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Weather-Based Landscape Irrigation Control Systems



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Introduction and Background Information

This standard describes testing procedures to evaluate how well landscape irrigation controllers respond to plant water demands when they are actively growing. This test standard was created in response to a request from the Irrigation Association based on a testing protocol created by the Smart Water Application Technologies committee in 2008 and has been used as the basis for the U.S. Environmental Protection Agency WaterSense program for labeling and certifying irrigation controllers. The standard includes Test Method #1 which is a 30-day test that measures the controller's capability to apply an adequate amount of water with minimal excess water application. Test Method #2, as described in Appendix A, is a separate test procedure that covers a 90-day period of time that utilizes an hourly soil moisture balance and evaluates a controller's capability to maximize the benefit of rainfall and irrigation frequency while considering the criteria of irrigation adequacy and excess water application.

1 Purpose and Scope

1.1 This standard describes a test method to determine an irrigation controller's ability to respond to weather and conditions found within the typical landscape. Sometimes called "smart control systems" or "smart controllers," these are controllers or devices that respond to environmental conditions by estimating or measuring depletion of available plant soil moisture in order to operate an irrigation system, replenishing water as needed while minimizing excess water use. A properly programmed smart controller requires initial site-specific set-up and will make irrigation schedule adjustments, including runtimes and/or required cycles throughout the irrigation season without human intervention. The standard will measure the ability of the controllers to provide adequate and efficient irrigation while minimizing potential losses.

It is recognized that controlling the irrigation of turf and landscape is a combination of scientific theory and subjective judgments. The attempt in developing this standard is to use only generally recognized theory and to avoid judgments involving the art of irrigation. The standard then recognizes that only the theory of irrigation is controllable by the skill of the controller manufacturer.

1.2 The objective of this standard is to provide a test method that evaluates how well technology has integrated scientific data into a practical system that meets the agronomic needs of the turfgrass and landscape plants. This evaluation concept requires the use of accepted formulas for calculating crop evapotranspiration (ET_c) or landscape evapotranspiration (ET_L). Versions of this type of controller could include one or more of the following:

- On-site weather sensors to determine irrigation needs;
- Weather data received from an off-site source;
- Technology that is added to existing time-based controllers that interfaces with either the controller program or electrical output to zone valves; and
- Historical reference evapotranspiration (ET_o) data characteristic of the site, in conjunction with other inputs.

1.2.1 This evaluation shall be accomplished by defining a virtual landscape and connecting an irrigation controller to a datalogger that records signals sent to irrigation control valves. Any weather sensors will be

subjected to actual, real-time climate conditions. The output of the irrigation controller will be evaluated to determine the ability of the landscape irrigation control system to adequately and efficiently manage water applied to the landscape. The individual irrigation zones within the virtual landscape represent a range of landscape conditions. As a standard from which to judge the control system's performance, a detailed moisture balance calculation shall be made for each zone. Irrigation adequacy is determined by the total accumulated deficit of irrigation over the test period. The accumulated surplus and runoff of irrigation over the test period is a measure of irrigation excess.

1.3 A control system meeting this standard may include additional features not covered in this document.

1.4 This standard is not intended for testing control systems used in agricultural settings.

1.5 This standard is a testing document; therefore, inputs and values provided in Tables 1, 2, 3 and Figure 1 are used for illustrative purposes only, and may not reflect the conditions at any specific location.

1.6 Test Method #1 evaluates a controller for irrigation adequacy and irrigation excess over a minimum 30-day period using daily soil moisture balance calculations. It does not constrain the frequency of irrigation events; however, it does have a minimum runtime requirement.

2 Normative References

The following referenced documents are indispensable for the application of this document, the latest edition of the referenced document (including any amendments) applies.

Allen, R. G., Walter, I. A., Elliott, R. L., Howell, T. A., Itenfisu, D., Jensen, M. E., Snyder, R. L. 2005. The ASCE standardized reference evapotranspiration equation. Reston, VA: American Society of Civil Engineers. 59 pp.

