Smart Water Application Technologies™ (SWAT)

Turf and Landscape Irrigation System Smart Controllers

CLIMATOLOGICALLY BASED CONTROLLERS

8th Testing Protocol (September 2008)

Developed by the

Irrigation Association™

SWAT Committee
8280 Willow Oaks Corporate Drive, Suite 400
Fairfax, VA 22031
www.irrigation.org

TABLE OF CONTENTS

FOREWORD

The Irrigation Association has established a Smart Water Application Technologies™, or SWAT, committee to oversee the development of product testing protocols. This committee is assisted by a Technical Working Group (TWG) and project leaders. The protocol development process involves a drafting of the document followed by a public review and comments period. If required, the document is redrafted and a second review process is initiated. Ultimately the SWAT committee votes on the acceptability of the last protocol. All protocols will be reviewed for possible revision every three years. The development of this testing protocol represents the first attempt by the Irrigation Association to develop product testing protocols. The actual product testing began in 2004 when the first commercial controller was tested using the 5th Draft Testing Protocol dated May 3, 2004. The documents have no known predecessors.

This protocol was developed to test products designed and sold for use at homes and similar scale light commercial and institutional properties. This protocol may not be suitable for testing products used in larger more demanding irrigation systems used at parks, golf courses, etc.

This testing protocol consists of the following parts under the general title of "Turf and Landscape Irrigation System Smart Controllers."

Climatologically Based Controllers

Another protocol addresses the following parts under the general title of "Turf and Landscape Irrigation System Smart Controllers."

Soil Moisture Sensor Based Controllers
- Phase 1: Indoor lab screening tests
- Phase 2: Operational test on a virtual landscape

INTRODUCTION

This protocol provides a procedure for characterizing the efficacy of irrigation system controllers that utilize climatological data as a basis for scheduling irrigations. They may also use on-site temperature or rainfall sensors. This evaluation concept requires the use of accepted formulas for calculating crop evapotranspiration (ETc). Commercial versions of this type of controller include the following:

- Controllers that store historical ETc data characteristic of the site
- Controllers that utilize on-site sensor as a basis for calculating real time ETc
- Controllers that utilize a central weather station as a basis for ETc calculations and to transmit the data to individual home owners from remote sites
- Controllers that utilize on-site rainfall and temperature sensors
- Control technology that is added on to existing time based controllers

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 protocol is to use only generally recognized theory and to avoid judgments involving the art of irrigation. The protocol then recognizes that only the theory of irrigation is controllable by the skill of the controller manufacturer. The protocol will measure the ability of the controllers to provide adequate and efficient irrigation while minimizing potential run-off.

The concept of climatologically controlling irrigation systems has an extensive history of scientific study and documentation. The objective of this protocol is to evaluate how well current commercial technology has integrated the scientific data into a practical system that meets the agronomic needs of the turf and landscape plants.

In general there are at least two types of standards. The first is a standard that defines the details of how a performance test is to be conducted and what data will be recorded. This Smart Water Application Technologies™ testing protocol is that type of test. It does not result in a pass or fail evaluation. The second type of standard defines performance limits that must be met to quantify the capabilities of the product. The performance standards in this case are established by related considerations and organizations.

In order to realize the full potential of the smart controller concept the following issues must be addressed:

- The quality of the input data must be verified by a certified professional
- The controller must be set up and programmed by individuals familiar with the technology
- The irrigation system must be properly designed and maintained

Turf and Landscape Irrigation System Smart Controllers – Climatologically Based

1.0 Scope

This evaluation will be accomplished by creating a virtual landscape subjected to a representative climate and to evaluate the ability of individual controllers to adequately and efficiently irrigate that landscape. The individual zones within the landscape will represent a range of exposure, soil types and agronomic conditions. As a standard from which to judge the controller's performance, a detailed moisture balance calculation will be made for each zone. The total accumulated deficit over time will be a measure of the adequacy. The accumulated surplus of applied water over time will be a measure of system efficiency. Water applied beyond the soil's ability to absorb it will be characterized as runoff, further degrading the application efficiency. The study will use ASCE-EWRI data from a representative accredited weather station. Further the study is not meant to include individualized water management strategies aimed at producing special physiological affects. If the controller maintains root zone moistures at the levels specified, the protocol assumes that the crop growth and quality will be adequate. The moisture balance calculation will assume that the plant materials are functioning as mature plants.

