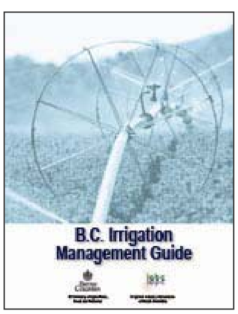
4 IRRIGATION SYSTEM OPERATIONAL ASSESSMENT

Efficient irrigation can be described as applying the crop's water needs, as required, to sustain optimum growth and production at the lowest capital and operating cost possible. Efficient irrigation is obtained by correctly designing and operating the irrigation system to match water, crop and soil management limitations. An effective irrigation schedule will match the irrigation water application to the soil and the crop's water needs. The key objective of irrigation scheduling is to reduce water loss due to overland flow or leaching.

Trickle and sprinkler systems are scheduled differently. The goal of a trickle system is to keep the soil moisture at a constant level by applying small amounts of water frequently. With sprinkler systems, the soil is allowed to dry between irrigations, allowing the soil moisture to reach the maximum soil water deficit (MSWD).

An irrigation schedule can be implemented by using the following practices:



1. Soil Moisture Monitoring
2. Climate Monitoring
3. Scheduling Using Water Budget Method
4. Scheduling Using Plant Water Requirements

Detailed scheduling information can be found in the B.C. Irrigation Management Guide

B.C. Irrigation Management Guide

4.1 Soil Moisture Monitoring

Soil Moisture Monitoring Devices

Figure 4.1 Tensiometer

Figure 4.2 Electrical Resistance Block

The need for irrigation should never be gauged by the moisture content of the soil surface layer alone. It is important to determine the moisture content throughout the root zone to make a wise decision on when to start irrigation. This can be done by using the hand-feel method or moisture monitoring devices, such as tensiometers, electrical resistance blocks, time domain reflectometery (TDR)/time domain transmissivity (TDT), and wetting front sensors.

A **tensiometer** (Figure 4.1) measures the soil water tension that can be related to the soil water content for specific soils. Tensiometers are responsive to soil water tensions of 5 – 70 centibars (cbars).

There are a number of **electrical resistance blocks** available on the market under various trade names. Watermark is one product that has been used in British Columbia (Figure 4.2). Watermarks require little maintenance and can be left in the soil under freezing conditions. The Watermarks are responsive to soil water tensions of 40 – 125 cbars, and are therefore well-suited for heavier soils.

TDR and **TDT** instruments give accurate readings of volumetric soil moisture. The Moisture Point® (Figure 4.3) uses TDR technology which measures the time a pulse takes to travel along a section of transmission line. The amount of water in the soil is proportional to the time it takes for the propagation of this pulse. The Moisture Point® is easier to use, but is quite expensive for small growers. The Gro-Point® (Figure 4.4) uses TDT technology. The TDT signal is simpler to analyze; therefore, the equipment is less expensive. The device can control an irrigation zone through the controller.

Irrigation Scheduling Techniques
Irrigation Scheduling with Tensiometers

Figure 4.3 Moisture Point® Meter

Figure 4.4 Gro-Point® Sensor

Irrigation Scheduling Using Soil Moisture Monitoring Devices

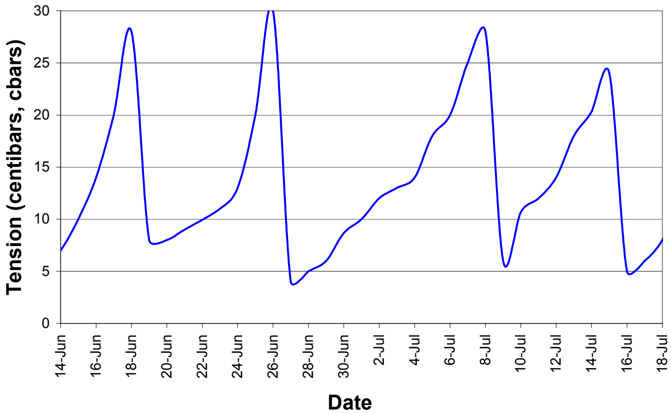


Figure 4.5 Soil Moisture Profile - Tensiometer Drying Curve

Soil moisture monitoring can be used to determine when to begin an irrigation and how long to irrigate, as well as provide a visual reference of soil moisture within the root zone. This method involves preparing a chart with the soil moisture tension readings over a specific period of time. A sample soil moisture curve for sprinkler systems is shown in Figure 4.5. The chart shows a "saw-tooth" pattern in the soil moisture tension. An upward slope indicates when the soil is dry; and a downward slope indicates when the field is irrigated.

