UNDERSTANDING CROP IRRIGATION

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REVISED

Irrigation Management in Wisconsin

The Wisconsin Irrigation Scheduling Program (WISP)

Scott Sanford and John Panuska

Most of the areas in Wisconsin that are under sprinkler irrigation have sandy soils with groundwater that is close to the surface.

Growers in Wisconsin irrigate about 473,000 acres of potato, vegetable, field, fruit, turf and nursery crops each year (2013 NASS) to ensure profitable crop production. Irrigation improves both crop yield and quality. Yield responses are due to increased dry matter production, more plants per acre and increased numbers of vegetative parts (tubers, roots, stems, leaves) or reproductive parts (flowers, pods, fruits).


Ron Nichols, USDA-NRCS

Irrigation enhances the quality of many crops by reducing moisture stress. A lack of moisture in a crop can produce misshapen fruit and tubers, poorly filled bean pods or ears of corn, and low protein content in forages. Moisture stress can deter uniform crop maturity, which is important for efficient harvesting of processing vegetables.

Successful irrigation management uses a combination of rainfall and applied water to conserve energy, reduce cost and protect groundwater. Most of the areas in Wisconsin that are under sprinkler irrigation have sandy soils with groundwater that is close to the surface, so the potential for groundwater contamination by nitrates and pesticides is high. Over-irrigation and excessive or untimely rains can add more water than crops can use or soils can store. The excess water moves past the root zone (leaches), carrying nitrates and pesticides into groundwater.

Sprinkler irrigation

Sprinkler irrigation is the most common type of irrigation in Wisconsin (98%). Drip irrigation is another type. Sprinkler irrigation waters crops through a pressurized system of pipes and spray or impact nozzles. The objective is to apply the right amount of water at the right time.

Overhead sprinkler irrigation can do more than water crops. Properly designed and managed sprinkler systems can regulate soil moisture and temperature, apply fertilizers and pesticides, provide frost protection and apply liquid waste and separated liquid manure.

Astrid Newenhouse


Center pivot sprinkler system.

Sprinkler irrigation of large crop acreages requires large volumes of water. On the average summer day in central and southern Wisconsin an average crop plant will use approximately 0.25 inches in evapotranspiration, which is the combination of *evaporation* from soil and plant surfaces and *transpiration* or the amount of water that plants use to grow. On a per-acre basis, 0.25 inches amounts to 6,789 gallons of water (27,154 gallons per acre-inch x 0.25 inch = 6,789 gallons). However, irrigation systems need to be sized for the maximum sustained evapotranspiration rate during any 5-7 day period, which equals about 0.3 inches per day in Wisconsin.

Not all of the water pumped to the field will reach the ground for plant use, because some is lost to wind and to evaporation. In Wisconsin about 95% of the irrigation water reaches the ground on most days, so irrigators need to apply about 0.32 inches to account for the wind and evaporation losses and have 0.30 inches for the crop to use. A capacity of about 0.32 inches of water per day equals 6.0 gallons per minute (gpm) per acre, based on pumping 24 hours per day. To apply 0.32 inch of water in 24 hours to 130 crop acres (a typical quarter-section pivot), a sustained pumping capacity of 800 gpm is needed. If you use a quarter-section pivot with a corner arm to cover about 154 acres, then a 950 gpm pumping capacity will be needed.

To reduce electric power costs, irrigators can take advantage of "time of day" programs. These programs offer substantially lower electric rates during off-peak periods. A typical program has off-peak periods of about 12 hours overnight weekdays and all weekend, totaling about 100 hours a week. Such programs require a pumping capacity of 1,300 gpm per 130 acres or 1,550 gpm for a quarter-section pivot with a corner arm. Shallow-rooted vegetable crops grown on sandy soils need consistent levels of soil moisture. Irrigators who pump only during off-peak hours may not be able to maintain crop quality on these vegetables. For deep-rooted crops such as field corn, off-peak pumping works well because there is enough water stored in the root profile to last 4-5 days.

Soil moisture control

The most common use of sprinkler irrigation is to maintain adequate soil moisture throughout the growing season, as either a supplemental or primary source of water for the crop. On finer texture (high-clay) soils, irrigation normally supplements rainfall that may not come at the right time or in sufficient amounts. On coarser texture (sandy) soils with low water storage, irrigation is the primary water source for crops.

Maintaining adequate soil water storage during the growing season is necessary to avoid moisture stress, which can reduce yields. In addition, many crops have specific growth stages during which moisture stress can significantly reduce yield or quality.