2.0 Normative References

The Environmental and Water Resource Institute (EWRI) of the American Society of Civil Engineers, study on the standardization of reference Evapotranspiration (ETo) formulas. See http://www.kimberly.uidaho.edu/water/asceewri/

3.0 Definitions

For the purposes of this IA Standard, the following definitions apply:

3.1 Allowable Surface Accumulation (ASA)
Free standing water created on top of the soil surface by application rates that exceed soil intake rates that is generally restrained from running off by the combined effects of surface detention and the presence of the crop canopy, thatch layer, or accumulated vegetative waste.

3.2 Crop (Turf) Coefficient (Kc)
Coefficients as determined for specific crops that relate ETo to ETc as follows:

$$ETc = Kc\ (ETo)$$

This provides a convenient method for calculating ETc when field data is not available.

3.3 Crop Evapotranspiration (ETc)
Specific crop moisture requirements as determined by lysimeter studies or calculated by formulas

3.4 Evapotranspiration (ET)
Water transpired by vegetation plus that evaporated from the soil

3.5 Field Capacity
The amount of water remaining in the soil after the soil has been saturated and allowed to drain away

3.6 Landscape Coefficient (K_L)
A functional equivalent of the crop coefficient for turf that integrates the effects of species factor (k_s), density factor (k_d) and microclimate factor (k_{mc}) for landscapes.

$K_L = (k_s)\ (k_d)\ (k_{mc})$
$ETc = K_L\ (ETo)$

3.7 Permanent Wilting Point
The largest content of water in a soil at which plants will wilt and not recover when placed in a humidity chamber

3.8 Reference Evapotranspiration (ETo)
Estimates of crop evapotranspiration as calculated using climatological information and accepted formulas. See: ASCE-EWRI, Ref. 5.2.

3.9 Root Zone Working Water Storage (RZWWS)
A root zone water storage value that integrates the effects of actual root zone depth, soil moisture storage capacity, and allowable moisture depletion

3.10 Precipitation Rate (PR)
The amount of irrigation water applied per unit of time.

3.11 Smart Controller
Smart controllers estimate or measure 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 run times and required cycles throughout the irrigation season without human intervention.

3.12 Soak Time
The time required for a given application to infiltrate into the root zone.

3.13 Zones
A portion of the system connected to a common water supply and intended to operate at the same time

3.14 Direct Runoff
Water applied that exceeded the maximum allowable runtime

3.15 Soak Runoff
Runoff losses attributable to scheduling multiple irrigation cycles without allowing sufficient soak time between cycles

3.16 Effective (Net) Irrigation
Water applied that was added to the root zone working storage and usable by the crop

3.17 Deficit
Required water that was not available in the root zone working storage

3.18 Surplus
Water applied in excess of the root zone working storage

3.19 Irrigation Adequacy
Ratio of crop ETc less deficit over crop ETc as a percentage

3.20 Scheduling Efficiency
Ratio of net irrigation less scheduling losses over net irrigation as a percentage

3.21 Net (Effective) Rainfall
Portion of total rainfall which becomes available for plant growth

3.22 Rainfall Efficiency
Ratio of the rainfall stored in the root zone over the net rainfall as a percentage

4.0 Test Methods

4.1 Sampling
A representative of the testing laboratory will select test specimen for each test at random from a sample of at least 10 units supplied by the manufacturer. The testing agency will retain the controller.

