IRRIGATION SYSTEM EVALUATION

INTRODUCTION

Efficient use of available water is essential because of a limited water supply and a serious drainage problem in a portion of the District. As early as 1986 Westlands Water District responded by increasing the resources devoted to its long-standing Water Conservation and Management Program.

These cost-sharing Programs, the Irrigation Improvement Program (IIP), 1986-1991, were sponsored by Westlands and DWR, through the Westside Resource Conservation District, and were designed to encourage farmers to utilize the services of approved, private-sector irrigation advisory teams to evaluate their irrigation systems and practices and to make water-conserving recommendations.

The goal of these Programs was to assist farmers in using less water without sacrificing optimum crop yields, thereby reducing the over-irrigation that percolates into the shallow groundwater table.

Irrigation system evaluations were performed by consultants early in an irrigation event and the information was reported as soon as possible. The intent was that the information gained from the evaluations would be available to the irrigation manager so that it might influence the irrigation in progress so that over application of irrigation water might be avoided and the efficiency would be improved.

The program was similar to the DWR Mobile Lab program, but the preirrigation and two seasonal irrigations were evaluated for each field enrolled. Mobile Lab services may be available to District water users for evaluations of irrigation system events and well pumps, on a cost-share basis. Check the website.

The District took the results of the many evaluations performed in the IIP and developed abreviated procedures that were intended to provide a quick estimate of the irrigation system performance, but with less effort and detail.

These procedures have been implemented in web pages and are available on this site. These pages are intended to minimize the calculations involved and facilitate the evaluation of furrow and sprinkler irrigation systems. It is not known if these procedures apply outside of the local conditions of the District.

IRRIGATION EFFICIENCY AND DISTRIBUTION UNIFORMITY

Irrigation efficiencies are directly related to the uniformity of water application (distribution uniformity) on the individual fields. Furrow irrigated field distribution uniformity is directly related to the advance ratio and the average depth of water infiltrated per hour. Improvements in distribution uniformity of furrow irrigations will result from improvements in the advance ratio.

Distribution uniformity can be visualized as a potential efficiency when the amount applied in the low quarter just equals the soil moisture depletion. Even so, approximately one-eighth of the field still will be under-irrigated.

A value for a high distribution uniformity is 80 percent in production agriculture, and it is considered to be excellent for all irrigation methods. Only a few specialized cases may have higher potential distribution uniformities for actual field conditions throughout an entire year. Most of the very high irrigation performance values reported by the media have been from small acreage research plots using new equipment and input from many technical personnel.

On-farm conditions are large scale with competing management interests (equipment scheduling, spraying, etc.), and farmers must use economical equipment, all of which cannot be brand new.

With only a small amount (less than 12.5 percent of a field) of under-irrigation, the highest potential on-farm Irrigation Efficiency is equivalent to:

IE = DU x [1-ML/100)]

Where:

DU = Distribution Uniformity
ML = Minor Losses (primarily on-farm conveyance losses) and Evaporation Losses

Evaporation losses vary with the method and frequency of irrigation, but conservatively equal 3 percent. Hand-move sprinklers typically have six to ten percent losses (from the plant surface and wind drift). Surface irrigation will have low soil surface evaporation losses (two percent) once the plant canopy is high. Micro-spray (a form of drip) on trees may have four to six percent losses.

Conveyance losses from ditch seepage equal about three percent based primarily upon ditch and pond seepage (conveyance) losses determined in studies by the District with furrow irrigation (Boyle Engineering Corporation, 1988). Even hand-move sprinklers have some losses due to worn gaskets and leaky pipe. Drip systems have losses due to line filling and emptying and due to lost filter back flush water.

Using these values, an estimated District-wide average Irrigation Efficiency, using excellent management and the proper equipment, would be:

IE = 80% x (1 - .06) = 75%

The Annual Irrigation Efficiency is defined as:

AIE = (SMR + LR)/AW

where:
SMR is the soil moisture replacement,
LR is the leaching requirement,
AW is the applied water.

Rearranging,
AIE = SMR/AW + LR/AW.

SMR/AW is the irrigation efficiency, not considering a leaching requirement, or this is the ability to replace water within the maximum root zone.

LR/AW is the portion of the applied water that must pass below the maximum root zone to maintain the salt balance.

