Your ETgage is fully assembled and ready to use. It was shipped with a Style # _______ cover mounted on the evaporator.

See instructions starting on page 1 for filling, priming and field

Diffusion Covers

The ETgage uses three different vapor diffusion covers to provide appropriate resistances for water vapor leaving the evaporator. They are identified as Style #30, Style #54 and Style #G2 (Gore-Tex). The number is written on the canvas fabric.

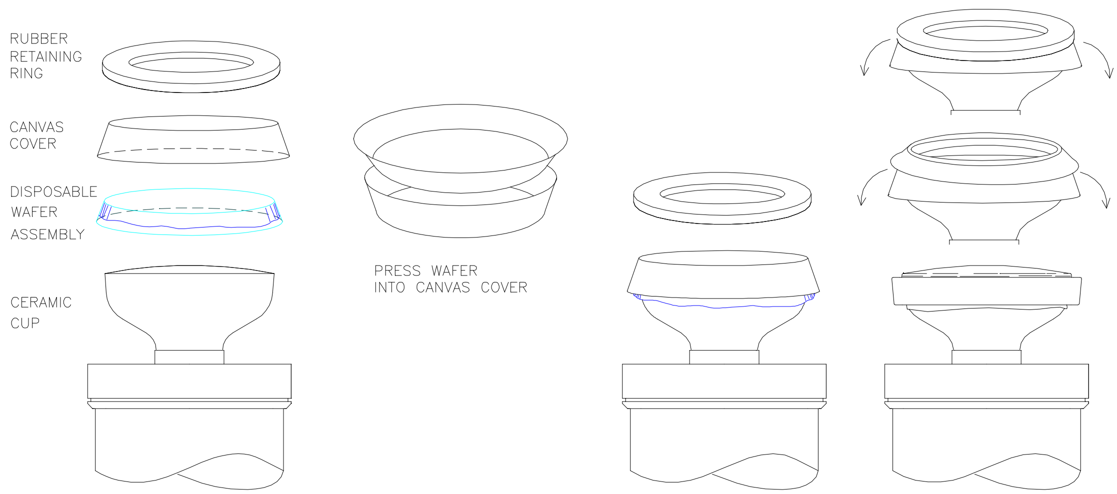
Canvas Covers

With a #30 canvas cover on the ceramic cup, evaporation readings will agree with grass reference evapotranspiration (ETo). A #54 canvas cover gives ETgage readings 10-15% greater than Style #30, equating with alfalfa reference (ETr). Each should be used with the evaporating surface of the ETgage one-meter above ground level. We recommend that one of these two canvas covers be the first choice when using the ETgage for irrigation management. Use the Style #30 for turf grass and the Style #54 for agricultural crops.

Gore-Tex® Cover

Style #G2 is a Gore-Tex® fabric. This material sheds rain but permits water vapor to pass through. It also has radiation absorption and thermal resistance qualities similar to vegetation. But it does not account for bulk air resistance between the top of a crop and the evaporation surface. Therefore, the evaporation surface (the top of the ETgage) should be in the crop and level with its canopy. Both canvas and Gore-Tex correctly simulate the reduction in plant ET caused by dew.

“Wafer” Evaporation Element <u>for Canvas Covers</u>



With both hands on the rubber ring, use your fingers to spread the ring in all directions, moving it out to the edge, and down the sides. The top of the rubber ring should be a little below the top edge of the ceramic. Keep the fabric tight; there must be no air space below it.

We recommend using the disposable wafer between the canvas cover and the ceramic evaporator surface. The wafer will protect the ceramic from accumulated contamination. When you remove a wafer, the ceramic should be visibly wet.

Any residues left from the evaporating water accumulate inside the wafer instead of on the surface of the ceramic, but you must still use distilled water to minimize contamination.

The wafer will last for about 12 months of continuous use.

If you see hard, crusty areas on the top of the wafer, these areas are no longer evaporating, and they will reduce the evaporation rate by an amount proportional to their size.

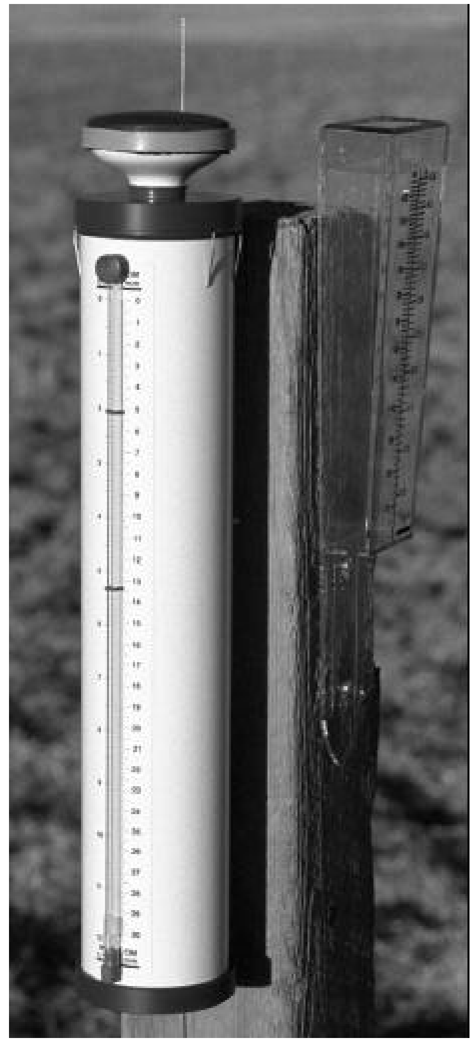
Replacing the wafer will bring the rate back up to the correct level.

The evaporation rate will be the same if you do not use a wafer, but without it, the ceramic surface will slowly become contaminated, and it will require vigorous sanding about every 4 months (use a medium grit silicon carbide abrasive paper under running water).

The top layer of the wafer sheds any rainwater that may get through the canvas. (This layer is made of porous PTFE. It allows water *vapor* to pass freely.)

Do not clean the porous ceramic surface or the wafer with soap or detergent. This would interfere with their water wicking properties.

ETgage Model A Instructions

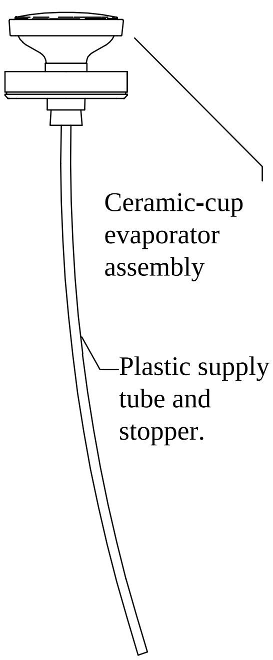


- The ETgage is ready to use.
- *Use only distilled water*. Distilled water can be purchased from a local grocery store.

FILLING AND PRIMING THE MODEL A

(1) Invert the ceramic cup (with its canvas covering) and fill it with distilled water. If the ceramic is dry, allow a little time to soak up, and fill it to the top. Fill the reservoir supply bottle about three quarters full with distilled water.

(2) Insert the rubber stopper and supply tube into the neck of the ceramic cup. Push and turn the stopper firmly into place. Water escaping from the cup will fill the supply tube. Since a good seal between the stopper and the ceramic cup is necessary to keep air out, be sure the stopper fits tightly in the neck.[1]



(3) Now load this assembly onto the water reservoir tube. The gray plastic part is secured to the top of the reservoir by two spring clips. Before snapping the top assembly down, fill the reservoir to the zero mark on the scale. (See a later page of these instructions for notes on Reading the Sight Tube.) If the bottle is too full, you can drain out excess water in a controlled manner by detaching the sight tube at its *upper* end. To do this, push the lower end to the side and pull down. The upper end will come free. Tilt the sight tube to allow water to drain.

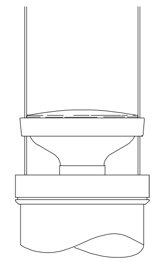
The ETgage is now ready for field use. Be sure to use only distilled water. If the green cover becomes very dirty, remove and wash it. The canvas cover should fit snugly to eliminate any air space. If the reservoir goes dry, repeat the filling procedure described above.

[1] A little air remaining in the supply tube does not matter. Air may accumulate in the ceramic cup over time, but the water will wick up the walls to reach the evaporating surface. A cup will continue to work properly even when almost empty, but to avoid temperature sensitivity due to expansion and contraction of the air, refill it when replenishing the reservoir.

FIELD INSTALLATION AND LOCATION

A typical field setup uses a wooden post to mount the ETgage and rain gauge. The green evaporation surface of the ETgage should be level and at a height of at least 39 inches (1 meter) above ground (soil surface). Mount the stainless steel bracket to a post with the two screws provided. If the top of the post is 37 inches above ground surface and the top of the mounting bracket is placed a half inch below the top of the post, the evaporating surface will be at 39". The top of the rain gauge also should be above the top of the post, and a few drops of oil in the rain gauge will stop its water from evaporating. Use a non-detergent oil such as household sewing machine oil.

Two stainless steel “bird wires” are included with the ETgage. They should be mounted under the silicone rubber ring that holds the cover on the ceramic cup. The 6-inch long wires are held vertically by inserting their bottom ends in small holes located on the surface of the gray plastic top. The wires will keep birds from perching on the instrument and fouling it.



Turf Grass

For landscape irrigation, use the ETgage with a Style #30 canvas cover for estimating grass ET. The best landscape location is an open area of turf not shaded by buildings. The location should represent the turf being managed. Landscape settings are composites of many irrigation zones of turf and shrubs. The water use or evaporation from these various micro climates may be different from evaporation at the ETgage site. Use the ETgage as a reference to help in setting the sprinkler controllers. For example, a turf island in the middle of a hot parking lot will have a higher multiplier than a large open area of turf grass that is not influenced by hot asphalt. Factors can be determined by trial and error: try a multiplier and see if the grass looks good without wasting water. This will become the factor for that area and will also include the efficiency of the irrigation system.

Agricultural Crops

An example of a good location for the ETgage in an agricultural setting is a border ridge in an alfalfa field. However, it may also be located for easy access alongside a dirt road if surrounded by low-growing irrigated crops. The location of the ETgage should represent the irrigated acreage, and should not be shaded or blocked by tall crops. Placing the instrument in a dry, fallow field, near farmstead buildings or near hot pavement generally will give high readings.

If used within a cornfield, the ETgage should always be mounted at least 1-foot above the canopy of the crop when using the Style #54 canvas cover. This is necessary for adequate exposure to sun and wind in the tall crop. When corn is at least 1-meter high, the Gore-Tex cover may be used. This diffusion cover is a good simulator of the canopy; but for Gore-Tex, the top of the ETgage must be maintained at a level even with the top of the canopy.

Do not put the ETgage under a sprinkler because minerals in the water could plug the evaporating surface. Instead, place it at the edge of a sprinkler-irrigated field.

