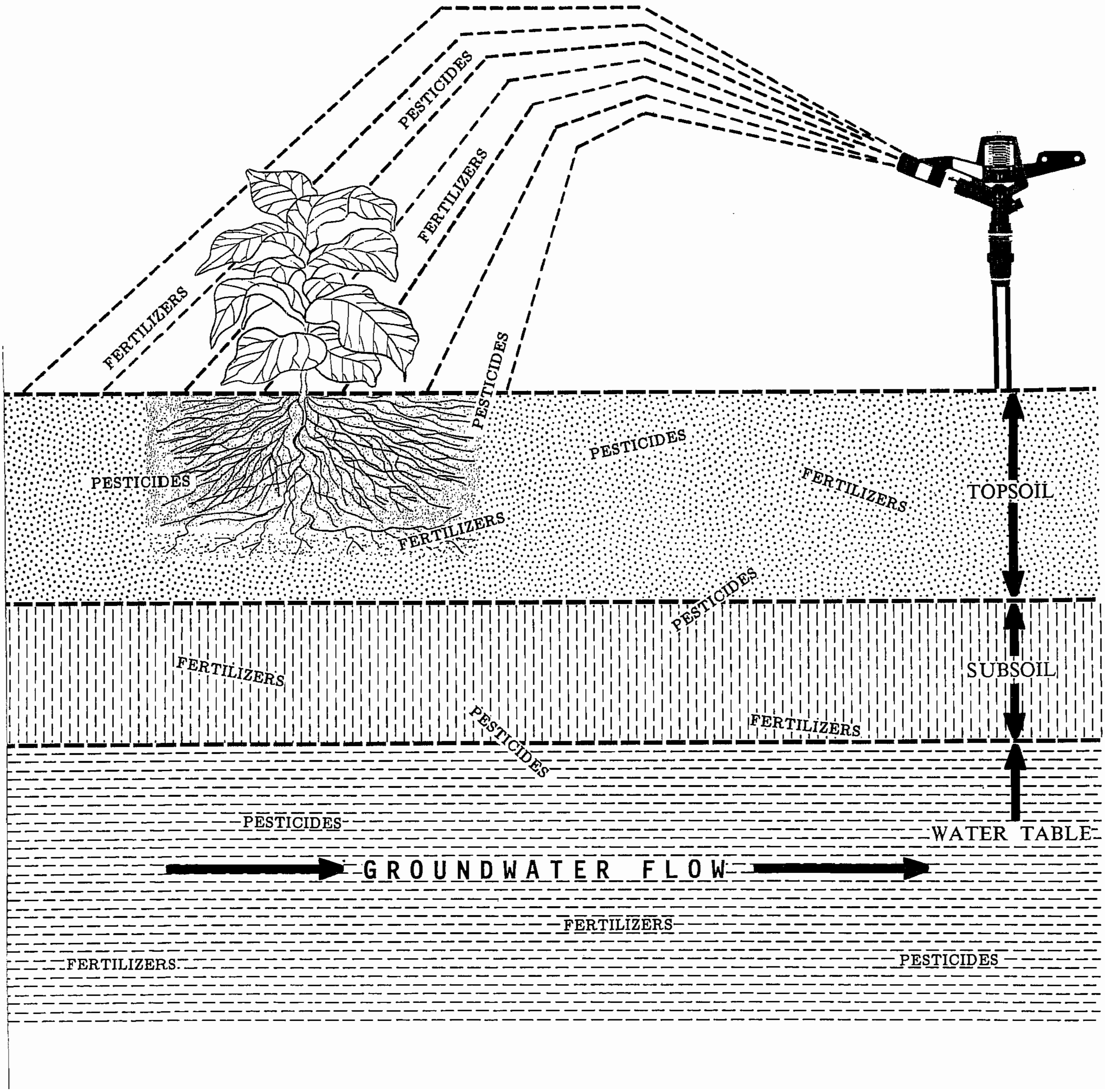
Franklin
Conservation
District

Pasco,
Washington

IRRIGATION SCHEDULING: A WATER QUALITY MUST!



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Prepared by:

Franklin Conservation District
1620 Road 44 North
Pasco, WA 99301
(509) 545-8546

Assisted by:

USDA-Soil Conservation Service

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Support Services by MarJon

FRANKLIN COUNTY

Franklin Conservation District
1620 Rd. 44 N • Pasco, WA 99301 • (509) 545-8546

1996 Addendum to Franklin CD's:

"Irrigation Scheduling: A Water Quality Must!"

Times have changed since this bulletin was published in 1989. Please note these updates:

1. USDA Soil Conservation Service has a "reinvented government" name, and is now the USDA-Natural Resources Conservation Service (NRCS).

2. Nearly all prices mentioned have increased in range of 20% to 40%.

3. Atmometer, P. 8 = Not sure if these are still commercially available.

4. Add to <u>IRRIGATION SCHEDULING</u> section as new item (P. 14):

DIELECTRIC CONSTANT

The dielectric constant of a soil is determined by measuring the transit time of an electromagnetic pulse launched along a pair of parallel metallic rods embedded in the soil. Dielectric constant is a function of volumetric moisture content. Time domain reflectometry (TDR) or frequency domain reflectometry (FDR) are methods based on measurement of dielectric constant.

<u>Advantages:</u>
1. Fast & accurate.
2. Averages soil moisture over length of rod.
3. Can be read remotely.
4. Low maintenance once installed.

