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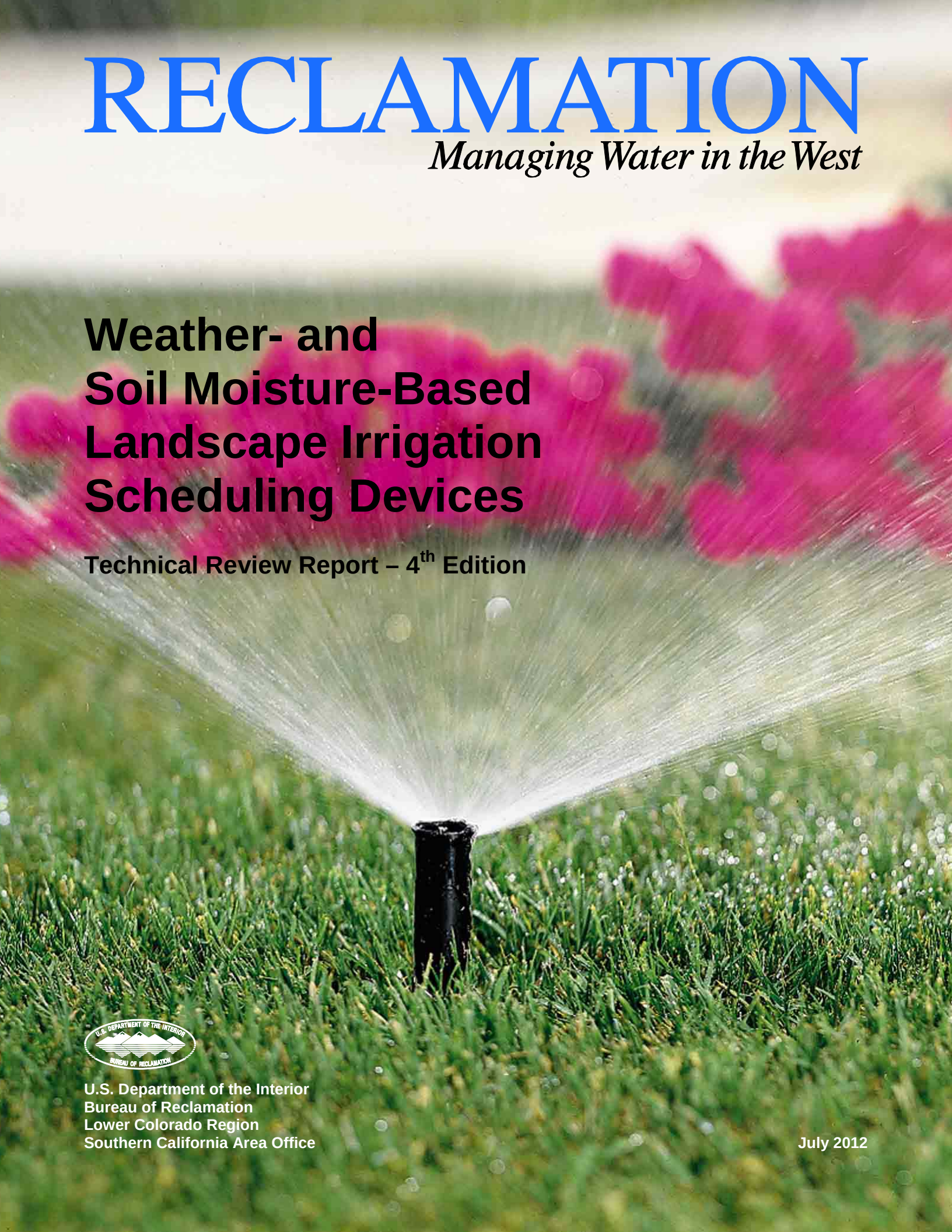

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

Technical Review Report – 4th Edition

U.S. Department of the Interior
Bureau of Reclamation
Lower Colorado Region
Southern California Area Office

July 2012

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

Technical Review Report – 4th Edition

prepared by

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U.S. Department of the Interior
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Lower Colorado Region
Southern California Area Office

July 2012

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Representatives of the reviewed product manufacturers provided product information and approval of their respective product discussion sections of the report. The preparers of this report very much appreciate each of these individuals' input. It is acknowledged that the report's level of detail could not have been achieved without the significant assistance provided by the product manufacturers' representatives. These individuals are identified in the product information and features summary tables located at the end of the report.

Disclaimer

Nothing in this report constitutes endorsement by the Bureau of Reclamation of a particular product or method. A significant portion of the information presented in this document was provided by the product manufacturers' representatives. Some of this information was verified by third parties as appropriate and as possible given the scope of the review. Every effort was made to accurately incorporate the information provided and to avoid errors and oversights, but it is recognized some may exist. The Bureau of Reclamation plans to continue to update this report periodically, and any identified deficiencies will be corrected in the next edition. Errors, omissions, and new product information should be reported to Mark Spears at 303-445-2514 or jspears@usbr.gov or to Reclamation's Southern California Area Office at 951-695-5310.

Introduction

Water agencies implementing water use efficiency programs have long struggled to achieve quantifiable and reliable water savings. Historically, programs targeting landscape savings have focused on education pertaining to irrigation system maintenance, irrigation scheduling, and climate appropriate plantings. Although these efforts have garnered savings, much potential exists for further landscape irrigation efficiency improvements.

In the late 1990s, the Irvine Ranch Water District, Municipal Water District of Orange County, and Metropolitan Water District of Southern California learned of an emerging irrigation management technology using weather-based irrigation scheduling devices. This technology removes the need to make manual scheduling adjustments because the "smart" device adjusts the schedule automatically as weather changes. A water savings evaluation of this technology was implemented, which is known as the "Residential Weather-Based Irrigation Scheduling – The Irvine ET Controller Study." This evaluation identified an average single-family home savings rate of 37 gallons per day (irwd.com, 2001).

In an effort to address nonpoint source pollution, a second weather-based irrigation scheduling study was performed to evaluate the linkage between improved residential irrigation management and reduced dry-weather runoff. The *Residential Runoff Reduction Study* (R3 Study) reported comparable water savings of 42 gallons per day per single-family home (irwd.com, 2004). Savings at nonresidential sites were 545 gallons per day. The R3 Study also quantified a reduction in runoff ranging from 64 to 71 percent (%). With this change in runoff volume, concentrations of pollutants did not change; therefore, pollutants were reduced by a like amount.

Although soil moisture sensors have been used in agricultural and research applications for many years, this technology only recently has been applied successfully in the landscape irrigation field. Initial attempts to use soil moisture sensors to control landscape irrigation were unsuccessful due to the state of the technology, maintenance requirements, and cost. Within the past several years, soil moisture sensor technology has advanced significantly with accurate and maintenance-free systems being offered by several companies at competitive prices. Recent study findings indicate water savings resulting from soil moisture-based smart systems are similar to those discussed above for weather-based systems (Allen, 1997; Cardenas-Lailhacar et al., 2005; DeOreo et al.; Mecham).

Water agencies throughout the country recognize smart irrigation control as an emerging tool to achieve landscape water savings and reduce nonpoint source pollution. When the first study began, the study team was aware of only a few

smart technologies. Today, over 20 smart irrigation control manufacturers exist, and the technology continues to evolve at a rapid pace.

In 2003, the Municipal Water District of Orange County approached the Bureau of Reclamation (Reclamation), Southern California Area Office, and requested an objective evaluation of weather-based residential irrigation scheduling technologies available to consumers. A technical review was performed to document the overall status of weather-based residential technologies and provide general descriptions of these products. The purpose of the review was to compile existing information and allow water agencies to quickly gain knowledge about the technologies for use in their residential incentive programs.

The results of the review were published in Reclamation's May 2004 Technical Review Report, *Weather-Based Technologies for Residential Irrigation Scheduling*. Since 2004, Reclamation has monitored the status of the products reviewed in the original report and researched many other smart irrigation scheduling products, including soil moisture sensor-based and commercial products. An updated technical review report, entitled *Weather and Soil Moisture-Based Landscape Irrigation Scheduling Technologies,* was published in August 2006, which included information on smart irrigation control products by 26 companies that were available as of June 2006. Second and third editions of the *Weather and Soil Moisture-Based Landscape Irrigation Scheduling Technologies Technical Review Report* were published in August 2007 and September 2009.

This fourth edition technical report includes information on smart irrigation control products by 23 companies that were available as of December 2011. One additional company has been added (Raindrip) and four companies' products are no longer available (Aquaspy, ECO Research, Lawn Logic, and Weathermiser). Previously reported product information (models, pricing, etc.) has been updated, with two exceptions; and minor revisions have been made throughout the document. Updated information was not available at the time of this report for products by The Toro Company and Tucor Inc. as noted in the product descriptions sections of the report. Reclamation intends to update the report on a 2-year cycle or as often as possible in an attempt to keep all information current.

Smart Irrigation Technology Overview

Smart irrigation control systems typically include either a stand-alone controller or an add-on device that interfaces with a conventional clock-type controller. The weather or soil moisture-based technologies incorporated into these devices allow them to function similar to a thermostat. Like a thermostat, the devices permit irrigation to occur when needed rather than on a preset schedule. Regardless of

the specific method or technology, the concept is for the appropriate irrigation quantity to be applied at the appropriate time.

Most of these systems are available in a variety of sizes appropriate for small residential to large commercial applications. For this report, a device with more than a 12-station (zone) capacity is considered large residential or light commercial. In most cases, light commercial products possess the same features as the residential products but have greater station capacity. Larger industrial type commercial products possess high station capacity and offer additional features such as flow sensing, surge and lightning protection, multiple master valve circuits, concurrent station operation, and other sophisticated features.

Computerized central control system type products are beyond the scope of this review. These consist of multiple "satellite" controllers that are controlled through a centralized computer system allowing for monitoring and control of multiple irrigation system parameters including flow rates, pressures, pumps, master valves, etc. from a single location. Several of these systems are mentioned since they are offered by the companies that sell stand-alone devices. Also, some of the stand-alone controllers reviewed possess central control system type features.

SWAT Testing

In an effort to set an industry conservation standard, the Irrigation Association® (IA) has organized the Smart Water Application Technologies™ (SWAT) initiative. This initiative functions as a partnership among water providers, the irrigation industry, and other related organizations with constituents from public entities and private companies. The first products for which testing protocols have been developed are for climatologically based irrigation control products. The current climatologically based testing protocol (8th Draft) was approved in September 2008 and has been implemented for testing. The current draft soil moisture sensor calibration protocol (3rd Draft) was released for public review in August 2011. This testing protocol combines Phase 1 Draft 8 and Phase 2 Draft 4 testing protocols into one testing protocol. Appropriate comments from the 30-day public comment period for Draft 2 have been incorporated into Draft 3, which will now be the testing protocol for soil moisture sensors and soil moisture-based controllers.

The Center for Irrigation Technology at California State University – Fresno (CIT) has been conducting SWAT smart controller bench mark testing. Climatologically based testing began in 2004. The testing is done in a laboratory environment using a "virtual landscape" that is subjected to a representative climate based on weather station data. The purpose of the testing is to evaluate the ability of a device to adequately and efficiently irrigate the virtual landscape without over watering. Although actual irrigation does not occur, the test

measures the irrigation quantities prescribed by the device for six different zones with varying site conditions (soil and plant types, ground slope, sun/shade, irrigation system, etc.) The test duration is for 30 consecutive days with total minimum rainfall and evapotranspiration (ET) of 0.4 and 2.5 inches, respectively. Testing results are summarized in performance reports (performance summaries and technical reports) which are posted at www.irrigation.org/SWAT/control_climate as test results are released by manufacturers. The summaries include percentage scores in the categories of Irrigation Adequacy and Irrigation Excess. The technical reports include details associated with these scores.

Soil moisture sensor calibration testing that began in 2003 is also done at CIT. Testing is in a laboratory environment to evaluate the sensors' ability to provide a consistent calibration curve or set points between drying cycles and between individual sensors. The manufacturer provides 20 sensors, and 3 are randomly selected for testing. Testing, performed over a 6- to 8-month period, is conducted on samples of fine, medium, and coarse textured soils. Certain samples are tested at various temperatures (-5, 15, 25 and 35 degrees Celsius [°C]) and with soil moisture water at conductivity levels at 2.5 and 5.0 decisiemens per meter (ds/m). Certain samples also undergo numerous wet/dry and freeze/thaw cycles in the development of calibration curves. Regression and confidence level analysis results are presented in the calibration reports that are posted at www.irrigation.org/SWAT/control_sensor as results are released by the manufacturer.

At the time of this report (July 2012), performance reports for 34 weather-based controllers had been posted, and calibration reports for 8 soil moisture sensors had been posted. SWAT's Technology and Promotions Working Groups are not apprised of products undergoing testing at CIT until the manufacturer releases test information to SWAT. Reports then are compiled, and both groups must approve them prior to posting. It is unknown how many of the other weather-based controller and soil moisture sensor products have been submitted for testing. Testing per the SWAT protocols and release of test results are voluntary by manufacturers. A few manufacturers have indicated concerns regarding the SWAT testing and reported they will not submit their products for testing unless certain protocol changes are made. Whether or not a device has been submitted for SWAT testing and the status of the testing, when a performance or calibration report is not posted, are discussed in this report only if this information was made available by the manufacturer.

While the above discussion is focused on irrigation controllers, the SWAT program also is intended to test other water-efficient product categories for residential and light commercial landscape use. Draft protocols have been

completed for add-on devices, rain sensors, and regulating sprinklers, and protocol development will begin in the near future for multiple stream, multiple trajectory sprinkler nozzles.

U.S. Environmental Protection Agency WaterSense Program

In 2006, the U.S. Environmental Protection Agency (EPA) introduced its voluntary public-private partnership WaterSense program. The mission of WaterSense is to protect the future of our Nation's water supply by promoting water efficiency and enhancing the market for water-efficient products, programs, and practices. WaterSense helps consumers identify water-efficient products by labeling those products that meet water efficiency and performance criteria. The program is in the process of developing a specification to label weather- or sensor-based irrigation control technologies, including weather-based controllers. WaterSense is evaluating the potential for adopting the SWAT protocols discussed above to certify these products.

On November 3, 2011, EPA published its specification for testing and certifying weather-based irrigation controllers; and manufacturers can now submit products for testing by independent laboratories. EPA considered the existing SWAT protocols and worked closely with the IA to develop the WaterSense specification for smart controllers. The specification applies to stand alone controllers, as well as add-on and plug-in devices that work with existing clock type controllers. EPA defines plug-in devices as add-on devices that are designed to connect only to a certain brand of controller. (See discussion under "Stand-Alone Controller Versus Add-On Device" in the "Weather-Based Control Product Features and Comparison Criteria" section of this report.)

Reported Water Savings

Most of the product descriptions in this report discuss water savings. In some cases, water savings associated with various studies and demonstration projects are discussed. In most cases, the water savings discussed are as reported by the manufacturer. It is discussed if water savings related study reports were submitted as part of this review and/or if the reports are publicly available. It is significant to understand that water savings can be calculated by numerous methods, and verification can be difficult.

In some cases, the reported water savings are average values for multiple installations; and in other cases, savings for a selected site are reported. Regardless of a product's reported water savings potential, actual savings will vary significantly from user to user depending on weather, irrigation system and

site conditions, and previous irrigation practices. It is imperative that weather conditions be considered when calculating water savings. A properly installed irrigation system (piping and sprinkler heads) with acceptable distribution uniformity is critical to realizing water savings and maintaining a healthy landscape.

No Rating of Products

No attempt has been made to rate the products relative to each other. Certain comparison criteria are discussed, and it is left to the reader to research further and determine which products may suit various applications most appropriately.

Weather-Based Irrigation Control System Principles

All of the weather-based products reviewed operate on the principle of scheduling irrigation as a function of weather conditions. Most of the products use real time or historic weather data to schedule irrigation based on evapotranspiration (ET), which is a function of weather conditions and plant type. ET is defined as the quantity of moisture that is both transpired by the plant and evaporated from the soil and plant surfaces.

The American Society of Civil Engineering's (ASCE) standardized reference ET equation parameters are maximum and minimum air temperature, net solar radiation, average vapor pressure, and average wind speed. Vapor pressure can be calculated from humidity, dry and wet bulb, or dew point data; and solar radiation can be derived from pyranometer or sunshine recorder data. The standardized reference ET equation is widely recognized as the best empirical method for estimating ET (Allen et al., 2005). Other less accurate equations also are used that require only temperature and solar radiation parameters, and solar radiation is sometimes estimated as an average value based on historic data for a given site latitude. The problem with using estimated solar radiation values is the significant variability due to cloud cover is neglected, and solar radiation is the single most important parameter in ET calculation using the ASCE standardized equation. Some of the products evaluated use these empirical ET equations in their scheduling algorithms. It is significant to consider which equation is used with regard to ET estimation accuracy, or what parameters are measured if the equation used is not referenced.

Each of the weather-based irrigation scheduling systems evaluated utilize microprocessing devices that calculate or adjust irrigation schedules based on one or more of the following parameter sets: weather conditions (temperature, rainfall, humidity, wind, and solar radiation), plant types (low versus high water use and root depth), and site conditions (latitude, soils, ground slope, and shade). Some of the systems are fully automatic, and others are semiautomatic. The semiautomatic systems typically require the user to enter a base daily irrigation schedule, and then the device determines the frequency (which days) irrigations occur or adjusts run times. Some of the semiautomatic system manufacturers provide guidelines for establishing the base schedule and others do not.

A significant factor in comparing the products that use real time weather data is the quality of the data used. The cost to install and maintain a complete weather station onsite to collect the data necessary to use the standardized reference ET equation is prohibitive in most cases. Two techniques are used to collect current weather data as alternatives to onsite weather stations. Specifically, irrigation

demand is calculated either using a limited set of onsite measurements or using a full set of weather station data from a remote site. There are tradeoffs associated with both methods.

If only a limited set of data is used to calculate ET with onsite sensors, the accuracy of the calculated ET may be poorer than ET calculated with a full set of weather station data. Conversely, if the remote weather station data used are not representative of the irrigator's site, the calculated ET value and/or rainfall sensing or measurement may not be accurate. Some of the weather station data being used may not be adequate for ET calculation. Specifically, some weather stations being used do not measure radiation but calculate it from other parameters; and some stations are not properly located for ET parameters data collection.