The *rain gauge* can be set under the sprinkler, on a separate post. This will allow the application amount to be compared to crop water loss. Use the comparison to find application efficiency.

With a style #54 canvas cover, the ETgage will estimate the evapotranspiration of a green well-irrigated crop. This alfalfa reference evapotranspiration, or ETr, assumes the crop covers or shades at least 75 percent of the ground surface. For row crops early in the season, the canopy of leaves will not shade 75 percent of the soil, and a crop coefficient, Kc, should be used to multiply the ETgage reading. For a typical alfalfa stand, a nine-inch crop height corresponds to about 75 percent ground cover. For small grains, 75 percent cover comes at about mid-boot stage, two weeks before heading. For corn, it is about two weeks before tasseling. For ground covers below 75 percent, use the following table to find a crop coefficient multiplier:

Percent ground cover	Kc
Above 75%	1
50%	0.8
25%	0.5
Below 10%	0.3

READING THE SIGHT TUBE

Water evaporated is measured directly by the sight tube on the side of the reservoir. A one-inch change in water level corresponds to one inch of reference ET. Note that the scale under the sight tube is calibrated in tenths of inches and millimeters. There is a short flexible connecting tube at the bottom of the sight tube. Squeeze this tube several times to force the water to rise and fall, allowing the water in the sight tube to find its natural level. By doing so, you can make repeatable readings to about .02 inch.

Two sliding red markers are provided on the sight tube to help you keep track of water use. They can also mark limits on allowable soil water depletion.

During heavy rainfalls, canvas covers may absorb rainwater. The absorbed water delays resumption of evaporation from the ceramic cup. This absorption can result in lower readings (an error of -0.02 to -0.05 inch).

To find reference ET for one day, take two measurements 24 hours apart and find the difference. Two measurements a month apart will show ET for the month, and average daily ET is found by dividing by the number of days. For purposes of determining irrigation requirements or irrigation efficiency, you may only want to take readings at the beginning of each irrigation. A general irrigation efficiency can be computed as the ratio of irrigation water actually used by a crop divided by water applied. Subtract rainfall from the ETgage measurement for an estimate of irrigation water used.

FREEZING CONDITIONS

Your ceramic evaporation cup was shipped with a roll of plastic foam[2] inside to protect it from breaking under the pressure of expanding ice in freezing conditions. If temperatures will never drop below freezing, the foam roll is not necessary and may be removed.

Protection against freezing is limited, however. Water in the ceramic cup freezes from the outside inward. As water turns into ice, it expands greatly (9% in volume) putting the remaining water under pressure if restricted. When the neck freezes, remaining water inside will burst the ceramic if it has nowhere to go. The roll of foam plastic provides relief, but only if it is not already encased in ice. If after freezing solid once, the cup thaws only partly, and the foam roll remains in a block of ice, it will not protect the cup from bursting. You should not rely on protection after the first freeze if you expect re-freezing conditions without complete thaws.

The reservoir of the Model A instrument does not appear to be damaged by being frozen solid once. But it too will burst after a succession of freezes with partial thaws.

LIMITED WARRANTY

The reliability and accuracy of the ETgage are functions of proper installation, operation, and maintenance. This product is warranted against defects in materials and workmanship for one year. During the warranty period, we will repair or, at our option, replace, without charge for parts and labor, a product that is defective. This warranty does not cover transportation costs. It does not apply if the product has been damaged by accident, or by misuse, or by modification. No other express warranty is given. The repair or replacement of a product is your exclusive remedy. Except as provided herein, we make no warranties express or implied, including warranties of merchantability and applicability for a particular situation. In no event shall we be responsible for consequential damages. Products are sold from specifications applicable at the time of manufacture.

[2] The foam roll is made of a 2-inch x 2-inch square of 1/8th-inch thick closed-cell polyethylene foam sheet that has been set at 150°F into a tight roll.

IRRIGATION MANAGEMENT

With the ETgage (A Modified Atmometer)

Sections

- Importance of ET in Irrigation Management
- Water Management
    - Lawn and Turf-grass
    - Agricultural Crops
        - Soil Water Balance
        - Irrigation Application Efficiency
- Measuring Irrigation Applications
- Tables

    Soil Water Balance Sheets (example and blank forms)

    Picture Indexes and Tables for Crop Coefficients (ETgage Multipliers)

    Table A: Allowable Soil Water Depletions

    Table B: “Feel Method” for Soil Moisture

    Water Measurement by weirs and flumes

    Siphon Tube flow rate

    Water Application for Center Pivots

    Farm Water Supply Required to Meet ET at a Given Efficiency

- Colorado State University Cooperative Extension Article (June 1999): *Atmometers – A flexible tool for irrigation scheduling*

Importance of ET in Irrigation Management

99.9 % of the water used by a lawn or crop is drawn through the roots and transpires through the leaves. Wet soil surfaces also evaporate water. This transpiration and evaporation process is called Evapo-Transpiration (ET).

ET information helps apply the correct amount of irrigation water at the right time. Your best irrigation efficiency comes when you just refill the root zone by the amount of water lost through ET since the last irrigation.[1]

Irrigation efficiency is ET divided by the amount of irrigation water applied. High irrigation efficiency means minimum waste. Excessive deep percolation below the root zone and excessive surface runoff is waste.[2] Minimizing waste saves water, fertilizer, energy, and labor.

Maximum irrigation efficiency for surface irrigation systems using furrows or borders occurs when ET empties the root zone to a lower limit. This limit is called the allowable depletion, and beyond this limit crop yield will fall. See Table A to find allowable depletion for your soil and plant types.

Irrigation systems with greater control over water application (center pivots, lawn sprinklers or drip systems) can irrigate at maximum irrigation efficiency for root zones that are not emptied to the lower limit. When you irrigate every few days with sprinklers or every day with drip, fill the root zone with the amount of ET since the last irrigation.

By knowing your ET and striving for a high efficiency, you can cover the most acres with your water supply. See table *Farm Water Supply Required to Meet ET at a Given Efficiency*.

* * * * * *

Reference ET can be calculated from equations that use weather station data for sun, wind, temperature, and humidity. The ETgage directly simulates ET. *It responds as crops do to sun and weather.*

For young crops with incomplete canopies, ET (Reference or ETgage) should be adjusted by a crop coefficient. See information later in this manual or the article *Atmometers - A flexible tool for irrigation scheduling,* also in this manual.

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1 Always start the season with a root zone filled to field capacity. Once full, you can manage later irrigations efficiently using ET values.

2 For furrow and border irrigation, some deep percolation at the top of the field and some surface runoff is needed to get a uniform irrigation. In addition, some deep percolation below the root zone may be required for salt leaching.

Water Management

Soil water is depleted by evapotranspiration and refilled by irrigation and rain. Evapotranspiration is the process by which water transpires through plants and evaporates from the soil.

Where irrigation water goes:

(1) stored in the root zone (to supply ET)

(2) lost by surface runoff

(3) lost by deep percolation

(4) lost by spray evaporation from sprinklers.

ET + surface runoff + deep percolation + spray loss = rain + irrigation

Without losses:

ET = rain + irrigation

Therefore:

Irrigation = ET - rain

RULE #1 for efficient irrigation, apply (ET - rain) since the last irrigation. Be sure to start the season with a root zone filled to field capacity.

Lawn and Turf-grass

To simulate grass ETo (grass reference evapotranspiration) mount the ETgage in a place where it gets the same sun and wind as the grass. Use the #30 canvas evaporator cover.

Keep track of ET over a period of time, and compare it to the amount of water applied by sprinklers and rain. The period can be as short as between two irrigations, or as long as an entire season.

Finding the amount of water actually applied requires knowledge of both application rate and area. If the delivery system doesn't have a flow meter, an inexpensive method for measuring rate is placing tin cans under the sprinklers to sample the application rate directly.

For this method, use a number of identical cans, such as soup cans, to broadly sample the area for good aerial average. Run the sprinklers for fifteen minutes, combine the collected water into one can, measure the water depth and divide by the number of cans to get the average depth delivered in fifteen minutes. Multiply by four for delivery per hour. With this application rate, and knowledge of the total time the sprinklers have run during the period of ET measurement, you can find the total application (inches/hour x hours = inches applied).

With a flow meter, inches applied is gallons times 1.61 divided by the number of square feet in the irrigated area.

Divide ET (minus rain) by the total application to find efficiency.

Spray loss from sprinklers can be 5% at night with low wind, 10% for cool days with low wind, and up to 30% for hot, dry windy daytime conditions. Use lawn sprinklers at night or during low wind to minimize the spray loss.

Agricultural Crops

The ETgage with the #54 canvas cover will simulate ETr. The ETr of a crop (alfalfa reference evapotranspiration) is the ET rate for well-irrigated agricultural field plants that shade at least 75% of the ground. This is the rate for most hay, grain, and row crops.

For row crops not yet at full ground cover, ETr should be multiplied by a crop coefficient to get crop ET (ETc). This manual contains Picture Indexes and Tables for determining these multipliers.

Soil Water Balance

Soil Water Balance sheets, included in this manual for copying, help determine Irrigation Water Requirements (IWR). They have columns for recording the necessary field data and for the calculations to reveal cumulative depletion. The sheets help decide when to irrigate to avoid water stress. You can also compute irrigation application efficiency.

A Soil Water Balance sheet keeps track of the loss of water from the soil profile by showing its Cumulative Depletion balance. This is sometimes called a checkbook method. ET increases the Cumulative Depletion while rainfall and irrigation decreases it.

You start the soil water balance with zero Cumulative Depletion the day after irrigating has completely refilled the root zone. Keep the record for the first irrigation-set (starting point) in a field. When the Cumulative Depletion balance reaches the Allowable Depletion level, it's time to start another irrigation cycle. Efficient irrigating adds enough water to fill empty profiles without excessive deep percolation or surface runoff.

Follow instructions on the Soil Water Balance Sheet for the calculations. You will find crop coefficients in the tables, and a Picture Index follows this section. Table A provides Allowable Depletion information.

The "Feel Method" can check Cumulative Depletion in the field. Table B shows how to use this method to determine moisture content from a root-zone soil sample taken with shovel or auger. The method should also be used to determine soil water deficits for the following:

(1) The first irrigation of the season

(2) Irrigations where crops have been water stressed

(3) After a heavy rainfall when some of the measured rainfall runs off the land

You can use the sliding red markers on the sight tube of the ETgage to keep a soil water balance – without paperwork. After the first irrigation of an irrigation cycle, slide the top marker to the present water level in the sight tube, and slide the bottom marker to the level you expect for the next cycle. Make the distance between the markers the allowable depletion for your soil. If the crop canopy does not completely shade the soil, ETgage will use water faster than the crop, and the distance between the markers should be increased to compensate for the faster rate. For example, if before the next irrigation your crop will be using on average only 3/4 of reference ET, expand the distance between the markers by a third (4/3 = 1 1/3). If a significant rainfall occurs (>0.1”), you can move the bottom marker down on the sight tube to factor in additional moisture.

