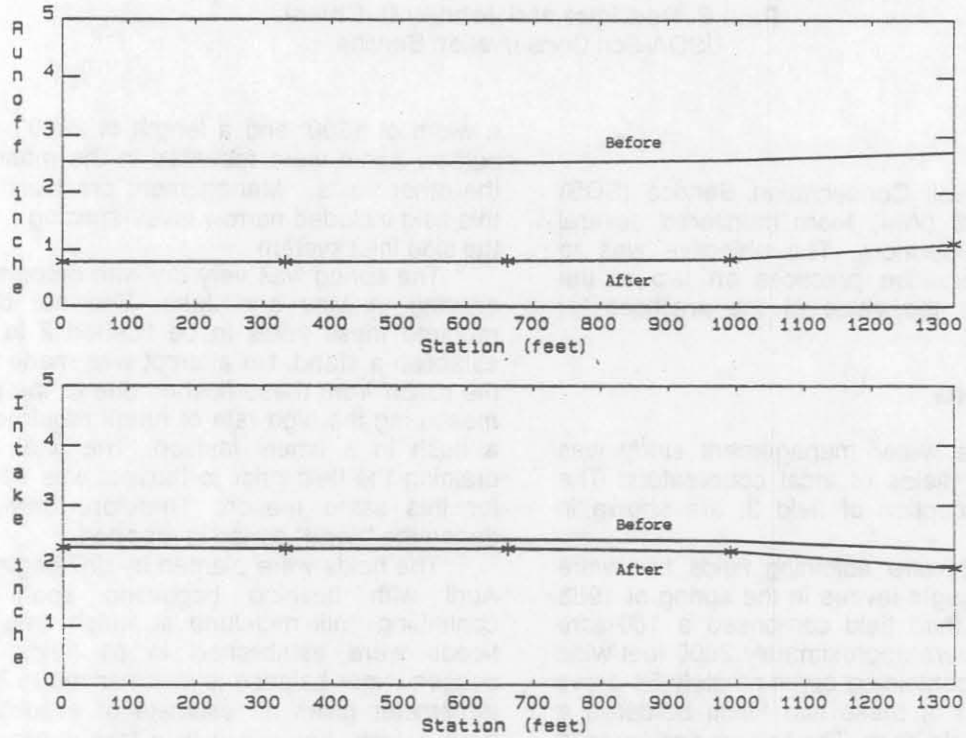

Figure 1. Improved Irrigation Furrow Efficiency