Certain products reviewed use onsite temperature measurements combined with historic monthly ET or solar radiation data in the daily ET calculation. The historic data used are a function of the site location. An obvious consideration with this technique is the accuracy of the historic data relative to a specific site. In one case, only five sets of data are available for the entire United States.

Several of the products reviewed calculate ET using a full set of remotely collected data from local weather stations or a network of weather sensors. The weather station data are collected from public and/or private weather stations. The weather station and sensor network data are processed by a centralized computer server and transmitted to the irrigation sites. There are ongoing service provider costs associated with the operation of the weather stations, sensor networks, computers, and information transmission systems associated with these products. These costs either are absorbed by water entities or are paid by the users.

In some cases, compelling study results were submitted by the manufacturers showing accurate ET calculation and/or significant water savings associated with their product as discussed under the product descriptions. In addition to the SWAT testing discussed above, a science-based evaluation of four of the weather-based products reviewed was conducted by the University of California Cooperative Extension in 2003; and the results are reported by Pittenger et al. (2004). Most studies to date have evaluated individual products rather than comparing the performance of multiple products. Given the general lack of data, it is difficult to draw conclusions about the overall performance of one product or technique versus another.

Weather-Based Control Product Features and Comparison Criteria

Significant weather-based controller product components and features are discussed below. The discussion also identifies different methods used to achieve similar results by the various products and associated advantages and disadvantages.

Installation

Although most of the manufacturers recommend professional installation and programming of their products, several indicate installation and programming of its residential models can be done by "do-it-yourself" type homeowners. Most of the individuals associated with residential product demonstration programs and pilot studies who were interviewed during this review expressed concerns about homeowner installation and programming. Based on the review of installation and programming instruction materials only, it appears some devices could be more difficult to install and program than others. The degree of difficulty to install any of the products can vary significantly depending on site-specific conditions. It appears that all of the commercial products should be professionally installed. Installation and programming instructions are available for many of the products at their Web sites. All potential customers should review this information when shopping for a device regardless of whether they plan to do their own installation and programming.

In the development of smart irrigation device promotion programs, water agencies should consider requiring professional installation or requiring users to attend workshops to receive training before performing self-installation.

Stand-Alone Controller Versus Add-On Device

The primary component of most of the products reviewed is an automatic irrigation controller in place of a traditional clock type controller. Alternatively, several of the products include a receiver or scheduler that is connected to an existing controller. In some cases, the lower cost of the add-on device is a significant attraction. Regardless of cost, the quality of an existing controller should be a factor when considering replacement. If the existing controller is a high quality unit with adequate features, an add-on receiver may be an attractive alternative. The level of automation is limited with some of these units relative to some of the stand-alone controller systems. Specifically, some devices only prescribe irrigation frequency or adjust preset run times and do not automatically

calculate run times. Certain add-on devices are designed to connect only with a certain brand of existing controller; and the EPA WaterSense Program defines these as plug-in devices.

Irrigation Schedules and Run Time Calculation and Adjustment

Some of the products reviewed will automatically generate irrigation schedules and run times for various zones as a function of sprinkler application rate, plant and soil types, slope and sun/shade conditions, and distribution uniformity. The ability of the automatic controllers to accurately generate an efficient schedule is dependent on the controller, the user's knowledge of the landscape parameters, and proper programming. Other devices require a base irrigation schedule with specific run times that are entered by the user. In which case, the user must manually calculate run times based on experience and/or guidelines provided by the manufacturer. Some of these controllers adjust the preset run times based on weather conditions, and others only control the irrigation run frequency. The product descriptions identify the manufacturers that provide guidelines for determining appropriate run times for the devices that require a base schedule. Automatic run time calculation can be a significant advantage if the required programming inputs are known and the controller calculates accurately.

Regardless of automatic or manual run times, many of the products have a fine-tune feature that allows adjustment of station run times by a percentage factor or by minutes giving the user the ability to compensate for inadequate run times.

Application Rates and Distribution Uniformity

Some of the products reviewed allow the user to enter actual sprinkler application rates versus preprogrammed rates based on irrigation type (spray, rotor, drip, etc.). Application rates can be measured by the user if not provided by the sprinkler manufacturer.

The irrigation system's distribution uniformity or efficiency factor (typically a percentage) describes the effectiveness of the sprinkler head coverage and reflects the quality and layout of the sprinklers. This setting allows the controller to compensate for low uniformity. The majority of a system with low distribution uniformity must be over irrigated for all areas to receive adequate water.

Irrigation Run and Soak Cycles

All of the stand-alone controllers reviewed provide multiple run and soak times to limit runoff. Some calculate them automatically by zone, based on soil and ground slope conditions, and others require manual programming. Of those that require manual programming and for the add-on devices, certain manufacturers provide guidelines or computer programs for calculating the times. Regardless of automatic or manual calculation, by zone multiple run/soak cycles ability is a very advantageous feature.

Landscape Establishment/Fertilizer and Syringe Programs

Some stand-alone controllers provide landscape establishment or fertilizer programs that allow for programming high irrigation quantities for a certain timeframe before reverting to the weather-based programming. Plant establishment programs can preclude over-irrigation and runoff occurring for extended periods due to a landscape contractor programming for establishing a new landscape.

Syringe programs are designed for installation and system testing purposes. The program provides a convenient means of executing a short run time for each station.

Crop Coefficients

All of the controllers that automatically calculate run times can use pre-programmed crop coefficients set by the manufacturer by plant type. Some provide the user the option of programming custom crop coefficients. This can be advantageous since crop coefficients typically vary geographically.

Rain Sensors and Gauges and Rain Interrupt or Delay

Most of the products reviewed include a rain sensor or rain gauge with the system or as an optional add-on accessory. These controllers have a rain interrupt and/or delay feature triggered by the sensor or gauge or an irrigation schedule adjustment feature that delays irrigation as a function of rainfall measured. Some of the products' only interrupt ongoing irrigation when significant rainfall is detected, and others initiate an adjustable preset irrigation delay period with or without the ability to interrupt ongoing irrigation. The more sophisticated systems interrupt ongoing irrigation and adjust the irrigation schedule based on the amount of rainfall measured. Although no documentation was reviewed for this report on

the measurement accuracy of different types of rain gauges and sensors, it is assumed that the tipping bucket type gauges are generally more accurate than hygroscopic type rain sensors that have an absorbent material that expands when wetted and electronic or conductor type rain sensors. The quality and accuracy of tipping bucket type gauges on the market also varies significantly.

Some of the receiver type systems have the ability to initiate a rain interrupt/delay or adjust the irrigation schedule based on rainfall detected or measured at a nearby weather station. Other receiver type systems use an onsite rain sensor or gauge that has the advantage of detecting or measuring rainfall that actually occurs at the site.

Other Sensors

Some of the products reviewed include standard or optional solar radiation, humidity, wind, temperature, and flow sensors. In addition to calculating irrigation demand using temperature data, some of the devices interrupt or delay irrigation when wind and/or temperature conditions are adverse to irrigation. Alternatively, some of the systems delay irrigation based on wind and temperature conditions measured at a local weather station. Most of the commercial products include flow sensor input terminals. In addition to monitoring to detect for high and low flows indicative of irrigation system problems, some of the controllers' factor flow conditions into automatic scheduling decisions.

Power Supply and Surge and Lightning Protection

With one exception, all of the stand-alone controllers include a power transformer that converts 110-120 volts of alternating current (VAC) to 24 VAC. The transformers are either hardwired inside the controller cabinet (internal), or plugged into a power outlet (external). The Alex-Tronix controller operates on a pulsed 9 volts of direct current (VDC) using battery power. The add-on scheduling devices operate on either 24 VAC, 9 VDC, or 12 VDC; and either receive power from the existing controller or from an external transformer. Most of the transformer devices include some type of current overload protection such as a fuse or breaker switch. Some controllers include lightning and/or surge protection or offer these as an optional feature. Surge and lightning protection limits damage to the controller's circuitry from transient voltage, current from the power source (surge), and from the valve circuits (lightning).

Station Circuit Rating, Wiring, and Terminal Wire Sizes

The compatibility of the existing electrical circuits (wiring from the controller to the station valves) should be considered in selecting a replacement irrigation controller. If the station wire terminals on the controller will not accept the existing wire, adapters must be used. Also, the circuit current capacity required for an existing system should be checked prior to installing a new unit. Reports from demonstration studies indicate installation problems associated with insufficient circuit capacity to operate some irrigation valves with high circuit resistance.

The traditional wiring system (circuitry) used for most controllers consists of a common and a dedicated wire from the controller to each valve and sensor. Some controllers use "two-wire" circuitry that consists of a single pair of wires connected to all of the valves and sensors in the system. These systems require the installation of a decoder device for each valve and sensor. Applications include large systems and linear systems (e.g., highway corridors) with large quantities of wiring required for traditional circuitry.

Clock Mode Operation

Most of the controllers reviewed will operate in a standard clock mode. Some of them can be programmed for clock mode operation by station. One of the controllers that receives a scheduling signal does not have clock mode capability. Therefore, if the signal subscription is cancelled, the controller must be replaced.

Display and Data Review

It is advantageous for a device to have a large, easy-to-read display that displays settings and data. Ideally, the data review control should be backlit and easy to use. It should display information by zone for run times, soak times, irrigation amounts, percent adjustments, ET and other weather information, watering window, and irrigation history.

Nonvolatile Memory and Batteries

All of the products reviewed have nonvolatile memory to protect their programming during power outages. Some of the products also include a backup battery for maintenance of the date and time during power failures. Those that do not include a backup battery provide this backup protection within the nonvolatile memory.

Warranty and Reliability

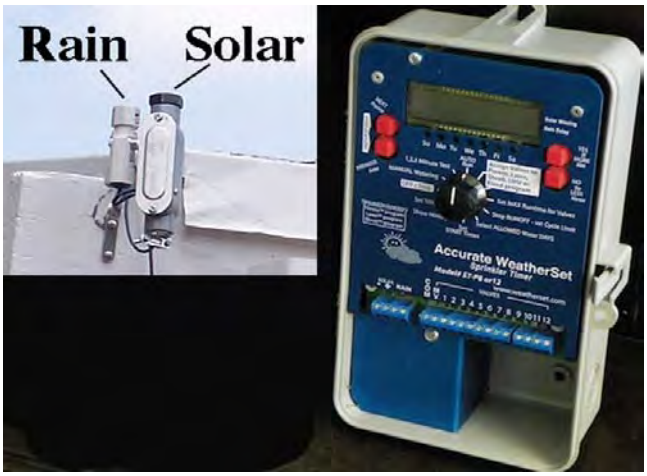
All of the products reviewed come with a warranty. Warranty periods are discussed separately in the review of each product. In some cases, the manufacturers' warranty periods vary for its different products. Although the warranty periods may or may not be indicative of the life expectancy of the products, in some cases there appears to be a correlation between the cost and overall quality of the product to the warranty period. It is assumed that the cost of a product somewhat reflects the quality of the construction materials and electronic components. Hence, the less expensive residential devices should not be expected to last as long and function as reliably as the more expensive residential and commercial products. Since most of the devices are relatively new products, it is difficult to speculate on how long they should last.

Depending on site conditions and maintenance, the weather sensors and other outdoor components may be vulnerable to degradation due to exposure to the elements. The availability of replacement sensors and their costs should be considered for those systems with onsite weather sensors.

Weather-Based Product Descriptions

The following product descriptions address operational characteristics and features and include discussions of available information from demonstration and pilot studies relative to documented water savings and operation. Each of the manufacturers was provided with copies of the product descriptions for their input prior to being incorporated into this report.

Accurate WeatherSet™



Accurate WeatherSet is located in Winnetka, California. WeatherSet has manufactured commercial weather-based irrigation controllers for landscapes, golf courses, and greenhouses since 1979. The company started development of its first residential controller prototypes in 2000 and began marketing the residential controllers in September 2001. All WeatherSet controllers utilize a solar sensor and rain sensor to automatically adjust irrigation schedules. The solar sensor, designed and fabricated by WeatherSet, measures solar radiation that is the major factor affecting the controller's ET calculation.

The WeatherSet controller is called the Smart Timer™, and it comes in 8-, 12-, 16-, 24-, 32-, 40-, and 48-station models. The Smart Timer is a stand-alone controller with no ongoing service costs and does not require communication with remote servers to obtain weather data or irrigation schedules. The controller calculates ET with input from an onsite solar radiation sensor. WeatherSet reports the solar sensor has functioned reliably in demanding environmental conditions to control greenhouse and outdoor misting systems since the late 1980s. Outdoor installation of solar sensor has performed for over 20 years in cold climates such as Wisconsin and high humidity climates like south Florida.

Operational Features

The WeatherSet controller calculates a daily ET estimate based on solar sensor SunFall™ measurements that are logged by the controller on a 2-minute

frequency. The sensor must be installed in a mostly sunny location to function accurately. Adaptive control logic allows the controller to function with some shading. From their work with commercial controllers, WeatherSet reports that SunFall reduces by about two-thirds from a clear day in summer to a clear day in winter, and that their five self-adjusting programs follow these changes.

The calculated ET information is combined with rain sensor data and user programmed information to schedule irrigation. To program the controller for automatic adjustments, the user assigns each station to one of three programs, which are labeled Flowers™, Lawns™, and Strubs™. The Flowers, Lawns, and Strubs programs are for shallow, medium, and deep-rooted plants, respectively. A fourth program, called LWU (low water use), will deliver water to California native plants that expect no rain from May through September and winter rains from October through April. A runoff limit, in minutes per hour, may also be entered for each station to stop runoff. The user enters a MAX Run time for each station, and the Smart Timer automatically adjusts the watering days and run times for each valve. The controller has a manual start function and an optional irrigation history review function. With the H-option, the controller keeps a running tab of total run time for each station.

The controller's hygroscopic rain sensor is an Ecologic RainBrain™. The sensor signals the controller to interrupt irrigation in its rain shutoff mode, and the rain sensor signals are also used by the controller for irrigation scheduling. The WeatherSet controller is preprogrammed to account for the duration that the rain shutoff circuit has been interrupted when scheduling irrigations.

The WeatherSet irrigation controller provides seven different runoff limits that are set for each station. A maximum cycle run time of 2, 4, 6, 8, 11, 15, 20, and unlimited number of minutes per hour may be set for each valve. The default cycle limit factor is 4 minutes per hour. As an example, if the controller calculates a total 12-minute run time for a station, this station will be irrigated in three 4-minute increments over a 3-hour period with the default setting. For stations that generate runoff, WeatherSet recommends the user measure the time required to cause runoff (using the manual run mode), divide the time by 2 and use that time to choose the runoff factor for the station. The runoff factor may be shut off to allow continuous watering when required. For example, valves controlling drip systems in LWU programs may best be watered with the runoff limit shut off.

Descriptions, Prices, and Warranty

Two Smart Timer residential controller models and seven outdoor commercial models are available. The indoor controller cabinets are constructed of aluminum with dimensions of 5.5 by 7.5 by 1.5 inches, and the indoor power transformer is an external plug-in type unit. The lockable outdoor cabinets are constructed of zinc plated steel with powder coating and stainless steel hinges, and they come in

three sizes. The respective dimensions for 8- to 12-, 16- to 24-, and 32- to 48-station models are 9 by 10.5 by 4 inches, 10.5 by 9.5 by 4.5 inches, and 14 by 12 by 4.5 inches. The outdoor models include internal power transformers. The 16-station and larger models include flow sensor connectivity, station circuit testing and surge/lightning protection features. The station circuit current rating for the indoor units is 0.75 amperes and 1.5 amperes for the outdoor units. All models' station circuit terminals will accommodate wiring sizes from 12 to 20 gauge. The controller's program memory is nonvolatile, and the time-keeping microprocessor chip uses a 3.3-volt coin-type battery that has a reported life of 10 years.

Low volume rebate program prices are summarized in table 1. (Retail prices are approximately 150 percent [%] higher.) The prices include the solar and rain sensors. The controllers are available directly from WeatherSet by telephone (818-993-1449) or e-mail (www.weatherset.com). The company plans also to distribute the product through select specialty irrigation contractors. The Smart Timer controllers come with a 3-year warranty.

Table 1 – Accurate WeatherSet Prices (Include Solar and Rain Sensors)

Controller Type	Model No.	Price
8-Station Indoor	ST8R	$148
12-Station Indoor	ST12R	$168
8-Station Outdoor	ST8C	$240
12-Station Outdoor	ST12C	$275
16-Station Outdoor	ST16C	$320
24-Station Outdoor	ST24C	$480
32-Station Outdoor	ST32C	$640
40-Station Outdoor	ST40C	$800
48-Station Outdoor	ST48C	$960
Solar and Rain Sensor Unit		$50
Irrigation History Function	H-option	$35

Installation

WeatherSet reports that 95% of homeowners included in the Municipal Water District of Orange County rebate program using the Smart Timer installed the controller themselves. Based on this, it appears that the typical homeowner can understand and program the WeatherSet Smart Timer. Technical support is available by telephone and through the company's Internet site. At this time, service by factory-trained contractors is limited to California, Oregon, Washington, and Colorado. WeatherSet reports this area will grow as their market expands. The installation and programming instructions, which include directions for locating the solar sensor, appear to be adequate and easy to follow.

Track Record, Water Savings, and SWAT Testing

Accurater WeatherSet controllers performed exceptionally relative to other products included in a multiyear study of ET controllers that were installed under funding from California Department of Water Resources (Aquacraft, 2009). The study results indicate a 33-percent average water savings; Accurate WeatherSet was one of only two companies that had statistically significant water savings. This study tested thousands of ET controllers purchased, installed, and programmed by homeowners and contractors and tested over 1 year in the field. The full report may be downloaded by Accurate WeatherSet's homepage.

SWAT testing results are not available for Accurate WeatherSet. Accurate WeatherSet has chosen **not** to submit its controllers for SWAT testing because it believes "SWAT testing does not test for water conservation and only tests for irrigation adequacy."