Irrigation Application Efficiency

One goal of irrigating is to refill the soil water profile without excessive waste. The amount needed to refill the soil water profile is the Irrigation Water Requirement (IWR), which is the same as the Cumulative Depletion found from the Soil Water Balance sheet. An efficient irrigation applies IWR while minimizing deep percolation below the root zone and surface runoff from the end of the field. The following describes these relationships:

Let: **E** = the Irrigation Application Efficiency

(IWR) = Irrigation Water Requirement (inches or mm)

Q = Quantity of irrigation water applied (inches or mm)

(1) Irrigation application efficiency $E = \frac{(IWR)}{Q}$, usually expressed in percent.

(2) Irrigation application amount required at an irrigation $Q = \frac{(IWR)}{E}$

(3) Amount stored in the soil profile $(IWR) = Q \times E$

Flood irrigation by furrows or borders have application efficiencies varying from 30% to 70%. An efficiency of 20% to 30% for flood irrigation is considered poor because of excessive waste (ie, 80% to 70% of the water applied becomes deep percolation or surface runoff). Changes to improve efficiency might include:

- Irrigating at maximum allowable depletion
- Shorter irrigation set times
- Shorter field lengths and set sizes
- Different flow rates in the furrows or borders
- Irrigating every other furrow
- Re-leveling the field
- Using cutback, surge or reuse systems

60% efficiency is very good for a typical furrow or border irrigation where there is no reuse or cutback. For typical furrow and border irrigating, 75% efficiency or greater may indicate under-watering on the lower end of the field: watch for signs of crop water stress such as small plants or leaves curled, drooped or duller and darker.

Center pivot sprinkler irrigation efficiencies vary between 70% to 90% depending mainly upon the operating pressure. Low-pressure systems, with spray nozzles on drop tubes, have the greatest efficiencies because they have minimal spray loss compared to high-pressure systems which have impact type nozzles placed on their overhead pipes.

Measuring Irrigation Applications

This Irrigation Manual includes various tables for determining flow rates from water sources. There are tables for Parshall flumes, contracted weirs, and suppressed weirs. Siphon tubes are good flow measurement devices, and a table is included to calibrate them. To calibrate gated pipe, use a bucket and stop watch to find flow rate for one opening, then multiply by the total number of openings. Wells should have properly maintained propeller-type flow meters that read both flow rate and cumulative acre-feet.

Following are the basic relationships between flow rate, the time water runs for an irrigation set, and the irrigation application amount:

$$\text{(1)}\quad \text{inches of water} = \frac{\text{acre-feet} \times 12}{\text{acres}}$$

$$\text{(2)}\quad \text{cubic feet per minute} = \frac{\text{gallons per minute}}{450}$$

$$\text{(3)}\quad \text{inches of water} = \frac{\text{cubic feet per second} \times \text{hours}}{\text{acres}} \quad \text{or} \quad \text{hours} = \frac{\text{inches} \times \text{acres}}{\text{cubic feet per second}}$$

- 1 CFS flowing on 1 acre for 1 hour covers the acre to a depth of 1 inch. A CFS flowing on 1 acre for 24 hours covers the acre to a depth of 24 inches or 2 acre-feet per acre.
- 1 acre = 43,560 square feet
- 1 acre-foot = 325,850.6 gallons

For center pivots, see the table derived from these formulae.

The table titled *Farm Water Supply Required to Meet ET at a Given Efficiency* summarizes the relationships in a useful format. This table answers the following questions:

(1) How much water supply is required for a given acreage, ET, and efficiency?

(2) How many acres can be irrigated with a given water supply, ET, and efficiency?

SOIL WATER BALANCE SHEET

FIELD #		CROP			Soil Type	
ETgage #			Planting Date	Emerge Date	Irrig. Method	
YEAR			Full Cover Date	Harvest Date		

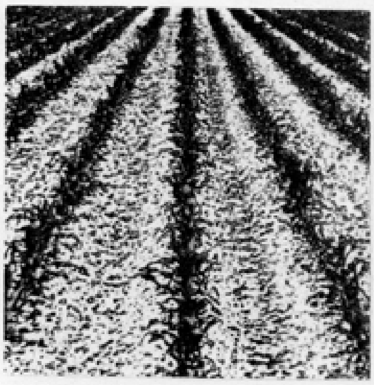
Date/Time	ETgage Reading (inches)	**G** ETgage Change (inches)	**R** Rain (inches)	**I** Irrigation Applied (inches)	**C** Crop coefficient from table	**Et** Crop ET **G x C**	**D** Cumulative Depletion ET-(Rain+Irrig) **Et - (R + I)**	Allowable Depletion from table	Efficiency **D / I**	

COMMENTS:

PICTURE INDEX 1

Corn (grain variety, 30 inch rows)

9 in. crop height
4 extended leaves (stem collar)
10 % shade
.35 atmometer multiplier (mean Kc)




18 in. crop height
6 extended leaves (stem collar)
25 % shade
.55 atmometer multiplier (mean Kc)


24 in. crop height
8 extended leaves (stem collar)
35 % shade
.65 atmometer multiplier (mean Kc)


32 in. crop height
10 extended leaves (stem collar)
65 % shade
.90 atmometer multiplier (mean Kc)


42 in. crop height
12 extended leaves (stem collar)
75 % shade
1.0 atmometer multiplier (mean Kc)


Safe water 50% for crop use (inches)

root zone depth (ft)	fine sand	sand loam	clay silt loam
.75	.4	.6	.8
1.25	.6	1.0	1.3
1.75	.9	1.3	1.8
2.5	1.3	1.9	2.5
3.0	1.5	2.3	3.0

INCH SCALE
to 1/10 inch

PICTURE INDEX 2

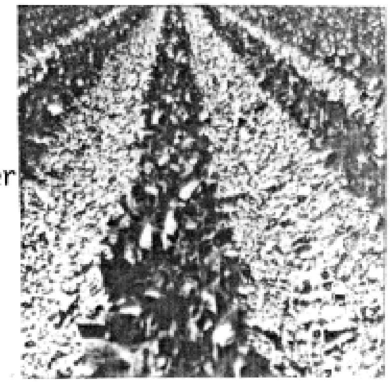
Beans (dry edible, 30 inch rows)

4 in. crop height
4 in. crop spread

10 % shade
.33 atmometer multiplier (mean Kc)


9 in. crop height
9 in. crop spread

30 % shade
.6 atmometer multiplier (mean Kc)




14 in. crop height
14 in. crop spread

45 % shade
.75 atmometer multiplier (mean Kc)


16 in. crop height
18 in. crop spread

55 % shade
.85 atmometer multiplier (mean Kc)


16 in. crop height
22 in. crop spread

75% shade
1.0 atmometer multiplier (mean Kc)


INCH SCALE
to 1/10 inch

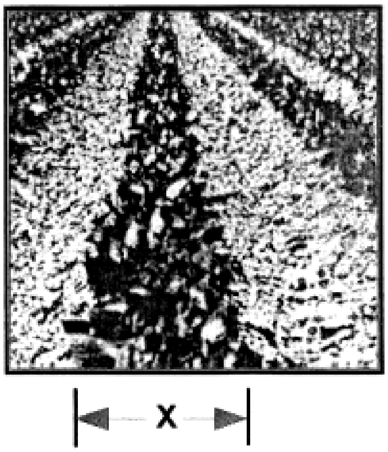
root zone depth (ft)	Safe water 50% for crop use (inches): fine sand	sand loam	clay silt loam
.75	.4	.6	.8
1.25	.6	1.0	1.3
1.75	.9	1.3	1.8
2.0	1.0	1.5	2.0
2.5	1.3	1.9	2.5

ETgage Multipliers
(Crop Coefficients)
for Low-Growing Bushy Plants
on 30 Inch Row Spacing
(ie, Potatoes, Beans, Beets)

Nominal Outside Spread of Plants by Tape Measure (Inches) (See Note 2)	Approx. ETgage Multipliers (Based on Mean Crop Coefficients, kcm)
Less than 1.5 inches	0.3 (See Note 1)
4	0.4
8	0.5
12	0.65
15	0.75
20	0.9
Greater than 25 inches	1.0

Note 1: Multiplier of 0.3 is based on average soil surface moisture conditions. Early season soil moisture management is related to germination requirements for moisture in the top 0 to 12 inches.

Note 2: Measure Distance X in inches.



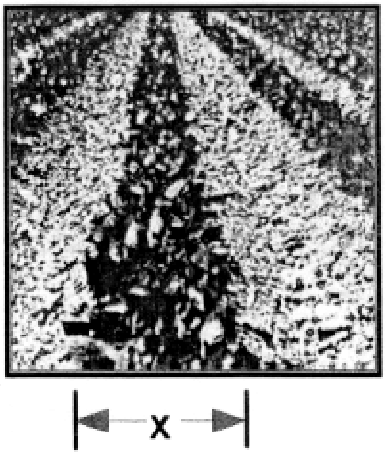
ETgage Multipliers
(Crop Coefficients)
Based on % Shading

% Shading = % of ground surface covered by actively growing green crop
(See Note 1)

% Shading	ETgage Multipliers (Based on Mean Crop Coefficients, kcm)
0 to 5%	0.3 (See Note 2)
10	0.4
20	0.5
30	0.6
40	0.7
50	0.8
60	0.9
70	0.95
75% and greater	1.0

Note 1: An approximate % shading is computed by dividing the nominal outside plant spread in a row (distance X below) by the row spacing. This table can also be used for broadcasted or drilled crops such as alfalfa or small grains.

Note 2: Multiplier of 0.3 is based on average soil surface moisture conditions. Early season soil moisture management is related to germination requirements for moisture in the top 0 to 12 inches.



How much water is available in your soil to meet crop ET?

Allowable Depletion

Exceeding the Allowable Depletion will reduce your crop yield

Multiply FACTOR 1 x FACTOR 2 x FACTOR 3 to get Allowable Depletion
This Table is good only when you start with a root zone completely full of water, as after irrigating.
(See table A-2 for examples.)

FACTOR 1: Total Soil Water Capacity per foot

(from field capacity to permanent wilting)

	inches/foot
Coarse Texture	
Fine sand	**0.9**
Loamy sand	**1.2**
Medium Texture	
Sandy loam	**1.6**
Loam	**2.0**
Fine Texture	
Silty loam	**2.3**
Clay loam	**2.1**

FACTOR 2: Root depth

	Feet			
Corn	**1.5**		40 days after planting	
	3.0	full growth	80 days after planting	14 days before tassel
Beans	**1.2**		25 days after planting	
	2.5	full growth	50 days after planting	10 days after 2nd bloom
Sugar beets	**1.5**		45 days after planting	
	3.0	full growth	90 days after planting	
Small grains	**1.5**		40 days after planting	
	3.0	full growth	80 days after planting	10 days before heading
Potatoes	**1.0**		40 days after planting	
	2.0	full growth	80 days after planting	10 days after bloom
Onions	**0.4**		50 days after planting	
	0.8	full growth	100 days after planting	max plant height
Cucumber	**1.0**		25 days after planting	
	2.0	full growth	50 days after planting	
Alfalfa	**4.0**	full growth	full ground cover	
Turf	**1.0**	full growth	full ground cover	
Pasture	**2.0**	full growth	full ground cover	

Full growth: mature roots, no confining soil layers.