4.2 General
System controllers will be installed at the test site complete with sensors and/or communication links. The controller output will be connected to 6 zone relays representing the control valves of the virtual yard. A data logger will be connected to the 6 zone relays. The data logger will record valve open and closing events. Valve run times will be used with application rate and efficiency data to provide the net irrigation application. This data is used in the moisture balance calculation.

Develop a day-by-day moisture balance calculation using the actual valve run times taken from the data logger. Calculate the system performance parameters as required to summarize the controller's performance including:

- Gross irrigation
- Direct runoff
- Soak runoff
- Effective irrigation
- Deficit
- Surplus
- Irrigation adequacy
- Scheduling efficiency

– Application efficiency
– Rainfall efficiency

4.3 Test for Adequacy, Efficiency and Runoff Potential

Communicate with the controller manufacturers the starting date of the test run, the source of the real time weather data, and the on-site weather data history.

Communicate with the controller manufacturers the definitions of the virtual yard as given in Table 1.

Table 1: Description of Zones

Item No.	Description	Zone #1	Zone #2	Zone #3	Zone #4	Zone #5	Zone #6
1	Soil Texture (1)	Loam	Silty Clay	Loamy Sand	Sandy Loam	Clay Loam	Clay
2	Slope, %	6	10	8	12	2	20
3	Exposure	75% Shade	Full Sun	Full Sun	50% Shade	Full Sun	Full Sun
4	Root Zone Working Water Storage (RZWWS), in. (2)	0.85	0.55	0.90	2.00	2.25	0.55
5	Vegetation	Fescue (Tall)	Bermuda	Ground Cover	Woody Shrubs	Trees & Ground Cover	Bermuda
6	Crop (Turf) Coefficient (K_c)	See Table 2	See Table 2	N/A	N/A	N/A	See Table 2
7	Landscape Coefficient (K_L) (3)	N/A	N/A	0.55	0.40	0.61	N/A
8	Irrigation System	Pop-Up Spray Heads	Pop-Up Spray Heads	Pop-Up Spray Heads	Pop-Up Spray Heads	Surface Drip	Rotors
9	Precipitation Rate (PR), in./h	1.60	1.60	1.40	1.40	0.20	0.35
10	Estimated Application Efficiency, %	55	60	70	75	80	65
11	Gross Area, ft^2 (4)	1,000	1,200	800	500	650	1,600

(1) See Table 3 for soil intake rate

(2) Root Zone Working Water Storage (RZWWS) calculations:

Item No.	Description	Zone #1	Zone #2	Zone #3	Zone #4	Zone #5	Zone #6
1	Vegetation	Fescue	Bermuda	Ground cover	Woody shrubs	Trees & ground cover	Bermuda
2	Soil Texture	Loam	Silty clay	Loamy sand	Sandy loam	Clay loam	Clay
3	Allowable Depletion	50	40	50	55	50	35
4	Available Water, in./in.	0.17	0.17	0.09	0.13	0.18	0.17
5	Root Zone Depth, in.	10.0	8.1	20.0	28.0	25.0	9.2
6	Root Zone Working Water Storage, in.	0.85	0.55	0.90	2.00	2.25	0.55

(3) Landscape coefficients work-up from section 6.0 Informative Annex, item 6.3

Parameter	Zone 3	Zone 4	Zone 5
k_s	0.5	0.5	0.5
k_d	1.0	1.0	1.1
k_{mc}	1.1	0.8	1.1
K_L	0.55	0.40	0.61

The protocol uses a simplified treatment of Zones 3, 4 and 5 where complete wetting of the surface area may not be required. A more studied analysis may be appropriate where high value vegetation is irrigated in drier climates.

(4) Area as defined by extent of vegetative planting. Make no allowance for geometrically complex boundaries.

Provide crop (turf) coefficients. See Table 2.