<u>Disadvantages:</u>
1. Calibration curves are soil specific.
2. Installation somewhat difficult & may require soil being disturbed.

<u>Cost:</u>
1. Your time & labor - high at installation, then low.
2. Aqua Tel (TM) @ $250 for probe and $125 for meter; Troxler (TM) @ $4-5,000; Aquaterr (TM) @ $500.

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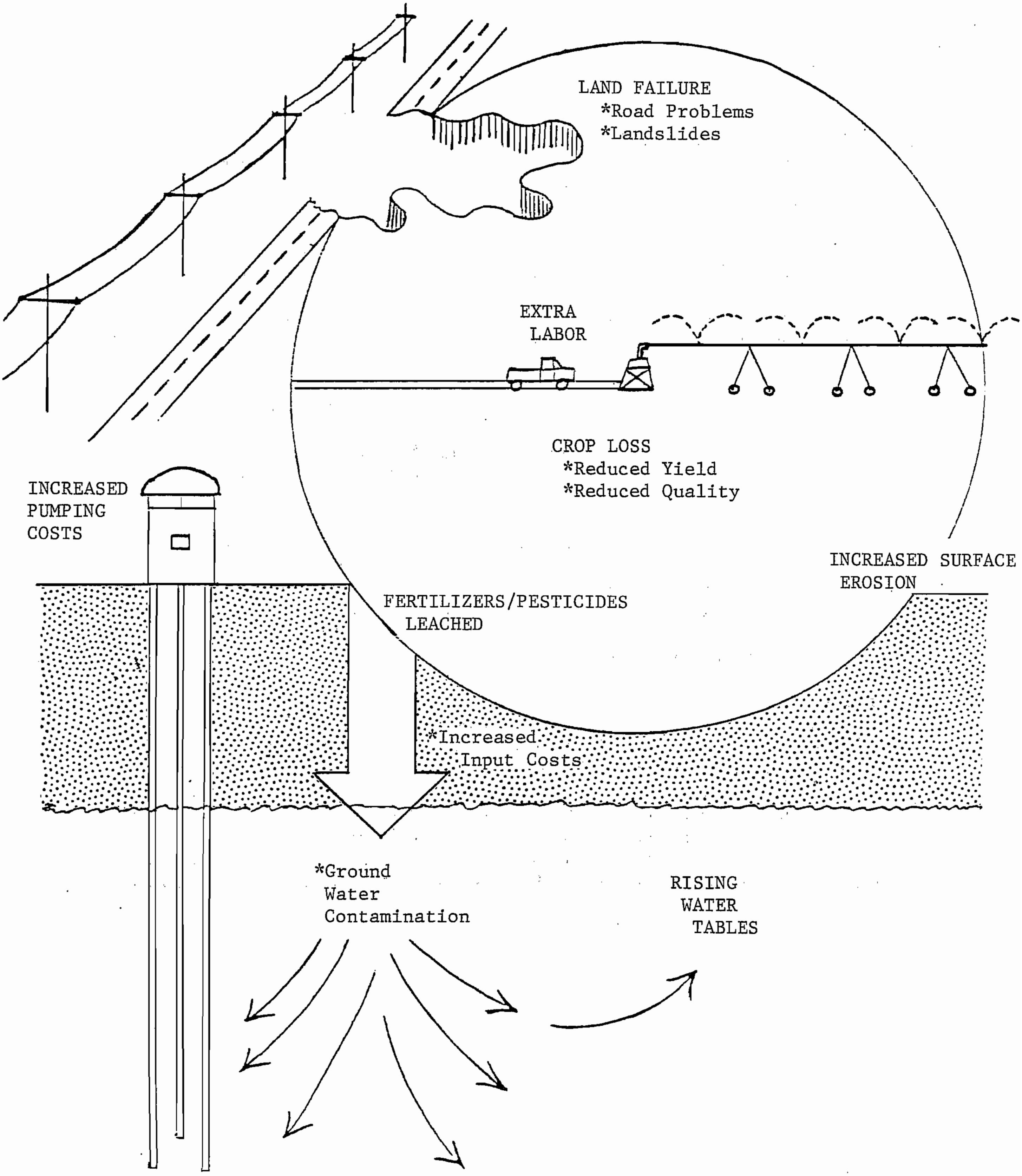
RISKS FROM OVER-IRRIGATION



INTRODUCTION

The Franklin Conservation District places a high priority on water quality and quantity issues. Concerns about ground water quality in Franklin County have increased substantially during the 1980's. In 1986 the US Geological Survey (USGS) sampled 115 wells in Franklin County and found that 40% of them had nitrate-nitrogen (NO_3-N) levels exceeding the EPA recommended health limit of 10 parts per million (ppm). Results of a study by the Washington Department of Ecology (Ecology) of 27 wells in Franklin County in 1988 also found that 40% exceeded this nitrate standard. In addition, there were 10 pesticide detections in the 1988 Ecology study.

Potential contamination comes from diverse sources such as agriculture, homes, industry, septic tanks, and urban waste. The chance for health risk is increasing because of the intensified use of groundwater for agriculture, waste assimilation, and drinking water.

The irrigated portion of Franklin County contains many coarse textured soils with little organic matter. These soils have low water holding capacities and allow rapid movement of excess water, leaching water soluble nutrients and other contaminants into the groundwater.