Irrigation started when the soil moisture reaches a "trigger level". Figure 4.6 should be used to determine the trigger level. For very stony soils or crops with shallow rooting depth, a slightly lower trigger level is chosen to allow for some flexibility in management.

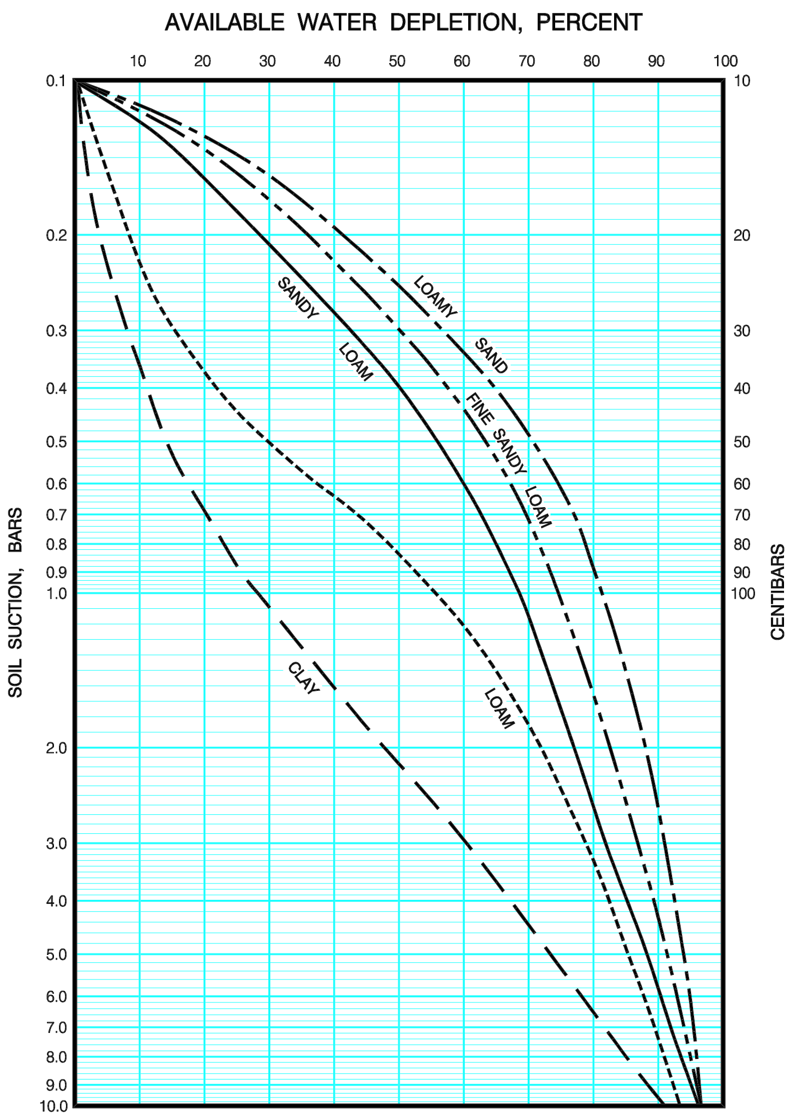


Figure 4.6 Soil Moisture Tension and Available Water

Drip/Trickle and Micro-Jet Systems

For drip/trickle and micro-jet systems, the crop is irrigated frequently (often daily), and requires the soil to be maintained at a moisture level about 80-90% of field capacity. Table 7.2 indicates the soil moisture tension reading required to maintain 15% depletion of the available water for various soils.

Table 4.1 Range of Soil Moisture for Drip/Trickle and Micro-Jet Systems		
Soil Type	**Soil Moisture Tension (cbars)**	
	Low (wet)	**High (dry)**
sand	10	15
loamy sand	10	15
sandy loam	15	20
loam	25	30

For drip systems, the moisture level can be maintained by adjusting the length of time each zone is irrigated on a daily or weekly basis. If the soil is always wet or dry, reduce or increase the amount of time the zone is irrigated to make up for the soil moisture difference.

Sprinkler System

Delaying the start of an irrigation cycle may be the most practical method of scheduling sprinkler irrigation systems that are not automated. If the system is automated, the irrigation set time can be adjusted to match crop water needs.