ASAE EP505, Measurement and Reporting Practices for Automatic Agricultural Weather Stations.

3 Definitions

3.1 allowable depletion (AD): That part of soil water capacity stored in the plant root zone managed for use by plants, usually expressed as a depth of water (mm or inches), and calculated as the product of the available water capacity (AWC), root zone depth, and management allowed depletion (MAD).

3.2 allowable surface accumulation (ASA): Initial depth of water, whether irrigation or rainfall, that can be applied before surface runoff occurs, typically by application rates that exceed basic soil intake rates (IR). This water is restrained from running off by the combined effects of surface detention, presence of the crop canopy, thatch layer, or accumulated vegetative waste/debris/mulch on the soil surface (mm or inches).

3.3 application efficiency (AE): The ratio of the average depth of irrigation water infiltrated and stored in the root zone to the average depth of irrigation water applied, expressed as a percentage.

NOTE: Using a constant application efficiency for each zone is a recognized simplification for purposes of this standard. Distribution uniformity is not equivalent to application efficiency.

3.4 application rate (AR): Rate that water is applied to a given area, usually expressed in units of depth per time (mm/h or in./h).

3.5 available water capacity (AWC): The portion of soil water that can be readily absorbed by plant roots of most crops, expressed in mm water per mm soil (inches water per inch soil) for a specific soil depth. It is the amount of water stored in the soil between field capacity (FC) and permanent wilting point (WP).

3.6 deficit (D): Depth of water needed to replenish root zone soil moisture to avoid undesirable or excessive plant stress, when depletion exceeds the allowable depletion (AD) (mm or inches).

3.7 effective irrigation (I_E): Depth (mm or inches) of irrigation water infiltrated and stored in the root zone and usable by the plants.

3.8 effective rainfall (R_E): The portion of total precipitation which becomes available for plant growth (mm or inches).

3.9 evapotranspiration (ET): The combination of water transpired by vegetation and evaporated from soil, water, and plant surfaces (mm or inches of water per time period (i.e., daily for Test Method #1 and hourly for Test Method #2)).

3.9.1 reference evapotranspiration (ET_o): The evapotranspiration (ET) from a dense, well-watered hypothetical crop with specified height, albedo, and surface resistance. The ASCE Standardized Reference Evapotranspiration Equation recognizes two reference surfaces: short crop reference ET (ET_o), which represents a clipped, cool-season grass (this is equivalent to FAO 56 reference ET), and a tall crop reference (ET_r), which represents alfalfa. Reference ET is a measure of the atmospheric demand for water and is used in conjunction with a crop coefficient or a landscape coefficient to estimate crop ET or landscape ET.

3.9.2 landscape evapotranspiration (ET_L): The water used by the given landscape plants in the irrigation zone where those plants have similar water requirements (mm or inches).

3.9.3 crop coefficient (K_c): The ratio of crop evapotranspiration to reference evapotranspiration.

3.10 field capacity (FC): Amount of water remaining in a soil when the downward water flow due to gravity becomes negligible. An estimate of field capacity ranges between soil water contents at matric potentials of -10 to -33 kPa (-0.1 to -0.33 bar) (mm or inches of water per mm or inches of soil).

3.11 gross irrigation (I_G): Total irrigation water supplied (mm or inches) to a given area.

3.12 gross rainfall (R_G): The measured depth (mm or inches) of naturally occurring precipitation.

3.13 irrigation adequacy: A measure of how well the plant's or landscape's consumptive water needs are met, expressed as a percentage and calculated as described in Table 4. .

3.14 irrigation cycle: The duration when water is being applied (minutes), such that there can be multiple irrigation cycles separated by soak times that comprise an irrigation event, calculated by zone for purposes of this standard.

3.15 irrigation event: Total duration (minutes) for all irrigation cycles and soak times after irrigation is initiated, calculated by zone for purposes of this standard.

3.16 irrigation excess: A measure of water applied in excess of the plant's or landscape's consumptive needs, expressed as a percentage and calculated as described in Table 4.