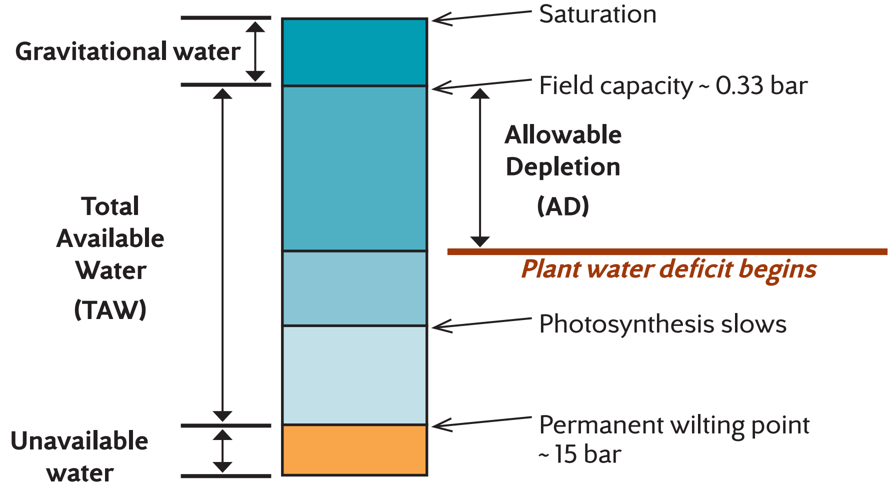
These critical growth stages are seed germination, bud formation, blossom-fruit set and fruit development for pod crops (snap beans, soybeans) and fruit crops (cucumbers, melons, strawberries). The critical growth stage for corn is from pollination to early ear development, and for potatoes, the critical growth stage is from tuber initiation to harvest.

Allowable depletion and evapotranspiration

There are two key factors that irrigators need to consider when planning an irrigation program to control soil moisture, allowable depletion (AD) and evapotranspiration (ET). Allowable depletion is the readily available water held in the crop root zone that is available for optimum, stress-free growth. Evapotranspiration is the amount of water a growing crop uses.

As illustrated in Figure 1, a soil's allowable depletion is less than its total available soil water (TAW). Total available water (sometimes called plant available water) is the amount of water a soil holds at field capacity minus the amount it holds when plants permanently wilt. Field capacity is the amount of water a soil will hold after drainage by gravity 24 to 48 hours after a soaking. Total available water

Figure 1 – Total Available Water versus Allowable Depletion



is not a measure of water that is completely usable and uniformly available to the plant without moisture stress or yield reductions occurring. Moisture stress can develop before TAW is depleted. Moisture stress slows down photosynthesis and can cause yield reductions before wilting becomes apparent. As the plant water deficit becomes more severe, wilting occurs, photosynthesis ceases and yields suffer dramatically. Severe and prolonged deficits result in plant death.

Allowable depletion is a percentage of total available water and may change for different crops and stages of growth. For most crops the maximum allowable depletion (MAD) equals 50% of the TAW. Figure 1 illustrates the relationships among field capacity, total available water, allowable depletion and wilting point.

The TAW for a soil varies with soil texture, structure, type and organic matter content. In general, sandy soils have the lowest TAW, clay soils have the highest and loam soils are intermediate (Table 1). Your county Natural Resources Conservation Service (NRCS) offices can provide AD or TAW information for various soils or you can find them on the USDA Web Soil Survey site (websoilsurvey.sc.egov.usda.gov). Total available water is the difference between the Field Capacity (FC) and the Permanent Wilt Point (PWP). The PWP is equivalent to the "Water Content at 15 bar" which is found under the Soil Data Explorer, Soil Physical Properties and Qualities tab. The FC is equivalent to the "Water Content at ⅓ bar".

The TAW and AD values are also determined by the crop's effective rooting depth – the portion of the soil profile from which most of the

Table 1 – Soil water properties by textural class

SOIL TEXTURE	Total Pore Space (% by volume)	Field Capacity (% by volume)	Permanent Wilting Point (% by volume)	Total Available Water (% by volume)
SANDY	38	15	7	8
SANDY LOAM	43	21	9	12
LOAM	47	31	14	17
CLAY LOAM	49	36	18	18
SILTY CLAY	51	40	20	20
CLAY	53	44	21	23

SOURCE: Campbell and Norman, 1998, and Fangmeier et al., 2006 water and nutrients are absorbed by the root system. Crops differ in their effective rooting depths and in the uniformity of water uptake within that depth. The effective rooting depth for a given crop may vary with soil texture, the presence of plow pans or other compaction problems and the effects of root diseases. The typical managed root zone for crops with unrestricted root growth is given in Table 2.