Trigger Level

For sprinkler systems, it is convenient to maintain a set time of 8, 12 or 24 hours and use a soil moisture trigger level to indicate when irrigation should begin. To trigger an irrigation, 40 – 50% of the available soil moisture should have been removed from the soil. Table 7.3 gives minimum trigger levels for various crop's rooting depths and soil types.

Table 4.2 Soil Moisture Trigger Levels for Sprinkler Systems			
Rooting Depth		**Soil Type**	**Trigger Level [cbars]**
[ft]	**[cm]**		
<1	<30	Sand – Loamy Sand	15 – 20
		Sandy Loam – Loam	25 – 35
2	60	Sand	20
		Loamy Sand	25
		Sandy Loam	30
		Loam	35
4	120	Sand	25
		Loamy Sand	30
		Sandy Loam	35
		Loam	40

Place the soil moisture device in the area irrigated by the first lateral as mentioned in the previous section. Turn on the first lateral when the soil moisture reaches the trigger level. The remainder of the crop is irrigated as usual. Wait for the soil moisture to reach the trigger level before beginning the next cycle.

For deep-rooted crops, both the shallow and deep readings should be taken into consideration. Plants obtain not only 40% of the moisture from the top 25% of the root zone, but also significant water from deeper roots. If soil moisture is adequate in a part of the root zone, then the amount of irrigation required to fill up the root zone can be reduced.

Rate of Change in Soil Moisture Readings

Another method of scheduling sprinkler systems is to watch the rate of change in soil moisture readings. As the soil dries, the rate of change in soil moisture readings increases. For example, it may take four days for the soil tension to go from 10 to 15 cbars, but only one day to go from 25 to 30 cbars. A sharp upward slope in the soil moisture curve indicates irrigation should be started soon. If the plot indicates a sharp upward slope, and the forecast is for hot dry weather, irrigation should take place in the next day or two. If the slope is shallow and the weather is cool, irrigation may be able to be held off for a number of days. The shallow soil moisture reading is usually used to determine the trigger level; however, if the crop has deep roots and there is plenty of soil moisture at depth (i.e., low tension readings), irrigation can be delayed past the shallow sensor trigger level. **Monitor soil moisture more frequently at high soil moisture tensions**.

Micro-Sprinkler System

A micro-sprinkler system is designed similar to a sprinkler system but because of the low application rates and frequent irrigations, the soil is not often filled up to field capacity. The soil moisture range available for operation is therefore much smaller. The soil should ***not*** remain as wet as soils being irrigated with drip systems, and should also ***not*** reach sprinkler trigger levels for deep-rooted crops.

For micro-sprinklers on a frequent schedule on a sandy soil, the upper limit of the soil moisture reading range should be about five cbars above that of a drip system (Table 7.2). The lower level remains the same.

When irrigating on a set irrigation interval, change the set time according to the soil moisture. Use the soil moisture readings to determine if the soil is wet or dry. If the soil remains too wet between irrigations, reduce the set time. Likewise, if the plants are becoming stressed, increase the set time. If the soil is constantly wet between irrigations, decrease the irrigation frequency to allow time for the soil to dry out a bit before the next irrigation.

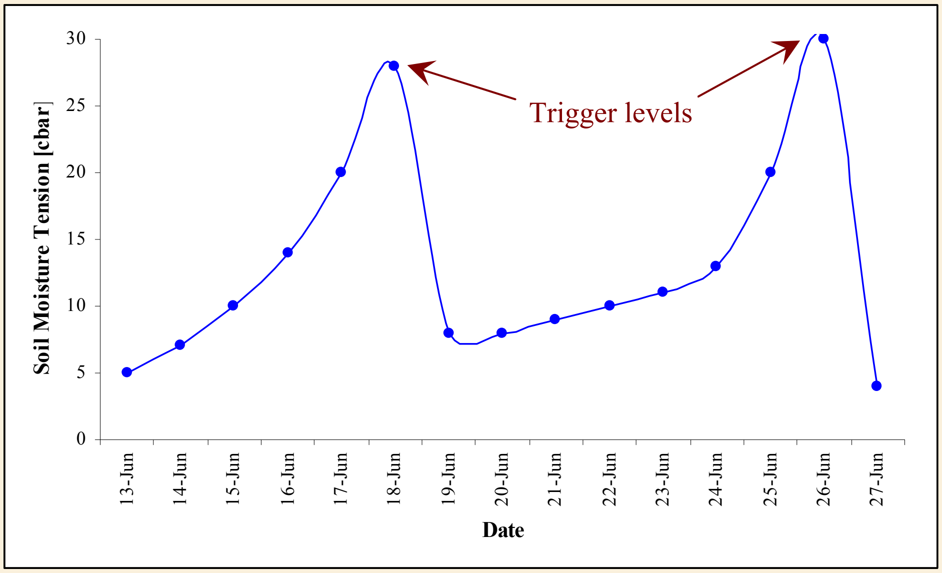
Example 4.1 Irrigation Scheduling Using a Tensiometer