3.17 irrigation scheduling efficiency: Ratio of effective irrigation (I_E) to net irrigation (I_N), expressed as a percentage.

3.18 irrigation zone: Section of an irrigation system served by a single control valve for distribution of water to a defined target area.

3.19 landscape coefficient (K_L): The plant factor (PF) multiplied by microclimate factors (k_{mc}) and density factors (k_d) to modify reference evapotranspiration (ET_o) to calculate landscape evapotranspiration (ET_L).

3.19.1 plant factor (PF): The fraction of reference evapotranspiration (ET_o) required for acceptable plant appearance. When multiplied by ET_o , the plant factor determines the depth of water required by plants.

3.19.2 microclimate factor (k_{mc}): This factor is used to estimate the impact of site conditions that could increase or decrease the amount of water for plants growing in those conditions. Plants growing in full sun have a microclimate factor of 1.0. If the plants are affected by shading, the factor will be less than 1.0, and if other factors that increase the intensity of heat are present, such as reflective glass or hard surfaces, the factor could be greater than 1.0.

3.19.3 density factor (k_d): This factor is a way to describe the foliage surface coverage. Turfgrass has a density factor of 1.0. Layered foliage with multiple types of plants growing in an area such as ground cover, shrubs and trees could have a density of greater than 1.0, while sparsely planted areas where foliage will not fully shade the ground at solar noon could have a density factor less than 1.0.

3.20 management allowed depletion (MAD): The desired soil-water deficit at the time of irrigation, expressed as a percentage of available water capacity (AWC).

3.21 net irrigation (I_N): The recorded amount of applied irrigation water (mm or inches) stored in the soil for plant use or moved through the soil for leaching salts. Also includes water applied for crop quality and temperature modification; i.e., frost control, cooling plant foliage and fruit. Application losses, such as evaporation, runoff and deep percolation are not included.

3.22 net rainfall (R_N): Portion of gross rainfall (R_G) that infiltrates the soil and expressed as a depth of water (mm or inches).

3.23 permanent wilting point (WP): Soil water content (mm of water per mm of soil or inches per inch) below which plants cannot readily obtain water and permanently wilt. Often estimated as the water content corresponding to a matric potential of -1.5 MPa (-15 bar).

3.24 rainfall efficiency (E_R): Ratio of the rainfall infiltrated and stored in the root zone and available for use by the plants to the gross rainfall (R_G), expressed as a percentage.

3.25 runoff: The portion of precipitation, snow melt, or irrigation that flows over the soil surface, eventually making its way to surface water supplies (mm or inches).

3.25.1 direct runoff (DRO): Depth of water (mm or inches) applied that exceeds the soil infiltration rate. For irrigation, this occurs when the recorded runtime exceeds the maximum allowable runtime.

3.25.2 soak runoff (SRO): The portion of runoff losses attributable to scheduling multiple irrigation cycles without allowing sufficient soak time between runtime (RT) cycles (mm or inches).

3.26 surplus (S): Irrigation water that infiltrates the soil but exceeds the holding capacity of the plant root zone (mm or inches).

3.27 runtime (RT): Recorded total duration water is being applied during an irrigation cycle (minutes).

3.28 soak time (ST): Duration between irrigation cycles (minutes).

3.28.1 minimum required soak time ($ST_{(min)}$): The minimum time required for a given irrigation cycle to finish infiltrating into the root zone without surface runoff (minutes).

3.29 soil moisture balance (MB): An accounting practice reported in depth of water (mm or inches) used to determine the amount of remaining water available in the soil after subtracting plant water use (ET_c or ET_L) and adding effective rainfall (R_E) and effective irrigation (I_E). The maximum soil moisture is equal to the allowable depletion (AD) and occurs at field capacity (FC). The MB is the remaining moisture in the root zone that is readily available for use by the plants at the end of the given time period.

4 Test Method #1

4.1 Sampling. The testing facility shall determine the appropriate method for random selection of the specific controller model to be tested from inventory that is available for sale to the public.