We have calculated a District leaching requirement of four percent. So the maximum attainable would be:

AIE = 75% + 4% = 79%

As deep percolation increases, irrigation efficiency decreases. Therefore, when deep percolation amounts are the least, the calculated irrigation efficiencies are the highest. Subsequently, when all the factors influencing distribution uniformity and irrigation efficiency are balanced, a 79 percent District-wide on-farm average Annual Irrigation Efficiency seems to be the maximum reasonably attainable. This level of performance is achieved on sprinkler/furrow irrigation systems with short furrows, but this is for a high value crop where the farmer has justified an intensive level of management and capital investment.

FURROW IRRIGATION SYSTEMS

The advance ratio is an important factor for managing a furrow irrigation system. Generally, water should get to the end of a furrow in less than 1/2 of the set time to achieve good distribution uniformity. Whether that should be as quickly as 1/4 of the set time would depend on the soil texture and conditions.

An irrigation system evaluation will help to more precisely determine the performance of an irrigation event. This section presents a simplified procedures to estimate the distribution uniformity, DU, and irrigation efficiency, IE. These procedures were developed from data collected on district fields for the Irrigation Improvement Program, 1985-1991. Their applicability outside of Westlands is unknown.

Soil characteristics and field conditions are major factors controlling the efficiency of furrow irrigation systems . Factors the farmer can readily vary or manage are: irrigation set time; furrow shape, roughness, and length; and furrow stream size:

- Irrigation set time is determined by furrow inflow rate, furrow shape, roughness, and length.
- Furrow conditions can be altered with torpedoes (heavy weights that are dragged in furrows to smooth, shape, and/or compact the soil). Torpedoes can reduce the differences in water infiltration rates between furrows in which tractor wheels have or have not traveled.
- Advance rates are influenced by both soil conditions and furrow inflow rates.

In most cases, tailwater reuse systems are essential to properly manage furrow irrigation systems so that the best distribution uniformity and irrigation efficiency may be achieved.

However, the economics of other cultural operations and irrigation system costs weigh heavily on any farmer's decision to use a little less water without decreasing net profit.

SIMPLIFIED PROCEDURES

The simplified furrow evaluation procedures basically involve collecting information on the inflow to the furrows and the times that it takes the water to reach mid-field, the end of the furrow and the set time (Worksheet , PDF format, 427K). With this information you calculate the advance ratios and the applied water and estimate the DU and the IE for the field. A list of recommendations is provided to suggest a course of action to help you decide what can be done to improve the situation.

The evaluation begins by logging the water meter reading and time. A section is provided to calculate the rate of flow because the Cubic Feet per Second (CFS) reading is the least accurate information on the meter. After, say an hour, take a second reading and calculate CFS by multiplying AF by 43,560 and dividing by the number of seconds. Multiply CFS by 450 to get gallons per minute, gpm.

Use the feel-method to determine the soil moisture depletion to the maximum root zone depth. This information should be recorded on the bottom of the evaluation worksheet. This information is important because this is the amount of water that needs to be replaced to refill the soil to field capacity. Be aware of situations where the whole root zone is not rewetted, such as mid-season tomato irrigations.

Enter the length and spacing of the furrows and the number of furrows being irrigated. Not all furrows will advance at the same rate. Typically wheel rows, where the tractor tires ran, will advance faster than non-wheel rows. Because of this the inflow to the wheel rows is typically smaller. Enter an estimate of the inflow to the typical wheel furrow and non-wheel furrow. An estimate can be made by filling a known volume container and measuring the time or using a plastic bag to catch the water in a period of time and pour the water into a measuring container.

Since the rows are advancing differently, the time at the mid-field point will be more of an average time for the set, as will be the time to the end of the field. If a cutback is made when the water gets out, note the time and new flow being used in the furrows. Note the time and water meter readings when the set is changed.

Other factors could affect the field DU, such as, set time differences and soil type differences, but these are not considered here.

You can link to the worksheet page and use it in place or save this page from your internet browser for later use offline, without being connected to the web site. The results of this worksheet can be printed right from the browser.

SPRINKLER SYSTEMS

Under low-to-moderate wind conditions, irrigations with well maintained sprinkler systems can produce good pre-irrigation efficiencies, since the water application rate is controlled by the irrigation system and not by soil characteristics. Well designed sprinkler systems must apply water at a rate that is less than the soil infiltration rate to minimize or eliminate runoff.

The amount of water applied by sprinkler irrigation systems is directly related to the set time. The set time is the period of time that water is applied with a specific irrigation system configuration.