Water movement downward through a soil profile occurs only when pushed by the addition of more water. Therefore, quality problems may be directly tied to quantity. Excess irrigation water (from either over-watering or canal seepage) may raise water tables, causing land use limitations as well as the leaching of contaminants into the aquifer.

The Franklin Conservation District has produced this brochure to provide information about irrigation scheduling methods. The goal is to achieve a higher level of irrigation water management, and minimize water quality problems from irrigated agriculture.

Irrigators must first consider their irrigation system performance and maintenance. They must know how much water their irrigation system can apply in a given time and how the water is being distributed over the field. A system that has deteriorated over the years, resulting in leaks and uneven application, must be operated a longer time and discharges more water than required to meet plant needs. Poor system performance and maintenance can result in excess water costs, as well as higher power bills. In addition, the potential for leaching and ground water pollution is increased. Detailed irrigation evaluations of system efficiencies and distribution uniformities should be performed when installing an irrigation system and every few years afterwards. Walk-through inspections of an irrigation system should be performed annually. Irrigation system evaluation information and instruction may be obtained from the Franklin Conservation District, Soil Conservation Service, Cooperative Extension, or private irrigation firms.

How much water to apply and when to irrigate are the two most important questions to be answered to prevent over-irrigation. The amount of water applied each irrigation will depend on:

1. Soil water holding capacity.
2. Crop rooting depth.
3. Maximum allowable depletion (MAD) for each crop.

HOW MUCH?

1. Soil water holding capacity.
   Sandy soils hold less water than do clay soils and need more frequent irrigations (Table 1).

Table 1. Available water-holding capacity of various soils.

Soil Texture	Inches of water per foot of soil
Sand, fine sand, loamy sand	1.0
Sandy loam	1.6
Very fine sandy loam	2.0
Loam, silt loam, clay loam	2.2
Gravel and/or cobble in medium texture	1.2
Gravel and/or cobble in coarse texture	0.7

Adapted from WSU Extension Bulletin 1304

2. __Crop rooting depth.__
The depth of soil from which your crop can extract water is the effective crop rooting depth. This depth will vary by crop (Table 2).

Table 2. Effective rooting depths and maximum allowable depletion (MAD) of available moisture for various crops.

Crop	Effective rooting depth (ft)	MAD (%)
Alfalfa, orchard, hops	4-5	50
Field corn	4	50
Sweet corn, raspberry, asparagus	3	40
Grapes	3-4	50
Mint	2	35
Onions and most vegetables	2	40
Pasture, turf, grass hay	2	50
Peas, strawberry	2	50
Potato	2	25
Small grains	3	50

Adapted from WSU Extension Bulletin 1304

3. __Maximum allowable depletion (MAD).__
Some water is not available to the plant and remains in the soil even when the plant wilts. MAD is the percentage of available water in the soil the plant can use before irrigation is needed (Table 2).

All these factors must be taken into account when determining how much water to apply (Example #1).

__Example #1__:

__Given__:
Crop: field corn
Soil Type: sandy loam

__From Tables__:
Rooting Depth (RD) = 4 ft.
Available Water Holding Capacity (AWC) = 1.6 in/ft
Maximum Allowable Depletion (MAD) = 50% or 0.5

To determine the amount of water to apply to the field each irrigation:

(RD) X (AWC) X (MAD) = inches of water to apply

__or__

(4 ft) X (1.6 in/ft) X (0.5) = 3.2 inches of water to apply*

Example #1 Cont....

*Note

A center pivot irrigator would never be able to "catch up" and fill their soil profile if they allow this much soil water depletion in the hottest part of the season. For center pivots and other systems that apply light, frequent irrigations, irrigation should be started when there is enough room in the soil profile to store the normal application of the system (Example #2).

Example #2:

Normal center pivot application rate = .30"/revolution

Irrigation should be started whenever .30" of soil water has been depleted.

The preceding tables and examples should be viewed as a general guideline to the irrigator. Specific application amounts need to be determined by a trained technician for each soil type, crop, and irrigation system.

WHEN?

After the amount of water to apply has been determined, the next step is to determine when to irrigate.

To help prevent over-irrigation, every irrigator in Franklin County should perform some type of irrigation scheduling. The following pages give a brief introduction and description of many of the current irrigation scheduling techniques. This pamphlet does not give in-depth procedural methods, but is designed to give irrigators a basis for deciding which technique they might use. For specific information and instruction on these scheduling methods, individuals may contact the Franklin Conservation District, Soil Conservation Service, Cooperative Extension, or private scheduling firms.

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IRRIGATION SCHEDULING

FEEL AND APPEARANCE METHOD

Obtain a soil sample from a selected depth. Squeeze a handful of the sample very firmly. Compare it with the Soil Conservation Service (SCS) written descriptions (Table 3). Estimate and record the available soil water content as a percentage.

Advantages:
1. Easy to do.
2. Fast results.
3. No special equipment needed.

Disadvantages:
1. Not very accurate, but better than no scheduling at all.

Cost:
1. Your time and labor - low.

Table 3. Soil moisture feel and appearance relationship.