FACTOR 3: Water withdrawn without stress

Corn	**50%**
Beans	**50%**
Sugar beets	**50%**
Small grains	**50%**
Potatoes	**40%**
Onions	**40%**
Cucumber	**40%**
Alfalfa	**70%**
Turf	**80%**
Pasture	**60%**

EXAMPLES

The crop can use this much water without being stressed

Corn, sandy loam, mature	1.6 X 3 X .50 = 2.4 inches
Corn, clay loam, mature	2.1 X 3 X .50 = 3.2 inches
Alfalfa, clay loam, mature	2.1 X 4 X .70 = 5.9 inches
Pasture, clay loam, mature	2.1 X 2.0 X .60 = 2.5 inches

Maximum irrigation efficiency
For *surface irrigation systems* (furrows or borders), empty the root zone up to the allowable depletion.

Table A-2

SOIL WATER AVAILABLE TO MEET CROP ET

Allowable Depletion

		ANNUAL CROPS														PERENNIALS		
CROP		Corn		Beans		Sugar Beets		Small Grains		Potatoes		Onions		Cucumbers		Alfalfa	Turf	Pasture
% allowable depletion	FACTOR 3	50%		50%		50%		50%		40%		40%		40%		70%	80%	60%
Days from planting		40	80	25	50	45	90	40	80	40	80	50	100	25	50	-	-	-
Rootzone Depth, unconfined (ft)	FACTOR 2	1.5	3.0 max	1.2	2.5 max	1.5	3.0 max	1.5	3.0 max	1.0	2.0 max	0.4	.75 max	1.0	2.0 max	4.0 max	1.0 max	2.0 max
Observations at max.		14 d. before tassel		10 d. after 2nd bloom				10 d. before heading		10 d. after bloom		Max. plant height				Full ground cover		
SOIL TEXTURE	Total Soil Water (inches / ft) FACTOR 1	INCHES OF ALLOWABLE DEPLETION																
COARSE																		
fine sand	0.9	0.7	1.4	0.5	1.1	0.7	1.4	0.7	1.4	0.4	0.7	0.15	0.3	0.4	0.7	2.5	0.7	1.1
loamy sand	1.2	0.9	1.8	0.7	1.5	0.9	1.8	0.9	1.8	0.5	1.0	0.2	0.4	0.5	1.0	3.4	1.0	1.4
MEDIUM																		
sandy loam	1.6	1.2	2.4	1.0	2.0	1.2	2.4	1.2	2.4	0.6	1.3	0.25	0.5	0.6	1.3	4.5	1.3	1.9
loam	2.0	1.5	3.0	1.2	2.5	1.5	3.0	1.5	3.0	0.8	1.6	0.3	0.6	0.8	1.6	5.6	1.6	2.4
FINE																		
silty loam	2.3	1.7	3.5	1.4	2.9	1.7	3.5	1.7	3.5	0.9	1.8	0.4	0.7	0.9	1.8	6.4	1.8	2.8
clay loam	2.1	1.6	3.2	1.3	2.6	1.6	3.2	1.6	3.2	0.8	1.7	0.3	0.6	0.8	1.7	5.9	1.7	2.5

INCHES OF ALLOWABLE DEPLETION = FACTOR 1 x FACTOR 2 x FACTOR 3

This Table is good only when you start with a root zone completely full of water as after irrigating.

Table B

ESTIMATING SOIL MOISTURE BY FEEL

Moisture deficit ***in/ft***	***Loamy Sand***	***Sandy Loam***	***Loam***	***Clay Loam***	*Moisture deficit* ***in/ft***
0 (field capacity)	Leaves wet outline on hand when squeezed.	Appears very dark, leaves wet outline on hand, makes a short ribbon.	Appears very dark, leaves a wet outline on hand, will ribbon out about one inch.	Appears very dark, leaves slight moisture on hand when squeezed, will ribbon out about two inches.	0 (field capacity)
0.2					0.2
0.3	Appears moist, makes a weak ball.		Dark color, forms a plastic ball, slicks when rubbed.		0.3
0.4		Quite dark color, makes a hard ball.		Dark color, will slick and ribbons easily.	0.4
0.5	Appears slightly moist, sticks together slightly.				0.5
0.6		Fairly dark color, makes a good ball.	Quite dark, forms a hard ball.		0.6
0.7				Quite dark, will make thick ribbon, may slick when rubbed.	0.7
0.8	Dry, loose, flows thru fingers.	Slightly dark color, makes a weak ball.			0.8
0.9	(wilting point)		Fairly dark, forms a good ball.		0.9
1.0		Lightly colored by moisture, will not ball.		Fairly dark, makes a good ball.	1.0
1.1			Slightly dark, forms a weak ball.		1.1
1.2				Will ball, small clods will flatten out rather than crumble.	1.2
1.3		Very slight color due to moisture.			1.3
1.4		(wilting point)	Lightly colored, small clods, crumbles fairly easily.		1.4
1.5				Slightly dark, clods crumble.	1.5
1.6					1.6
1.7			Slight color due to moisture, small clods are hard.		1.7
1.8				Some darkness due to unavailable moisture, clods are hard, cracked.	1.8
1.9			(wilting point)		1.9
2.0				(wilting point)	2.0

from ASAE V3 N1

How much water to refill the root zone? Add up the moisture deficit in each foot of roots.

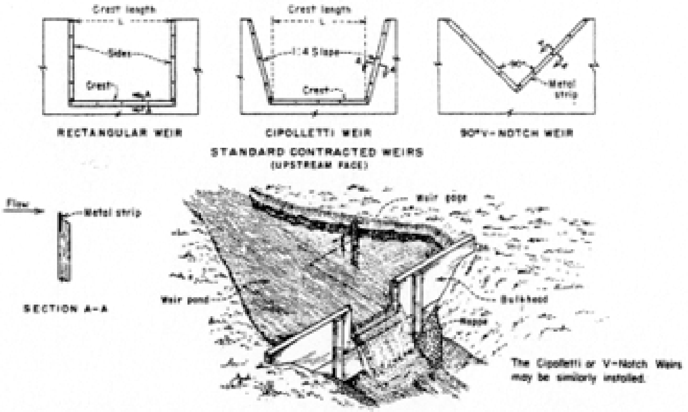


Figure 2.—Standard contracted weirs, and temporary bulkhead with contracted rectangular weir discharging at free flow. 103–D–858.

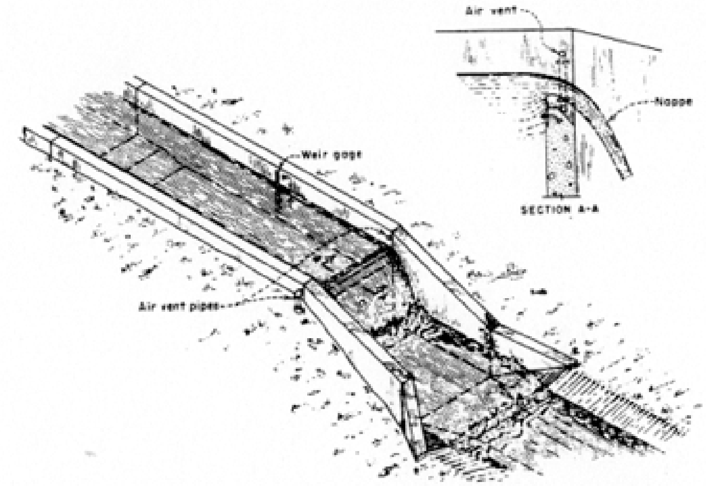


Figure 3.—Typical suppressed weir in a flume drop. 103–D–854.

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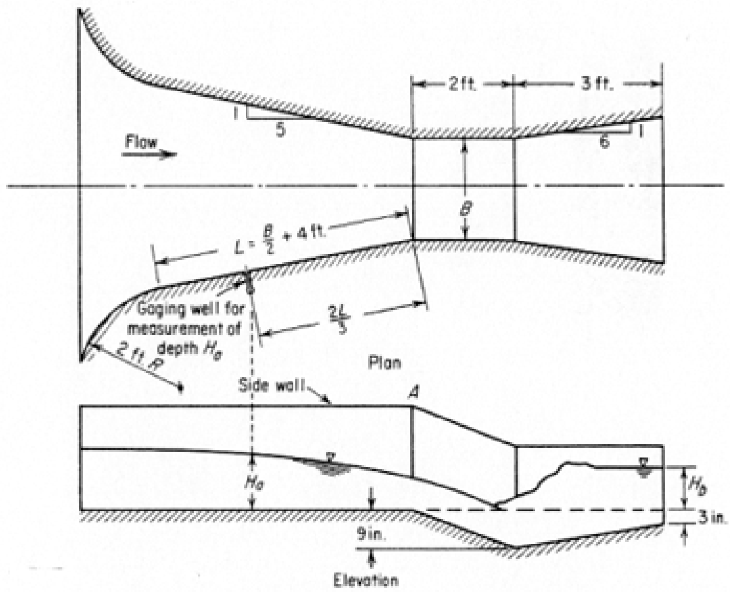


Parshall Flume Dimensions for Widths (B) of 1 to 8 ft.
Elevation View shows free-flow discharge condition

Table 8.—Discharge of standard contracted rectangular weirs in second-feet. Values below and to left of heavy line determined experimentally; others computed from the formula $Q=3.33(L-0.2H)H^{3/2}$. (See sec. 15.)