Another testing program in Texas shows that Accurate WeatherSet's controllers performed very well. To look for seasonal water conservation, the Texas testing program ran for 8 months in 2010; but it tested only one controller from each manufacturer; that controller was programmed by technical personnel rather than by homeowners and contractors. This testing program found that Accurate WeatherSet watered only 6% more than the Texas plants needed.

Alex-Tronix®

Alex-Tronix® is a division of GNA Industries, Inc. and is located in Fresno, California. This manufacturer of agricultural and turf irrigation controllers was established in 1977. Alex-Tronix currently has two battery-powered smart irrigation controllers and two add-on modules that can make any existing controller smart. The Enercon Plus and the Enercon Plus Jr are the battery powered stand-alone controllers, while the Universal Smart Module® (USM®) and the Aqua Saver® are add-on modules.

The Enercon Plus has been on the market since 2007 and is lithium battery powered. It is guaranteed to provide 25,000 valve cycles with a single lithium battery pack and can operate valves up to 2,000 feet away with 14-gauge wire. It can operate the Rain Bird TBoss or Hunter latching solenoids directly or most other valves with an available latching solenoid. It is modular with four stations per module from 4–24 stations and mounted in a stainless steel pedestal with an internally mounted temperature sensor. A standard rain switch (not supplied) input is available. The Enercon Plus has been SWAT tested.

The Enercon Plus Jr is a new battery powered controller that is also guaranteed to provide 25,000 valve cycles with one lithium battery pack. The smart algorithm and irrigation schedule programming is identical to the Enercon Plus. This model is available with 4, 8, or 12 stations; nonmodular; and is housed in a shorter, stainless steel pedestal than the Enercon Plus.

The Enercom Plus uses "Set it, Don't Sweat" programming. For smart use, the controller is programmed with its summer irrigation schedule, and the local ZIP code is entered. Starting the next day, it adjusts the summer station run times according to the location, time of the year, and current conditions by the percentage of the summer run times. It has four programs with four starts per day with timing in 1-minute increments up to 24 hours.

Operational Features

The programming capability of the Enercon Plus Jr is identical to the Enercon Plus with four programs and four starts per day and 1-minute increments up to 24 hours. Both are stand-alone controllers and can accommodate 12- through 18-gauge wire. They both operate nominally 12-VDC pulsed latching solenoids.

The USM has been available for about a year and is an add-on that attaches to the station outputs of any indoor alternating current (AC) powered controller with up to eight stations. It "learns" the station run times and modifies them according to the time of the year, location, and current conditions with an automated water budget percentage of the summer run times. It comes with a hard-wired temperature sensor that requires outdoor exposure. The USM uses the same algorithm as the Enercon Plus and the Enercon Plus Jr and has also been SWAT tested. A standard rain switch (not supplied) is recommended for use.

The Aqua Saver is also an add-on device that can make any existing controller smart or comply with municipal restricted watering schedules. This model attaches to the output common line of any existing conventional AC-powered controller, with any number of stations. It accumulates the water budget percentages until 100% is reached and then allows the controller to irrigate. This model is housed in an outdoor enclosure and includes a 25-foot hard-wired temperature sensor. Another function

of the Aqua Saver is that it can make existing irrigation controller observe municipally restricted watering schedules. Programming the ZIP code makes existing controllers smart. Selecting a watering schedule makes the controller comply with watering restrictions and enables it to automatically adjust itself to seasonal restriction changes.

Descriptions, Prices, and Warranty

The Enercon Plus base four-station unit wholesale lists for $2,112, with each additional four-station module listing at $205, making the list price range from $2,112 to $3,137. The four-station Enercon Plus Jr lists for $1,399, the eight-station module for $1,599, and the 12-station module for $1,799.

The USM wholesale lists for $249, and the Aqua Saver lists for $399. All models are available through wholesale irrigation distributors. The Enercon Plus and the USM qualify for smart controller rebates in many areas.

All four models have freeze shutdown capability and have an onsite temperature sensor with estimated solar radiation based on location. All the models have a 2-year warranty. Rain switches are not provided, but recommended.

Installation

Alex-Tronix reports installation and setup to be easy and that installation of the residential Smart Clock™ and USM controllers may be accomplished by most homeowners. The installation time and setup required for an inexperienced user is reported to be 2 hours. An experienced professional should be able to install and setup the Smart Clock in 1 hour or less.

Installation of the Enercon Plus and the Enercon Plus Jr is similar to any pedestal-mounted field controller on a concrete slab. The USM is normally placed next to the existing controller for easy access to the output terminals. The Aqua Saver can be used indoors or outdoors or inside a field controller pedestal. The temperature sensor drops to ground level inside the sweep L, and the two white wires break the valve common line. If the Aqua Saver is used indoors, the temperature sensor is routed to a location where a good ambient temperature reading can be taken, preferably in a shaded area such as under an eave.

Detailed step-by-step installation and setup instructions are included in the owner's manual, which is available with the controller and at www.AlexTronix®.com.

The Alex-Tronix battery-powered controllers are compatible with Hunter and Rain Bird latching solenoids as well as the Alex-Tronix latching solenoid. In general, they are compatible with nearly all currently manufactured valves.

Both the smart technology and the restricted watering schedule automation are multiple patented technologies.

Track Record, Water Savings, and SWAT Testing

Alex-Tronix performed a 5-year analytical study comparing their Set It, Don't Sweat It® temperature budget calculated irrigation demands at 25 locations to nearby California Irrigation Management Information System (CIMIS) station reference ET. Results of the study are summarized in the graph shown in figure 1. The plot shows monthly percentage of peak temperature budget demand compared to the monthly percentage of peak CIMIS reference ET.

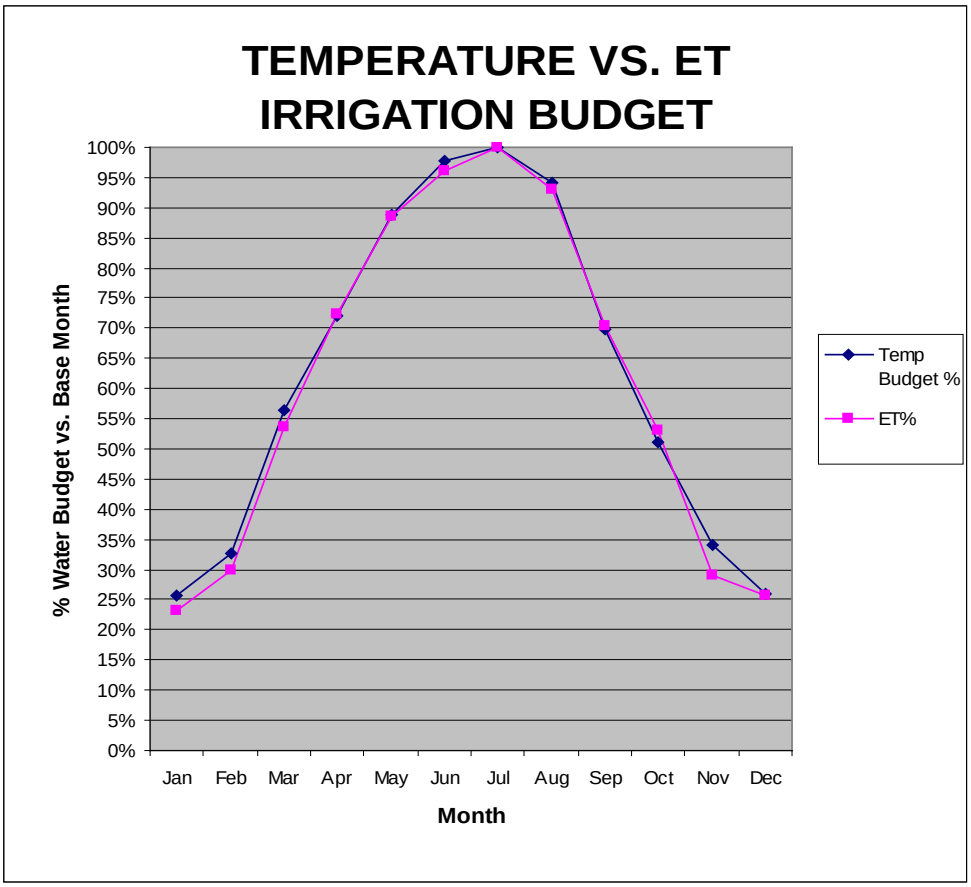


Figure 1 – Alex-Tronix temperature budget compared to CIMIS ET.

The city of Indian Wells, in cooperation with the Coachella Valley Water District, recently completed a 1-year study to determine how much water could be saved in a commercial application with a combination of water saving methods. In addition to using Alex-Tronix Enercon Plus controllers, some drip irrigation was used, along with more efficient sprinklers and some artificial turf. Results showed that about 75% of the water and the water costs were saved over the

previous year. Currently, a larger study is being conducted by Indian Wells using the Alex-Tronix Smart Clock® and the Enercon Plus.

The Alex-Tronix Smart Clock, Universal Smart Module, and Enercon Plus controllers have completed SWAT testing, and performance summary reports are posted at the Irrigation Association Web site. These are the first battery powered controllers to complete SWAT testing. The USM had not completed SWAT testing at the time of this writing

Aqua Conserve®

Aqua Conserve, Inc., located in Riverside, California, has been in business since 1996. The company manufactures five residential ET controller models, a large variety of commercial ET controllers, and controller replacement panels and accessories. The Aqua Conserve controller operation is based on adjusted historic ET data, with the adjustment made as a function of onsite temperature sensor readings. Combined rainfall/temperature sensors are included with some controller.

Aqua Conserve's residential and commercial controllers have been on the market for approximately 15 years. Three indoor residential models are available, which accommodate 6, 9, or 14 stations; and the two outdoor residential models accommodate 8 or 12 stations. Aqua Conserve offers the ET8 Series commercial controllers, which come in wall mount and top entry pedestal models and replacement panel options for other manufactures' housings. The commercial controllers are outdoor units housed in stainless steel and will accommodate from 16 to 48 stations. Aqua Conserve's wall mount commercial models come in 16-, 24-, and 32-station models. The ET8 ULTIMO pedestal commercial controller series offer 16-, 24-, 32-,40- and 48-station models. ET8 Series replacement panels are available in 16, 24 and 32 stations for wall mount units. ET8 ULTIMO pedestal replacement panels are available in 16, 24, 32, 40, and 48 stations.

Operational Features

Aqua Conserve's ET controllers are preprogrammed with 17 individual historic ET curves, each representing geographic regions within the States of Arizona, California, Washington, Nevada, New Mexico, Utah, Colorado, and Texas. The

user enters one of the seventeen regions into the controller. The controller then makes automatic seasonal changes to the run times based on the historic ET curves and daily changes based on the onsite temperature sensor. Peak summer temperature run times are entered into the controller for each station by the user. Aqua Conserve provides suggested run times that are specific for plant types and for either spray or rotor sprinkler heads. Suggested run times for drip systems are not provided. The suggested run times are available at Aqua Conserve's Web site (www.aquaconserve.com) for each of the 17 geographic regions mentioned above. Refinements to the suggested run times to compensate for soil, slope, and shade conditions also are provided. Further refinement of run times can be made based on visual observations.

The various Aqua Conserve® controllers provide four programs that allow the user to specify different watering days for different stations. Four start times are available for each program to allow for refining total run times into multiple cycles and soak times to compensate for soil and slope conditions to limit run off. The maximum station run time is 99 to 240 minutes for the various models. There is a separate feature that will provide up to 480 minutes for drip irrigation. The minimum irrigation frequency is once per week for low water plants. A new plant/landscape establishment option (two additional nonadjusting programs) allows added watering by station for a specified period (1–60 days) to establish new landscaping, and then automatically reverts to the ET-based schedule. The controllers include one to four station circuits that may run concurrently with all the other stations to control a master valve, drip system, or other accessories. On residential and small commercial controllers, other stations may not run concurrently. On the ET8 ULTIMO controllers, up to six stations on other programs may run concurrently.

The actual irrigation run times for a given day are dependent on the programming described above and an automatic adjustment made by the controller, which is based on the measured onsite average temperature and historic ET data. The controllers have an accumulation feature that eliminates short cool period run times. The short cool period run times are accumulated until 50% of the July run time has been reached, and then irrigation will occur.

Descriptions, Prices, and Warranty

All Aqua Conserve controllers come with a wired rain/temperature sensor. The combined sensors signal the controller once every second, initiating the rain delay (shutoff) function when significant rainfall is detected. In the rain delay mode, the controller will not re-initiate irrigation for at least a 24-hour period after significant rainfall has ceased. Depending on the duration of

the rain event, the rain delay can cause the controller to interrupt irrigation for up to 5 days. The user also has the capability to trigger the controller's rain delay feature manually.

Residential controllers have nonvolatile memory and a 9-volt backup battery. The backup battery powers the controller clock in the event of a power outage for the residential and basic commercial units. ET8 Series controllers use an incorporated real time clock to maintain system time during power outages. The controller terminals accept 12- to 18-gauge wiring.

The residential indoor controllers provide four programs and four start times, and the outdoor models provide four programs and four start times. Both have one station circuit that may run concurrently with all the other stations to control a master valve or drip system. The indoor models are constructed of plastic, and the outdoor controllers are housed in lockable stainless steel cabinets. The indoor models' dimensions are 8.3 by 6 by 2 inches, and the outdoor models' dimensions are 9.5 by 10.5 by 4.5 inches. The controller panel features dial type controls and a two-line liquid crystal display (LCD). The indoor controller models have a station circuit current capacity of 0.5 amperes, and the outdoor models' station circuit current capacity is 0.75 amperes. All residential indoor controllers are powered through an external transformer (included with purchase). Residential outdoor units are hardwired to the electrical system and supplied with an internal transformer.

All commercial controller models are housed in lockable stainless steel wall mount or top entry cabinets. The top entry units are designed for placement on a concrete foundation and are vandal resistant. The ET8 Series commercial controllers include all of the features of the basic models, plus additional master circuits, flow meter monitoring, and other features.

The basic wall mount commercial models are powered through an internal 24-VAC transformer (included with purchase) and provide four programs and four start times. The basic top entry commercial models are powered through an internal transformer and include four programs and four start times. The wall mount cabinet dimensions are 9.5 by 10.5 by 4.5 inches, and the top entry dimensions are 34.5 by 17.5 by 11.5 inches. All of the basic commercial models' panels feature dial type controls and a two-line LCD display. The station circuit capacity for the basic commercial controllers is 0.75 amperes, and one station circuit may run concurrently with all the other stations to control a master valve or drip system.

All of the ET8 ULTIMO pedestal models are powered through an internal transformer and provide four programs and eight start times. The top entry dimensions are 34.5 by 17.5 by 11.5 inches. The ET8 ULTIMO controllers provide for manual, semiautomatic and timed operations. The ET8 ULTIMO controllers can also detect leaks and excessive flows, notify the operator, or shut

down the affected zone or master valve. Other ET8 ULTIMO features include water meter connections, current and historic programming information access and start time stacking for all programs. The station circuit capacity for the ULTIMO controllers is 2.0 amperes, and they have four station circuits that may run concurrently with all the other stations to control a master valve or drip system. In addition, up to six programs can run concurrently.

All products are available directly from Aqua Conserve by telephone, email and through a limited number of local distributors. Controller retail prices are summarized in table 2. All models come with combined rain/temperature sensors. There is no ongoing service cost associated with these controllers, and all Aqua Conserve® products come with a limited 3-year warranty.

Table 2 – Retail Prices for Aqua Conserve Controllers

Controller Description	Model No.	2011 Price
6-Station Indoor Residential Wall Mount	ET-6	$250.00
9-Station Indoor Residential Wall Mount	ET-9	$285.00
14-Station Indoor Residential Wall Mount	ET-14	$335.00
8-Station Outdoor Residential Wall Mount	ET-8B	$560.00
12-Station Outdoor Residential Wall Mount	ET-12B	$640.00
16-Station Commercial Wall Mount	ET8-16	$970.00
24-Station Commercial Wall Mount	ET8-24	$1,195.00
32-Station Commercial Wall Mount	ET8-32	$1,400.00
16-Station ET8 ULTIMO Top Entry Pedestal	ET8-16SP-1	$2,575.00
24-Station ET8 ULTIMO Top Entry Pedestal	ET8-24SP-1	$2,775.00
32-Station ET8 ULTIMO Top Entry Pedestal	ET8-32SP-1	$2,950.00
40-Station ET8 ULTIMO Top Entry Pedestal	ET8-40SP-1	$3,200.00
48-Station ET8 ULTIMO Top Entry Pedestal	ET8-48SP-1	$3,525.00
16-Station Replacement Panel Wall Mount	ET8-16RPX	$795.00
24-Station Replacement Panel Wall Mount	ET8-24RPX	$885.00
32-Station Replacement Panel Wall Mount	ET8-32RPX	$975.00
16-Station Replacement Panel Pedestal	ET8-16RSP	$1,100.00
24-Station Replacement Panel Pedestal	ET8-24RSP	$1,175.00
32-Station Replacement Panel Pedestal	ET8-32RSP	$1,250.00
40-Station Replacement Panel Pedestal	ET8-40RSP	$1,325.00
48-Station Replacement Panel Pedestal	ET8-48RSP	$1,400.00

Installation

The findings of a 2003 study by the University of California Cooperative Extension indicate installation and programming of an Aqua Conserve residential controller is relatively simple and that the controller performed well (Pittenger

et al., 2004). Professional installation of commercial controllers is recommended. Aqua Conserve® provides toll free telephone technical support and provides technical information on their Web site. Aqua Conserve will participate in training contract installers upon request. Aqua Conserve reports that their support system meets or exceeds industry standards and the installation and programming instructions reviewed for this report are complete and easy to understand.

Track Record, Water Savings, and SWAT Testing

Reported outdoor water use savings for pilot studies with Aqua Conserve controllers, which were performed by the city of Denver, Colorado; Sonoma, California; and the Valley of the Moon Water District in Northern California were 21, 23, and 28%, respectively (Addink and Rodda, 2002).

SWAT test performance summaries and technical reports for Aqua Conserve controllers are posted at http://www.irrigation.org/swat/control_climate/.