Table 2: Crop (Turf) Coefficients (Kc)

	Full Sun		75% Shade	
Month	**Fescue**	**Bermuda**	**Fescue**	**Bermuda**
January	0.61	0.52	0.41	0.35
February	0.69	0.64	0.46	0.43
March	0.77	0.70	0.52	0.47
April	0.84	0.73	0.56	0.49
May	0.90	0.73	0.60	0.49
June	0.93	0.71	0.62	0.48
July	0.93	0.69	0.62	0.46
August	0.89	0.67	0.60	0.45
September	0.83	0.64	0.56	0.43
October	0.75	0.60	0.50	0.40
November	0.67	0.57	0.45	0.38
December	0.59	0.53	0.40	0.36

(1) As modified from Table A.1 Ref: 5.4
(2) The Kc values in this table are meant to be representative for test purposes only. They should be verified before being accepted in specific locations.

Provide basic soil intake rate and allowable surface accumulation for the soil textural classes and field slopes as shown in Table 3.

Table 3: Basic Soil Intake Rate (IR) and Allowable Surface Accumulation (ASA) as it Relates to Soil Textural Class (1) and Slope

Soil Textural Class	Basic Soil Intake Rate in./h	Allowable Surface Accumulation (ASA) in.			
	(IR)	Slope, 0 to 3%	Slope, 4 to 6%	Slope, 7 to 12%	Slope, 13% <
Clay	0.1	0.2	0.15	0.1	0.1
Silty Clay	0.15	0.23	0.19	0.16	0.13
Clay Loam	0.2	0.26	0.22	0.18	0.15
Loam	0.35	0.3	0.25	0.21	0.17
Sandy Loam	0.4	0.33	0.29	0.24	0.2
Loamy Sand	0.5	0.36	0.3	0.26	0.22
Sand	0.6	0.4	0.35	0.3	0.25

(1) As taken from the IA-CLIA Training Manual Table Pg. 73 (September, 2004)

Access the valve run time monitors to determine the run times per valve as specified by the manufacturer's system. Use the run times, the specified precipitation rate, and application efficiency to calculate the net application. Develop a moisture balance calculation assuming the calculation starts with a one-half full root zone. Continue the calculation for a time period long enough to demonstrate the controller's ability to adequately meet a range of climatic conditions. Accumulate surplus and deficit values during the evaluation period and express as system adequacy and efficiency.

The Maximum Runtime allowable before runoff occurs will be calculated from the following formula:

$$Rt\ (_{max}) = 60\ (ASA)/(PR - IR), \text{ minutes}$$

All time in excess of $Rt\ (_{max})$ will be accumulated, converted to inches of water and logged as runoff. It will also affect system adequacy and efficiency characterizations.

The required minimum soak time between the starting of consecutive irrigation cycles will be calculated by dividing the design application (Da) by the basic soil intake rate (IR). Soak times less than the required minimum will result in runoff and be accounted for in a lower scheduling efficiency value and system adequacy.

4.4 Related Considerations

Avoid irrigating during electrical peak use periods as defined by utility servicing the location represented by the weather data records.

4.5 Test Report

The moisture balance by zones for each manufacturer's controller will be developed. Total deficit and surplus for each zone will be calculated. The magnitude of the deficit will suggest an effect on the quality of the vegetation. The magnitude of the surplus will impact the scheduling and overall efficiency. The total accumulated amount by which the actual free water exceeded the allowable value will be determined as a measure of run-off potential. In the calculation of the moisture balance, the protocol credits rainfall before accounting for the irrigation contribution.

4.6 Test Duration

In addition to testing to the parameters given in Table 1 of the protocol, performance results are only valid if the controller must make adjustments for varying weather conditions relative to evapotranspiration and rainfall. Therefore actual time undergoing testing may be longer than one month. Valid performance data is then downloaded from the 30 consecutive day period of testing exhibiting a minimum of 0.40 in. of gross rainfall and a minimum of 2.50 in. of ETo.