Therefore, irrigation set time is a significant management factor. The set time can be varied so the water applied matches the soil moisture deficit. The interval between irrigations also can be varied to match the soil moisture deficit. Properly adjusting these two factors can result in optimum irrigation efficiency.

The management for set times that are not a multiple of 12 hours are not desirable since the lateral move times will constantly vary. It is possible to have an "effective" set time that is the desired set time but the laterals are actually changed on convenient 24 hour sets.

The method involves changing the move distance to produce the application rate that will apply the amount of water desired while moving on a 24 hour set. The table below presents a move distance that will give the equivalent hourly set, based on a standard 40 foot move, 24-hour set.

Hour Set	18	20	22	24	26	28
Move, Feet	53.3	48.0	43.6	40.0	36.9	34.2
Factor	0.75	0.83	0.92	1.00	1.08	1.17
Hour Set	30	32	34	36	38	40
Move, Feet	32.0	30.0	28.2	26.7	25.3	24.0
Factor	1.25	1.33	1.42	1.50	1.58	1.67

Note that the distribution uniformity will vary with the move distance. In general, as the move distance increases the uniformity tends to decrease, but this varies with the wind speed. Moves over 40 feet must take this into consideration. Realize also that the number of moves increases as the move distance decreases. The reduction in water cost will offset this increase in labor costs.

The factor presented is used to determine the amount of water applied. Multiply the depth applied by the system with 40 foot moves by this factor to determine the new depth applied. As the amount of water applied in a 24 hour set goes increases, the rate of application increases, which can exceed the ability of the soil to infiltrate water, causing runoff. The width of the beds will determine the number of beds for each set move. With 40 inch beds an equivalent 36 hour set will move 8 beds where a 24 hour set would move 12 beds. The new number of beds to be moved can be determined by dividing the old number of beds by the factor.

SIMPLIFIED SYSTEM EVALUATION

This web page worksheet is based on a previous Water Conservation Program worksheet.

SIX EASY STEPS TO OPTIMUM SPRINKLER SYSTEM OPERATION

A one percent increase in sprinkler system field distribution uniformity (DU) can result in nearly a one percent savings in water. By using this worksheet, you will be able to determine with reasonable accuracy the field DU and necessary set time of your sprinkler system as currently operated. You also can estimate the effects of any changes you choose to evaluate. The worksheet will guide you in combining the factors that have the greatest effects on sprinkler system DU (http://www.wateright.org/site2/reference/evalsprink.asp) to arrive at your system's DU. The field DU can then be applied to the system's flow rate to determine optimum set time. Other links are available that deal with with sprinkler evaluations from another point of view.

GETTING STARTED

Most of the necessary information to complete an evaluation can be gathered in less than one hour by inspecting you system in operation. With the water off, use a feeler gauge or drill bit to measure nozzle orifices for sand wear and check for mixed sizes. You will also need a gauge with a pitot tube to take water pressure measurements at the beginning and the end of your pipeline and laterals. The remaining information, lateral spacing, leakage, non-rotating sprinklers. and plugged nozzles should be readily apparent. The only other requirements are a clipboard and a sharp pencil.

Fill in the Blanks

Once you've gotten your boots muddy and your overalls wet, it is time to sit down and enter the data. This evaluation page can be completed in less than 15 minutes. This page will do the work that previously required referring to several easy-to-use charts and graphs to determine DU reduction factors, including pressure uniformity (http://www.aom.ufl.edu/aom3734/handouts/Lecture28.htm) and miscellaneous losses. After these factors are multiplied together, you will arrive at an estimated field DU.

THE RESULTS: SET TIME, TROUBLE SPOTS, DOLLARS

Once you know the field DU, you can easily calculate the required set time for a given irrigation, thus, maximizing irrigation efficiency. Trouble spots will also be apparent so that system repairs and improvements can be considered based on their relative value compared to other available options. You can now convert water savings to dollar savings.

Note: The equipment required to measure pressures at the sprinkler head is a Pitot Tube attached to a Liquid Field Pressure Gauge. One possible source is the Rainbird part number A90917 and D22810, respectively. This reference is given because it is readily available and no recommendation is intended.

You can link to the worksheet page and use it in place or save this page from your internet browser for later use offline, without being connected to the web site. The results of this worksheet can be printed right from the browser.