Calsense®

Calsense, started in 1986, is a Carlsbad, California, based company that manufactures water management systems for large commercial customers. Since its startup, the company has specialized exclusively in water management systems using weather-based irrigation, real-time flow monitoring, moisture sensors, and a wide variety of communication technologies. Calsense markets its products to municipalities, school districts, universities, transportation departments, and other high volume landscape irrigators. Calsense provides free onsite training with its products and emphasizes their commitment to customer service, support, and successful utilization of its products.

The Calsense ET2000e controller functions either as a stand-alone unit or as a field controller component for their water management central control system. The Calsense Command CENTER Software is the central component of the system. Although the ET2000e is fairly new, its basic design is unchanged from its predecessor, the ET2000, and favorably improved from the ET1, originally introduced in 1993.

Operational Features

The ET2000e can automatically adjust daily irrigation schedules with onsite reference ET measurements from the optional Calsense ET gauge or with historic average monthly ET. CIMIS-based historic monthly average values are preprogrammed into the controller, or the user can enter monthly values. Measurements from an optional tipping rain bucket are incorporated into the irrigation schedule calculation to account for effective precipitation. Irrigation can be interrupted in the event of rain and high winds with the use of optional switch type sensors. A soil moisture sensor can be used with the ET2000e also and override the decision determined through onsite ET.

In the ET scheduling mode, the user programs the controller's run times based on field knowledge for the time of year and soil moisture content. This base schedule is adjusted daily as a function of weather conditions. Monthly ET adjustment percentage factors are fine tuned for each station depending on plant types, sun/shade conditions, and soil moisture content. Crop coefficients can be entered as well for each month for seven different kinds of plant material. Cycle-and-soak times are programmed manually into the base schedule to minimize runoff.

The Calsense ET gauge is an automated atmometer for estimating reference ET for turf (tall fescue). The covered ceramic evaporator at the top mimics solar energy absorption and vapor diffusion resistance of irrigated plants. A reservoir below the evaporator holds distilled water. The evaporator draws water from the reservoir at approximately the same rate that grass removes water from soil by ET. Water drawn from the reservoir passes through a calibrated measuring vial and corresponds to 0.01 inch of ET. Electronic circuitry components sense when the vial is empty. It is then immediately refilled, and the 0.01-inch event is marked by a switch-closure type pulse that is transmitted to the controller. The controller uses a 28-day ET table to calculate run times based on station precipitation rates. The ET gauge operates on 24 VAC supplied from the controller. An optional stainless steel vandal proof enclosure is available for the ET gauge.

The Calsense Weathersense option is available in the Command Center software version 4.4.8 and later and allows the user to get real-time ET data from local weather stations via the Internet without the need for onsite weather stations. This information can be shared to the ET2000e controllers in the field through central control communications and setting up a task to do so within the software. This option is provided at no charge.

Descriptions, Prices, and Warranty

The ET2000e provides a complete water management system as a stand-alone field controller, which can easily be expanded into a central control system.

The ET2000e is available in 6-, 12-, 16-, 24-, 32-, 40-, and 48-station models. The controllers have two additional outputs for master valve and pump circuits. In addition, the controllers may be ordered with hardware and software for four additional 24-VAC outputs for the operation of lights, gates, water features, etc., at no additional cost. These outputs are controlled independently from the irrigation programs.

The controller has seven regular programs and several syringe/propagation programs. A maximum number of start times or repeats per station is determined by station total minutes (programmed or ET calculated) and by a fixed set run time per cycle and a fixed set soak time between cycles. The cycle-and-soak times are set manually. The user selects 7-, 14-, 21-, or 28-day watering schedules to accommodate watering requirements, and no-water days can be designated by program. Programs can operate simultaneously based on the system capacity of the mainline and flow management.

A Calsense Model FM flow meter can be connected to the controller to continuously monitor flow through the irrigation mainline and learn each station's flow rate automatically when irrigation occurs. This feature detects and alerts the user to mainline breaks, no flows, high flows (due to broken risers and pipe) for each individual station, and low flows due to pressure drops, malfunctioning valves, and or clogged heads.

An optional remote control receiver board is integrated into the ET2000e allowing the user to activate valves and view operational details without going to the controller. The Calsense Remote Sense remote control transceiver allows the user to view valve-on, area description, flow rate, electrical use, and remaining time.

A water volume budget feature determines when the monthly actual usage, with projected usage, will exceed the programmed monthly budget and alerts the user before the month ends. This capability helps maintain water rates and keeps staff accountable to a water management program. Table 3 and figure 2 below present data from an actual site, which demonstrate the use of the water budget feature, and shows the correlation between historical and measured ET. The adjusted budget shown is the result of the automatic scheduling performed by the controller. The controller also possesses a laptop computer interface for field uploads and downloads so that detailed reports can be produced and potential expansion to a central system can be evaluated.

Table 3 – Calsense ET2000e Water Budget Feature Data

Date	# of Days	*CONTROLLER HISTORICAL ET	ACTUAL ET TABLE	ADJ %	**CONTROLLER BUDGET GALLONS	***ADJUSTED BUDGET GALLONS	****USAGE ACTUAL GALLONS	SAVINGS GALLONS	PERCENT SAVED
Jun-2010	30	5.07	7.51	48 %	435,162	644,160	270,832	373,328	**58 %**
Jul-2010	31	6.92	9.59	39 %	593,950	823,214	645,462	177,752	**22 %**
Aug-2010	31	6.01	9.25	54 %	515,844	794,553	629,791	164,762	**21 %**
Sep-2010	30	3.70	7.31	98 %	317,103	626,371	499,373	126,998	**20 %**
Oct-2010	31	1.90	3.61	90 %	162,763	309,706	79,657	230,049	**74 %**
Nov-2010	30	0.59	1.73	194 %	50,542	148,669	3,147	145,522	**98 %**
Dec-2010	31	0.24	1.03	332 %	20,559	88,713	0	88,713	**100 %**
Jan-2011	31	0.00	0.00	0 %	0	0	0	0	**0 %**
Feb-2011	28	0.29	2.08	621 %	24,842	179,166	0	179,166	**100 %**
Mar-2011	16	0.44	1.72	288 %	38,024	147,565	0	147,565	**100 %**
TOTAL	289	25.15	43.83	74 %	2,158,789	3,761,563	2,128,262	**1,633,301**	**43 %**

ET values and usages set to zero when budget is zero
*County and city settings for controller are Salt Lake and Salt Lake City
** Controller Budget was Calculated at 125% of Controller Historical ET.
*** Adjusted budget uses actual ET to modify the controller budget.
**** Usage based on: Test usage, manual usage, scheduled usage, noncontroller usage, radio remote usage

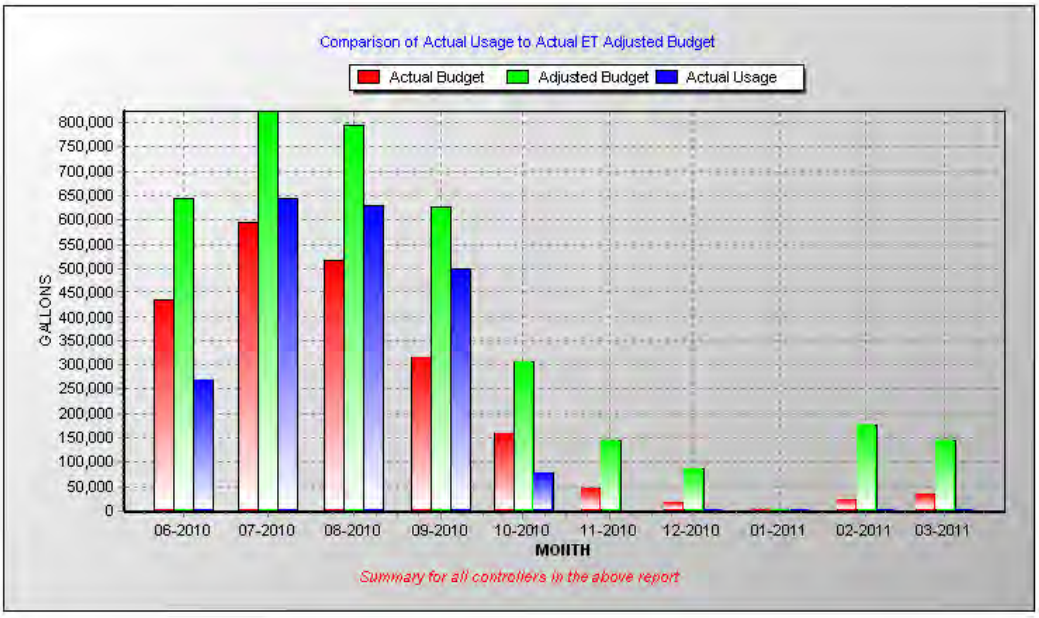


Figure 2 – Graph of Calsense 2000e water budget feature data.

Extensive current and historic irrigation information can be viewed at the display or downloaded from the controller. The controller monitors and keeps a record of all site water usage by month for up to 2 years. Scheduled irrigation usage is recorded on a station-by-station basis and on a total controller basis for the current month and the previous month. Unscheduled water usage (pressing the manual water or test key) and noncontroller water usage (e.g., quick-couplers, manually bleeding valves, etc.) is recorded separately showing how the water is being applied.

The ET2000e is a weatherproof wall mount unit and the cabinet is powder-coated, rolled steel. The front panel includes an ergonomic key layout and a large 16-line

by 40-character LCD display (English or Spanish). The cabinet dimensions are 11.38 by 11.13 by 7.25 inches. The controller has nonvolatile memory, and the clock maintains time during power outages without the need for a backup battery. It is powered through an internal transformer. The controller accepts 14-gauge wire size, and the station current capacity is 1.5 amperes. Optional AC power line overload protection consists of a sealed unit suitable for outdoor installation and carries full Underwriters Laboratories (UL) approval. Optional transient (lightning and surge) protection is provided with the TP-1 board. The transient protection board can be purchased either with or without an outdoor cabinet. The ET2000e will detect, alert, and identify open and shorted circuits in field wires and solenoids. The affected station is skipped until repaired.

Calsense products are available from many distributors located throughout the United States. A list of these distributors is available from Calsense upon request (1-800-572-8608 or www.calsense.com). Current prices for all ET2000e models and certain accessories are summarized in table 4. All Calsense products come with a 5-year warranty.

Table 4 – Calsense Products Price Summary

Controller Description	Model No.	Price
6-Station ET2000e Controller	ET2000e-6	$1,075
8-Station ET2000e Controller	ET2000e-8	$1,400
12-Station ET2000e Controller	ET2000e-12	$1,945
16-Station ET2000e Controller	ET2000e-16	$2,150
24-Station ET2000e Controller	ET2000e-24	$2,550
32-Station ET2000e Controller	ET2000e-32	$3,100
40-Station ET2000e Controller	ET2000e-40	$3,515
48-Station ET2000e Controller	ET2000e-48	$3,950
ET Gage	ETG	$1,375
ET Gage Controller Interface	-G	$435
Rain Gage	RG-1	$575
Rain Gage Controller Interface	-RG	$435
Wind Gage	WG-1	$545
Wind Gage Controller Interface	-WG	$435
Soil Moisture Sensor	1000-S	$199
1-inch Brass Flow Meter*	FM1B	$575
1.5-inch PVC Flow Meter*	FM1.5	$490
Transient Protection	TP-1	$265
Enclosure for TP-1	TPB	$199
AC Line Protection	TP-110	$165

[1] Other brass and polyvinyl chloride (PVC) flow meter sizes are available up to 3-inches.

Installation

Calsense recommends professional installation of the ET2000e, and installation times vary significantly depending on site conditions.

Water Savings, SWAT Testing, and WaterSense Certification

Although Calsense has not participated in any outside studies or demonstration projects, its track record speaks for itself. During Calsense's 20 years of existence, they have developed a large database on its products' performance and customer success.

Calsense submitted data for this report prepared by their in-house research and development department showing average water savings of 22 and 33% for two typical installations. Calsense reports an overall average water savings rate of approximately 20–40% depending on past water usage and project history.

Although the controller models have evolved, the Calsense ET scheduling technology has been in place since 1992. Many of the Calsense systems installed since that time continue to function today. Several articles written by end users in Calsense's niche market testifying to the successful operation of their Calsense systems were submitted for this report.

Calsense provides potential clients with a reference list of all past and current users so that they can listen to their personal and professional experiences. In some cases, Calsense loans controllers to potential clients to demonstrate its system.

The Calsense ET2000e was SWAT tested in 2007, and the associated technical report and performance summary are posted at http://www.irrigation.org/swat/control_climate/.

Calsense plans to pursue WaterSense certification in the near future.

Cyber-Rain™

Cyber-Rain, Inc. is based in Encino, California, and began business in 2006. The Cyber-Rain XCI is a stand-alone, weather-based, wireless irrigation controller that accesses weather forecasts via the Internet and automatically adjusts irrigation

scheduling. The controller is scheduled and monitored via the Internet through a reportedly easy-to-use and intuitive interface. An unlimited number of controllers can be remotely scheduled, operated, and monitored through a single Internet account. A free app is available to operate and monitor Cyber-Rain controllers via a smart phone. Water usage and savings are tracked and reported.

Operational Features

The Cyber-Rain XCI can be installed as a new controller or one that replaces an existing clock type controller. Cyber-Rain supplies a small device called an Access Point that is plugged into a router so that Cyber-Rain can access the Internet. The Access Point communicates with an unlimited number of Cyber-Rain controllers through its own two-way wireless network. The standard 2.4 gigahertz 802.15.4 radio can communicate from up to 450 feet while the longer range 900 megahertz radio can reach up to 2 miles. Users can schedule, operate, and monitor their Cyber-Rain controllers through any Internet-connected computer or smart phone. Schedules and user commands are automatically sent via the Internet to the Access Point, which wirelessly communicates them to the Cyber-Rain controller. All irrigation activity is wirelessly communicated back from the controllers to the Access Point and is reported back to the user. The XCI is programmed on a computer, and all scheduling operations can be performed through the Web user interface as shown in figure 3 below. In addition, users have the option to run valves using the buttons on the controller.

Cyber-Rain offers 8-, 16- and 24-station controllers. For larger requirements, additional controllers can be added and operated from a single Access Point. Multiple Access Points can be managed from a single Internet Account, allowing the central controller of multiple sites.

Valve circuits are connected to the controller via a pluggable terminal block harness, and the controller is mounted on the wall. After the Access Point is plugged into a router, a wizard automatically finds nearby controllers and guides the user through a short setup process. Custom zone names can be entered by the user as text such as “Rose Bushes” or “Front Grass.” Cyber-Rain’s Smart Scheduling Wizard will prepopulate a watering schedule using information about the user’s landscape and location. This schedule can be modified easily by adjusting the number of watering minutes per day across four start times. Restricted watering schedules, such as limiting watering to certain hours of the day or blocking watering on certain days are also available.

Figure 3 – Cyber-Rain Web interface example.

After the initial setup and schedule entry, no further user intervention should be required. Cyber-Rain automatically checks the weather forecast every few hours on Weather Underground. Irrigation schedule adjustments are calculated based on temperature and humidity and wirelessly transmitted to the controller. If rain is forecasted, irrigation is suspended until it stops raining. An optional rain sensor also can be easily attached.

Weather adjustments are transmitted automatically—the user does not need to be online nor does a computer need to be on. If the Internet is not available, the system reverts to irrigation schedule adjustments based on a built-in Watering Index. The Watering Index is based on historical temperature, precipitation, and other weather patterns (the potential evapotranspiration or "PET") for a given geographical area.

The XCI includes a cycle and soak feature to eliminate or reduce run-off when landscapes are sloped. Individual zones can be put on a temporary hold for a

user-defined number of days. An antifreeze feature automatically suspends all watering when the temperature forecast approaches the freezing point. Cyber-Rain maintains a log of all water usage and displays a variety of water usage and saving reports and graphs.

The XCI includes built-in diagnostics features. The current on each valve is measured during watering with email alerts automatically sent if the current is outside the typical range and automatically shut-off if it is too high. The temperature within the controller is similarly monitored and controlled. Communication between the controller and the personal computer (PC) is checked every hour. If an optional flow meter is attached, the controller can detect breakages or blocks causing abnormal flow patterns, automatically alerting the user and shutting off any broken valves.

Cyber-Rain can be operated and monitored from a smart phone using a free app. Users can manually turn on/off valves and check the system status. Users can also take pictures of each zone, which are automatically uploaded into the Cyber-Rain software for easy zone identification.

Description, Prices, and Warranties

Cyber-Rain XCI controllers are available in 8-station, 16-station or 24-station XCI models. A wireless Universal Serial Bus (USB) Access Point device that connects to the user's router is needed to communicate between the Cyber-Rain Web-based software and the XCI controllers. If additional zones are needed, another controller can be installed and operated from the same Access Point. Additional Access Points also can be added to a user's account and managed through the same software. In this way, multiple sites and large properties can be centrally controlled from any Internet-connected computer.

The XCI is constructed of weather-proof NEMA box and is suitable for outdoor installation. Its dimensions are 12 by 12 by 6 inches, and it includes a 4-line by 20-character LED display panel. Stainless steel and indoor-only enclosures are also available. Station circuit capacity is 1A, and the controller accepts wire sizes up to 14-gauge solid or 16-gauge stranded. The XCI has nonvolatile memory to retain programming during power outages, and its clock is maintained during power outages with a super capacitor and a real-time clock chip. Surge and lightning protection is provided with metal oxide varistors (MOVs) and extra inductors on each circuit.

The pricing of Cyber-Rain XCI professional controllers vary depending on the number of zones and range of the radio (table 5 below). Optional antennae are available to further increase the range between the Access Point and XCI controllers.

Table 5 – Cyber-Rain XCI Price Summary

XCI Component	ListPrice
8 zone controller – 2.4 GHz	$850
8 zone controller – 900 MHz	$1,500
16 zone controller – 2.4 GHz	$1,000
16 zone controller – 900 MHz	$1,800
24 zone controller – 2.4 GHz	$1,150
24 zone controller – 900 MHz	$2,100
Access Point – 2.4 GHz	$400
Access Point – 900 MHz	$900

Cyber-Rain has a 30-day "satisfaction or money back" guarantee, plus a 2-year limited manufacturer's warranty. There are no monthly fees or additional charges for basic software functionality. Premium reporting and alerts are available for a modest monthly fee. Software and firmware updates are free and can be downloaded from the Cyber-Rain Web site.