Question: A sprinkler system in a loam soil is scheduled to begin irrigation when the available water has been depleted by 15%, i.e., when the tensiometer reads 30 cbars. Record soil moisture tension readings once a day. Plot the readings against date to illustrate the

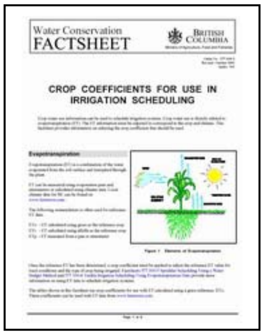
Information:

Date	Reading [cbar]	Action
13 Jun	*5*	–
14 Jun	*7*	–
15 Jun	*10*	–
16 Jun	*14*	–
17 Jun	*20*	–
18 Jun	*28*	*Irrigate*
19 Jun	*8*	–
20 Jun	*8*	–
21 Jun	*9*	–
22 Jun	*10*	–
23 Jun	*11*	–
24 Jun	*13*	–
25 Jun	*20*	–
26 Jun	*30*	*Irrigate*
27 Jun	*4*	–

Answer:



4.2 Climate Monitoring


Water Conservation
FACTSHEET
BRITISH COLUMBIA

CROP COEFFICIENTS FOR USE IN IRRIGATION SCHEDULING

Farmwest at www.farmwest.com is an agricultural website that provides production and climate information for farmers across B.C. Information from Farmwest is useful when creating an irrigation schedule using climate data. The climate tab contains links to a number of options including evapotranspiration (ET) and precipitation information for irrigation scheduling. The website allows users to obtain climate information by selecting the climate station closest to their location. A summary page is provided with real-time information on cumulative and daily reference ET (ET_o), precipitation and moisture deficit for any chosen time period up to the previous day.

www.farmwest.com

The reference ET (ET_o) on this website is calculated based on a reference grass crop of 10 to 15 cm tall. This ET_o can be adjusted to represent ET for a specific crop using a crop coefficient (K_c).

Crop Coefficients for Use in Irrigation Scheduling

Although Farmwest reports precipitation, rainfall patterns can vary over a region much more than ET. Having an on-site rain gauge will improve the accuracy of irrigation management using climate data. Farmwest reports effective precipitation as 75% of rainfall over five mm. The effective precipitation (EP) shown on Farmwest is always calculated using Equation 2.1. Therefore, during cool wet periods, EP could be low, resulting in a higher moisture deficit than what actually exists. Soil moisture monitoring should be done under these conditions to ensure that irrigation is only applied when necessary. The five-day forecast on Farmwest is a useful tool for determining how often to monitor the data, and when the next irrigation should take place.

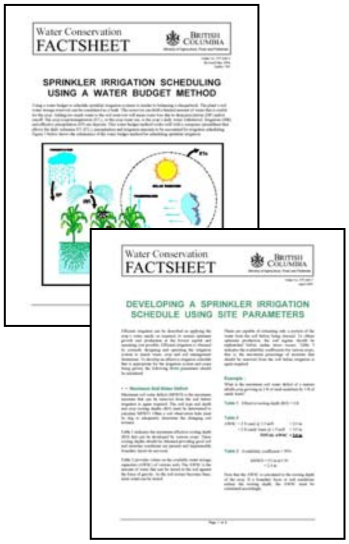
Table 4.1 gives a summary of irrigation scheduling techniques for several types of irrigation systems.