Table 2 – Effective root zone depths in unrestricted soils
(top 50% of root zone)

6 INCHES	Lettuce, bunching onions, spinach, strawberries, cranberries, turf grass
12 INCHES	Dry onions, celery, shallots, Swiss chard
18 INCHES	Potatoes, beets, cabbage, broccoli, carrots, cauliflower, cucumbers, peas, peppers, rutabagas, turnips, sweet potatoes, snap beans
24 INCHES	Sweet corn, dry beans, melons, parsnips, pumpkins, squash, tomatoes, watermelons, can fruit, small grains, pastures
30 INCHES	Apples, blueberries, seed corn, soybeans
36 INCHES	Alfalfa, grapes, asparagus, field corn

Adapted from USDA Irrigation Handbook, 210-vi-NEHY 652, IG Amend NJ1, 06/2005

Some allowable depletion (AD) values for major crop/soil systems are shown in Appendix A. Sandy soils typically have smaller AD values than do silt loams. A Plainfield loamy sand at field capacity and under normal July climatic conditions could carry a field corn crop for 6 to 8 days before moisture stress occurs, while potatoes could only go about 2 to 3 days before needing water. Under the same conditions, a Plano silt loam could carry a field corn crop for 13 to 18 days and potatoes for 5 to 6 days before stress would occur. The appendix also shows ways to find the AD value for any crop/soil system.

A crop's evapotranspiration (ET) is the sum of daily water loss through direct evaporation from the soil surface and water loss from plant transpiration. In Wisconsin, the typical ET can vary from 0.12 to 0.30+ inch per day depending on crop growth stage, soil and climatic factors. As plants grow larger and crop canopy expands, the ET rate increases. Increasing air temperatures, more intense sunlight, longer days, higher wind velocity and decreasing relative humidity can all cause higher ET losses. On a warm, bright, sunny day with low relative humidity and a light breeze, the ET rate may average 0.25 inch/day. Under cloudy, humid conditions, the ET rate may be 0.15 inch/day or less.

As the growing season advances from April to July, the ET rate generally increases in Wisconsin. ET rates may approach 0.25 to 0.30 inch/day during July's hot weather. ET rates usually decrease from August through October (Table 3).

Table 3 – Evapotranspiration (ET) – unadjusted for canopy cover

	EVAPOTRANSPIRATION – INCH/DAY				
WEATHER	May	June	July	August	September
DULL, CLOUDY	0.12	0.15	0.15	0.12	0.09
NORMAL	0.15	0.20	0.20	0.15	0.12
BRIGHT, HOT	0.20	0.25	0.25	0.20	0.15

Irrigation application losses

During application some water is lost to evaporation in the air before it reaches the soil surface, some clings to vegetation and evaporates, and some is carried away by wind. The relative humidity, air temperature, wind speed, nozzle pressure, and nozzle or water droplet size all effect evaporation losses.

High relative humidity, regardless of air temperature, will result in low evaporation losses. Evaporation varies over a day; typically early morning will have the coolest air temperatures, highest relative humidity and lowest evaporation losses while mid to late afternoon will have the highest air temperatures, lowest relative humidity and highest evaporation losses. The daily average summer condition is a temperature of 70° F, relative humidity of 73% and a wind speed of 7 mph for the southern part of Wisconsin. Table 4 compares the estimated evaporation loss for a standard pressure center pivot system versus a low pressure system at average and high temperature; low and high relative humidity and wind speed. The low pressure system has less than 5% estimated evaporation loss even under high temperature, low humidity, and windy conditions while the standard pressure system ranged from about 5% to 16% evaporation loss.

Some low pressure nozzles will have higher evaporation losses than this example due to small water droplet size. If the water droplet size is decreased by half, the surface area doubles which allows greater area for evaporation. Irrigation managers need to be aware of this potential loss and make adjustments in the application rates to accommodate varying conditions.

Table 4 – Irrigation evaporation loss

LOW PRESSURE CENTER PIVOT: Average nozzle pressure 20 psi, nozzle diameter 9/32 inch			
Air Temperature	**% Relative Humidity**	**Wind Speed (mph)**	**% Evaporation Loss**
70° F	70%	7 mph	1.5%
70° F	*30%*	7 mph	2%
90° F	70%	7 mph	1.8%
70° F	70%	*15 mph*	2.2%
90° F	*30%*	*15 mph*	4.5%
STANDARD PRESSURE CENTER PIVOT: Average nozzle pressure 55 psi, nozzle diameter 7/32 inch			
Air Temperature	**% Relative Humidity**	**Wind Speed (mph)**	**% Evaporation Loss**
70° F	70%	7 mph	4.7%
70° F	*30%*	7 mph	6.1%
90° F	70%	7 mph	5.5%
70° F	70%	*15 mph*	7.5%
90° F	*30%*	*15 mph*	16%

Source: Zazueta, 2011

Irrigation frequency

How often you need to irrigate depends upon the soil's AD value, the stage of crop development and existing climatic conditions including rainfall. In general, irrigation will be most frequent on sandy soils under high evapotranspiration conditions for crops with full canopy.