Installation

Professional installation is recommended for commercial installations, particularly those with longer-range radios and/or antennae. Professional installation is not required for residential, indoor models.

Track Record, Water Savings, and SWAT Testing

Cyber-Rain reports systems installed during January 2008 through May 2009 reported an average water savings of 38%. No study data are available on the Cyber-Rain XCI. Cyber-Rain was SWAT tested in February/March 2008, and performance reports were posted in April 2008. Cyber-Rain is an EPA WaterSense Partner and has submitted its products for WaterSense Certification.

ETwater Systems™

ETwater Systems, Inc., based in Novato, California, is a manufacturer of weather-based irrigation controllers for the residential and commercial markets. ETwater controllers operate under its centralized weather-based irrigation management system. ETwater™ was incorporated in 2002 and began manufacturing controllers in March 2005. The company manufactures and distributes its system throughout the United States.

The ETwater system schedules irrigation based on ET and precipitation data received from existing weather stations and user-programmed information associated with specific landscape features. Currently, the ETwater system uses a data network of over 9, 000 public and private weather stations, most of which are located in populous areas. ETwater controllers are sold in eight-module increments from 8 to 48 stations. The two-way communication service provides features similar to a central control system. For example, the Global Changes feature is suited to the needs of a water manager responsible for multiple controllers at multiple sites. A site can be organized into groups of stations with similar landscape characteristics; then, a few keystrokes will make changes that apply to all stations within the group. For example, if a water manager needed to change the run time for all 200 turf stations on a large commercial site to comply with drought restrictions, it would take a couple of minutes to create a group that contains all turf stations, enter a new water budget percent, save the change, and update the schedules for all 200 stations. For larger sites, where it can be difficult to squeeze all the required run times into the time available, the Multi Valve Watering feature can be used to dramatically reduce the length of the water window by scheduling multiple valves to water simultaneously. This can conserve water by ensuring that irrigation is completed during the night.

To improve water management decisions, ETwater Manager includes a reporting tool that provides custom reports of irrigation activity, performance, and settings. For any site or controller, for any time period, it takes a few clicks to create and view a Run Time Report on minutes of irrigation, by controller, in relation to weather (reference ET). The Over/Underwatering Reports display a simple graph that flags controllers or stations that may need attention, along with help text that offers specific suggestions for resolving problems online. The Landscape Report summarizes all landscape settings, by station, for quick reference online or in the field.

In late 2011, the company introduced an enhanced version of ETwater Manager including:

At-A-Glance Dashboard: A new dashboard feature provides a single, at-a-glance view of alarms, controller status, and schedules across all controllers on all sites.

Water Budgeting Toolkit: Calculates water usage and provides graphs and reports to track a site's water usage against monthly water budgets to identify over-watering.

Troubleshooting: A new filtering tool provides instant access to critical data such as high flow faults and faulty valve wiring.

Bundled Configuring: A new configuration tool allows managers to configure multiple zones with similar landscape characteristics at one time.

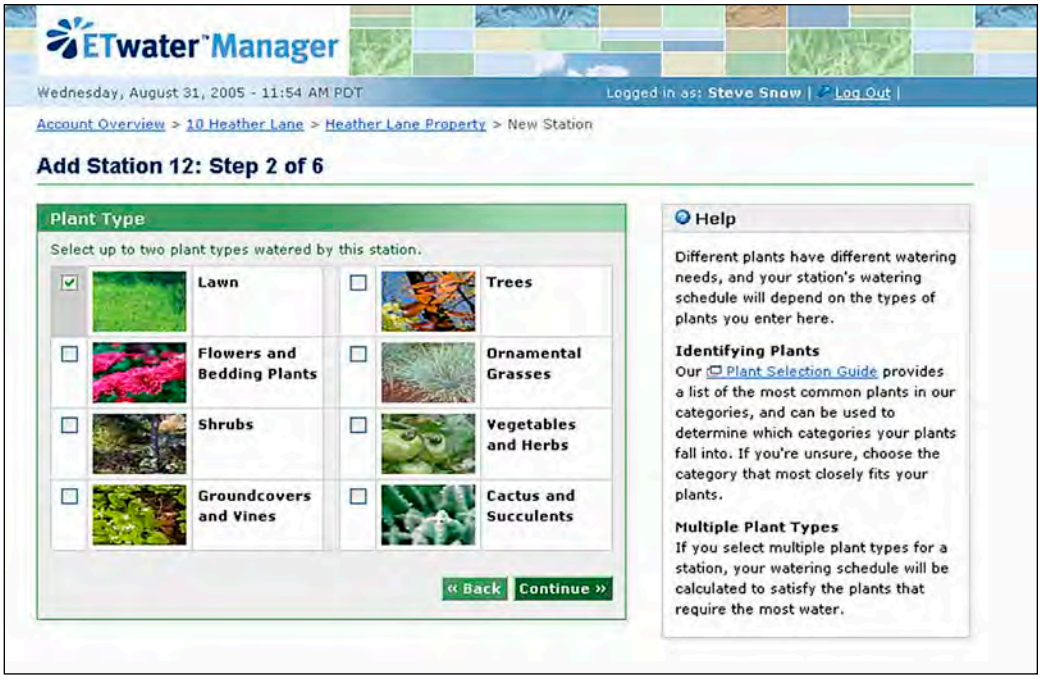
Customized Alerts: Alert preferences can be customized for each user's preferences.

With the ETwater System, ET and precipitation data are automatically retrieved daily from the weather station network by the ETwater's host server. The data are obtained from existing weather stations that provide localized weather, most often available at the town or even the suburb level in most metro areas. A WeatherBug® weather station can be installed onsite, and the onsite data is utilized via the ETwater server as discussed below. In addition, weather data from certain other public and private weather stations can be used.

Operational Features

The ETwater server automatically processes the ET and rainfall data in combination with the user-programmed landscape information to develop irrigation schedules. The user enters the landscape information from any computer with an Internet connection via the ETwater Web site (www.etwater.com); however, a personal computer is not required at the installation site for the system to function. In commercial applications, the user may access special screens that enable selection of multiple accounts and thereafter select any controller or zone for each account. Scores of accounts may be accessed remotely from any computer at any time. ETwater's central server architecture means that ongoing feature enhancements are automatically available to all customers, without requiring hardware upgrades.

Communication between the user's controller and the ETwater server may be by wireless connection or land-based telephone link. The ETwater central server communicates with each field controller on a daily basis to send any required watering adjustments. In addition, all ETwater controllers send a 30-day log of all watering activity so users can review their watering history on the ETwater Web site. ETwater controllers can operate independently if communication to the server is temporarily interrupted. In such a case, the controller continues to operate using the latest schedule stored in memory and then revises the schedule once communication is reestablished with the server. The ETwater controller can accommodate schedules of any duration and frequency, including schedules that require watering on a very infrequent basis (e.g., every 30 days).



To enter landscape information, users go to the ETwater Web site and log into their account using a user name and password. The program interface to enter the site-specific landscape information is set up with a choice of either Windows®-based pull-down menus or click-on picture options (e.g., plant type pictures), and it is intuitive and easy to use. The program is well organized and covers a comprehensive set of landscape factors, including plant type, irrigation type or optional application rate, soil type, slope, root depth, sun exposure, and distribution uniformity. User-defined sprinkler precipitation rate (PR) and distribution uniformity (DU) may be entered, or default measures may be selected in the absence of precise PR and DU information. A wide selection of plant types is available. Multiple plant types may be selected for one station, and the program will automatically set the watering schedule based on the plants with the highest water requirement. Irrigation types available include spray, rotor, high efficiency matched precipitation rate rotors (e.g., MP Rotator®), impact, stream spray, drip emitter, bubbler, and subsurface inline tubing. The default distribution uniformity factor is 55% for popup spray heads. The user may specify customized distribution uniformity for any zone. Default root depths for all plant types are provided but may be changed.

The user may also enter nonirrigation days, adjust the total station run times by a percentage factor, and initiate manual irrigations by station at the controller. The user may review system and irrigation history information on the Web site. The ETwater setup program includes help screens to answer questions common to first time users. Once the user becomes familiar with the program, an advanced setup mode may be used that offers a more efficient means of programming.

Adjustments to specific site factors may be made at any time via the ETwater Web site. Site factor changes will generate new irrigation schedules.

The ETwater controller also has an offline programming feature that allows users to manually set a watering schedule for each station. This feature is intended for use during periods when phone service is temporarily unavailable (e.g., a newly constructed home prior to sale). Offline programming may be performed at the controller using the keypad and the two-line LCD display. The manual start mode also may be initiated at the controller. ETwater's objective is for the system automatically to generate and execute irrigation schedules. The need for program modification in the field typically is limited.

ETwater provides email alerts when there is a failure of communication between the field controller and central server. It also provides email alerts when manual adjustments are made on the field controller—the user may review such changes and override them remotely from any PC if desired.

ETwater Systems reports that the irrigation scheduling algorithms it uses are based on current state-of-the-art horticultural science. The program reportedly incorporates all landscape factors needed to accurately determine soil moisture depletion and irrigation scheduling. ETwater uses a different algorithm for scheduling sprinkler and drip irrigation stations. The company's proprietary algorithms automatically generate daily schedules for each station with run and soak times based on a station's sprinkler application rate, soil intake rate, and slope conditions. The station run/soak cycles for each irrigation period remain constant, based on replenishment of a 50% plant root zone moisture depletion level. Alternatively, it is possible to override the system's cycle and soak times to accommodate unique field situations. The "User Entered Cycle and Soak" option permits entry of a maximum cycle time and/or a minimum soak time. Irrigations are delayed until a soil moisture depletion level of 50% is calculated, based on the measured daily ET and rainfall. If the user desires more frequent watering, he may adjust the depletion level downward.

If the optional flow monitoring and control feature has been selected, the controller will bypass valves where an alarm condition is read and close a master valve in the event of a catastrophic flow. The user receives an email alert for high flow, low flow, no flow, and leak conditions. Desired high and low flow limits are set online, and the controller "learns" individual station flow during normal watering. ETwater controllers are compatible with Data Industrial flow sensors or their equivalents.

The optional QuickDraw™ mobile control application lets users control watering via smart phone. The QuickDraw "Water Now" feature will manually water a station from 1 to 60 minutes. "Instant Suspend" suspends a current watering event for one or all controllers until a specified date. Plus, from any computer

with Web access, QuickDraw users gain instant control to start/stop stations, apply/remove suspensions, and "Connect Now" to update schedules immediately.

The ETwater Manager Service includes daily watering schedule updates, telecommunication and wireless access charges, ability to remotely monitor and adjust the controller from any PC, email alerts in case of onsite problems, and online and phone-based customer service.

The ETwater computer interface method of programming and monitoring the system is reportedly comprehensive and user friendly. The water use monitoring option also should be attractive to progressive water agencies interested in quantifying water savings.

Descriptions, Prices, and Warranty

All ETwater controllers are currently constructed of weatherproof fabricated aluminum enclosures with a key lock. In addition to the regular station circuits, the controllers provide a master valve/pump start circuit. The station circuit capacity is 1.1 amperes, and the station terminals will accept 12- to 20-gauge wire.

The use of a standard rain sensor (approximately $59) will cause circuit interruption and suspend irrigations when significant rainfall occurs. Remote monitoring features for commercial applications include email notification of any adjustments to a controller; such as suspend, power interruption, failure to connect to the Internet, increase in percent watering for any zone, and flow monitoring. For response to these occurrences, the user may remotely re-set or adjust these features from its PC.

An ETwater controller sells for approximately $1,200 to $3,000, depending upon the number of stations and the communication method—an 8-station telephone-connected unit sells for about $1,200, while a 48-station wireless-connected unit sells for $3,000. The ETwater controller will accommodate popular brands of rain sensors or rain gauges.

ETwater offers panel replacements for certain nonweather-based models of many popular brand controllers, including Rain Bird,® Rain Master,® and Irritrol.® These panels make installation very rapid and sell for less than a full ETwater controller, yielding savings on both installation labor and equipment.

In 2011, ET Water introduced the ETwater HermitCrab, a unique device that upgrades most brands of conventional controller to the same ETwater Web-based technology

used by other ETwater controllers and panel replacements. The HermitCrab plugs into the conventional "host" controller via the host's remote control access port. The customer configures stations online with ETwater Manager, and the ETwater server generates a custom irrigation schedule. Via wireless modem, the weather-adjusted schedule is downloaded daily from the server to the HermitCrab, which signals the host controller to open and close valves.

Typical "plug & play" installation time is under 10 minutes because there is no need to rewire valves or make a new power connection. For irrigation managers who are responsible for numerous brands of controllers, installing HermitCrabs offers a common-platform solution to efficiently manage hundreds of controllers of various brands at multiple sites from one Web-based ETwater Manager account.

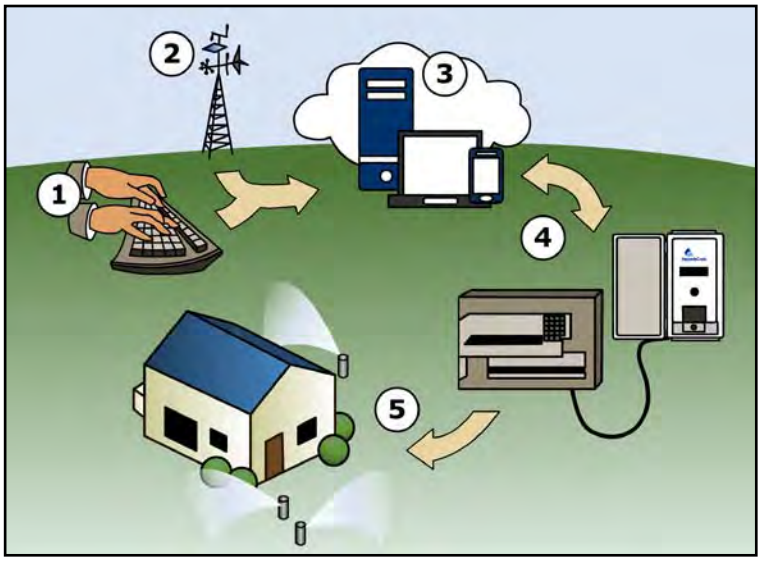
The HermitCrab is compatible with most brands of controllers that have a remote access port, including Hunter, Irritrol, Rain Bird, Rain Master, and Superior/Sterling. List price for a HermitCrab is $850, which includes the first year of ETwater Manager wireless service.

The ETwater Manager Service includes daily watering schedule updates, telecommunication and wireless access charges, ability to remotely monitor and adjust the controller from any PC, email alerts in case of onsite problems, and online and phone-based customer service. The annual service fee ranges from $75 for telephone connections to $199 for wireless connections. Optional flow monitoring and control service is $59 annually. Optional annual QuickDraw service is $99 per user, plus $10 per controller.

Since telephone or wireless communication allows two-way information transfer, ETwater can manage the information received from individual controllers. This may be beneficial to water agencies by allowing analysis of customer water use data.

Installation

ETwater Systems reports that its controllers do not require professional installation, although the company recommends professional installation and will provide or recommend factory-trained individuals or



irrigation contractors to install all units. A typical professional commercial installation should take 1–3 hours, which includes a site assessment and discussion of the assessment with the user. Typical residential installations can be completed in less time. The professional installation/consultation cost is estimated to be $75–$225 depending on location, size, and other site conditions. Technical support is available by toll free telephone (800-685-5505), in addition to the support provided on the company's Web site.

Water Savings, SWAT Testing, and WaterSense Certification

The ETwater system has completed SWAT testing, and a performance report is posted on the Irrigation Association Web site. ETwater also plans to submit its product for Water Sense certification testing.

ETwater submitted information from three of its large commercial customers documenting significant water savings. ETwater reports overall average water savings in the range of 20–50%.

Hunter®

Hunter Industries was established in 1982 and is headquartered in San Marcos, California. Hunter manufactures and distributes a full line of landscape irrigation products worldwide. Hunter offers two weather-based control products to the industry, the ET System and Solar Sync. Both systems consist of weather sensors that gather onsite weather data, and each includes a module that provides irrigation scheduling for Hunter controllers. The ET System is compatible with Hunter's SRC, Pro-C, and ICC controllers while the Solar Sync is compatible with Hunter's X-Core, Pro-C, ICC, I-Core, and ACC controllers. The Solar Sync and ET System are not compatible with other brands of controllers. Depending on the controller, the Solar Sync and ET System are suitable for residential and commercial applications.

The ET System creates an irrigation program automatically based on weather conditions measured onsite. The irrigation programs are operated via the compatible irrigation controller and run automatically on water days and at start times set by the user. Compatible controllers include Hunter models SRC, Pro-C, and ICC controllers. The irrigation schedule is based on the ET Sensor's

calculated ET value; and programmed plant, soil, slope, sun/shade, and sprinkler type information provide the basis for calculation of the irrigation schedule. The result is a new, revised irrigation program every water day, based on the weather conditions measured onsite. Once installed, each zone is scheduled from the ET module, rather than the controller itself.

The Solar Sync is designed to be a simple to use, easy to install, and affordable option for weather-based irrigation control. The user programs their controller as they normally would, and only a few programming steps are required to set up the Solar Sync module. Similar to the ET System, the Solar Sync adjusts irrigation programs automatically based upon onsite weather conditions measured by the sensor. The Solar Sync module receives ET information from the sensor, and the module adjusts programming daily through the seasonal adjust feature on Hunter controllers. Compatible controllers include Hunter's X-Core, Pro-C, ICC, I-Core, and ACC controllers.

Operational Features

The ET Sensor calculates ET by its daily measurement of solar radiation, air temperature, and relative humidity. The accuracy of the ET calculation can be improved with the addition of an optional anemometer (ET Wind), along with an automatic wind shutdown capability. The ET System also will shutdown irrigation if the air temperature drops below 35 degrees Fahrenheit (°F). The ET Sensor includes a tipping bucket type rain gauge, which measures rainfall to one-hundredth of an inch. The user programs the ET Sensor to stop irrigation in progress at a specific rainfall depth and at a percentage of the rainfall is accounted for in the irrigation schedule. The ET Module calculates specific run times for each zone individually. The ET Module also possesses an optional wilt guard feature (Wiltgard™) that triggers irrigation when extreme temperatures occur if enabled by the installer. The user-selectable WiltGard triggers emergency irrigation (regardless of time of day) when the ET System determines that plants are threatened by monitored conditions.