	SOIL TEXTURE			
Available Moisture	Coarse (Sand, Loamy Sand)	Moderately Coarse (Sandy Loam, Fine Sandy Loam)	Medium (Loam)	Fine (Silt Loam, Clay Loam)
100% (field capacity)	Leaves wet outline on hand when squeezed. (0.0)	Appears very dark, leaves wet outline on hand; makes a short ribbon. (0.0)	Appears very dark, leaves wet outline on hand; will ribbon out about 1". (0.0)	Appears very dark, leaves slight moisture on hand when squeezed; will ribbon out about 2". (0.0)
70%-80%	Appears moist; makes a weak ball. (0.2-0.3)	Dark; makes a hard ball. (0.3-0.4)	Quite dark; makes tight plastic ball; ribbons out ½". (0.4-0.6)	Quite dark; ribbons and sticks easily; makes plastic ball. (0.5-0.7)
60%-65%	Appears slightly moist; forms weak brittle ball. (0.4)	Fairly dark; makes a good ball. (0.6)	Fairly dark; forms firm ball; barely ribbons. (0.8)	Fairly dark; forms firm ball; ribbons ¼"-½". (0.9)
50%	Appears dry; forms very weak ball or will not ball. (0.5)	Slightly dark; forms weak ball. (0.8)	Fairly dark; will form ball; slightly crumbly. (1.0)	Balls easily; small clods flatten out rather than crumble; ribbons slightly. (1.1-1.2)
35%-40%	Dry; will not ball. (0.6-0.7)	Light color; will not ball or forms brittle balls. (0.9-1.0)	Slightly dark; forms weak ball; crumbly. (1.2-1.3)	Slightly dark; forms weak balls; clods crumble. (1.4-1.5)
Less than 20% (wilting point)	Very dry; loose, flows through fingers. (0.8-1.0)	Dry; loose, flows through fingers. (1.3-1.6)	Light color; powdery, dry. (1.6-2.0)	Hard, baked, cracked, light color. (1.8-2.3)

NOTE: Figures in parentheses at end of each entry represent approximate moisture deficit from field capacity when soil is uniform with depth. Ball is formed by squeezing soil hard in fist. Ribbon is formed by rolling soil between thumb and forefinger. From WSU EB 1304

IRRIGATION SCHEDULING

GRAVIMETRIC

Obtain a soil sample from a selected depth. Weigh the sample to determine wet weight. Dry the sample and determine dry weight, bulk density, and soil water content (Table 4).

Advantages:
1. The most accurate method for determining the soil water content.

Disadvantages:
1. Need special equipment.
2. When a conventional oven is used there is at least a 24 hour lag time between sampling and results. Acceptable results may be obtained in approximately 1 hour if a microwave oven is used.

Cost:
1. Your time and labor - high.
2. Scale accurate to 0.1 gram = $120
3. Soil auger .... = $135
4. Bulk density core sampler = $50 - $150
(Bulk density values may also be obtained from published values).

Table 4. Gravimetric calculation example.

SAMPLE DEPTH	SAMPLE WITH CONTAINER WET WEIGHT	SAMPLE WITH CONTAINER DRY WEIGHT	SAMPLE WITH CONTAINER WATER LOSS	CONTAINER WEIGHT (TARE)	NET DRY WEIGHT	VOLUME OF SAMPLE	MOISTURE PERCENTAGE	BULK DENSITY	TOTAL WATER	TOTAL WATER
(in)	WW(g)	DW(g)	Ww(g)	TW(g)	Dw(g)	Vl(cc)	%	Dbd	in/in	in/ft
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6"	142.2	129.6	12.6	47.7	81.9	60	15.4	1.36	0.209	2.51
18"	141.1	129.4	11.7	48.4	81.0	60	14.4	1.35	0.195	2.34

(1) = sample depth
(2) = wet weight of soil plus sample container
(3) = dry weight of soil plus sample container
(4) = (2) - (3)
(5) = weight of sample container
(6) = (3) - (5)
(7) = Volume of sample (cc)
(8) = (4)/(6)
(9) = (6)/(7) or from published values
(10) = (8) X (9)
(11) = 12" X (10)

IRRIGATION SCHEDULING

PAN EVAPORATION

Research has shown that crops which have developed a full leaf canopy use water at rate proportional to evaporation from a standard 4 ft. diameter US Weather Bureau evaporative pan, approximated by a #2 washtub. Different crops have different adjustment factors due to differences in leaf area, plant structure, etc. (Table 5). Daily evaporation reports are given in the weather section of many local newspapers. Average crop water use can be estimated using the evaporation data.

Advantages:

1. Fast.
2. No special equipment needed.

Disadvantages:

1. Distance from the pan to your farm may affect accuracy.
2. Estimates soil water content based on environmental data. Not a direct soil water measurement.
3. Dependant on accuracy of adjustment factors used.

Cost:

1. Your time and labor - low.

Table 5. Average pan evaporation adjustment factors for various crops under full-effective-cover or full leaf canopy conditions.
Crop water use = factor X pan evaporation.