The amount of water applied per irrigation should replace the ET loss, but should not exceed the AD value for the crop/soil system. Applying more water than the soil can hold wastes water and power and may leach nitrogen and pesticides from the root zone. Likewise, the rate of application should not exceed the soil's ability to take up water, or runoff will occur.

Applying irrigation water frequently in small amounts can lead to shallow root development and plants that are prone to lodging. Early in the growing season, plan to irrigate less frequently to help plants establish deep roots.

The Wisconsin Irrigation Scheduling Program (WISP)

The Wisconsin Irrigation Scheduling Program (WISP) is a research-based program that uses a water budget approach to irrigation scheduling much like balancing a checkbook.

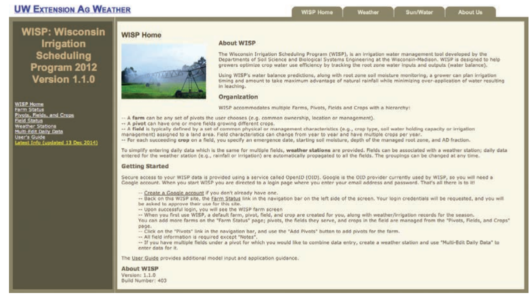
Consider rainfall and irrigation to be deposits while plant water use and evapotranspiration (plant water use) is a debit. The program uses potential evapotranspiration (ETp) to estimate plant water use to calculate the amount of water stored in the plant's root zone, termed "Allowable Depletion Balance" (AD BAL). The AD BAL helps growers determine frequency and amounts of irrigation needed. This approach provides the scheduling flexibility essential in humid areas like Wisconsin, where rainfall patterns vary and change. The WISP-2012 program is a free web-based application that is available online (wisp.cals.wisc.edu). Refer to the user guide on the website to set up your irrigation management systems.

Once you enter data about your farm, the program will automate some tasks such as entering the daily Potential ET and doing calculations. You will need to enter the more dynamic inputs such as rainfall, irrigation, percent soil moisture and possibly crop canopy cover every day or every few days depending on soil type and weather. The program has a dashboard that will alert you if any fields have reached their Allowable Depletion threshold so action can be taken on whether to irrigate or not.The program retains field and irrigation system hierarchy year to year so it doesn't have to be re-entered. Farm data entered on this site is not shared with anyone.

Irrigation scheduling using a spreadsheet program

If you don't have internet access or would prefer not to use a web-based program, you can use a spreadsheet program on your home or office computer to schedule irrigation based on estimated allowable depletion (AD).

You will need to enter daily potential ET values, irrigation and rainfall amounts, and percent of crop canopy development. To track multiple irrigation systems or fields, you may need to add a page to the spreadsheet program for each irrigation system to be tracked.



Online WISP program home page

The WISP spreadsheet scheduling program can be downloaded at: https://wisp.cals.wisc.edu

Irrigation scheduling without a computer

Without a computer, you can use the WISP accounting form at the end of this publication to record the data you need to derive values for Allowable Depletion Balance (AD BAL) and make irrigation decisions. Each form allows for one month of irrigation scheduling, so make several copies of the form. Calculate and record the estimates onto the form to help you make irrigation decisions.

Steps to using the WISP accounting form

The following steps can be used with the WISP Accounting Form. The computer-based methods require similar input data as described below. Refer to the user guides for specific information needed by each program. Default values are provided in some cases if you don't know your farm's values.

Step 1:

Fill in the information at the top of the WISP form.

The AD value for the crop/soil system is the amount of readily available soil water storage at field capacity. Select an AD value for the crop/soil system from Appendix A or find it from the USDA Natural Resources Conservation Service (NRCS) Soil Survey Information or the USDA Web Soil Survey, as discussed previously in this fact sheet.

Step 2:

Enter the Initial AD BAL.