DRIP/TRICKLE SYSTEMS

Drip/trickle systems often are perceived to be the most efficient irrigation systems available. However, the few systems analyzed in this program were used on trees and had lower distribution uniformities than the average of the other types of systems.

While the efficiencies were significantly better than the other systems in this study, it appears to have been achieved by under-irrigation since the distribution uniformities were considerably less than the efficiencies.

Drip systems do not reduce the crop water requirement, but usually increase evapo-transpiration because water is applied frequently in small quantities. Drip/trickle systems usually require more careful management than other irrigation systems.

The following equations are after the Hardie Irrigation Micro-Irrigation Design Manual(1984). Drip emitters are classified as either a laminar flow or turbulent flow. Flow through an emitter is described in the following equation:

$$Q = Kd\,(H)^X$$

where:
Q = Flow Rate (gph)
H = Operating Pressure (psi)
Kd = Flow Coefficient
X = Flow Coefficient

The flow exponent will range from 0 to 1.0. The lower the exponent, the more pressure compensating is the emitter, with zero as fully compensating.

UNIFORMITY

Since the pressure is the variable in the equation, the Emission Uniformity (EU) is the measure of the performance of the system. The EU is related to the manufacturer's coefficient of variation for the emitters(variation in the manufacturing process) and the variation in the flow rates in the various parts of the system.

$$EU = (1-1.27Cv/ (n)^{0.5}) (Qm/Qa)$$

Where:
n = For a point-source emitter on a permanent crop, the number of emitters per plant. For a line-source emitter on a annual crop, either the spacing between plants divided by the same unit length of lateral line used to calculate Cv, or 1, whichever is greater.

Cv = The manufacturer's coefficient of variation for point or line-source emitters, expressed as a decimal. Cv is typically less than .10, but can vary up to .40.

Qm = The minimum emitter flow rate for the minimum pressure Hm in the system in gph

Qa = The average, or design, emitter flow rate for the average or design pressure Ha in gph.

This equation is used by the designer to design to a specific level of performance. A system cannot be more uniform that it was designed to be. An evaluation will attempt to establish the current EU, given aging of the system and other factors that degrade the system performance.

The EU equation can be written in terms of pressures as follows:

$$EU = (1-1.27Cv/ (n)^{0.5}) (Hm/Ha)^{X}$$

Where the variables are as defined above. Note that with a perfect pressure compensating emitter the EM is dependent only on the coefficient of variation for the manufacturing process.

These two equations suggest two methods that a system EU could be evaluated:

1. Measure flow rates.
2. Measure pressures.

With a buried system it might be more practical to measure pressures. With point emitters on the surface it might give better information to measure flows from individual emitters. Consider this additional source of information about evaluating drip irrigation systems .

It is not that easy since distribution pressures would help explain differences in flow rates, and additional information, X, is needed to use measured pressures and the original X may not still be the value. Pressure test points, Schrader valves, on the distribution are important to setting up the pressure regulators for the individual irrigation blocks.

The EU can be thought of as a distribution (DU)uniformity, which is the amount applied at the point receiving the least water to the average amount applied. In other systems distribution uniformity is usually defined in relation to the average amount applied to the quarter of the field receiving the least amount of water. Thus the standard DU for the system will be higher than the EU. The EU is more stringent, since no part of the field would be under-irrigated, where 1/8 of the field would be under-irrigated if the standard DU definition was utilized to describe the uniformity. Even though more water is applied to refill the same depletion using the EU, the EU values possible with a micro-irrigation system are higher than the DU for most other systems, so the net result can be better with a well maintained micro-irrigation system. EU = 0.9 are typically used for a new system design and could be designed for values up to 95 percent, but field topography can cause design values to be as low as 75 percent. Cost for systems in varied topography is usually higher to achieve the pressure regulation necessary for high EU.

DRIP/TRICKLE SYSTEMS, EVALUATION

System evaluations are necessary because system components do not maintain a constant performance with age. This performance is not just related to age of the materials used to manufacture the components, but can be greatly affected by contaminants introduced during the operation of the system. Proper maintenance is very important and can significantly increase the life and efficiency of the system.

A proper evaluation does not just look at the emitter performance, but it must consider all components from the filtration system, to the pressure regulation in the distribution system, to the lateral lines and the emitters. An evaluation must look at the pressure distribution throughout the entire system. The District may have a Mobil Lab program that can perform these services and consultants are also available.