Crop	Crop Factor	Crop	Crop Factor
Alfalfa and hay grass	0.95	Onion (green)	0.80
Apple (with cover crop)	1.05	Pasture	0.95
(w/o cover crop)	0.90	Peach (with cover crop)	1.00
Apricot (with cover crop)	1.00	(w/o cover crop)	0.85
(w/o cover crop)	0.85	Peas	1.00-1.05
Cherry (with cover crop)	1.05	Pear & Plum (with cover crop)	1.00
(w/o cover crop)	0.90	(w/o cover crop)	0.85
Corn (grain and sweet)	0.95	Potato	1.00
Grape (with cover crop)	0.95-1.00	Raspberry	1.00
(w/o cover crop)	0.70	Small grains	0.90-0.95
Hops (at top wire)	1.40-1.60	Strawberry	0.40-0.45
Mint	0.95-1.00	Turfgrass	0.80
Onion (dry)	0.70		

From WSU Extension Bulletin 1304

IRRIGATION SCHEDULING

ATMOMETERS

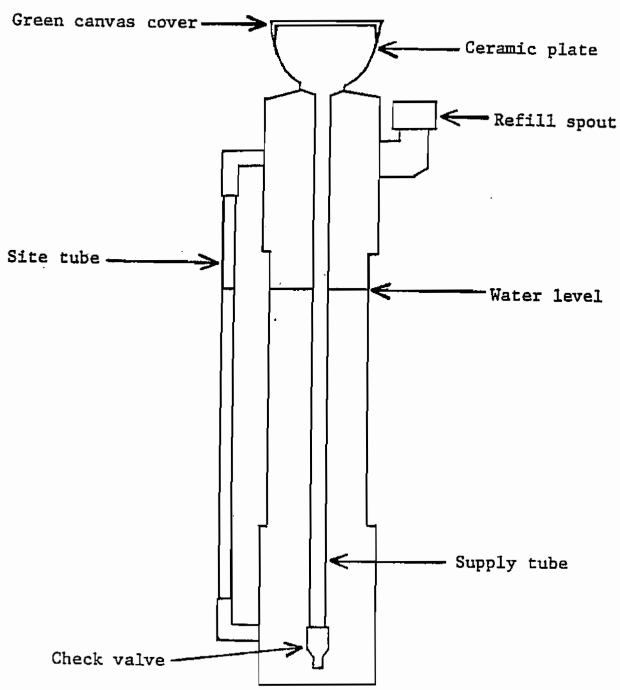
Atmometers (Figure 1) are similar to pan evaporative methods in that crop water use is estimated from evaporative data. However, atmometers are designed to evaporate water in a way that more closely resembles plant evapotranspiration. Adjustment factors, based on crop cover, are also used with atmometers.

Advantages:
1. Fast.
2. Can be installed in your field.

Disadvantages:
1. Estimates soil water content based on environmental data. Not a direct soil water measurement.
2. Dependant on accuracy of adjustment factors used.
3. Maintenance/green covers may fade.

Cost:
1. Your time and labor - low.
2. Atmometer = $60

Figure 1. Diagram of an Atmometer.



IRRIGATION SCHEDULING

TENSIOMETERS

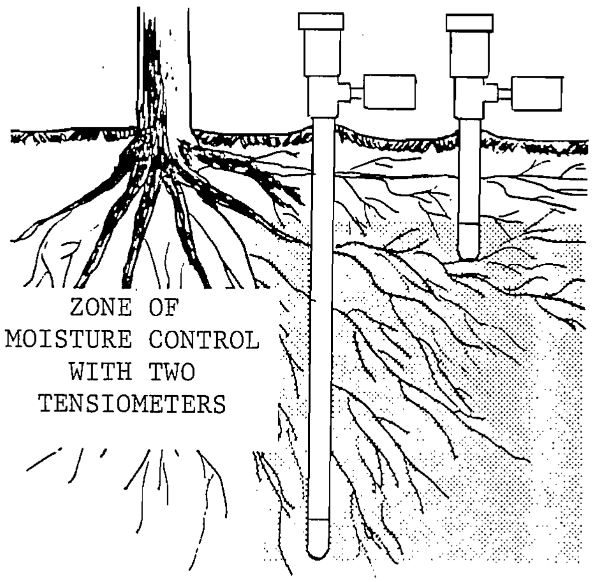
A tensiometer is a water filled tube with a special porous tip and a vacuum gauge (Figure 2). This instrument measures soil water suction, which is similar to the process a plant root uses to obtain water. Irrigation is started when the gauge reads a predetermined value based on crop and soil type.

Advantages:
1. Fast.
2. Direct soil suction reading.
3. Accurate.

Disadvantages:
1. Not recommended for use in heavy silt or clay soils.
2. Maintenance/loss of vacuum.
3. Should be calibrated at each site.

Cost:
1. Your time and labor - medium to low.
2. Hand pump and maintenance kit = $30
3. Tensiometers cost about $40 apiece. The number of sites needed (at least two tensiometers per site) will depend on your type of irrigation system and size of your field. The following is an estimate of the number of sites you will need:
   - Center pivot = 2 to 3 sites.
   - Handline/wheelline = 1 to 2 sites per system.
   - Solid Set = 1 site per irrigation block.
   - Furrow = 2 sites per irrigation block.