This is the amount of readily available soil water when irrigation scheduling starts, normally when greater than 50% of the crop has emerged or when alfalfa or other forage crops resume their growth. If the soil is at field capacity when irrigation scheduling starts, then the initial AD BAL equals the AD value. If the soil is not at field capacity, then estimate the initial AD BAL using soil moisture sensors. Refer to University of Wisconsin–Madison Division of Extension publication *Methods to Monitor Soil Moisture,* for more information. The initial AD BAL will be a value between 0 and the AD value for the crop/soil system unless you are experiencing drought conditions (then the value could be negative).

Step 3:

Enter rainfall and irrigation in inches.

Any amount of rain greater than 0.1 inch is available for crop growth and should be recorded in WISP. Measure rainfall by placing rain gauges in the fields in areas not affected by irrigation. To determine applied irrigation, monitor system operating time and pumping rates, or place rain gauges under the system.

Step 4:

Enter the evapotranspiration (ET) estimate.

University of Wisconsin–Madison Division of Extension calculates Potential ET each day from mid-April to mid-October. The Potential ET is for a well-watered crop at full cover (defined as 80% canopy cover or more). Potential ET values are calculated for the entire state using climatic and satellite data (agweather.cals.wisc.edu/sun_water/et_wimn).

You can request ET values for your farm be emailed to you daily during the growing season or you can look it up on the website. You will need to include the latitude and longitude of your irrigated fields with your request. Latitude and longitude can be determined from a number of websites. One such site that is easy to use is getLatLong (getlatlong.net).

Enter your address and click "GO". Scroll down to the map, place the pointer on the red marker and while holding the left mouse button down, drag the marker to the irrigated field. You can use the controls on the left side of the screen to change the field-of-view and pan to a different location. Once you've placed the marker in the desired field, scroll down to and record the latitude and longitude from the box entitled "Get the latitude and longitude of a point". You can also use Google Maps. Place the pointer over the field you are interested in and select by clicking the left button on the mouse – the latitude and longitude is displayed in the upper left-hand portion of the screen. If ET values are not available, rough ET estimates can be derived using Table 2. Use crop development and prevailing climatic conditions to help determine more accurate estimates.

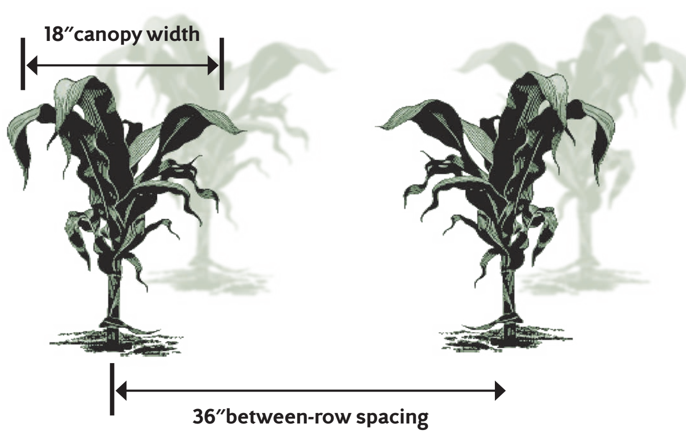
Step 5:

Enter percent cover.

Determine the percent cover, or crop canopy development, from crop emergence until 80% of the soil surface is covered by crop canopy. Estimate the percent cover for row crops by measuring crop canopy width in one row and dividing this figure by the between-row spacing at ground level. This should be measured about once per week until it reaches 80%.

Figure 2 – Example of calculating cover

To calculate percent cover, divide the canopy width by the between-row spacing at ground level. Here the calculation is (18 ÷ 36 = 50%).



Step 6:

Determine the adjusted ET estimate.

Use the percent cover and Potential ET values to determine the adjusted ET estimate from Appendix B. You must adjust the daily Potential ET until the percent cover reaches 80%. Once 80% cover is reached the adjusted ET will be equal to the Potential ET. No further adjustment is needed for most vegetable crops except potatoes, field corn and alfalfa. For potatoes, the percent cover should be reduced by 5% per week when vine senescence (natural dying) begins about mid-August. For field corn, reduce the percent cover by 5 percent per week when the crop reaches the dent stage. For recently harvested alfalfa, the percent cover increases uniformly from 0 to 80% cover over a 12-to-14-day period after mowing. These adjustments in percent cover prevent late-season over-irrigation.

Step 7:

Calculate the daily balance.

Subtract the adjusted ET from the combined amount of rainfall and irrigation for the day. The resulting number will usually be negative except on days when there is irrigation and rainfall that is greater than the adjusted ET.

Step 8:

Use the daily balance to determine the allowable depletion balance (AD BAL) in inches.