Head H, feet	Length of weir, L, feet										
	0.5	1.0	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
0.01	0.002	0.003	0.005	0.007	0.010	0.013	0.016	0.020	0.023	0.026	0.030
.02	.005	.009	.014	.019	.028	.037	.047	.056	.066	.075	.085
.03	.009	.017	.026	.034	.052	.069	.086	.104	.121	.138	.155
.04	.013	.026	.040	.053	.079	.106	.133	.159	.186	.213	.239
.05	.018	.037	.055	.074	.111	.148	.186	.223	.260	.297	.334
.06	.024	.048	.073	.097	.146	.195	.244	.293	.342	.391	.439
.07	.030	.061	.092	.123	.184	.246	.308	.369	.431	.493	.554
.08	.036	.074	.112	.149	.225	.300	.375	.451	.526	.601	.676
.09	.043	.088	.133	.178	.268	.358	.448	.538	.628	.718	.807
.10	.051	.103	.156	.208	.314	.419	.524	.630	.735	.840	.945
.11	.058	.119	.179	.240	.362	.483	.605	.726	.848	.969	1.09
.12	.066	.135	.204	.273	.412	.550	.689	.827	.965	1.10	1.24
.13	.074	.152	.230	.308	.464	.620	.776	.933	1.09	1.24	1.40
.14	.082	.169	.257	.344	.518	.693	.867	1.04	1.22	1.39	1.56
.15	.091	.188	.284	.381	.575	.768	.962	1.16	1.35	1.54	1.74
.16	.100	.206	.313	.419	.632	.845	1.06	1.27	1.48	1.70	1.91
.17	.109	.225	.342	.459	.692	.926	1.16	1.39	1.63	1.86	2.09
.18	.122	.245	.372	.499	.754	1.01	1.26	1.52	1.77	2.02	2.28
.19	.132	.265	.403	.541	.817	1.09	1.37	1.64	1.92	2.20	2.47
.20	.142	.286	.435	.584	.881	1.18	1.48	1.78	2.07	2.37	2.67
.21	.152	.307	.467	.627	.948	1.27	1.59	1.91	2.23	2.55	2.87
.22	.162	.328	.500	.672	1.02	1.36	1.70	2.05	2.39	2.73	3.08
.23	.173	.350	.534	.718	1.08	1.45	1.82	2.19	2.55	2.92	3.29
.24	.184	.373	.568	.764	1.16	1.55	1.94	2.33	2.72	3.11	3.50
.25	.195	.395	.603	.811	1.23	1.64	2.06	2.48	2.89	3.31	3.72
.26	.....	.419	.639	.860	1.30	1.74	2.18	2.63	3.07	3.51	3.95
.27	.....	.442	.675	.909	1.38	1.84	2.31	2.78	3.24	3.71	4.18
.28	.....	.466	.712	.959	1.45	1.95	2.44	2.93	3.43	3.92	4.41
.29	.....	.490	.750	1.01	1.53	2.05	2.57	3.09	3.61	4.13	4.65
.30	.....	.514	.788	1.06	1.61	2.16	2.70	3.25	3.80	4.34	4.89
.31	.....	.539	.827	1.11	1.69	2.26	2.84	3.41	3.99	4.56	5.14
.32	.....	.564	.866	1.17	1.77	2.37	2.98	3.58	4.18	4.78	5.39
.33	.....	.590	.905	1.22	1.85	2.48	3.12	3.75	4.38	5.01	5.64
.34	.....	.615	.945	1.28	1.94	2.60	3.26	3.92	4.58	5.24	5.90
.35	.....	.638	.986	1.33	2.02	2.71	3.40	4.09	4.78	5.47	6.16
.36	.....	.666	1.03	1.39	2.11	2.82	3.54	4.26	4.98	5.70	6.42
.37	.....	.714	1.07	1.44	2.19	2.94	3.69	4.44	5.19	5.94	6.69
.38	.....	.743	1.11	1.50	2.28	3.05	3.84	4.62	5.40	6.18	6.96
.39	.....	.772	1.15	1.56	2.37	3.18	3.99	4.80	5.61	6.42	7.24
.40	.....	.801	1.20	1.62	2.46	3.30	4.14	4.99	5.83	6.67	7.51
.41	.....	.830	1.24	1.68	2.55	3.42	4.30	5.17	6.05	6.92	7.80
.42	.....	.860	1.28	1.74	2.64	3.55	4.46	5.36	6.27	7.18	8.08
.43	.....	.890	1.33	1.80	2.74	3.68	4.61	5.55	6.49	7.43	8.37
.44	.....	.920	1.37	1.86	2.83	3.80	4.77	5.75	6.72	7.69	8.66
.45	.....	.950	1.42	1.92	2.93	3.93	4.94	5.94	6.95	7.95	8.96
.46	.....	.981	1.46	1.98	3.02	4.06	5.10	6.14	7.18	8.22	9.26
.47	.....	1.01	1.51	2.04	3.12	4.19	5.26	6.34	7.41	8.48	9.56
.48	.....	1.04	1.56	2.11	3.22	4.32	5.43	6.54	7.64	8.75	9.86
.49	.....	1.08	1.60	2.17	3.32	4.46	5.60	6.74	7.88	9.03	10.17
.50	.....	1.11	1.65	2.24	3.41	4.59	5.77	6.95	8.12	9.30	10.48

Table 8.—Discharge of standard contracted rectangular weirs in second-feet. Values below and to left of heavy line determined experimentally, others computed from the formula $Q=3.33(L-0.2H)H^{3/2}$. (See sec. 15.)—Continued

Head H, feet	Length of weir, L, feet								
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
0.51	1.70	2.30	3.52	4.73	5.94	7.15	8.37	9.58	10.8
.52	1.74	2.37	3.62	4.86	6.11	7.36	8.61	9.86	11.1
.53	1.79	2.43	3.72	5.00	6.29	7.57	8.86	10.1	11.4
.54	1.84	2.50	3.82	5.14	6.46	7.79	9.11	10.4	11.8
.55	1.89	2.57	3.92	5.28	6.64	8.00	9.36	10.7	12.1
.56	1.94	2.64	4.03	5.43	6.82	8.22	9.61	11.0	12.4
.57	1.99	2.70	4.14	5.57	7.00	8.44	9.87	11.3	12.7
.58	2.04	2.77	4.24	5.71	7.18	8.66	10.1	11.6	13.1
.59	2.08	2.84	4.35	5.86	7.37	8.88	10.4	11.9	13.4
.60	2.14	2.91	4.46	6.00	7.55	9.10	10.6	12.2	13.7
.61	2.19	2.98	4.57	6.15	7.74	9.32	10.9	12.5	14.1
.62	2.24	3.05	4.68	6.30	7.93	9.55	11.2	12.8	14.4
.63	2.29	3.12	4.79	6.45	8.12	9.78	11.4	13.1	14.8
.64	2.34	3.19	4.90	6.60	8.31	10.0	11.7	13.4	15.1
.65	2.39	3.26	5.01	6.75	8.50	10.2	12.0	13.7	15.5
.66	2.44	3.34	5.12	6.91	8.69	10.5	12.3	14.0	15.8
.67	2.50	3.41	5.23	7.06	8.89	10.7	12.5	14.4	16.2
.68	2.55	3.58	5.35	7.22	9.08	11.0	12.8	14.7	16.6
.69	2.60	3.66	5.46	7.37	9.28	11.2	13.1	15.0	16.9
.70	2.65	3.74	5.58	7.53	9.48	11.4	13.4	15.3	17.3
.71	2.70	3.82	5.69	7.69	9.68	11.7	13.7	15.7	17.6
.72	2.76	3.90	5.81	7.84	9.88	11.9	13.9	16.0	18.0
.73	2.81	3.98	5.93	8.00	10.1	12.2	14.2	16.3	18.4
.74	2.87	4.06	6.05	8.16	10.3	12.4	14.5	16.6	18.8
.75	2.92	4.14	6.16	8.33	10.5	12.7	14.8	17.0	19.1
.76	.....	4.22	6.28	8.49	10.7	12.9	15.1	17.3	19.5
.77	.....	4.30	6.40	8.65	10.9	13.2	15.4	17.7	19.9
.78	.....	4.38	6.52	8.82	11.1	13.4	15.7	18.0	20.3
.79	.....	4.46	6.64	8.98	11.3	13.7	16.0	18.3	20.7
.80	.....	4.54	6.77	9.15	11.5	13.9	16.3	18.7	21.1
.81	.....	4.62	6.89	9.32	11.7	14.2	16.6	19.0	21.5
.82	.....	4.70	7.01	9.48	12.0	14.4	16.9	19.4	21.8
.83	.....	4.79	7.14	9.65	12.2	14.7	17.2	19.7	22.2
.84	.....	4.87	7.26	9.82	12.4	15.0	17.5	20.1	22.6
.85	.....	4.96	7.38	10.0	12.6	15.2	17.8	20.4	23.0
.86	.....	5.05	7.51	10.2	12.8	15.5	18.1	20.8	23.4
.87	.....	5.14	7.64	10.3	13.0	15.7	18.4	21.1	23.8
.88	.....	5.23	7.76	10.5	13.3	16.0	18.8	21.5	24.3
.89	.....	5.32	7.89	10.7	13.5	16.3	19.1	21.9	24.7
.90	.....	5.41	8.02	10.9	13.7	16.5	19.4	22.2	25.1
.91	.....	5.50	8.15	11.0	13.9	16.8	19.7	22.6	25.5
.92	.....	5.59	8.28	11.2	14.2	17.1	20.0	23.0	25.9
.93	.....	5.68	8.40	11.4	14.4	17.4	20.4	23.3	26.3
.94	.....	5.77	8.53	11.6	14.6	17.6	20.7	23.7	26.7
.95	.....	5.86	8.66	11.7	14.8	17.9	21.0	24.1	27.2
.96	.....	5.95	8.80	11.9	15.1	18.2	21.3	24.5	27.6
.97	.....	6.04	8.93	12.1	15.3	18.5	21.7	24.8	28.0
.98	.....	6.13	9.06	12.3	15.5	18.8	22.0	25.2	28.4
.99	.....	6.22	9.19	12.5	15.8	19.0	22.3	25.6	28.9
1.00	.....	6.31	9.32	12.7	16.0	19.3	22.6	26.0	29.3

Table 9.—Discharge of standard suppressed rectangular weirs in second-feet. Computed from the formula $Q=3.33LH^{3/2}$. (See sec. 17.)