To program the ET module, the user first enters the type of controller used, date and time, water days, and start times. Then the site condition settings are made for each station. These settings consist of plant type, soil type, sprinkler type, percent ground slope, sun/shade, and plant maturity. The rain sensor setting is programmed for the minimum amount of rainfall that will cause interruption of irrigation.

Available plant type settings include numerous types of grasses, shrubs, ground covers, vines, trees, perennials, and desert plants. Alternatively, a custom crop coefficient setting can be used in place of plant type. Available soil type settings consist of sand, sandy loam, loam, clay loam, silt, clay, and silty clay. Soil type selection determines both infiltration rate (used for cycle-and-soak calculation, along with the slope setting) and water-holding capacity of the soil. Sprinkler type can be set to rotor, spray, drip, bubbler, or custom. The custom option allows for entering a sprinkler application rate (0.01-inch-per-hour or 0.254-millimeter-per-hour increments). The ground slope setting is by percentage. Available sun/shade settings consist of full sun, part shade (75% sun), part sun (50% sun), and full shade. The maturity setting is set to either new or established. With maturity set to new, the irrigation quantity is doubled and then decreases linearly to the normal or established rate based on the plant type. The ET source setting can be set to manual to override automatic ET calculation. The wilt guard feature is programmed either on or off.

The ET module is wired into the controller's SmartPort; and once programmed, it uses the controller's Program "A" to create and run irrigation on water days (except with the Hunter ACC controllers where it works independently of any programs). Each day, the ET System evaluates the current soil moisture depletion level, ET rate, plant type (crop coefficient and root zone), and whether the next day is an allowable watering day. Then, the system performs a "look ahead" on the allowable watering days to see if not watering at that time would deplete soil moisture critically by the time a watering day is scheduled. Irrigation will not occur, however, if the calculated quantity is below the minimum irrigation amount, to prevent shallow watering. The calculation for minimum sprinkler run time is based upon the soil type and capacity.

The Solar Sync sensor calculates ET by daily measurement of solar radiation and air temperature. The sensor also integrates Hunter's Rain-Clik and Freeze-Clik functionality to provide shutdown of the irrigation system during rain and/or freeze events. The ET data from the sensor is sent to the Solar Sync module that reprograms the controller's seasonal adjustment value daily, thus adjusting all of the station run times in all programs automatically. From a programming standpoint, the user needs to program the controller for peak summer watering requirements. Only a few steps are required to program the Solar Sync module:

1. Set the current time/day.
2. Select the Hunter controller model.
3. Set the region in which they are located (corresponds to regional ET).

The Solar Sync has a global adjustment feature that makes it easy for the user to adjust the module to fine tune irrigation scheduling. The Solar Sync module also includes a No Water Window feature that allows the user to set a period of time

during the day for which irrigation will not occur. Hunter also offers a wireless version of the Solar Sync that offers a range of 800 feet between the sensor and receiver.

Descriptions, Prices, and Warranty

The ET module is housed in a weatherproof plastic cabinet, and its dimensions are 6 by 4 by 1.8 inches. The ET Sensor standard model dimensions are 10.5 by 7.3 by 12 inches, and the ET Sensor with ET Wind standard model dimensions are 11.5 by 7.3 by 20 inches. The ET module operates on 24 VAC from the controller's SmartPort and requires no additional AC wiring. It has nonvolatile memory and a replaceable 10-year lithium battery.

The Solar Sync module is housed in a water resistant enclosure that includes a rubber cover to protect it from the weather. The Solar Sync module is 5 by 1.5 by .75 inches. The Solar Sync sensor is based upon Hunter's existing Rain-Clik sensor design and includes a metal mounting arm and gutter mount. The sensor dimensions are 3 by 8 by 1 inches. The Solar Sync module has nonvolatile memory and uses a replaceable lithium battery for backup timekeeping.

The ET System and Solar Sync are available from Hunter distributors worldwide, and further information can be accessed at Hunter's Web site. The retail price for the ET System basic model is $475, and the optional ET Wind is an additional $480 (table 6). The retail price for the Solar Sync is $135. The price range for compatible Hunter controllers is from $150–$1,250. The ET System and Solar Sync come with a 2-year warranty.

Table 6 – Hunter Products Price Summary

Description	Price
ET Systems (base)	$475
Optional Wind	$480
Solar Sync (Pro-C, ICC, I-Core)	$135
Wireless Solar Sync (Pro-C, ICC, I-Core)	$235
Solar Sync (X-Core, ACC)	$110
Wireless Solar Sync (X-Core, ACC)	$210

Installation

Installation and programming of the ET System and Solar Sync can be performed by the user or irrigation professional. The module for both products can be wall-mounted near the controller, and the sensor is installed in the field. The Solar Sync module is designed to be wall-mounted next to the controller or can be mounted inside the Hunter PCC controller, making it easier for the user to install

and wire to the controller. The X-Core and ACC controllers have the Solar Sync software internally and do not require the Solar Sync module. The ET Sensor is provided with 100 feet of wire, which is the maximum distance the sensor can be installed from the module. The Solar Sync's compact sensor design makes it easy to attach to the eave of a house or on a gutter. The sensor is provided with 40 feet of wire, which can be extended a maximum of 200 feet. The wireless version of Solar Sync has a maximum range of 800 feet. The ET System and Solar Sync owner's manual are available at Hunter's Web site (hunterindustries.com). They contain detailed installation and programming information.

Water Savings, SWAT Testing, and WaterSense Certification

Hunter has had 10–15 years experience with ET-based irrigation. Both Solar Sync and ET Systems use the Modified Penman-Monteith equation. In creating the ET System's crop coefficients for the various plant type settings, Hunter generally has followed the principles of Water Use Classification of Landscape Species as prescribed on the State of California Office of Water Use Efficiency Web site (www.owue.water.ca.gov/index.cfm). Use in other States may require some adjustment for crop coefficients, which can be customized in the ET System.

The ET System and Solar Sync have completed SWAT testing, and associated performance summaries and technical reports are posted at http://www.irrigation.org/swat/control_climate/. Hunter is seeking WaterSense certification for its products.

HydroPoint™

HydroPoint Data Systems Inc., of Petaluma, California, is the provider of WeatherTRAK® Smart Water Management products and related services for commercial and residential applications. HydroPoint, incorporated in 2002, offers WeatherTRAK products that combine a wireless daily ET data service with its Scheduling Engine™ irrigation software to update watering schedules at each landscape valve.

All WeatherTRAK controllers integrate proprietary Scheduling Engine software proven to match the Irrigation Association standard for "Best Water Management Practices" in calculating irrigation run times and schedules. This, combined

with daily collection and modeling of local weather conditions, is intended to ensure that the controller applies the right amount of water when and where it is needed.

HydroPoint initially introduced a one-way communication residential series controller line called the WeatherTRAK ET plus series available in 9-, 12-, 18-, and 24-station models in both indoor and outdoor models in early 2003.

HydroPoint released an Internet-enabled commercial controller application called the WeatherTRAK ET Pro^2 Smart Water Manager Series in station counts from 12 to 48 stations.

This WeatherTRAK ET Pro^2 Smart Water Manager Central product line integrates flow monitoring and management with remote visibility, programming and system alerts for light commercial, and commercial landscape irrigation applications via any desktop, laptop, or smart phone The WeatherTRAK system collects weather data each day from over 44,000 weather stations across the United States, including the National Oceanic and Atmospheric Administration (NOAA Fisheries) network, State and county networks, and private weather stations. HydroPoint reports that the WeatherTRAK system integrates advanced climatologic modeling techniques (developed at Pennsylvania State University) and proprietary software (called WeatherTRAK ET Everywhere™) to determine site-specific weather conditions down to a 1-square-kilometer resolution across the entire continental United States. HydroPoint reports that this methodology of data collection, modeling, and sending is the most independently studied and validated product offering within a standard deviation of .01 inch of daily ET.

The HydroPoint Climate Center validates the weather data and daily transmits calculated ET through three paging carriers for one-way users and one carrier for two-way users to each controller. Three paging servers provide overlapping coverage of the United States to ensure signal reception to WeatherTRAK controllers located anywhere, while the two-way carrier covers 95% of populated areas.

Operational Features

The WeatherTRAK ET controller independently calculates irrigation schedules for each valve station on a site. The controller does not use preset irrigation schedules input by the user. Instead, it asks a series of questions to define the site-specific and environmental variables that influence watering requirements. The controller is programmed by entering the following station-specific information: sprinkler type, sprinkler efficiency, precipitation rate, plant type, root depth, soil type, microclimate (sun or shade), and slope (including if the valve is at the top, middle, or bottom of the slope. The schedule for each station is adjusted daily according to the local weather data received via the ET Everywhere service.

With these inputs, the WeatherTRAK controller calculates an irrigation schedule for each irrigation valve. Soil moisture depletion tracking, triggered at a 50% depletion level (along with daily ET updates), allows the controller to adjust schedules as the weather changes. The number of water days, minutes, and cycles (with appropriate soak times between cycles) are generated automatically and change as weather and water need fluctuates. The WeatherTRAK controller has an 8-week scheduling window. This allows for infrequent watering of low water use or native plants.

Programming options for all WeatherTRAK controllers include sequential stacking of overlapping start times or the ability to run multiple programs simultaneously depending on the product series. The WeatherTRAK ET controllers have a manual feature providing any amount of time setting for plant establishment or to check the irrigation system on a valve by valve basis. An adjust feature provides percentage adjustments (in 5% increments) to increase or decrease the run time for any station. The controller accepts rain, rain/freeze, and flow sensors. Independent master valve and pump start functions are also available on the commercial series line to address site-specific requirements, including the type of master valve. A rain pause mode allows the user to shut off irrigation for up to 14 days during or after rain for the residential series and up to 200 days for commercial series. HydroPoint also can be contacted to automatically "rain pause" controllers and groups of controllers using the wireless data service. Nonwaterering days can be selected. A "help" mode alerts the user to the HydroPoint Customer Service toll free telephone number (800- 362-8774) to answer questions and walk users through any situation occurring on the site.

Other features include inputs for crop coefficient values, community water restrictions (odd/even or selected watering days), and unlimited programs. The independent station adjust feature allows for individual station adjustments from -50 to +25% in 5% increments. All WeatherTRAK controllers have heavy-duty surge protection on the 24-VAC output board. WeatherTRAK controllers have nonvolatile memory and do not require a backup battery to maintain date and time information. The controller terminals will accept 10- to 22-gauge size wiring. In some cases, an optional antenna is required to receive the scheduling signal for one-way models when installed in metal vandal-resistant enclosures.

Descriptions, Prices, and Warranty

The WeatherTRAK ET plus is an indoor/outdoor residential controller. Its cabinet is of extruded high-impact plastic with dimensions of 8.6 by 11 by 4.7 inches. Programming is done with the programming dial, copy button, two selector knobs, and three-line LCD display. The internal power transformer for the 6-, 9-, 12-, 18-, and 24-station models includes a 2.0-ampere fuse, has a maximum total circuit capacity of 1.5 amperes, and the individual station circuit current capacity is 0.375 amperes. All residential models include a manual valve test program to identify open valves and short circuits as a standard feature. One

year of WeatherTRAK ET Everywhere subscription service is included with the purchase of all residential models. Additional multiyear subscriptions can be purchased, up to 10 years.

The WeatherTRAK ET Pro^2 Smart Water Manager Series is offered in a wide range of enclosures and station counts based on application and customer needs. This is further augmented by a large number of chassis or preassembled components on a frame that can be installed easily in an existing enclosure for retrofit applications. One-way ET Pro^2 models can be upgraded easily to two-way Internet remote management models with a hardware and software field update.

The ET Pro^2 Smart Water Manager is compatible with the WeatherTRAK.net service that allows Internet-based irrigation control 24 hours a day, 7 days a week (24/7) with a secure Web-hosted service. Any feature that can be viewed on the controller can be viewed and remotely monitored or changed from www.weathertrak.net, a secure Web application. With WeatherTRAK.net, the user has remote visibility to single or multiple controllers from any location with access to the Internet. A single user or multiple users can be assigned to multiple controllers as needed. The HydroPoint customer service team provides initial setup assistance. WeatherTRAK.net delivers instant notifications of adjustments made in the field and enables fast, one-click synchronization. Through a wireless modem, www.weathertrak.net transmits real-time updates and system alerts to the user's personal computer, network workstation, laptop, smart phone, or cell phone.

WeatherTRAK controllers are available from HydroPoint and local distributors. A distributor search engine is accessible via the HydroPoint Web site, www.hydropoint.com. WeatherTRAK residential controllers come with a 3-year warranty; toll-free telephone customer service is available Monday through Saturday during business hours; and online customer service is available 24/7. WeatherTRAK commercial models come with a 5-year warranty, unlimited access to www.weathertrak.net Central Internet Management software, and toll-free, bilingual telephone customer service at (800) 362-8774, Mondays through Saturdays.

A full listing of WeatherTRAK ET controllers and accessories can be obtained from www.hydropoint.com. Current prices for popular WeatherTRAK controller models are included in table 7. For current pricing on all controller models and accessories, call HydroPoint at the above toll free number and select the voice prompt for "sales."

Table 7 – WeatherTRAK Controller Prices and Fees

Description	Model	Price
6-Station Residential/ Light Commercial Controller	ET-Plus	$398
18-Station Residential / Light Commercial Controller	ET-Plus	$858
12-Station Two-Way Commercial Controller	ET-Pro Central	$2,274
48-Station Two-Way Commercial Controller	ET-Pro Central	$4,299
6- to 12-Station ET Everywhere Annual Fee		$48
18- to 24-Station ET Everywhere Annual Fee		$84
48-Station ET Everywhere Annual Fee		$120
WeatherTRAK.net Annual Fee		$225

Installation

Typical installation times, as seen in public agency studies and distribution programs, range from 1 hour to 2.5 hours, depending upon the size of the landscape covered and mounting issues. HydroPoint offers professional services to help large and small customers with field assessments of existing controller equipment, initial programming and training, and quarterly followup services as a trusted third party advisor to ensure the maximum water savings and product usage.

Technical support is available by a toll free number, the HydroPoint Web site (www.hydropoint.com), and through field-certified contractors.

Track Record, Water Savings, and SWAT Testing

WeatherTRAK controllers have been tested in 22 public agency settings since 1998. HydroPoint reports the overall results from these tests indicate significant water savings (16–58%) and reductions in runoff (64–71%). Information provided by HydroPoint about several of these studies is summarized in table 8.

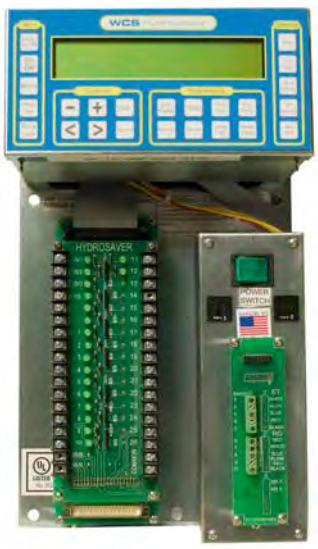
Table 8 – Summary of WeatherTRAK Demonstration Projects[1]

Test Sponsor	No. of Test Sites
Irvine, California	80
Los Angeles Dept. of Water and Power	540
Boulder, Colorado	10
Colorado State University, Ft. Collins	3
University of Las Vegas, Nevada	15
Santa Barbara, California	200
Lake Arrowhead, California	78
Victor Valley, California	12
Marin, California	8
Park City, Utah	24
Santa Clara Valley Water District, California	125
Newhall County Water District	25

[1] SWAT performance summaries and technical reports for WeatherTrak controllers were posted in 2006 and are available at http://www.irrigation.org/swat/control_climate/.

Hydrosaver™

Water Conservation Systems (WCS) Hydrosaver™ of Riverside, California, has been a manufacturer of water conservation-based commercial landscape irrigation technologies for over 20 years. Hydrosaver entered the smart controller market in 1992 with a soil moisture-based controller. Its current ET controller, the ETIC, was introduced in 1994 and is distributed by HydroEarth Inc. The Hydrosaver ETIC functions as either a stand-alone controller, or as a satellite controller of a centralized control system. WCS developed its own electronic tensiometer soil moisture sensor, electronic rain sensor, and ET sensor. It reports over 3,000 of their commercial weather-based controllers have been installed, mostly in southern California.



The ETIC controller comes in standard sizes from 12 to 56 stations. The ETIC adjusts irrigation schedules based on ET data received from the WCS Hydrosaver ET sensor. The controller comes with the ET sensor and the Hydrosaver Rain Guard™ rain sensor. Optional soil moisture and flow sensors may also be connected to the ETIC.

Operational Features

As a stand-alone controller, the user programs the ETIC with a base irrigation schedule. The base schedule includes irrigation days and run times. Total run times are entered for July, and the controller automatically decreases the run times based on the accumulated ET sensor inputs since the last irrigation. The controller includes an ET percent feature that allows the user to vary the ET adjustment rate by program up to 300%, in 10% increments. The ET schedule adjustment function can be switched ON or OFF. The controller's ET scheduling feature is based on real time ET using historical ET as a baseline. Historical ET data are programmed into the controller by the user.

The Hydrosaver ET sensor measures temperature, humidity, and solar radiation. The controller calculates ET using these measurements. (The ET calculation assumes a 3-mile-per-hour [mph] wind speed.) The ET sensor is in a vandal resistant housing and is maintenance free. ET is calculated to within one-hundredth of an inch using the Penman-Monteith equation. When the Rain Guard detects one-fourth of an inch of rain, irrigation is interrupted, and the controller can be programmed for a rain delay up to 99 days. The Rain Guard includes a built-in bypass switch for controller testing during periods of extended rain.