If the daily balance is negative, subtract its value from the AD BAL of the previous day (or the initial AD BAL when beginning data entry). If the daily balance is positive, add its value to the AD BAL from the previous day. If the daily balance is greater than the full AD value for the crop/soil system, then add only that amount of the daily balance needed to bring the previous day's AD BAL to the AD Value for the crop/soil system. The rest of the daily balance represents excess water that will probably move through the root zone and contribute to leaching.

The frequency of calculating and updating AD BALs depends on the soil type and current climatic conditions. Under normal conditions, wait no longer than two to three days to update inputs for crops grown on sandy soils, and no more than four to five days for crops grown on heavier soils. Under stress-causing conditions, update inputs daily.

Deciding to irrigate

The AD BAL indicates current levels of readily available soil water, in inches, and will help you determine how much, (if any) irrigation to apply. Usually, you will decide to irrigate when the AD BAL approaches zero, but one must consider the time required to irrigate an entire field when deciding when to start irrigation. How much to irrigate at a time will depend on the AD value, rain forecast and stage of crop growth. Under no circumstances should the amount of a single irrigation exceed the AD value for the crop/soil system. This volume of water would exceed the soil's water storage capacity and cause leaching. Normally, apply enough irrigation to keep soil water storage below field capacity, but within the AD range.

When properly used, WISP will help maintain your field's AD BAL between zero and the full AD value for the crop/soil system. This balance ensures adequate, readily available soil water for crop growth, while avoiding soil water extremes that can stress the crop (too little soil water), or result in leaching (too much soil water). Careful irrigation management using WISP helps you obtain profitable yields and top quality with minimum adverse impacts to our water resources.

Examples of completed WISP accounting forms

On the next page are examples of completed WISP accounting forms for two months of irrigation scheduling. The field name – "Palmorro" in this case – and other information is recorded at the top of the form. The allowable depletion (AD) value for the field corn/Richford loamy sand system (as derived from Appendix A) is 2 inches for the 36-inch rooting depth of corn.

The inputs needed to derive AD BALs are entered in the designated columns below the field information. An initial AD BAL of 0.80 inch, derived using the soil moisture monitoring data, is entered only for the first month of scheduling. For subsequent months, the grower carries over the AD BAL from the last day of the previous month.

The dates and amounts of rainfall (greater than 0.1 inch) and irrigation are recorded as they occur. On June 1, total rain and irrigation was 0 inch. The grower calculated an adjusted ET of 0.12 inch and subtracted it from 0 water input for the day to get a daily balance of -0.12 inch. This daily balance is subtracted from the initial AD BAL of 0.80 inch, resulted in a new AD BAL of 0.68 inch. The AD BAL then declined steadily until 0.70 inches of rain fell on June 27, resulting in a positive daily balance of 0.50 inch and an AD BAL of 0.62 inch. A forecast of rain likely caused the grower to delay irrigation on June 26, even though the AD BAL was approaching 0.

On June 30, the grower applied a 1-inch irrigation. This exceeded the adjusted ET value of 0.19 inch, so a daily balance of +0.81 inch resulted. This daily balance, when added to the previous day's AD BAL of 0.17 inch, resulted in a new AD BAL of 0.98 inch, or nearly 50% of the AD value for the crop/soil system. Not irrigating to field capacity provides a storage buffer to absorb any rain that may follow irrigation, which saves water and power.

On July 4, the 0.06 inch AD BAL was approaching zero, but the grower again decided not to irrigate. No rain fell and, as a result, the AD BAL goes below zero (-0.19 inch) on July 5. This indicated that the crop had depleted all readily available water and was coming under stress. A 1.25-inch irrigation on July 6 removed the stress.

Three inches of rain on July 7 followed the 1.25-inch irrigation on July 6. But only 1.18 inch of the resulting +2.88 daily balance was needed to restore the previous day's AD BAL of 0.82 inch to the 2.0-inch AD value for the crop/soil system. The rest of the daily balance (1.7 inches) was excess water and moved below the root zone, where it likely contributed to leaching. Excess irrigation can't always be avoided. However, if rain is forecasted within 24 hours, delay irrigation or reduce the amount to take advantage of any forthcoming rain.

On July 9, a light rain shower of 0.08 inches of rain was received. When calculating the daily balance, the rainfall of less than 0.1 inch is not included because it is not enough to be greater than what would be held by plant leaves or evaporate before the plant can use it.