Head H, feet	Length of weir, L, in feet						
	0.5	1.0	1.5	2.0	3.0	4.0	5.0
0.01	0.002	0.003	0.005	0.007	0.010	0.013	0.017
.02	.005	.010	.014	.019	.028	.038	.047
.03	.009	.017	.026	.035	.052	.069	.087
.04	.013	.027	.040	.053	.080	.106	.133
.05	.019	.037	.056	.074	.112	.149	.186
.06	.025	.049	.073	.098	.147	.196	.245
.07	.031	.062	.093	.123	.185	.247	.309
.08	.038	.075	.113	.151	.226	.301	.377
.09	.045	.090	.135	.180	.270	.360	.450
.10	.053	.105	.158	.211	.316	.421	.527
.11	.061	.122	.182	.243	.365	.486	.608
.12	.069	.138	.208	.277	.415	.554	.692
.13	.078	.156	.234	.312	.468	.624	.781
.14	.087	.174	.262	.349	.523	.698	.872
.15	.097	.194	.290	.387	.581	.774	.968
.16	.107	.213	.320	.426	.639	.852	1.07
.17	.116	.233	.350	.467	.700	.932	1.17
.18	-----	.254	.382	.509	.763	1.02	1.27
.19	-----	.276	.414	.552	.827	1.10	1.38
.20	-----	.298	.447	.596	.893	1.19	1.49
.21	-----	.321	.481	.641	.962	1.28	1.60
.22	-----	.344	.515	.687	1.03	1.37	1.72
.23	-----	.367	.551	.735	1.10	1.47	1.84
.24	-----	.392	.587	.783	1.18	1.57	1.96
.25	-----	.416	.624	.832	1.25	1.67	2.08
.26	-----	.442	.662	.883	1.33	1.77	2.21
.27	-----	.467	.701	.934	1.40	1.87	2.34
.28	-----	.493	.740	.987	1.48	1.97	2.47
.29	-----	.520	.780	1.04	1.56	2.08	2.60
.30	-----	.547	.821	1.09	1.64	2.19	2.74
.31	-----	.575	.862	1.15	1.72	2.30	2.87
.32	-----	.603	.904	1.21	1.81	2.41	3.01
.33	-----	.631	.947	1.26	1.89	2.53	3.16
.34	-----	.660	.990	1.32	1.98	2.64	3.30
.35	-----	-----	1.03	1.38	2.07	2.76	3.45
.36	-----	-----	1.08	1.44	2.16	2.88	3.60
.37	-----	-----	1.12	1.50	2.25	3.00	3.75
.38	-----	-----	1.17	1.56	2.34	3.12	3.90
.39	-----	-----	1.22	1.62	2.43	3.24	4.06
.40	-----	-----	1.26	1.68	2.53	3.37	4.21
.41	-----	-----	1.31	1.75	2.62	3.50	4.37
.42	-----	-----	1.36	1.81	2.72	3.63	4.53
.43	-----	-----	1.41	1.88	2.82	3.76	4.70
.44	-----	-----	1.46	1.94	2.92	3.89	4.86
.45	-----	-----	1.51	2.01	3.02	4.02	5.03
.46	-----	-----	1.56	2.08	3.12	4.16	5.19
.47	-----	-----	1.61	2.15	3.22	4.29	5.37
.48	-----	-----	1.66	2.22	3.32	4.43	5.54
.49	-----	-----	1.71	2.28	3.43	4.57	5.71
.50	-----	-----	1.77	2.35	3.53	4.71	5.89

Table 9.—Discharge of standard suppressed rectangular weirs in second-feet. Computed from the formula $Q=3.33LH^{3/2}$. (See sec. 17.)—Continued

Head H, feet	Length of weir, L, in feet						
	0.5	1.0	1.5	2.0	3.0	4.0	5.0
0.51	-----	-----	-----	2.43	3.64	4.85	6.06
.52	-----	-----	-----	2.50	3.75	5.00	6.24
.53	-----	-----	-----	2.57	3.85	5.14	6.43
.54	-----	-----	-----	2.64	3.96	5.29	6.61
.55	-----	-----	-----	2.72	4.08	5.43	6.79
.56	-----	-----	-----	2.79	4.19	5.58	6.98
.57	-----	-----	-----	2.87	4.30	5.73	7.17
.58	-----	-----	-----	2.94	4.41	5.88	7.35
.59	-----	-----	-----	3.02	4.53	6.04	7.55
.60	-----	-----	-----	3.10	4.64	6.19	7.74
.61	-----	-----	-----	3.17	4.76	6.35	7.93
.62	-----	-----	-----	3.25	4.88	6.50	8.13
.63	-----	-----	-----	3.33	5.00	6.66	8.33
.64	-----	-----	-----	3.41	5.12	6.82	8.53
.65	-----	-----	-----	3.49	5.24	6.98	8.73
.66	-----	-----	-----	3.57	5.36	7.14	8.93
.67	-----	-----	-----	3.65	5.48	7.31	9.13
.68	-----	-----	-----	-----	5.60	7.47	9.34
.69	-----	-----	-----	-----	5.73	7.63	9.54
.70	-----	-----	-----	-----	5.85	7.80	9.75
.71	-----	-----	-----	-----	5.98	7.97	9.96
.72	-----	-----	-----	-----	6.10	8.14	10.17
.73	-----	-----	-----	-----	6.23	8.31	10.39
.74	-----	-----	-----	-----	6.36	8.48	10.60
.75	-----	-----	-----	-----	6.49	8.65	10.81
.76	-----	-----	-----	-----	6.62	8.83	11.03
.77	-----	-----	-----	-----	6.75	9.00	11.25
.78	-----	-----	-----	-----	6.88	9.18	11.47
.79	-----	-----	-----	-----	7.02	9.35	11.69
.80	-----	-----	-----	-----	7.15	9.53	11.91
.81	-----	-----	-----	-----	7.28	9.71	12.14
.82	-----	-----	-----	-----	7.42	9.89	12.36
.83	-----	-----	-----	-----	7.55	10.07	12.59
.84	-----	-----	-----	-----	7.69	10.26	12.82
.85	-----	-----	-----	-----	7.83	10.44	13.05
.86	-----	-----	-----	-----	7.97	10.62	13.28
.87	-----	-----	-----	-----	8.11	10.81	13.51
.88	-----	-----	-----	-----	8.25	11.00	13.75
.89	-----	-----	-----	-----	8.39	11.18	13.98
.90	-----	-----	-----	-----	8.53	11.37	14.22
.91	-----	-----	-----	-----	8.67	11.56	14.45
.92	-----	-----	-----	-----	8.82	11.75	14.69

Table 16.—Free-flow discharge through Parshall measuring flumes, 1- to 8-foot size, in second-feet. Computed from the formula $Q=4WH_a^{1.522W^{0.026}}$. (See secs. 41 and 42.)

Upper head H_a		Discharge per second for flumes of various throat widths							
		1 foot	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
Feet	Inches	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet
0.20	2 3/8	0.35	0.66	0.97	1.26	-----	-----	-----	-----
.21	2 1/2	.37	.71	1.04	1.36	-----	-----	-----	-----
.22	2 5/8	.40	.77	1.12	1.47	-----	-----	-----	-----
.23	2 3/4	.43	.82	1.20	1.58	-----	-----	-----	-----
.24	2 7/8	.46	.88	1.28	1.69	-----	-----	-----	-----
.25	3	.49	.93	1.37	1.80	2.22	2.63	-----	-----
.26	3 1/8	.51	.99	1.46	1.91	2.36	2.80	-----	-----
.27	3 1/4	.54	1.05	1.55	2.03	2.50	2.97	-----	-----
.28	3 3/8	.58	1.11	1.64	2.15	2.65	3.15	-----	-----
.29	3 1/2	.61	1.18	1.73	2.27	2.80	3.33	-----	-----
.30	3 5/8	.64	1.24	1.82	2.39	2.96	3.52	4.08	4.62
.31	3 3/4	.68	1.30	1.92	2.52	3.12	3.71	4.30	4.88
.32	3 13/16	.71	1.37	2.02	2.65	3.28	3.90	4.52	5.13
.33	3 15/16	.74	1.44	2.12	2.78	3.44	4.10	4.75	5.39
.34	4 1/16	.77	1.50	2.22	2.92	3.61	4.30	4.98	5.66
.35	4 3/16	.80	1.57	2.32	3.06	3.78	4.50	5.22	5.93
.36	4 5/16	.84	1.64	2.42	3.20	3.95	4.71	5.46	6.20
.37	4 7/16	.88	1.72	2.53	3.34	4.13	4.92	5.70	6.48
.38	4 9/16	.92	1.79	2.64	3.48	4.31	5.13	5.95	6.74
.39	4 11/16	.95	1.86	2.75	3.62	4.49	5.35	6.20	7.05
.40	4 13/16	.99	1.93	2.86	3.77	4.68	5.57	6.46	7.34
.41	4 15/16	1.03	2.01	2.97	3.92	4.86	5.80	6.72	7.64
.42	5 1/16	1.07	2.09	3.08	4.07	5.05	6.02	6.98	7.94
.43	5 3/16	1.11	2.16	3.20	4.22	5.24	6.25	7.25	8.24
.44	5 1/4	1.15	2.24	3.32	4.38	5.43	6.48	7.52	8.55
.45	5 3/8	1.19	2.32	3.44	4.54	5.63	6.72	7.80	8.87
.46	5 1/2	1.23	2.40	3.56	4.70	5.83	6.96	8.08	9.19
.47	5 5/8	1.27	2.48	3.68	4.86	6.03	7.20	8.36	9.51
.48	5 3/4	1.31	2.57	3.80	5.03	6.24	7.44	8.65	9.84
.49	5 7/8	1.35	2.65	3.92	5.20	6.45	7.69	8.94	10.17
.50	6	1.39	2.73	4.05	5.36	6.66	7.94	9.23	10.51
.51	6 1/8	1.44	2.82	4.18	5.53	6.87	8.20	9.53	10.85
.52	6 1/4	1.48	2.90	4.31	5.70	7.09	8.46	9.83	11.19
.53	6 3/8	1.52	2.99	4.44	5.88	7.30	8.72	10.14	11.54
.54	6 1/2	1.57	3.08	4.57	6.05	7.52	8.98	10.45	11.89
.55	6 5/8	1.62	3.17	4.70	6.23	7.74	9.25	10.76	12.24
.56	6 3/4	1.66	3.26	4.84	6.41	7.97	9.52	11.07	12.60
.57	6 13/16	1.70	3.35	4.98	6.59	8.20	9.79	11.39	12.96
.58	6 15/16	1.75	3.44	5.11	6.77	8.43	10.07	11.71	13.33
.59	7 1/16	1.80	3.53	5.25	6.96	8.66	10.35	12.03	13.70
.60	7 3/16	1.84	3.62	5.39	7.15	8.89	10.63	12.36	14.08
.61	7 5/16	1.88	3.72	5.53	7.34	9.13	10.92	12.69	14.46
.62	7 7/16	1.93	3.81	5.68	7.53	9.37	11.20	13.02	14.84
.63	7 9/16	1.98	3.91	5.82	7.72	9.61	11.49	13.36	15.23
.64	7 11/16	2.03	4.01	5.97	7.91	9.85	11.78	13.70	15.62
.65	7 13/16	2.08	4.11	6.12	8.11	10.10	12.08	14.05	16.01
.66	7 15/16	2.13	4.20	6.26	8.31	10.34	12.38	14.40	16.41
.67	8 1/16	2.18	4.30	6.41	8.51	10.59	12.68	14.75	16.81
.68	8 3/16	2.23	4.40	6.56	8.71	10.85	12.98	15.10	17.22
.69	8 1/4	2.28	4.50	6.71	8.91	11.10	13.28	15.46	17.63