4.7 Weather Data Source

The testing agency and the controller manufacturer shall mutually agree on an accredited weather data source to be used in the evaluation. The protocol uses weather source data available on a daily basis.
Note: SWAT Committee to study and define the term “accredited.”

4.8 Onsite Weather Collection Devices

When controllers use on-site weather collection devices, the protocol uses data obtained from CIMIS Station 80, located approximately ½ mile northwest of the test site.

5.0 Normative Annex

5.1 Moisture Balance and Run-off Potential Calculation Details:

Symbols:	Definition:
ASA	Allowable surface accumulation, in.
D	Deficit crop consumptive use not satisfied by moisture from rainfall or storage, in.
Da	Design application, in.
E	Irrigation system application efficiency, %
ETc	Turf or landscape moisture requirements, in./d
ETo	Reference crop evapotranspiration, in./d
Fw	Free water, water applied that exceeds soil intake properties, in.
I	Gross irrigation water applied, in.
In	Net irrigation water applied since last moisture balance calculations, in.
IR	Basic soil intake rate, in./h
K_L	Landscape coefficient
kc	Crop (turf) coefficient
k_d	Density factor
k_{mc}	Microclimate factor
k_s	Species factor
MB	Daily calculation of root zone moisture balance, in.
MBo	Beginning daily moisture balance, in.
PR	Precipitation rate, in./h
R	Gross amount of daily rainfall as reported, in.
Rn	Net amount of daily rainfall to be used in moisture balance calculation, in.
Rt	System runtime per cycle, min.
RZWWS	Maximum amount of moisture that can effectively be stored in the root zone, in.
S	Surplus applied irrigation water that exceeds the RZWWS capacity (surplus), in.
St	Required minimum time between the start of consecutive irrigation cycles, min.

5.2 Formulas:

Formulas:	**Comment:**
ETc = Kc (ETo), in./d	Turf evapotranspiration
ETc = K_L (ETo), in./d	Landscape evapotranspiration
$K_L = (k_s)\ (k_d)\ (k_{mc})$	Landscape coefficient
R_N = 0.8 (R), in.	Allows for an arbitrary loss of 20% of the rainfall to non-uniformity and runoff
$MB = MBo + \frac{I^{*}\ (E)}{100} + 0.8\ (R^{**}) - ETc$, in.	Daily moisture balance calculation
D = Sum of MB < 0, in.	Definition of Deficit
S = Sum of MB > RZWWS, in.	Definition of Surplus
$St = \frac{Da\ (60)}{IR}$, minutes	Minimum soak time calculation
$Fw = \frac{Rt}{60}\ (PR - IR)$, in.	Free water calculation
$Rt = \frac{Da\ (60)}{PR}$, min.	Runtime calculation per cycle
$Rt\ (_{max})$ = 60 (ASA) / (PR - IR), min.	Maximum allowable runtime to avoid runoff
I = (Rt) (PR) / 60, in.	Gross irrigation amount calculation
Da = (I) (E), in.	Net irrigation calculation

* "I" must be corrected for direct and soak runoff. It is also limited to the maximum amount of RZWWS available after allowing for rainfall storage.

** "R" is limited to the maximum amount of RZWWS available for rainfall storage.

6.0 Informative Annex

6.1 Costello, L.R.
"WUCOLS a guide to the water needs of landscape plants" University of California, Cooperative Extension, 1994

6.2 ASCE-EWRI
http://www.kimberly.uidaho.edu/water/asceewri/

6.3 University of California, Cooperative Extension leaflet #21493
"Estimating Water Requirements of Landscape Planting – The Landscape Coefficient Method" July, 1991

6.4 Walker, Robert E. and Gary F. Kah
"Landscape Water Management Handbook" Office of Water Conservation, Department of Water Resources, State of California, Version 3.1 September, 1987

6.5 Certified Landscape Irrigation Auditor Training Manual
The Irrigation Association. September, 2004

6.6 Glossary of Irrigation Terms
The Irrigation Association. August, 2006