4.2 General. Irrigation controllers shall be installed at the test site complete with sensors and/or communication links. The controllers shall include instructions that list the settings and specific parts and/or accessories used for this test. Controllers shall be programmed and installed per these instructions. Controller output shall be connected to six irrigation zone relays representing the control valves of the virtual irrigation zones (Table 1). A data logger shall be connected to the six zone relays and shall record valve open and closing events. Valve

runtimes (RT) shall be used with given application rate (AR) and efficiency data to provide net irrigation (I_N) application. These data, along with calculations of runoff, surplus, and effective rainfall, are used in the soil moisture balance (MB) calculation.

A daily moisture balance calculation shall be developed using the recorded valve runtimes taken from the data logger. System performance parameters shall be calculated as required to summarize the controller's performance, including the following:

- gross irrigation (I_G)
- direct runoff (DRO)
- soak runoff (SRO)
- effective irrigation (I_E)
- deficit (D)
- surplus (S)
- irrigation adequacy
- irrigation excess
- irrigation scheduling efficiency

4.3 Test for irrigation adequacy and irrigation excess. The test lab will communicate with the controller manufacturer to determine the required setup and settings needed for the controller performance to satisfy the conditions defined in the virtual irrigation zones as given in Table 1.

Table 1 – Description of virtual irrigation zones for Test Method #1

Item No.	Description	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
1	Soil texture	Loam	Silty clay	Loamy sand	Sandy loam	Clay loam	Clay
2	Slope	6%	10%	8%	12%	2%	20%
3	Basic soil intake rate (IR), mm/h (in./h)	8.9 (0.35)	3.8 (0.15)	12.7 (0.50)	10.2 (0.40)	5.1 (0.20)	2.5 (0.10)
4	Allowable surface accumulation (ASA), mm (in.)	6.4 (0.25)	4.1 (0.16)	6.6 (0.26)	6.1 (0.24)	6.6 (0.26)	2.5 (0.10)
5	Available water capacity (AWC), mm/mm (in./in.) ^[a]	0.17	0.17	0.09	0.13	0.18	0.17
6	Root zone depth, mm (in.)	254 (10.0)	206 (8.1)	508 (20.0)	711 (28.0)	635 (25.0)	234 (9.2)
7	Management allowed depletion (MAD)	50%	40%	50%	55%	50%	35%
8	Allowable depletion (AD), mm (in.)	21.6 (0.85)	14.0 (0.55)	22.9 (0.90)	50.8 (2.00)	57.2 (2.25)	14.0 (0.55)
9	Vegetation	Tall fescue	Bermuda grass	Ground cover	Woody shrubs	Trees & ground cover	Bermuda grass
10	Exposure	75% Shade	Full sun	Full sun	50% Shade	Full sun	Full sun
11	Crop coefficients (K_c) for turf	Table 3	Table 3	N/A	N/A	N/A	Table 3
12	Landscape coefficients (K_L) ^[b]	N/A	N/A	0.55 (Table 2)	0.40 (Table 2)	0.61 (Table 2)	N/A
13	Irrigation system	Spray sprinkler	Spray sprinkler	Spray sprinkler	Spray sprinkler	Drip irrigation	Rotor sprinkler
14	Application rate (AR), mm/h (in./h)	40.6 (1.60)	40.6 (1.60)	35.6 (1.40)	35.6 (1.40)	5.1 (0.20)	8.9 (0.35)
15	Application efficiency (AE) ^[c]	55%	60%	70%	75%	80%	65%

^[a] Available water capacity varies with changes in soil composition and compaction. These values may not represent actual field conditions.

^[b] The values used here are an example of a case where site conditions are used to modify the plant factors to determine the landscape coefficient. The landscape coefficients used in this standard are examples only and should not be hard coded directly into a controller.

^[c] This standard is a testing document; numbers given in this standard are used for illustrative purposes only, and may not reflect the conditions or equipment at any specific location.