Table 4.3 Summary of Irrigation Scheduling

Irrigation System	Scheduling Method	Notes
Drip/Trickle/ Microjets	Set Time	▪ Maintain the frequency of irrigation but change the set time to maintain a constant soil moisture ▪ Use climate data to alter the operating time on a weekly basis
Sprinkler and Micro-sprinklers	Set Time	▪ Monitor soil moisture throughout the entire root zone and adjust the set time to fill up the soil profile ▪ Reduce or stop irrigation if the soil is wet
	Irrigation Cycle	▪ Monitor the soil moisture at the first irrigation set and initiate an irrigation cycle once the soil moisture trigger level has been reached. ▪ Use climate data to determine when the crop has used up the amount of water applied by the system during one irrigation set. Irrigation is initiated when this trigger level has been reached.

4.3 Irrigation Scheduling Using Evapotranspiration Data

Sprinkler Systems



Evapotranspiration data can be used to schedule sprinkler irrigation systems using a **water budget method**. The methodology is to balance the amount of water applied with the amount taken out through evaporation and transpiration.

Using a water budget method to schedule sprinkler irrigation is similar to balancing a chequebook. The plant's soil water storage reservoir can be considered as a bank. This reservoir can hold a limited amount of water that is available to the crop. Adding too much water to the soil reservoir will mean water is lost due to deep percolation (DP) and/or runoff. The crop evapotranspiration (ET_c), or the crop water use, is the crop's daily water withdrawal. Irrigation (IRR) and effective precipitation (EP) are deposits. This water budget method works well with a computer spreadsheet that allows the daily reference ET (ET_o), precipitation and irrigation amounts to be accounted for. This method can be done daily or over a time period. Equation 4.1 determines the current soil water content.

Sprinkler Irrigation Scheduling Using a Water Budget Method

Developing a Sprinkler Irrigation Schedule Using Site Parameters

Equation 4.1 Current Soil Water Content — *Worksheet 10*

$$CSWS = PSWS + EP + IRR - ET_c - DP$$

where
- CSWS = current soil water storage (today) [mm]
- PSWS = previous soil water storage (yesterday) [mm]
- EP = effective precipitation since yesterday [mm]
- IRR = irrigation since yesterday [mm]
- ET_c = crop evapotranspiration [mm]
- DP = deep percolation, water lost beyond the root zone [mm]

The water budget equation does not provide a factor for runoff as good irrigation management practices should eliminate runoff. Deep percolation (DP) is also assumed to be zero in most cases as it is difficult to measure and should be minimal if good irrigation practices are followed. If leaching is desired in some instances, then the amount of irrigation applied would need to exceed the soil water storage capacity.

Soil Water Capacity and Deficit

The existing soil moisture level must be known to use the budget method. It is often easier to start the water budget after a thorough irrigation or rainfall that fills the entire root zone. The water budget would then start with a full storage value equal to the maximum soil water storage (SWS). If the soil is not full, the actual soil moisture may be determined using tensiometers or other soil moisture monitoring devices. The current soil water storage (CSWS) of the current day will be the previous soil water storage (PSWS) of the following day. Irrigation should start once the CSWS reaches the maximum soil water deficit (MSWD) – the maximum amount of water that can be depleted without stressing the plant.

➔ **Historical Climate Information for Irrigation Planning, Chapter 2**

Effective Precipitation (EP)

Precipitation data can be collected with an on-site rain gauge as described previously in this chapter, or obtained from climate stations. Daily climate data in real-time can be obtained from www.farmwest.com for various climate stations throughout B.C.

Dry Climate

In dry climate during the irrigation season, rainfall of less than five mm does not add any moisture to the soil reservoir as most of it is evaporated before entering the soil. Therefore, if rainfall is less than five mm, the effective precipitation (EP) is zero. If rainfall is over five mm, only 75% of it will be considered as EP. Refer to Equation 2.1 in Chapter 2.

➔ **Climate Information, Chapter 2**

Wet Climate

In wetter climates or periods of the year when there are many days of rainfall in succession, the summation of the total amount of rainfall can be added without using Equation 7.1. For example:

Day	Rainfall [mm]
1	10
2	5
3	2*
4	7

* Not included in the summation as it is considered as a trace amount (< 3 mm)

The total EP for this wet period would be 22 mm, the summation of all the rainfall events except for Day 3. Days with only a trace of rainfall (<3 mm) during a wet period would not be added.

Net Depth of Irrigation Water Applied (IRR)

Equation 4.2 determines the amount applied by a sprinkler irrigation system.