Figure 2. Diagram of installed tensiometers:



IRRIGATION SCHEDULING

ELECTRICAL RESISTANCE

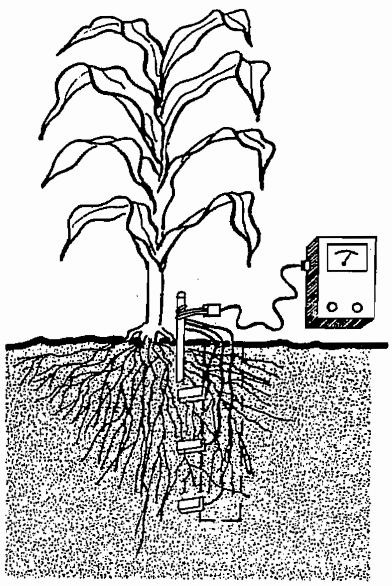
These instruments use the principle that a change in moisture content produces a change in electrical resistance of the soil. They consist of two electrodes permanently mounted in blocks of plaster of paris, nylon, fiber glass, or gypsum. The electrodes are connected to a resistance meter that measures changes in electrical resistance in the blocks (Figure 3). Irrigation is started when the meter reads a predetermined value based on crop and soil type.

Advantages:
1. Fast.
2. Can be accurate if instructions are followed.

Disadvantages:
1. Accuracy can be affected by salt and fertilizer concentrations in the soil and by temperature.
2. Must be calibrated at each site.
3. Limited to use on coarse textured soils.

Cost:
1. Your time and labor - high at installation, then low.
2. Blocks = $3.50 - $13.25 per block. Need three blocks per site. Site numbers same as tensiometers.
3. Resistance meter = $85 - $800

Figure 3. Diagram of installed resistance blocks.



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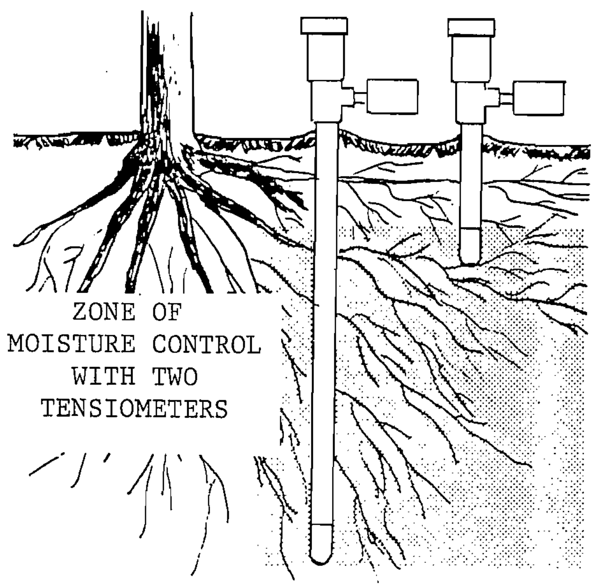

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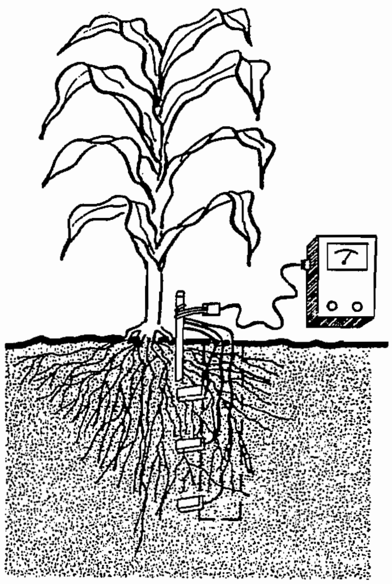


IRRIGATION SCHEDULING

NEUTRON PROBE

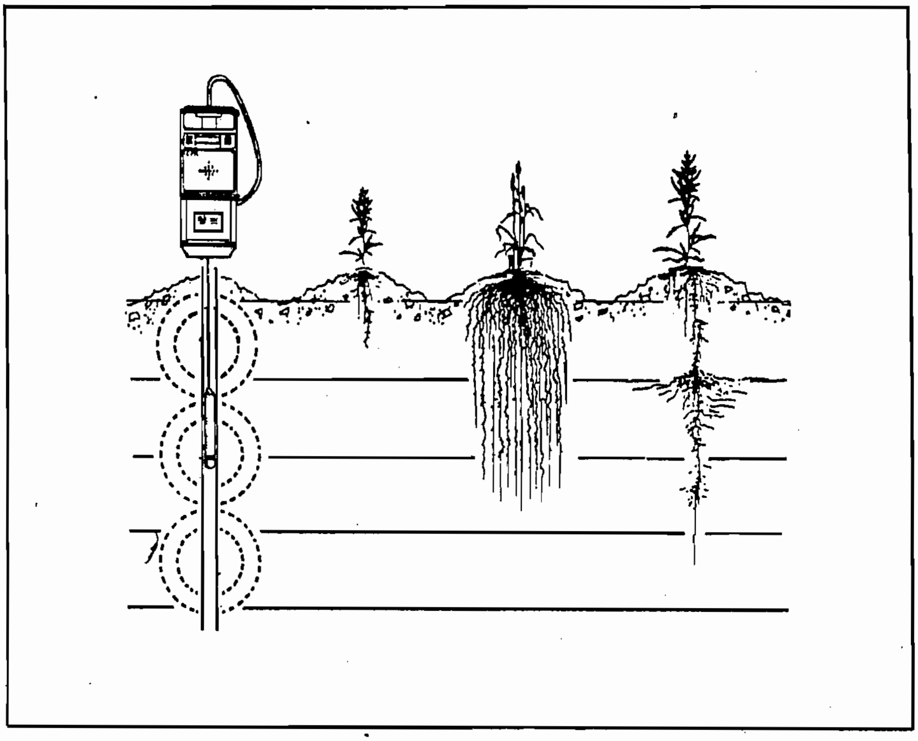
A neutron probe is basically a hydrogen analyzer. Water is the primary source of hydrogen in the soil. The neutron probe emits high energy neutrons which collide with the hydrogen atoms and then are reflected back to the probe and counted (Figure 4).