(example)
Month 1

Field Palmorro

Crop/Soil System Field corn/Richford loamy sand

Growing Year 2009

Beginning Day of Data 6-01-09

AD Value for Crop/Soil System 2.0 inches

Month/Day	Rainfall	Irrigation	Potential ET	% Cover	Adjusted ET	Daily Bal.	AD BAL
June						Initial AD Bal (Ad Bal forward)	0.80
1	0	0	0.22	30	0.12	-0.12	0.68
2	0	0	0.21	35	0.14	-0.14	
26	0	0	0.15	76	0.15	-0.15	0.12
27	0.70	0	0.20	78	0.20	+0.50	0.62
28	0	0	0.22	80	0.22	-0.22	0.40
29	0	0	0.23	80	0.23	-0.23	0.17
30	0	1.00	0.19	80	0.19	+0.81	0.98
31	-	-	-	-	-	-	-
TOTALS							

(example)
Month 2

Field Palmorro

Crop/Soil System Field corn/Richford loamy sand

Growing Year 2009

Beginning Day of Data 6-01-09

AD Value for Crop/Soil System 2.0 inches

Month/Day	Rainfall	Irrigation	Potential ET	% Cover	Adjusted ET	Daily Bal.	AD BAL
July						Initial AD Bal (Ad Bal forward)	0.98
1	0	0	0.24	80	0.24	-0.24	0.74
2	0	0	0.23	80	0.19	-0.23	0.51
3	0	0	0.19	80	0.23	-0.19	0.32
4	0	0	0.26	80	0.26	-0.26	0.06
5	0	0	0.25	80	0.25	-0.25	-0.19[a]
6	0	1.25	0.24	80	0.24	+1.01	0.82
7	3.0	0	0.12	80	0.12	+2.88	2.00[b]
8	0	0	0.20	80	0.20	-0.20	1.80
9	0	0	0.22	80	0.22	-0.22	1.58
10							

[a]An AD BAL of less than 0 is recorded as negative, as the crop is still using water. It is just below the desired threshold of available water in the soil.

[b]Any amount of an AD BAL greater than the SD value for the crop/soil system is not recorded, as this excess water has probably moved below the root zone.

APPENDIX TABLE A – AD values for major crop/soil systems irrigated in Wisconsin[a]

	CROP EFFECTIVE ROOTING DEPTH[b]			
	(to 12″)	(to 24″)	(to 30″)	(to 36″)
	Potato, strawberry	Snap bean, pea	Soybean, sweet corn, seed corn	Field corn, alfalfa
SOIL TYPE	**ALLOWABLE DEPLETION IN INCHES**			
Plainfield loamy sand	0.7	1.1	1.4	1.6
Gotham loamy sand	0.7	1.1	1.3	1.8
Richford loamy sand	0.7	1.4	1.7	2.0
Chetek sandy loam[c]	0.7	1.0	1.0	1.0
Pence sandy loam[c]	0.9	1.3	1.3	1.3
Billet sandy loam	0.9	1.7	2.1	2.4
Onemia sandy loam[c]	1.0	2.0	2.0	2.0
Plano silt loam	1.2	2.4	3.0	3.4
Antigo silt loam[c]	1.3	1.8	2.3	2.4

[a]Allowable depletion (AD) values are for well-drained soils at field capacity.

[b]Effective rooting depth – depth of soil profile from which most of the water is absorbed by the root system. Assumes no barrier to root development.

[c]These soils restrict root development to the following depths: Chetek–17″, Pence–16″, Onemia–28″ and Antigo–33″.

Other Soil types

You can calculate allowable depletion (AD) values for soils not listed in the table. The method here uses the 36-inch effective rooting depth for corn, and data on available water capacity (AWC, also called TAW) from Natural Resource Conservation Service (NRCS) Soil Survey information, available through the NRCS office in your area, or from the USDA-NRCS Web Soil Survey web site (websoilsurvey.sc.egov.usda.gov).

The AWC for a soil varies with depth, as the following NRCS soils survey data for a salter very fine sandy loam shows:

0-7 inches of profile depth – 0.22-inch AWC per 1-inch depth
7-36 inches of profile depth – 0.15-inch AWC per 1-inch depth

Calculate the AWC for each profile zone, then add the totals together to derive the AWC for the entire rooting depth.

7 x 0.22 = 1.54 AWC for the first 7 inches of rooting depth
29 x 0.15 = 4.35 AWC for the next 29 inches of rooting depth
1.54 + 4.35 -5.89 AWC for the 36-inch rooting depth of corn

The AD value for most crop/soil systems is 50% of the total AWC. Thus, for Salter very fine sandy loam:

AD value = 2.9 inches (5.89″ x 50%)

The AD value is an estimate of the soil's readily available water storage. You may need to modify your AD estimate as you gain experience with the WISP scheduling program.