Equation 4.2 Net Depth of Irrigation Water Applied (IRR)

$$IRR = \frac{227 \times Q \times T \times AE}{S_1 \times S_2 \times 100\%}$$

where
IRR = net depth of irrigation water applied [mm]
Q = sprinkler flow rate [US gpm]
T = irrigation time [hr]
AE = application efficiency [%]
S_1 = sprinkler spacing along lateral [m]
S_2 = lateral spacing [m]

Crop Evapotranspiration (ET_C)

Crop evapotranspiration (ET_c) can be determined by using Equation 4.3. Basic crop coefficients (K_c) can be obtained from Table 4.2. More detailed information on crop coefficients is available in the B.C. Irrigation Management Guide and on Farmwest.

Crop Coefficients for Use in Irrigation Scheduling

B.C. Irrigation Management Guide

Daily ET_o rates are available at www.farmwest.com for various climate stations throughout B.C. The climate information in Chapter 2 can also be used if a schedule is being developed for the peak of the growing season.

www.farmwest.com

Equation 4.3 Crop Evapotranspiration (ET_c)

$$ET_c = ET_o \times K_c$$

where
ET_o = crop evapotranspiration or crop water use [mm]
ET_o = reference ET [mm] (available from www.farmwest.com)
K_c = crop coefficient (Table 7.5)

Table 4.4 Crop Coefficients for Tree Fruits and Grapes

Crop	May	Jun	Jul	Aug	Sep	Oct
Apples, Cherries and Pears with Cover Crops*						
Lower Mainland and Vancouver Island	0.70	0.90	1.00	1.00	0.95	0.75
Okanagan and Thompson	0.85	1.15	1.25	1.25	1.20	0.95
Kootenays	0.80	1.10	1.20	1.20	1.15	0.70
Apricots, Peaches and Other Stone Fruit with Cover Crops*						
Lower Mainland and Vancouver Island	0.90	1.00	1.00	1.00	0.95	0.80
Okanagan and Thompson	0.80	1.10	1.20	1.20	1.15	0.90
Kootenays	0.70	1.00	1.05	1.10	1.00	0.80
Grapes						
Lower Mainland and Vancouver Island	0.55	0.65	0.65	0.65	0.65	0.50
Okanagan and Thompson	0.50	0.70	0.80	0.85	0.80	0.70
Kootenays	0.45	0.70	0.85	0.90	0.80	0.70
* No cover crop, reduce values by	10%	20%	20%	20%	10%	10%

NOTE: ***Irrigation scheduling using the water balance method is based on estimation and should therefore be checked with soil moisture periodically. It is important to monitor soil water content in the field and compare the calculated soil water content to the actual measured water use once a week or every other week, and correct the calculated water balance when necessary.***

Example 4.2 Sprinkler Irrigation Scheduling – *Daily*

Worksheet 10 Sprinkler Irrigation Scheduling Using Water Budget Method

Question: The soil has a maximum soil water storage capacity of 110 mm. The maximum soil water deficit is 55 mm. Therefore, when 55 mm of moisture has been depleted from the soil, a total of 55 mm can be added by the irrigation system. At the beginning of the season, it has been determined that the soil reservoir is full, storing 110 mm of water. For the month of May, the crop irrigated has a crop coefficient of 0.75. Determine when the field should be irrigated.

Information:

Maximum soil water storage (SWS) capacity	*110*	mm
Maximum soil water deficit (MSWD)	*55*	mm
Crop coefficient (K_c)	*0.75*	

Analysis:

Nomenclature:

PSWS	=	Previous Soil Water Storage
EP	=	Effective Precipitation
IRR	=	Net Depth of Irrigation Water Applied
ET_o	=	Reference Evapotranspiration
K_c	=	Crop Coefficient
CSWS	=	Current Soil Water Storage

All units are in millimetres (mm) except for Date and K_c.

Date	PSWS	+	EP	+	IRR	–	ET_o	x	K_c	=	CSWS
May 1	*110*	+	*0*	+	*0*	–	*4.0*	x	*0.75*	=	*107*
May 2	*107*	+	*0*	+	*0*	–	*4.2*	x	*0.75*	=	*104*
May 3	*104*	+	*10*	+	*0*	–	*1.0*	x	*0.75*	=	*110*[1]
May 4	*110*	+	*0*	+	*0*	–	*3.8*	x	*0.75*	=	*107*
May 5	*107*	+	*0*	+	*0*	–	*4.0*	x	*0.75*	=	*104*
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
May 15	*59*	+	*0*	+	*0*	–	*4.5*	x	*0.75*	=	*56*[2]
May 16	*56*	+	*0*	+	*55*	–	*4.0*	x	*0.75*	=	*108*

[1] Even though the total water storage would be 113 mm, the maximum soil water storage can only be 110 mm. The rest of the water is therefore assumed to be lost due to deep percolation and/or runoff.