Advantages:
1. Fast.
2. Accurate.
3. Measures soil moisture at any depth.

Disadvantages:
1. High degree of training required and requires federal operators license.
2. Must be calibrated at each site.
3. Impractical for most landowners to own.

Cost:
1. Your time and labor - low if you hire a service. High at first, then medium if you purchase a probe.
2. Neutron probe, training, licensing = $5,000 - $10,000
3. Professional scheduling service = $6 - $10/acre.

Figure 4. Diagram of neutron probe.



IRRIGATION SCHEDULING

COMPUTER PROGRAMS/WEATHER STATIONS

Computer programs can be simple "checkbook" programs which just keep track of water applied and water used as entered by the farmer; or they may be predictive, based on soil water data, and current and historical weather data. Data supplied to the programs may be from many sources, such as evaporation data, neutron probes, or from automated weather stations (Figure 5).

Advantages:

1. Fast.
2. Predictive.
3. Maintains good records.

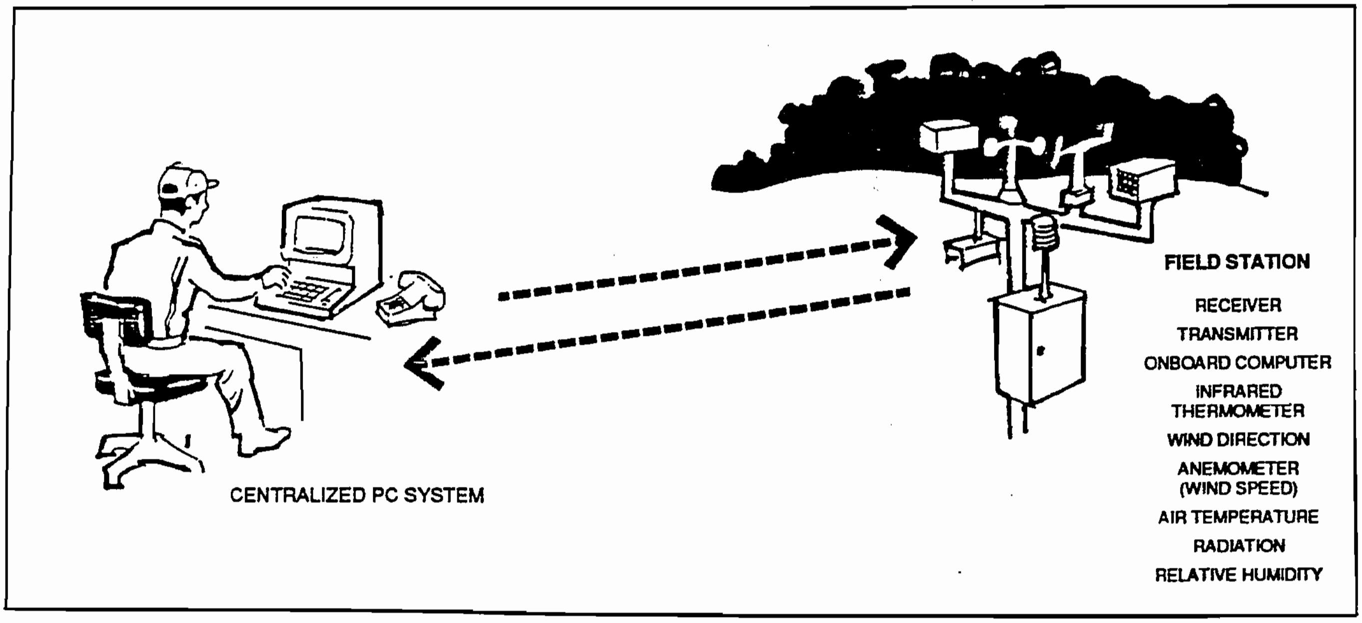
Disadvantages:

1. Results only as good as input data entered. (Garbage in = Garbage out)
2. Some programs not "user friendly".

Cost:

1. Your time and labor. High at first then low.
2. Computer hardware (computer, printer) = $500 - $2500
3. Computer software (scheduling programs) = $25 - $200

Figure 5. Diagram of computer and weather station system.



IRRIGATION SCHEDULING

INFRA RED GUN

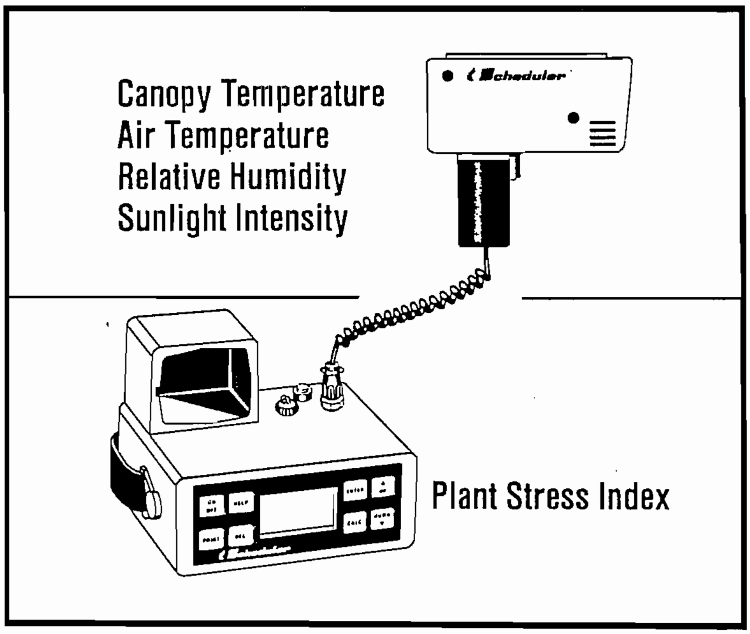
Infra red (IR) guns are plant stress indicators. IR gun readings are based on leaf temperature, air temperature, relative humidity, and sunlight intensity (Figure 6).