The controller accepts Data Industrial flow sensors. Once the user programs flow limits with the install cycle, the flow-sensing feature will trigger an alarm and shut off irrigation when flow limits are exceeded in the event of line breaks and valve failure. A shutoff delay feature is provided, and the flow sensing capability also can be used for fertigation purposes. The controller also possesses a faulty circuit feature that senses valve and wiring problems.

The ETIC includes six regular programs with up to twelve start times each. The controller has a valve test program, and up to four stations may run concurrently. In addition to the regular station circuits, the controller has three independently programmable master valve outputs. There is also a pump start output that goes on with all irrigation. The controller automatically divides total run times into appropriate cycle-and-soak times to minimize runoff based on soil and slope conditions entered by the user for each zone. The irrigation schedule calendar includes 7-, 14-, and 28-day and even- or odd-day options. Irrigation days can be specified, and the controller has a watering window feature.

Descriptions, Prices, and Warranty

The ETIC comes in standard wall mount models and complete stainless steel (CSS) top entry enclosure models. The ETIC home model for residential use has 12 stations. The standard wall mount cabinet is constructed

of rolled steel with dimensions of 12 by 16 by 6 inches. The CSS dimensions are 16 by 14 by 36 inches, and the enclosure must be mounted to a concrete foundation. Both models are designed for outdoor installation and are lockable, weatherproof, and vandal resistant. The controller's 4-line by 48-character LCD display can be set to English or Spanish. Current and historic irrigation, ET, weather, and flow information is displayed. All ETIC controllers include an internal transformer, and the station circuit capacity is 2 amperes. The controller has nonvolatile memory, and the date and time information is protected without backup batteries. Surge and lightning protection is provided through a relay system to create circuit isolation protection, separate power transformers for controller processing and valve circuitry, MOVs, and an isolation transformer.

WCS Hydrosaver products are available directly from Hydrosaver and HydroEarth (949-636-7749 or hydroearth.com) or from commercial distributors. The current retail price for a standard wall mount 24-station ETIC controller with the Rain Guard and ET sensor is $1,800. A 24-station CSS controller currently is priced at $2,800. Prices for other controller sizes and accessories can be obtained from Hydrosaver or HydroEarth. The CSS controllers come with a 5-year warranty, and the standard controllers come with a 3-year warranty. The warranties include free field service, with a renewable option.

Installation

According to WCS Hydrosaver, the ETIC should be installed by an irrigation professional. Installation and programming time will vary depending on system size and site conditions. Toll-free telephone customer support is available during business hours at 800-821-1322.

Track Record, Water Savings, and SWAT Testing

WCS Hydrosaver reports that its controllers are being included in several current studies, including research work on wireless valves and ET controllers. Hydrosaver reports significant variance in ET measurements by multiple ET sensors tested within close proximity to a CIMIS weather station. Specifically, hill top ET measurements were found to be significantly higher than those at the bottom of the hill and at the nearby CIMIS site. A SWAT test performance report for Hydrosaver controllers was not available at the time of this study.

Irrisoft™

Irrisoft, Inc., of North Logan, Utah, offers weather-based irrigation control products to residential and commercial irrigation systems through the Weather Reach® Water Management System. Established in 1999, Irrisoft became a subsidiary of Campbell Scientific, Inc. in 2001 and partnered with Rain Bird

Corporation to offer weather- based irrigation control solutions to both commercial and homeowner water users. Rain Bird® has a long relationship with Campbell Scientific, Inc. who manufactures weather stations.

The Weather Reach Water Management System provides smart irrigation control using real-time ET and rainfall data. Irrisoft began offering the model WR-7 that provided multiple interfaces to adapt to most controllers. Today, there are several "smart" devices offered with this system—the ET Manager™ and ET Manager Cartridge™ for the ESP-LX Modular controller, which are offered through Rain Bird Corporation (see the "Rain Bird" section), the WR-7RKD offered by Irrisoft for Tucor controllers—and recently, Irrisoft introduced a new product called the Controller Link™ that receives weather data through the Internet.

The Controller Link and Rain Bird ET Manager are used in combination with the user's existing irrigation controller to interrupt scheduled irrigation until it is needed; irrigation is based on ET and rainfall measurements. The Rain Bird ET Manager Cartridge provides weather-based control for the Rain Bird ESP-LX Series controller and can independently adjust each of the four programmed schedules according to ET and rain. The WR-7RKD Weather Reach Receivers provide ET and rain data to the Tucor RKD controllers using an ET pulse. The receiver sends a pulse for every 0.01 inch of ET to the controller. A similar pulse also is sent for measured rain.

Operational Features

The Weather Reach Water Management System uses Campbell Scientific ET weather stations with a full set of sensors to measure accurate weather data. Weather Reach Service Providers use an Irrisoft computer software program called the Weather Reach Server to communicate with ET weather stations (often using existing stations in an area). The server broadcasts weather information hourly through a pager network to Weather Reach Receivers. The server also makes weather data available through the Internet. Data includes temperature, wind speed, relative humidity, solar radiation, and rainfall. Weather Reach Receivers use this information to calculate ET accumulation on an hourly cycle and to process it into a running ET balance.

A growing network of Weather Reach Service Providers exists throughout the United States. For a covered area, data from multiple weather stations is received, processed, and then transmitted by a Signal Provider. The Weather Reach

Receivers are programmed to receive data from the appropriate weather station based on a weather region code. The data is transmitted hourly by the provider using a Motorola® Flex® paging system.

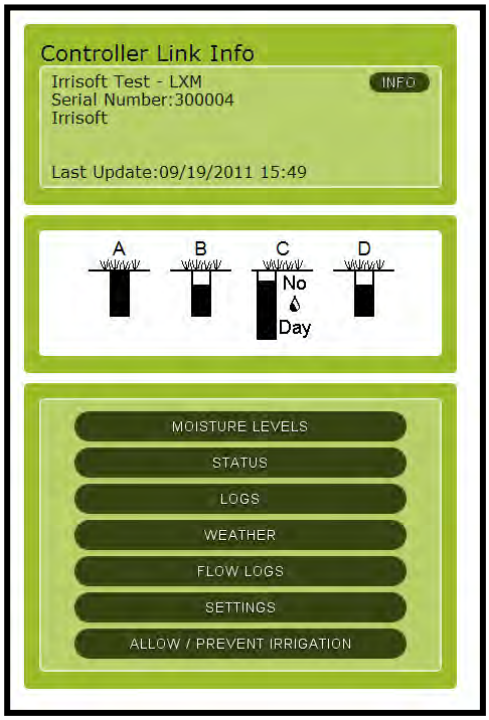
Potential ongoing costs are dependent on the signal provider for a given area. Public providers typically absorb the cost of weather stations, computer server and software, and the paging system; and there is no ongoing end user cost. Commercial providers pass on these costs to the end user. Private providers offer the service to a specific entity such as a home owners association. A list of current Signal Providers is maintained at www.irrisoft.net as well as at www.rainbird.com/wrsp. The typical price range for private providers surveyed for this report is $50 to $350 per year. Where a signal is not available, Irrisoft offers a variety of solutions to establish a public or private Weather Reach Signal (contact Irrisoft for details).

Most weather conditions are relatively constant over large areas, but rainfall can be localized. A tipping bucket rain gauge is offered as an optional add-on component to a receiver to measure onsite rain as opposed to the rain measurement provided at the weather station. This allows the receiver to calculate more accurately the amount of water a landscape needs and to interrupt irrigation when a user-specified amount of rainfall occurs.

The Controller Link is the most recent addition to the Weather Reach Water Management System. New technology enables the Controller Link to manage up to four programs by interrupting a controller's valve common at the right time. The Controller Link responds to a Program Start Sensor then decides whether or not to allow a watering cycle.

Internet communication via Wi-Fi or wired Ethernet allows a Controller Link to retrieve weather data from the Weather Reach Server. There are no special requirements of the Internet connection, and there is no need for a static IP address. Data from public ET weather station networks is offered at no charge. A data subscription is required when acquiring data from private networks.

An optional flow sensor may be connected to the Controller link to log water use and interrupt watering in the event of a high-flow condition.



Remote Web access to logs, status, and settings is available by subscription. Computer control systems can acquire weather data and ET via the Internet from a Weather Reach Server.

Irrisoft provides a free program called InSite Irrigation Scheduling™ to help a user create an irrigation schedule for a controller. InSite tailors the schedule to a specific sprinkler controller's capabilities as well as the capabilities of the sprinkler system and factors in the landscape dynamics such as plant type, soil type, root depth, slope, and sprinkler precipitation rates.

Users enter the information through a series of questions that help to tailor the schedule to each station on the property. InSite performs all the calculations automatically but still allows a user to adjust any of the calculations for a custom schedule and gives users the opportunity to see how the calculations are made. InSite also can calculate accurate settings for programming the Weather Reach Receiver.

Once the schedule has been created, the user enters it into the sprinkler controller and programs the Weather Reach Receiver with the proper settings. Weather Reach then automatically manages irrigation based on ET. Weather Reach Receivers can accommodate any available or non-available watering day requirement.

Descriptions, Prices, and Warranty

The Controller Link is suited for outdoor installations and measures 8 by 4.2 by 2 inches. The WR-7RKD and ET Manager are small (WR-7 – 4.8 by 5.3 by 1.5 inches; ET Manager – 5.6 by 6.5 by 2.0 inches) with plastic cabinets designed for indoor installation. A lockable fiberglass outdoor enclosure is available as an accessory for these receivers. In the event a power supply is not available from the existing controller, an optional power transformer is available. A 9-volt backup battery is included with ET Managers for operation during power outages. In some cases, an external antenna is required for the receivers. Receiver and add-on component prices are summarized in the table 9. Controller Link and WR-7RKD come with a 1-year warranty.

Table 9 – Irrisoft Products Prices

Component	Model	Price
Controller Link – Wi-Fi	CLw	$565
Controller Link – Ethernet	CLe	$420
Weather Reach Receiver	WR-7RKD	$595
Pronamic Rain Gauge	WR-PRG	$140

Installation

Irrisoft recommends installation by a professional irrigation system specialist and markets their products through water managers and specialty irrigation product suppliers. The typical installation cost ranges from $200 to $400.

Water Savings, SWAT Testing, and WaterSense Certification

Irrisoft reports that, during recent years numerous, demonstration projects using the Irrisoft System have proven its ability to save water. Irrisoft reports that the overall results from these projects indicate water savings of 20–60%. A summary of select water savings study results are available on the Irrisoft Web site (click "Poduct Benefits" at the Products tab). Irrisoft plans to submit the Control Link for SWAT testing and WaterSense certification in the near future.

Irritrol

Irritrol® is a brand of professional irrigation products manufactured by The Toro® Company. The Toro® Company, which was established in 1914, is a Fortune 1000 internationally recognized supplier of irrigation and landscape products. Toro's corporate headquarters are located in Bloomington, Minnesota, and its Irrigation Division resides in Riverside, California. Toro acquired the Irritrol® brand of products in the early 1990s. The Irritrol Climate Logic® weather sensing system consists of a wireless weather sensor, for mounting at an appropriate onsite location, a receiver module that plugs into Irritrol's latest models of residential and commercial controllers, and a smart digital (SD) card with an historical weather database for most of North America.

The Climate Logic sensor wirelessly sends data to the receiver module during the day. Each evening, the receiver module calculates the change in percent of irrigation time required to replenish water lost to ET and then appropriately alters the controller's program. Because the weather sensor (about the size of a coffee mug) does not have all the instruments of a large weather station, the system uses an SD card with a 40-year, average weather information dataset to characterize the local climate. Entering the ZIP code at time of installation accurately sets the

system's location and loads the local historic weather data. Compatible with Irritrol's Rain Dial®-R, Total Control®-R, KwikDial® and MC-E "Blue" irrigation controllers, Climate Logic entered the market in early 2011.

The Rain Dial-R and Total Control-R front panel modules are backward compatible to most Rain Dial cabinets (up to 20 years old) and Total Control cabinets (up to 15 years old). This allows convenient, fast, plug-in upgrades to older Rain Dials and Total Controls in the field. No tools are required for the front panel change out that makes the controllers Climate Logic ready.

Operational Features

The three water saving functions of the Irritrol Climate Logic are system shutdown during rainfall, system shutdown during cold weather, and automatic self-adjusting irrigation time, based on the weather.

Other features: (for ease of setup, the majority of adjustable settings have defaults)

- Set or Get controller's clock time
- Set location by ZIP code or latitude/longitude (United States, Southern Canada and Northern Mexico)
- Change or add sensor (several receiver modules can answer to one weather sensor)
- Assign which controller program or programs to adjust to the weather (most controllers)
- Set daily water restricted time (if needed to comply with local nonwatering hours)
- Set daily schedule update time
- Set number of previous days' settings to include in daily calculation (averaging)
- Set cold temperature shutdown point
- Set number of days to "dry out" after a rain event
- Set PIN number for optional remote control
- Display history list of settings by date
- View history of settings as a bar graph
- Manually set irrigation for a little drier or a little wetter

Display information in idle mode:

- Outside air temperature
- Percent of hot weather setting in use today
- "Rain – No Irrigation" with rain cloud icon
- "No Rain – Irrigation" with sun icon
- Current time
- Current date
- Signal strength from sensor
- Battery level in sensor

Descriptions, Prices, and Warranty

The Climate Logic system is a plug-in, weather-following accessory for use with several series of irrigation controllers. Table 10 lists the items available separately and the system and the current list prices for each (subject to change without notice).

Table 10 –Irritrol Climate Logic® Accessory and Module Prices

Description	Model	List Price
Climate Logic, wireless, weather sensor/receiver combo	CL-100-Wireless	$229
Climate Logic, wireless receiver module (only)	CL-M1	$130
Climate Logic, wireless weather sensor (only)	CL-W1	$99
Climate Logic, handheld remote (available mid-2012)	CL-R1	$99.50
Remote kit, handheld w/non-Climate Logic mini-receiver	R-100-KIT	$165
Mini-receiver (only)	CL-MR	$68
(List prices above do not include the compatible irrigation controllers to which the Climate Logic system is to be connected. There are over 40 individual models.)		

The Climate Logic system and compatible irrigation controllers, available through authorized Irritrol wholesale distributors, are intended for professional installation. The system carries a 5-year warranty with a first year over-the-counter exchange at the distributor. Weather sensors and receiver modules are "cULus" listed, and the modules can be mounted outside with outdoor controllers.

In case of a power outage, the module's nonvolatile memory retains programming. The irrigation controller provides current date/time information. If communication is lost between the sensor and the receiver module, the system switches to using the historical weather data. Both signal strength and sensor's battery level are shown in the receiver module's display.

Because the Climate Logic system includes its own weather sensor, there are no service fees from weather data providers.

Installation

Designed for professional installation, Climate Logic uses the installer's knowledge of local weather conditions to set the controller up for adequate irrigation during the hottest/driest time of year. The receiver module mounts next to the controller and a short cord, with a single jack, and connects the two devices. When mounted indoors, "hook and loop" tape is provided for the module. This allows the module to be pulled off the wall for programming in the palm of one's hand, like a cell phone. Factory-supplied stainless steel screws allow secure outdoor mount. The SD card inserts into a card reader in the bottom of the receiver module. Under "Location" in the display, the installer chooses "ZIP" for ZIP code or "LAT" for latitude/longitude for setting the system's location. After entering the ZIP code, for example, the installer presses SAVE to load the local, historical weather information. The card then can be removed. With a 15-second depression of the test spindle on the weather sensor, the installer activates the sensor and automatically starts up communication with the address-matched receiver. The weather sensor's built-in rain sensor is settable for ⅛-, ¼-, ½-, or ¾-inch of precipitation before automatic system shutoff. Once set, the weather sensor is ready for mounting outside on a rain gutter with its Quick Clip mount or on a flat surface with the stainless steel screws provided. The sensor must be installed where it will receive direct rainfall. Range between the sensor and receiver is up to 1,000 feet line of sight.

Each evening, in automatic mode, the receiver module takes the air temperature and solar exposure data sent by the sensor throughout the day and mixes this "real time" information with other local, historical data. The module then recalculates the percent of irrigation time appropriate for the day's ET based on the weather and then changes the programmed time.

Track Record, Water Savings, and SWAT Testing

Since the Climate Logic system is a relatively new product, it's understandable that no water savings study results for the Climate Logic system were available at the time of this report. As with all smart controller products, actual water savings will vary as a function of pre-installation watering practices.

As a plug-in, weather adjusting system for irrigation controllers, Climate Logic underwent SWAT testing with each series of controllers to which compatibility was claimed. Following successful completion of the testing, each irrigation controller series was listed on the Irrigation Association's Smart Water Application Technologies™ Web page for climatologically based controllers (http://www.irrigation.org/SWAT/swat.aspx?id=298).

Those listings include:

Irritrol KwikDial® with Climate Logic kit (CL-100-WIRELESS)

Irritrol Rain Dial®-R with Climate Logic kit (CL-100-WIRELESS)

Irritrol CLIMATE LOGIC® Kit with Total Control®-R series controllers

Irritrol MC-E Series with Climate Logic Kit

Toro® TMC-212 controller with Irritrol Climate Logic Kit

Toro® TMC-424E controller with Irritrol Climate Logic Kit

Since achieving SWAT listing, the above controllers, when coupled with the Climate Logic weather sensing system are appearing on many water purveyor, municipality and other agency lists for water saving rebates.

As a recently established WaterSense partner with the EPA, The Toro Company plans to submit its Irritrol Climate Logic and compatible controllers for testing to qualify for WaterSense certification.

Rain Bird

Rain Bird Corporation, based in Glendora, California, began business in 1933. Over 13,000 Rain Bird® products are sold in more than 120 countries. Rain Bird® owns more than 130 patents and 30 additional trademarks. For more than two decades, Rainbird has used weather technology in the golf and commercial irrigation markets with their central control products, including the Maxicom™, SiteControl™, and Nimbus II™, systems.

Rain Bird® currently markets several smart controller solutions for conserving water and efficiently watering

residential and commercial landscapes. These include the ET Manager, ET Manager Cartridge, and the ESP-SMT series of controllers.