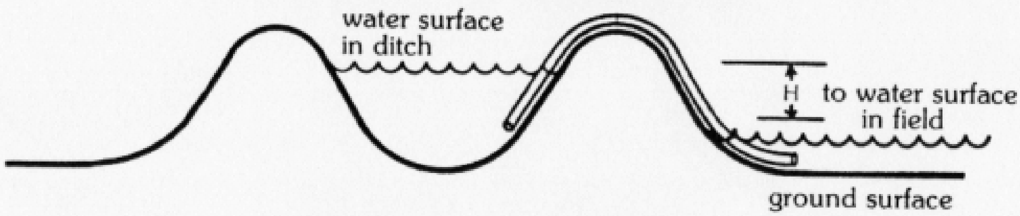
Table 16.—Free-flow discharge through Parshall measuring flumes, 1- to 8-foot size, in second-feet. Computed from the formula $Q=4WH_a^{1.522W^{0.026}}$. (See secs. 41 and 42.)—Continued

Upper head H_a		Discharge per second for flumes of various throat widths							
		1 foot	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
Feet	Inches	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet
.70	8 3/8	2.33	4.60	6.86	9.11	11.36	13.59	15.82	18.04
.71	8 1/2	2.38	4.70	7.02	9.32	11.62	13.90	16.18	18.45
.72	8 5/8	2.43	4.81	7.17	9.53	11.88	14.22	16.55	18.87
.73	8 3/4	2.48	4.91	7.33	9.74	12.14	14.53	16.92	19.29
.74	8 7/8	2.53	5.02	7.49	9.95	12.40	14.85	17.29	19.71
.75	9	2.58	5.12	7.65	10.16	12.67	15.17	17.66	20.14
.76	9 1/8	2.63	5.23	7.81	10.38	12.94	15.49	18.04	20.57
.77	9 1/4	2.68	5.34	7.97	10.60	13.21	15.82	18.42	21.01
.78	9 3/8	2.74	5.44	8.13	10.81	13.48	16.15	18.81	21.46
.79	9 1/2	2.80	5.55	8.30	11.03	13.76	16.48	19.20	21.91
.80	9 5/8	2.85	5.66	8.46	11.25	14.04	16.81	19.59	22.36
.81	9 3/4	2.90	5.77	8.63	11.48	14.32	17.15	19.99	22.81
.82	9 13/16	2.96	5.88	8.79	11.70	14.60	17.49	20.39	23.26
.83	9 15/16	3.02	6.00	8.96	11.92	14.88	17.83	20.79	23.72
.84	10 1/16	3.07	6.11	9.13	12.15	15.17	18.17	21.18	24.18
.85	10 3/16	3.12	6.22	9.30	12.38	15.46	18.52	21.58	24.64
.86	10 5/16	3.18	6.33	9.48	12.61	15.75	18.87	21.99	25.11
.87	10 7/16	3.24	6.44	9.65	12.84	16.04	19.22	22.40	25.58
.88	10 9/16	3.29	6.56	9.82	13.07	16.33	19.57	22.82	26.06
.89	10 11/16	3.35	6.68	10.00	13.31	16.62	19.93	23.24	26.54
.90	10 13/16	3.41	6.80	10.17	13.55	16.92	20.29	23.66	27.02
.91	10 15/16	3.46	6.92	10.35	13.79	17.22	20.65	24.08	27.50
.92	11 1/16	3.52	7.03	10.53	14.03	17.52	21.01	24.50	27.99
.93	11 3/16	3.58	7.15	10.71	14.27	17.82	21.38	24.93	28.48
.94	11 1/4	3.64	7.27	10.89	14.51	18.13	21.75	25.36	28.97
.95	11 3/8	3.70	7.39	11.07	14.76	18.44	22.12	25.79	29.47
.96	11 1/2	3.76	7.51	11.26	15.00	18.75	22.49	26.22	29.97
.97	11 5/8	3.82	7.63	11.44	15.25	19.06	22.86	26.66	30.48
.98	11 3/4	3.88	7.75	11.63	15.50	19.37	23.24	27.10	30.98
.99	11 7/8	3.94	7.88	11.82	15.75	19.68	23.62	27.55	31.49
1.00	12	4.00	8.00	12.00	16.00	20.00	24.00	28.00	32.00
1.01	12 1/8	4.06	8.12	12.19	16.25	20.32	24.38	28.45	32.52
1.02	12 1/4	4.12	8.25	12.38	16.51	20.64	24.77	28.90	33.04
1.03	12 3/8	4.18	8.38	12.57	16.76	20.96	25.16	29.36	33.56
1.04	12 1/2	4.25	8.50	12.76	17.02	21.28	25.55	29.82	34.08
1.05	12 5/8	4.31	8.63	12.96	17.28	21.61	25.94	30.28	34.61
1.06	12 3/4	4.37	8.76	13.15	17.54	21.94	26.34	30.74	35.14
1.07	12 13/16	4.43	8.88	13.34	17.80	22.27	26.74	31.20	35.68
1.08	12 15/16	4.50	9.01	13.54	18.07	22.60	27.13	31.67	36.22
1.09	13 1/16	4.56	9.14	13.74	18.34	22.93	27.53	32.14	36.76
1.10	13 3/16	4.62	9.27	13.93	18.60	23.26	27.94	32.62	37.30
1.11	13 5/16	4.68	9.40	14.13	18.86	23.60	28.35	33.10	37.84
1.12	13 7/16	4.75	9.54	14.33	19.13	23.94	28.76	33.58	38.39
1.13	13 9/16	4.82	9.67	14.53	19.40	24.28	29.17	34.06	38.94
1.14	13 11/16	4.88	9.80	14.73	19.67	24.62	29.58	34.54	39.50
1.15	13 13/16	4.94	9.94	14.94	19.94	24.96	30.00	35.02	40.06
1.16	13 15/16	5.01	10.07	15.14	20.22	25.31	30.41	35.51	40.62
1.17	14 1/16	5.08	10.20	15.34	20.50	25.66	30.83	36.00	41.18
1.18	14 3/16	5.15	10.34	15.55	20.78	26.01	31.25	36.50	41.75
1.19	14 1/4	5.21	10.48	15.76	21.05	26.36	31.68	37.00	42.32

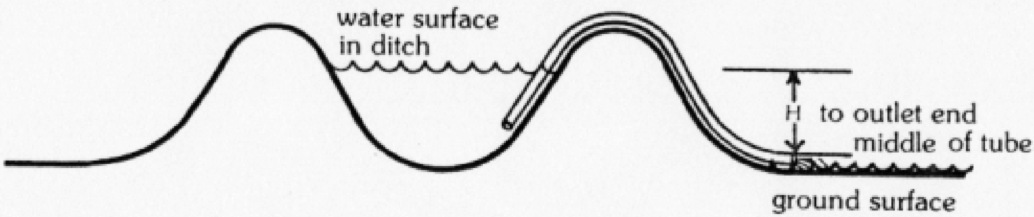
APPROXIMATE SIPHON TUBE FLOWRATES

Tube Diameter (inches)	Flow Per Tube in Gallons Per Minute at Given Head (Height Diff., H in Inches) 2″	4″	6″	8″
½	1.3	1.8	2.2	2.5
¾	2.9	4.1	5.0	5.8
1	5.1	7.3	9.0	10.5
1¼	8.1	11.5	13.7	16.3
1½	11.7	16.5	20.2	23.0
2	20	29	35	41
3		66	81	92
4		117	142	166
5		176	220	255
6		260	320	370

Siphon Tube with Submerged Outlet



Siphon Tube with Free Outlet



Measure H by raising downstream end of tube alongside a measuring stick until flow just stops.

INCHES OF WATER APPLIED BY A 136 ACRE CENTER PIVOT

GPM HR/Circle	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96
400	0.08	0.12	0.16	0.20	0.24	0.28	0.31	0.35	0.39	0.43	0.47	0.51	0.55	0.59	0.62
450	.08	.13	.18	.22	.26	0.31	0.35	0.40	0.44	0.48	0.53	0.58	0.62	0.66	0.70
500	.10	.14	.20	.24	.30	0.34	0.39	0.44	0.49	0.54	0.59	0.64	0.68	0.74	0.78
550	.10	.16	.22	.27	.32	0.38	0.43	0.48	0.54	0.60	0.64	0.70	0.76	0.81	0.86
600	.12	.18	.24	.30	.35	0.41	0.47	0.53	0.59	0.64	0.70	0.76	0.82	0.88	0.94
650	.12	.19	.26	.32	.28	0.44	0.51	0.58	0.64	0.70	0.76	0.83	0.89	0.96	1.02
700	.14	.20	.28	.34	.41	0.48	0.56	0.62	0.68	0.76	0.82	0.89	0.96	1.03	1.10
750	.14	.22	.30	.36	.44	0.52	0.59	0.66	0.74	0.81	0.88	0.96	1.03	1.11	1.18
800	.16	.24	.31	.39	.47	0.55	0.62	0.70	0.78	0.86	0.94	1.02	1.10	1.18	1.26
850	.16	.25	.33	.42	.50	0.58	0.66	0.75	0.84	0.92	1.00	1.09	1.17	1.25	1.34
900	.18	.26	.35	.44	.53	0.62	0.70	0.80	0.88	0.97	1.06	1.15	1.24	1.33	1.42
950	.18	.28	.37	.46	.56	0.65	0.74	0.84	0.93	1.03	1.12	1.21	1.31	1.40	1.49
1000	.20	.30	.39	.49	.59	0.68	0.78	0.88	0.98	1.08	1.18	1.28	1.38	1.47	1.57
1050	.20	.31	.41	.52	.62	0.72	0.82	0.92	1.03	1.14	1.24	1.34	1.44	1.55	1.65
1100	.22	.32	.43	.54	.64	0.76	0.86	0.97	1.08	1.19	1.30	1.41	1.51	1.62	1.73
1150	.22	.34	.45	.56	.68	0.79	0.90	1.02	1.13	1.24	1.36	1.47	1.58	1.70	1.81
1200	.24	.35	.47	.59	.70	0.82	0.94	1.06	1.18	1.30	1.42	1.53	1.65	1.77	1.89
1250	.24	.36	.49	.61	.74	0.86	0.98	1.11	1.23	1.35	1.47	1.60	1.72	1.84	1.97
1300	.26	.38	.51	.64	.76	0.89	1.02	1.15	1.28	1.41	1.53	1.66	1.79	1.92	2.04
1350	.26	.40	.53	.66	.80	0.92	1.06	1.19	1.33	1.46	1.59	1.72	1.86	1.99	2.12
1400	.28	.41	.55	.68	.82	.96	1.10	1.24	1.38	1.51	1.65	1.79	1.93	2.06	2.20
1450	.28	.42	.57	.71	.86	1.00	1.14	1.28	1.42	1.57	1.71	1.85	2.00	2.14	2.28
1500	.30	.44	.59	.74	.88	1.03	1.18	1.33	1.47	1.62	1.77	1.92	2.06	2.21	2.36

EXAMPLE: On a 136 acre center pivot, where 900 gallons per minute is being pumped and a circle is completed every 72 hours, the application is 1.06 inches.