[2] The maximum depletion of 55 mm is reached, so irrigation should start.

Trickle Systems


Water Conservation FACTSHEET
TRICKLE IRRIGATION SCHEDULING USING EVAPOTRANSPIRATION DATA

Water Conservation FACTSHEET
DEVELOPING A TRICKLE IRRIGATION SCHEDULE USING SITE PARAMETERS

Evapotranspiration data can be used to schedule trickle irrigation systems using a plant water requirement or water budget method. In both cases, the methodology is to balance the amount of water applied with the amount taken out through evaporation and transpiration.

Trickle Irrigation Scheduling Using Evapotranspiration Data

Developing a Trickle Irrigation Schedule Using Site Parameters

Plant Water Requirement Method

The plant water requirement method adjusts the trickle system operating time by comparing the actual ET data to the theoretical peak ET used in system design. This method can be used in situations where the system is designed to irrigate each individual plant with one or more emitters. The system operating time is determined by using a ratio of the peak design ET rate and the actual ET_c rate (Equation 4.4).

Equation 4.4 Zone Operating Time – Plant Water Requirement ***Worksheet 11***

$$Zone\ Operating\ Time = Maximum\ Zone\ Operating\ Time \times \frac{ET_c}{Peak\ ET}$$

Units:

Zone Operating Time [hr/day]
Maximum Zone Operating Time [hr/day]
ET_c [mm]
Peak ET [mm]

Unless the system is set up to change automatically, it may be more convenient to adjust the irrigation operating time weekly. In this case, the average daily ET_o for the week should be calculated and used to estimate the operating time for the following week. The weekly adjustment ensures the soil moisture depleted in the previous week is replaced. While not as effective as altering the schedule daily, a weekly schedule will help to adjust the irrigation schedule as the climate and crop change throughout the growing season. When performing a weekly adjustment, visit www.farmwest.com for a five-day forecast on daily ET_o.

Example 4.3 Trickle Irrigation Scheduling in Osoyoos

Worksheet 11 Trickle Irrigation Scheduling Using *Plant Water Requirement Method*

Question: A trickle system is irrigating an apple field in Osoyoos on a loam soil. The peak design evapotranspiration rate is 7.1 mm/day. Each plant has two emitters running at a flow rate of 2 L/hr per emitter. The design zone operating time is 10 hr/day. The plant water requirement is 40 L/day with a crop coefficient of 0.95 in July. The actual daily reference evapotranspiration data from July 20th to July 26th are collected from www.farmwest.com and shown in the table below. Determine the operating time for the next seven days.

Information:

Maximum zone operating time	10	1	hr/day
Peak ET	7.1	2	mm

Analysis:

Date	Daily ET_o [mm]	x	K_c	=	ET_c [mm]		Operating Time [hr/day]	
July 20	6.2	x	0.95	=	5.9	3	8.3	4
July 21	7.0	x	0.95	=	6.7	3	9.4	4
July 22	7.1	x	0.95	=	6.7	3	9.5	4
July 23	7.5	x	0.95	=	7.1	3	10	4
July 24	6.9	x	0.95	=	6.6	3	9.2	4
July 25	6.5	x	0.95	=	6.2	3	8.7	4
July 26	7.4	x	0.95	=	7.0	3	9.9	4
Weekly Total	48.6		–		46.4		–	
Average	6.9		–		6.6		9.3	

Sample Calculations (July 20):

Equation 4.4

$$\text{Zone Operating Time} = \text{Maximum Zone Operating Time} \times \frac{ET_c}{\text{Peak ET}}$$

= 10 [1] hr/day x (5.9 [3] mm) / (7.1 [2] mm)

= **8.3** [4] hr/day

Answer: An average operating time of 9.3 hr/day can then be used for the next seven days.

Water Budget Method

The water budget method can be used for row crops, such as vegetables, strawberries or any crop that is spaced close enough together so that the system is irrigating the entire field. If the plants or rows are spaced far apart so that portions of the field are not irrigated, then the plant water requirement method will be a better approach.