Advantages:
1. Fast.
2. Easy to use.
3. Accurate plant stress indicator.

Disadvantages:
1. Cannot use under heavy cloud cover.
2. Measurement of stress does not necessarily indicate soil moisture deficit.

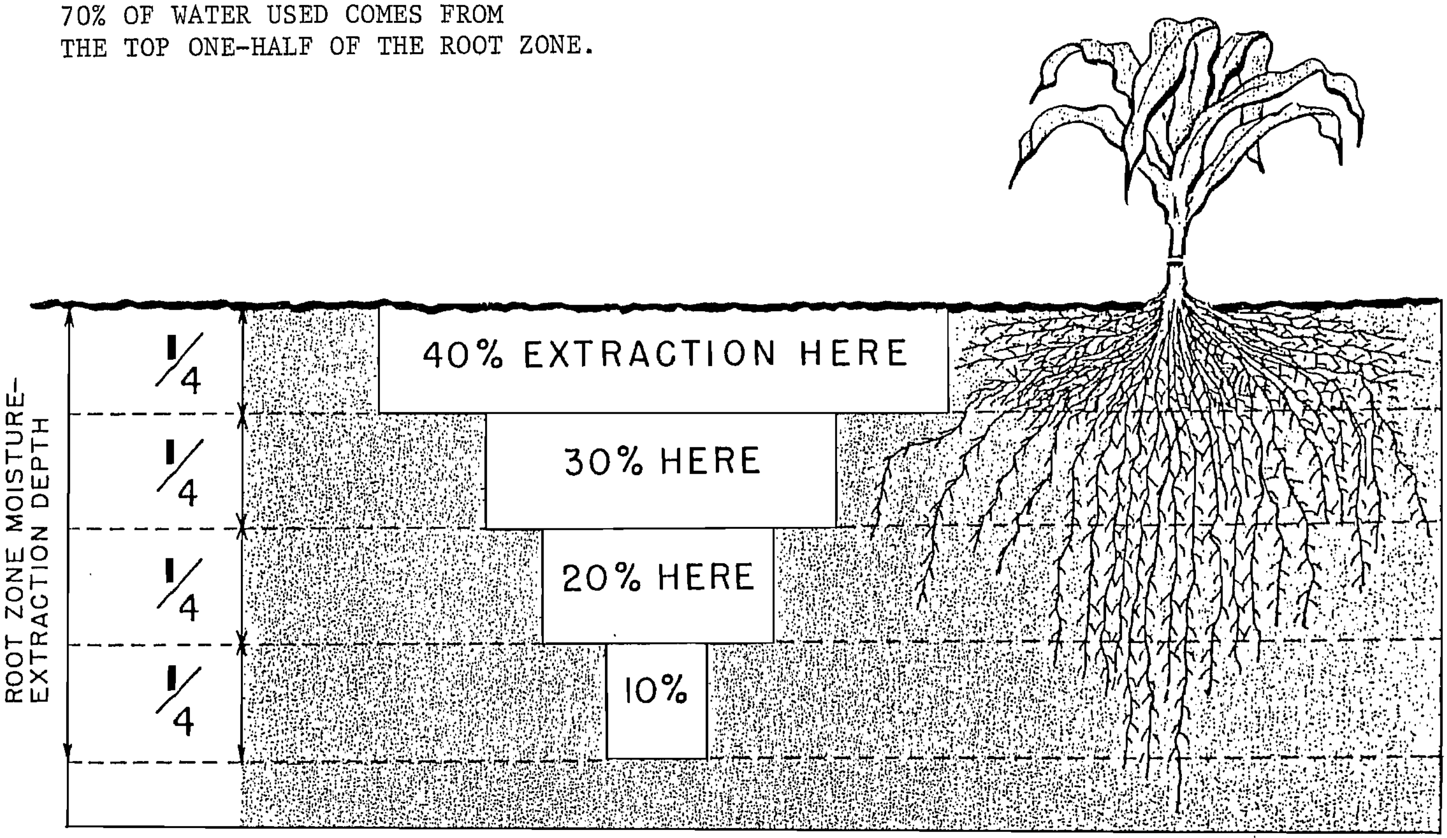
Cost:
1. Your time and labor - low.
2. Infra red gun = $5000

Figure 6. Diagram of Infra Red Gun.



WATER USE FACT:

70% OF WATER USED COMES FROM
THE TOP ONE-HALF OF THE ROOT ZONE.



*Average moisture-extraction pattern of plants.
(From SCS NEH Section 15, Chpt. 1)