450 GPM = 1 cfs

$$\text{INCHES APPLIED} = \frac{(\text{GPM}) \times (\text{HOURS})}{450 \times (\text{ACRES})}$$

This formula for computing inches applied is also applicable for other sprinkler systems such as solid sets, side-rolls, and hand-moves.

FARM WATER SUPPLY REQUIRED TO MEET ET AT A GIVEN EFFICIENCY

	% IRRIGATION EFFICIENCY							
	20	30	40	50	60	70	80	90
ET, inch/day	GPM per Acre (Continuous Flowrate per Acre)							
0.05	4.7	3.1	2.4	1.9	1.6	1.3	1.2	1.0
0.10	9.4	6.3	4.7	3.8	3.1	2.7	2.4	2.1
0.15	14.1	9.4	7.1	5.7	4.7	4.0	3.5	3.1
0.20	18.9	12.6	9.4	7.5	6.3	5.4	4.7	4.2
0.25	23.6	15.7	11.8	9.4	7.9	6.7	5.9	5.2
0.30	28.3	18.9	14.1	11.3	9.4	8.1	7.1	6.3
0.35	33.0	22.0	16.5	13.2	11.0	9.4	8.2	7.3
0.40	37.7	25.1	18.9	15.1	12.6	10.8	9.4	8.4
0.45	42.4	28.3	21.2	17.0	14.1	12.1	10.6	9.4
0.50	47.1	31.4	23.6	18.9	15.7	13.5	11.8	10.5

NOTES:

(1) GPM = Gallons per minute (=cubic feet per sec X 448.8)

(2) ET = EvapoTranspiration from ETgage (inch/day).

Use a daily value for ET which represents a high ET day.

(3) % IRRIGATION APPLICATION EFFICIENCY:

Flood irrigation (furrow/border) is 30% to 70%

Sprinkler is 70% to 90%

(4) Equation for above table: GPM / Acre = (ET / .eff) * 18.8571

EXAMPLE:

(1) For a daily ET of 0.35 inch/day and an efficiency of 50%, 13.2 GPM per Acre required.

160 acres would require 2,112 GPM

1,000 GPM would supply 76 acres

If your GPM per Acre is greater than the value in the above table then you do not have to irrigate continuously.

If your GPM per Acre is less than the value in the above table then you do not have enough water and your crops will go into water stress.

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Atmometers

A flexible tool for irrigation scheduling.

Irrigation scheduling based upon crop ET (evapotranspiration) is often perceived as too difficult or too time consuming for many producers and crop advisers. However, there are tools available that reduce the work and the complexity associated with sound ET-based irrigation scheduling. Atmometers are one of these tools. The primary purpose of these instruments is to provide actual crop ET at any field location they are installed. This information is visually displayed on a site tube mounted in front of a ruler on the instrument. Reading the site tube is as easy as reading a rain gauge. Therefore, a grower or consultant can use an atmometer to quantitatively gauge how crop water use varies with changing weather conditions.

Essentially, an atmometer acts as mini-weather station that, when properly installed, will provide reference ET (ET_r) at a reasonable cost and with little effort. One Colorado supplier sells a modified atmometer (ETgage®). They are easy to install and require little maintenance. Studies conducted by CSU and the USDA in Fort Collins show that an atmometer will provide ET_r values that closely match ET_r calculated from weather station data (Figure 1). This ability to provide reliable ET makes atmometers especially useful for areas that do not have nearby weather stations or for people that do not have ready access to this information. A consultant or grower can install an atmometer to help schedule irrigations for many fields within a several mile radius. Also ET data from an atmometer may be more convenient and site specific than other sources.

Atmometer placed between irrigated fields.

Atmometer

Atmometers basically consist of a wet, porous ceramic cup mounted on top of a cylindrical water reservoir. The ceramic cup is covered with a green fabric (canvas or Gor-Tex®) that simulates the canopy of a crop. The reservoir is filled with distilled water that evaporates out of the ceramic cup and is pulled through a suction tube that extends to the bottom of the reservoir. Underneath the fabric, the ceramic cup is covered by a special membrane that keeps rain water from seeping into the ceramic cup. A rigid wire extending from the top keeps birds from perching on top of the gauge.

Atmometers are typically mounted on a wooden post near irrigated fields. A good location for placement is a border ridge in an alfalfa field. However, you may also locate the instrument alongside a dirt road if surrounded by low-growing irrigated crops. The site should represent average field conditions. Do not install near farm buildings, trees, or tall crops that may block the wind. Additionally, avoid placement near dry, fallow fields. The top of the ceramic cup should be 39 inches above the ground. The manufacturer of a modified atmometer sold in Colorado (ETgage®) provides detailed instructions on how to install and maintain their instrument.

The following is a brief description of how to use an atmometer to help schedule irrigations.

♦ The atmometer has two movable red markers on the site tube. Record height of water in the sight tube at the start of an irrigation event. The top marker can be used to record the initial height of water.

♦ Crop water use can be estimated by recording the drop in water level over a period of days. To determine the actual water use for a crop that has not fully completed its canopy, you need to multiply the drop in water level by a crop coefficient (multiplier) supplied in literature that comes with the atmometer (see Table 1) to estimate actual water use over a period of days. For crops at full canopy, water loss from the atmometer will be practically equal to actual crop ET.

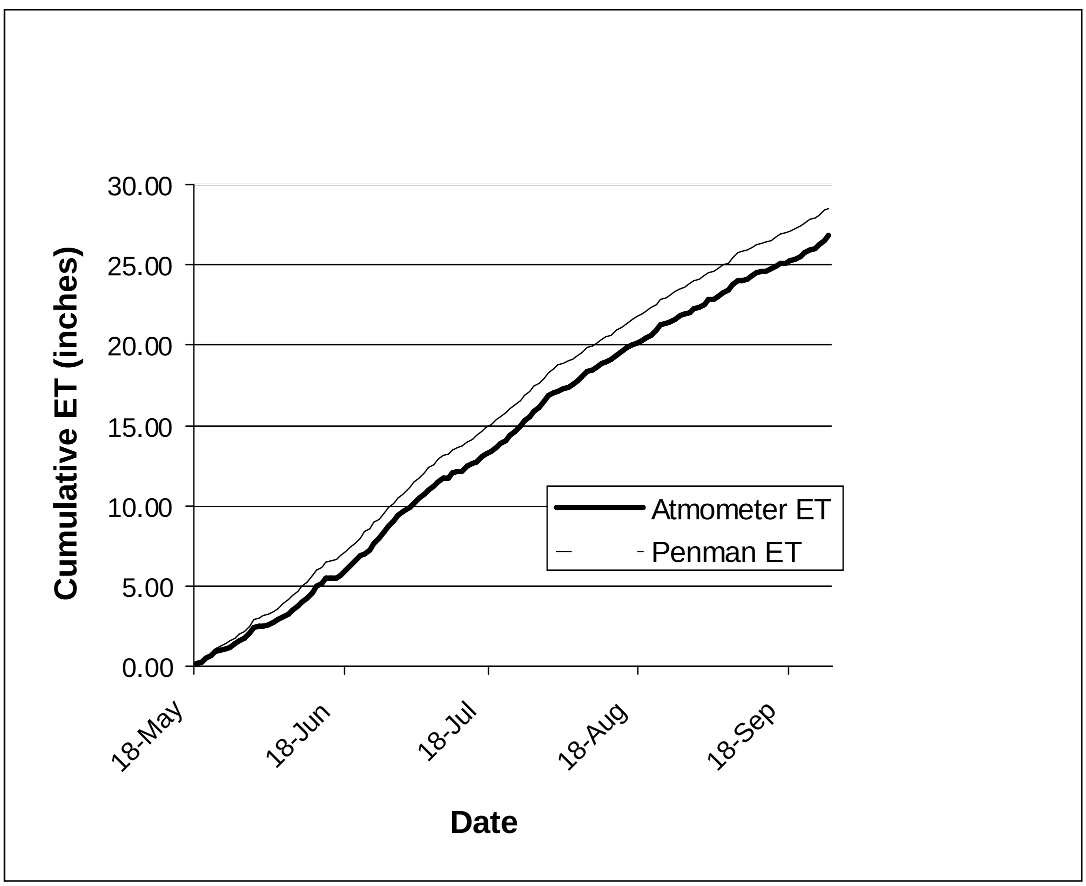

Figure 1: Comparison of Atmometer ET to Penman ET. **Source: Bausch and Altenhofen.**

Atmometer

♦ Irrigation is needed when the accumulated ET_r x crop multiplier equals the allowable depletion for that soil type and growth stage (see Table 1).

Example #1:

- The crop corn is 6-leaf and the ETgage drops 1.45" over an 8-day period from the last irrigation.
- The crop coefficient is 0.55 so the crop used about 0.8" during this time. This value is equal to the 0.8" depletion for this growth stage.
- Irrigation water should be applied to refill the soil profile (~0.8") in time to avoid crop stress.

♦ Another way to estimate the next irrigation event with an atmometer is to move the 2nd marker on the sight tube below the marker set at the last irrigation to the amount of allowable depletion for the crop growth stage. However if the crop has not covered canopy, you have to divide the allowable depletion by the crop coefficient to determine actual depletion. When the water in the sight tube reaches the bottom marker, irrigation is required if no rain is received.

Example #2:

- The corn is 8-leaf, the multiplier is 0.65", and the allowable depletion is about 1.25". 1.25 ÷ 0.65 = 1.9"
- If you set the 2nd marker 1.9 inches below the initial water level, you should irrigate in time to refill the profile before the water level approaches the 2nd marker.

♦ If a significant rainfall occurs (>0.1") you can move the markers down on the site tube to factor in the additional moisture.

As these examples illustrate, once an allowable depletion is determined, using the atmometer to help schedule irrigations is as simple as reading a rain gauge. It is especially useful for center-pivot users or surface irrigators that know their applications amounts. In these cases, you should irrigate when the site gauge drops to the same amount as the typical irrigation application.

When using any ET-based irrigation scheduling, field verification of soil moisture status is a good idea. Field probing can confirm needed irrigation and provide confidence in using ET-based scheduling. An atmometer can also be used in conjunction with computer scheduling software such as Cropflex, especially if users do not have internet access. This tool can also help growers deal with salinity problems by providing ET over a period of time to determine leaching rations.

Growers interested in trying an atmometer for a season should contact your regional CSU Cooperative Extension water specialist.

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Table 1. Examples of allowable depletion for corn for typical Colorado sandy loam soil.

Corn leaf stage	Rooting depth (inches)	Crop coefficient	Total rootzone available H_2O (inches)	Allowable rootzone depletion (inches)
4	9	0.35	0.9	0.54
6	15	0.55	1.6	0.8
8	21	0.65	2.3	1.25
10	30	0.90	3.4	1.7
12 & up	36+	1.0	4.1	2.0