APPENDIX TABLE B – Evapotranspiration (ET) estimates adjusted for percent crop canopy cover

(for use with WISP)

Potential ET in inches	% CROP CANOPY COVER								
	0	10	20	30	40	50	60	70	80
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02
0.04	0.00	0.00	0.01	0.02	0.03	0.03	0.04	0.04	0.04
0.06	0.00	0.01	0.02	0.03	0.04	0.05	0.05	0.06	0.06
0.08	0.00	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.08
0.10	0.00	0.02	0.04	0.05	0.07	0.08	0.09	0.10	0.10
0.12	0.00	0.03	0.05	0.06	0.08	0.09	0.11	0.11	0.12
0.14	0.00	0.03	0.05	0.07	0.09	0.11	0.12	0.13	0.14
0.16	0.01	0.04	0.06	0.08	0.11	0.13	0.14	0.15	0.16
0.18	0.01	0.04	0.07	0.09	0.12	0.14	0.16	0.17	0.18
0.20	0.01	0.05	0.08	0.11	0.13	0.16	0.18	0.19	0.20
0.22	0.01	0.05	0.08	0.12	0.15	0.17	0.19	0.21	0.22
0.24	0.01	0.06	0.09	0.13	0.16	0.19	0.21	0.23	0.24
0.26	0.01	0.06	0.10	0.14	0.17	0.20	0.23	0.25	0.26
0.28	0.01	0.06	0.11	0.15	0.19	0.22	0.25	0.27	0.28
0.30	0.01	0.07	0.12	0.16	0.20	0.23	0.26	0.28	0.30
0.32	0.02	0.07	0.12	0.17	0.21	0.25	0.28	0.30	0.32
034	0.02	0.08	0.13	0.18	0.23	0.26	0.30	0.32	0.34
0.36	0.02	0.08	0.14	0.19	0.24	0.28	0.32	0.34	0.36

To use this table you will need an estimate of the current percent crop canopy and the Potential ET from the University of Wisconsin–Madison Division of Extension Ag Weather website (agweather.cals.wisc.edu/sun_water/et_wimn). You can also subscribe to have the Potential ET emailed to you daily – link to subscribe is above the website map.

To adjust the Potential ET for the crop growth stage. Go down the left column – Potential ET – until you find the value closest to the Potential ET, then move right along the row until you intersect with the column closest to the current percent crop canopy cover. The value at the intersection is the adjusted ET estimate.

WISP accounting form

Field ____________________

Crop/Soil System ____________________

Growing Year ____________________

Beginning Day of Data ____________________

AD Value for Crop/Soil System ____________________

Month/Day	Rainfall	Irrigation	Potential ET	% Cover	Adjusted ET	Daily Bal.	AD BAL
	Initial AD Bal (Ad Bal forward)						
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
TOTALS							

For more information

Visit the UW–Madison Division of Extension web page "Understanding Crop Irrigation" for links to suppliers, the WISP software, and more information (fyi.extension.wisc.edu/cropirrigation/wisconsin-irrigation-scheduling-program-wisp).

References:

Campbell, G.S., J.M.Norman. 1998. *An Introduction to Environmental Biophysics,* 2nd Ed. New York: Springer Science+Business Media, Inc.

Fangmeier, D.D., W.J. Elliot, S.R. Workman, R.L. Huffman, G.O. Schwab. 2006. *Soil and Water Conservation Engineering,* 5th Ed. New York: Thomson Delmar Learning.

James, L.G. 1988. *Principles of Farm Irrigations System Design.* John Wiley & Sons, New York.

Panuska, J.C., S.A. Sanford, A.C. Newenhouse. 2015. *Methods to Monitor Soil Moisture,* A3600-02 University of Wisconsin–Madison Division of Extension.

Scherer, T.F., W. Kranz, D. Pfost, F. Werner, J.A. Wright, C.D. Yonts. 1999. *Sprinkler Irrigations Systems,* MWPS-30, Midwest Plan Service, Iowa State University, Ames, IA.

USDA Irrigation Handbook, Chapter 3 – Crops (New Jersey Amendments 6-2005) http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs141p2_018371.pdf

Zazueta, F.S. 2011. *Evaporation Loss During Sprinkler Irrigation,* Bulletin 290, University of Florida, Extension.

Irrigation Management in Wisconsin

The Wisconsin Irrigation Scheduling Program (WISP)

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Revision of original work by David Curwen, Department of Horticulture (deceased), and Leonard Massie, Department of Biological Systems Engineering.

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