The water budget method for trickle systems is basically the same as that for sprinkler systems except that a desired soil moisture range is set, and the operating time is determined using Equation 4.5.

Equation 4.5 Zone Operating Time – Water Budget Requirement *Worksheet 12*

$$T = \frac{S_1 \times S_2 \times IRR \times 100\%}{Q \times AE}$$

where

T = irrigation time [hr]
IRR = net depth of irrigation water applied [mm]
Q = emitter flow rate [L/hr]
S_1 = emitter spacing along line [m]
S_2 = line spacing [m]
AE = application efficiency [%]

Trickle irrigation systems normally keep the soil moisture at a level higher than sprinkler systems to reduce stress on the plants. The maximum allowable depletion for trickle system scheduling is therefore less. The maximum allowable depletion should not exceed 25% of the maximum soil water capacity.

Example 4.4 Trickle Irrigation Scheduling

Worksheet 12 Trickle Irrigation Scheduling Using *Water Budget Method*

Question: A trickle irrigation system is irrigating vegetables with emitters spaced 0.3 m apart in a row, with the rows being 0.4 m apart. The crop is growing in a loam soil, and has a rooting depth of 0.4 m; therefore, the soil water storage (SWS) capacity is 70 mm. The crop coefficient is 0.80 in June and 0.95 in July. Each emitter has a flow rate of 1.0 L/hr. The system has an application efficiency of 92%

Information:

	Value	Ref.	Unit
Emitter spacing (S_1)	0.3	1	m
Row spacing (S_2)	0.4	2	m
Maximum soil water storage (SWS) capacity	70	3	mm
Emitter Flow Rate (Q)	1.0	4	L/hr
Application efficiency (AE)	92	5	%

Calculation:

(a) The maximum soil water deficit (MSWD) for trickle systems is 25% of the SWS; therefore,

MSWD = 70 [3] **mm x 25%**

= 17.5 [6] mm

= **Net Depth of Irrigation Water Applied (IRR)**

(b) Irrigation should start when the balance reaches:

= 70 [3] mm – 17.5 [6] mm

= 52.5 [7] mm

(c) Determine operating time

Equation 4.5

$$T = \frac{S_1 \times S_2 \times IRR \times 100\%}{Q \times AE}$$

$$= \frac{0.3\,[1]\ \text{m} \times 0.4\,[2]\ \text{m} \times 17.5\,[4]\ \text{mm} \times 100\%}{1.0\,[4]\ \text{L/hr} \times 92\,[5]\ \%}$$

= 2.3 [8] hr

(d)

Nomenclature:

PSWS	=	Previous Soil Water Storage
EP	=	Effective Precipitation
IRR	=	Net Depth of Irrigation Water Applied
ET_o	=	Reference Evapotranspiration
K_c	=	Crop Coefficient
CSWS	=	Current Soil Water Storage

All units are in millimetres (mm) except for Date and K_c.

Date	PSWS	+	EP	+	IRR	–	ET_o	x	K_c	=	CSWS
June 24	70	+	0	+	0	–	5	x	0.80	=	66
June 25	66	+	0	+	0	–	4.8	x	0.80	=	62.1
June 26	62.1	+	15	+	0	–	2	x	0.80	=	70[1]
June 27	70	+	0	+	0	–	4.2	x	0.80	=	66.6
June 28	66.6	+	0	+	0	–	6.6	x	0.80	=	61.3
June 29	61.3	+	0	+	0	–	5.4	x	0.80	=	57
June 30	57	+	0	+	0	–	5.3	x	0.80	=	52.8[2]
July 1	52.8	+	0	+	17.5	–	5.2	x	0.95	=	65.3
July 2	65.3	+	0	+	0	–	6.0	x	0.95	=	59.6
July 3	59.6	+	0	+	0	–	6.5	x	0.95	=	53.4[2]
July 4	53.4	+	0	+	17.5	–	5.6	x	0.95	=	65.6
July 5	65.6	+	4	+	0	–	4.5	x	0.95	=	65.3

[1] Even though the total water storage would be 75.5 mm, the maximum soil water storage can only be 70 mm. The rest of the water is therefore assumed to be lost due to deep percolation and/or runoff.

[2] The desired depletion of 55 mm is reached, and is close to the maximum allowable deficit (52.5 mm), so irrigation should start.