The ET Manager and ET Manager Cartridge work with an existing conventional controller and use hourly weather information transmitted from remote weather stations to calculate net ET or irrigation demand. The weather parameters used in the ET calculation include solar radiation, temperature, wind speed, relative humidity, and rainfall. In addition, an optional rain gauge is available for onsite rainfall measurement and to interrupt irrigation when a user specified amount of rainfall occurs. The result of these measurements is that Rain Bird ET Management products automatically update every hour and only allow the controller to water as needed to maintain proper soil moisture.

The ESP-SMT series is comprised of three controller models:

1. An indoor model (ESP-SMT4i)

2. An outdoor model (ESP-SMT4)

3. An upgrade model (ESP-SMT-UPG) that can be used to upgrade previously installed Rain Bird ESP-Modular controllers to a smart control system

The ESP-SMT smart control system consists of an onsite weather sensor and smart controller. The controller is shipped as a 4-station base model that can be expanded to accommodate up to 13 stations using 3-station expansion modules (ESP-SM3).

Operational Features

ET Manager and ET Manager Cartridge

The ET Manager (ETMi) is an add-on device that is compatible with essentially any controller on the market. The ET Manager Cartridge (ETC-LX) is a device that works with the Rain Bird ESP-LXME Controller (new or retrofit). Both items use ASCE standardized ET equation to calculate ET on an hourly basis and maintain a user specified soil moisture balance. Typically, controllers irrigate on time-based (day, time, and minutes to water) schedules regardless of changing weather and landscape needs, whereas the Rain Bird ET Manager interrupts the controller only allowing it to irrigate when calculated soil moisture levels reach user set levels. Historical ET by location is also programmed into both units as backup in case weather data are temporarily not available.

To help users create an irrigation schedule and program settings into an ET Management product, Rain Bird offers a free ET Management scheduler. This computer program tailors an irrigation schedule to a specific irrigation controller's capabilities and the characteristics of the irrigation system. The user enters

information for each station and landscape characteristics including plant type, soil type, root depth, ground slope, and sprinkler precipitation rates to create the schedule. All calculations are done automatically, and the user has the ability to adjust any of the results for a custom schedule. Once a schedule has been created with the scheduler, it can be printed out and entered into the irrigation controller. The scheduler program can be found on the ET Manager Resource CD or downloaded at no charge from Rain Bird's Web site (www.rainbird.com).

The optional ETM programming software allows settings for the ET Manager or ETC-LX to be programmed quickly and easily. Users select the appropriate local weather station, site elevation, and available watering days (the ET Management products can accommodate any available or nonavailable watering day requirement). When the required parameters have been entered, the user can transfer the settings automatically into the ET Manager product through the cable supplied with the programming software kit. This kit is very convenient for professionals performing higher volumes of ET Manager or ETC-LX installations. The controller schedule should be set to irrigate every day so that it can properly adjust the settings and watering cycles according to soil type, plant type, altitude, zone, and conditions.

ESP-SMT Series

The ESP-SMT series consists of stand-alone controllers that automatically calculate irrigation demand once programmed for the installation site. To enable the controller to calculate daily reference ET values, the user enters the site location (ZIP code or custom values—latitude, elevation, etc.). Based on the site's location, a daily solar radiation value is determined, and monthly historical values for wind speed and humidity are retrieved from the controller memory. These three data points (daily solar radiation, historical monthly wind speed, and historical monthly humidity) are combined with daily high and low temperatures that are retrieved from the onsite ESP-SMT weather sensor. Using the ASCE reference ET equation, the controller calculates the daily reference ET rate based on daily site-specific solar radiation, temperature data, wind speed, and humidity values. The irrigation frequency and amount of irrigation per zone is determined based on the managed allowed depletion soil moisture tracking method.

The controller is programmed for "Allowed Irrigation Days." The user selects from the Days of week, Odd days –No 31, Even days, or Cyclical (2 to 14 days) options. The user can set two "Allowed Water Windows" for weather-based

schedules, and an optional “Grow-In Water Window” is available for establishing newly planted areas. After a user-set number of days, the controller will automatically convert these zones to weather-based irrigation.

To simplify controller programming, a menu-driven “programming wizard” allows the user to enter default or custom values for each zone. The specific zone parameters include: sprinkler type (precipitation rate and efficiency), soil type and slope, plant type (species factor and root depth), plant water need, plant density, zone microclimate (shade factor), and plant maturity.

The ESP-SMT onsite weather sensor employs a “tipping bucket” rain measurement device that:

1. Suspends irrigation when it rains based on a user-set threshold

2. Measures gross rainfall

Based on the timing, intensity and amount of the rainfall event, the ESP-SMT determines how much rainfall is actually usable by the plant material.

A temperature threshold can be set by the user that will disable irrigation when the ESP-SMT weather sensor measures temperature below a temperature threshold.

Based on the user-entered sprinkler precipitation rate and efficiency, soil type, and slope, the controller will automatically create a “cycle and soak” schedule for each zone that will prevent water waste and pollution runoff.

The daily weather data (high and low temperature, reference ET, rainfall) for the past 30 days can be viewed on the controller display. The previous 400 events (irrigation events, shutdown events, alarms, notes, etc.) are logged and viewable “by date” or “by zone.” All controller and zone parameter information can also be viewed.

The faceplate text on the backlit display is in English or Spanish. All programmed information is saved indefinitely in nonvolatile memory, and date and time are maintained in the event of a power outage by an internal lithium battery. A Contractor Default Program is retrievable if needed. In the unlikely event that the controller does not receive communication from the sensor for more than a day, the controller will base the irrigation schedule on the highest daily reference ET value over the past 7 days. Up to 6 kilovolts surge protection is provided.

Descriptions, Prices, and Warranty

ET Manager and ET Manager Cartridge

The Rain Bird ET Manager has a large graphic display and is designed for indoor or outdoor installations. Its dimensions are 5.6 by 6.5 by 2 inches. A lockable outdoor fiberglass enclosure is available as protection for outdoor mounting if necessary. The ET Manager should be powered using the existing irrigation controller. A 9-volt backup battery is included for operation during power outages. In some cases, an external antenna is required for the receiver.

The Rain Bird ET Manager Cartridge is a cartridge that snaps into place within the ESP-LXME modular controller as well as a receiver to mount on top of the controller. The dimensions of the cartridge are 5 by 6.5 inches. In some cases, the receiver will require a remote mounting kit to receive a consistent weather signal.

Current suggested list prices for the ET Management products and accessories are summarized in the table 11.

Table 11 – Rain Bird ET Manager and Accessories Prices

Description	Model No.	Price
ET Manager	ETMi	$845
ET Manager Cartridge	ETC-LX	$658
ESP-LXME Controller	ESPLXM	$325
Optional ET Manager Antennae	ETM-ANT	$272
Optional ETC Remote Mounting Kit	ETM-RMK	$220
Optional Tipping Rain Gauge	ETM-RG	$230
Optional ETM Programming Software Kit	ETM-PS	$676

ESP-SMT Series

The controller consists of 10 color-coded dial positions, an English/ Spanish language button, four navigation buttons, a large dot matrix backlit display, and an “alarm” light. Programming wizards are employed along with menu-driven selections to simplify controller programming.

The CUL rated transformer has a capacity of 1.0 ampere that will generally allow up to two irrigation control valves plus a master valve/pump start relay to operate at the same time. The station terminals will accept wire sizes from 20 to 12 American wire gauge (AWG).

The wire that is connected to the back of the controller panel to the onsite weather sensor provides both power to the sensor (no batteries required) and

communication of the weather data from the sensor back to the controller. This power/communication wire can be run over a maximum 200-foot distance.

Controller Dimensions – 10.7-inch width, 7.7-inch height, 4.4-inch depth
Sensor Dimensions – 6.0-inch width, 8.8-inch length, 5.9-inch height
Materials – Ultraviolet rated ABS and ASA plastic resin and stainless steel hardware

Current suggested list prices for the ESP-SMT series products and accessories are summarized in table 12.

Table 12 – ESP-SMT Series Prices

Model	Description	Price
ESP-SMT4i	Four-station/zone smart control system for indoor installations – includes the controller and on-site weather sensor	$425
ESP-SMT4	Four-station/zone smart control system for outdoor installations—includes the controller and on-site weather sensor	$450
ESP-SMT-UPG	Smart control system to upgrade ESP-Modular controllers—includes smart controller panel and on-site weather sensor	$325
ESP-SM3	Three-station expansion module to expand the ESP-SMT to a maximum of 13 stations/zones	$50

Rain Bird products are available from any authorized Rain Bird Wholesale Distributor Branch location. A distributor search engine can be accessed at Rainbird's Web site (http://rainbird.know-where.com/rainbird/cgi/index?mapid=US&option=T). All Rain Bird controller products come with a 3-year trade warranty.

Installation

Although installation by a Rain Bird trained professional is strongly recommended, Rain Bird reports installation may be performed by some homeowners. A comprehensive online-tutorial for the ESP-SMT series is available at www.rainbird.com/ESP-SMT. Installation and programming instructions in English and Spanish are provided with the controller.

Track Record, Water Savings, and SWAT Testing

Rain Bird has field tested its smart controller products at numerous locations throughout the United States, and SWAT test performance reports are posted for the ET Manager, ET Manager Cartridge, and ESP-SMT series.

Rain Bird reports ESP-SMT field test contractors that participated in its field test survey gave an average score of over 4.5 out of 5.0 in the "ease of use" rating with some individuals indicating that it was easier to use than a traditional time-based controller.

Rain Bird is a registered partner in the WaterSense Program and is planning on submitting all smart controllers to be EPA WaterSense certified.

Raindrip

Raindrip (a division of National Diversified Sales, Inc.) is located in Fresno, California, and offers a broad range of drip/micro-irrigation products and automatic watering timers for the residential market. For more than 30 years, Raindrip has been a leader in efficient irrigation solutions producing innovative irrigation products such as the SimpleDrip™ 1-2-3 drip conversion system and the recently introduced WeatherSmart™ and WeatherSmartPRO™ smart irrigation controllers that entered the market in 2009. These controllers can be used with traditional solenoid valve controlled underground irrigation systems for watering turf and other landscapes with popup or stationary sprinklers, as well as with drip/micro-irrigation devices.

WeatherSmart and WeatherSmartPRO were designed and built to meet the needs of homeowners who want a simple, modern, yet inexpensive weather-based irrigation control solution with no monthly fees. The Raindrip RSC600i's WeatherSmartPRO is a six-station landscape and turf irrigation smart controller that includes a wireless weather sensor. It is a feature rich, self-adjusting smart irrigation controller that uses a wireless weather sensor to gather real-time, onsite temperature and rainfall information to automatically adjust and/or suspend irrigation watering throughout the year. The RSC600i WeatherSmart is also a six-station controller with most of the features of the WeathSmartPRO, except that its weather-based control function is based on historic weather data preprogrammed into the controller.

Operational Features

The WeatherSmartPRO uses proprietary patented and patent pending technology; some of which has been used in smart controllers since 2002. The controller

determines and uses a water budget ratio to automatically adjust watering run times on a daily basis. This ratio is calculated using current time of year and weather sensor data that includes outside temperature and measured onsite rainfall; as well as geographical location (ZIP code), solar radiation, and other historical weather data preprogrammed into the controller.

The included weather sensor communicates wirelessly with the controller using industry standard radio frequency communication protocols. Temperature readings and other operational information are sent to the controller every 15 minutes. The sensor sends rainfall information to the controller immediately once a sufficient amount of rain is measured. The controller uses information from the weather sensor to automatically adjust watering run times; temporarily stop irrigation for rainfall events; suspend irrigation when the outside temperature drops below 40 degrees; display connection status of the sensor; and notify the user when batteries are low in the sensor.

During rainfall events, the controller calculates a rainfall irrigation shutdown duration. The calculation uses the amount of rainfall measured by the weather sensor and historical weather data for the geographic location (ZIP code). The shutdown duration timer is displayed for the user to know how long the controller has suspended irrigation.

Communication range tests through various multiple obstructions have been proven successful to distances exceeding 75 feet. A recommended sensor distance from the controller is typically within 50 feet, depending on type and number of obstructions. One weather sensor can be used to control multiple controllers for larger, higher station count installations.

The controller keeps the user informed of various operational information and system status using the large backlit 3- by 2-inch display and audible notifications. The controller displays water savings (daily and year-to-date), measured rainfall (daily and year-to-date), and shutdown duration times during rain events. Other system information includes outside temperature, low temperature shutdown (when activated), low battery indicators for the controller and sensor, valve wire fault/short detection by zone, and sensor connection status.

Programming and managing the WeatherSmart and WeatherSmartPRO is reported to be simple and is accomplished using four buttons and a modern navigation pad/enter button methodology. The controller prompts the user for various settings and water schedule information to be entered throughout the setup and water schedule programming sequence. This is initiated by using two buttons under the removable door at the bottom of the controller, settings and edit schedule. Managing manual watering interruptions or exceptions is done by using two buttons near the top of the controller, auto run (on/skip/off) and water now (start/stop).

The controller settings are entered by the user and include date, time, ZIP code, and optional watering modes; (specific days of week, interval days, or odd/even dates). The watering schedule also is entered by the user; (number of watering cycles per day, watering durations per cycle, and watering start times). The controller watering schedule is entered using values for the hottest time of the year—summer season.

Descriptions, Prices, and Warranty

The RSC600i's WeatherSmartPRO is a six-station landscape and turf irrigation smart controller that includes a wireless weather sensor, 110-VAC power transformer wall adapter, mounting hardware, and installation and programming manual. It is compatible and can be used with traditional 24-VAC solenoid valve-controlled underground automatic irrigation systems. The individual station wire circuit capacity is 0.45 amperes with wiring terminals accepting 16- to 24-gauge wire. All of the above applies to the WeatherSmart controller except there is no weather sensor.

The controller dimensions are 6.5 inches square by 2 inches deep, and it is designed for indoor use but also can be mounted in a weather resistant timer box for use outdoors. A docking station system is incorporated into the controller and can be undocked for convenient programming. The controller uses batteries to keep the real time clock current in the event of a power failure and for undocked programming. Settings and watering schedule programming are protected and maintained using nonvolatile memory.

The weather sensor dimensions are 3.5 by 5 by 2.5 inches deep. It uses a tipping bucket rain gauge, temperature sensor, and is designed for outdoor use. Both the controllers and weather sensor are Federal Communications Commission approved and require 2 AA alkaline batteries.

RSC600is WeatherSmartPRO Feature Summary:

- Six stations with up to four independent start times (cycles) per day per zone.
- Includes a wireless weather sensor—can be used with multiple controllers.
- Optimizes and automatically adjusts watering durations by ZIP code.
- Automatically suspends programmed watering schedules when rainfall is detected and when low temperatures occur—less than 40 degrees.
- Daily and year-to-date water savings and measured rainfall is displayed.
- Outside temperature is displayed.

- "Percent Adjust" function for adjusting watering durations for all zones.
- "Skip" function timer for manual interruption of watering schedules.
- "Water Now" function timer for manual watering or to test irrigation system.
- Built-in diagnostics automatically troubleshoots and alerts of wiring short circuit.
- Easy to read, oversized 3- by 2-inch backlit display.
- Nonvolatile memory saves program settings in the event of power loss.
- Audible beep to alert for low batteries, wiring faults, and sensor status.
- Controller "undocks" to allow for convenient programming.
- Automatically adjusts for daylight savings.
- Conventional timer mode (nonsmart) option.

The WeatherSmart and WeatherSmartPRO include a 1-year warranty and are available at home improvement retailers in the Western United States. Retail prices range from $69 to $109. Both also can be purchased online at www.raindrip.com.

Installation

Installation of the Raindrip controllers is reported to be straightforward and can be accomplished by typical residential homeowners.

Controller installation involves adding batteries, mounting the docking station, attaching sprinkler valve wires, plugging in the power adapter, and docking the controller. The controller then steps the user through settings and watering schedule inputs.

Weather sensor installation is accomplished by placing the controller into paring mode, adding batteries to the sensor, waiting 40 seconds for the self-test, then mounting the weather sensor. Installation times for prewired systems near an electrical outlet can be accomplished in less than an hour.

Installation and technical support is available from Raindrip during extended hours through a toll free number (877-502-7952). Additional information and details are included in the installation and programming manual and is available for download online at www.raindrip.com.

Water Savings, SWAT Testing, and WaterSense Certification

The WeatherSmart and WeatherSmartPRO indicate daily and year-to-date water savings on the display of the controller. These savings are based upon actual operation when the controller compares the programmed watering schedule to the actual watering applied. Raindrip reports annual water savings of up to 30% by end users over extended periods of time.

The Raindrip RSC600's WeatherSmartPRO has completed SWAT testing, and performance summary reports are posted at the Irrigation Association SWAT Web site.

Raindrip is an EPA WaterSense partner and has submitted the WaterSmartPRO for WaterSense certification

Rain Master's Internet-Based iCentral™ Irrigation Control System

For the last 31 years, Rain Master (located in Riverside, California) has specialized in the design and manufacture of irrigation water management solutions, including: Traditional and Internet-based Central Control Software systems (Oasis™ and iCentral™), Pro Max™ handheld maintenance remotes, commercial-grade weather centers (wired and wireless), flow sensors, and communication cable. In the summer of 2007, Rain Master was purchased by The Toro Company, and the products were placed under the company's Irritrol brand.

Rain Master's iCentral Control System was introduced in 2003 with the RME Eagle™ weather-based commercial irrigation controller that functions either as a stand-alone unit, or as a satellite controller component of the iCentral™ Internet system. The new for 2011 RME Eagle-I Plus /iCentral system (Patent No. 6,823,239) was also designed to meet a single controller need as well as mid- to large-sized irrigation systems.

The Eagle-i Plus retains all the features and benefits of the standard Eagle™ controller, including iCentral™ Internet control programming capabilities and ZipET™, plus increased capacity and new features that provide greater functionality to equip the user with the tools necessary to maximize irrigation efficiency and water savings. It has a high-speed microprocessor to enhance "real time" irrigation control and it calculates the amount of "effective" rainfall absorbed by the landscape as a function of soil type, slope, root depth, and rainfall intensity for more accurate irrigation scheduling. The Eagle Plus is offered in a 48-station conventional configuration or a 200-station two-wire configuration.

**Rain Master Eagle-i
In Stainless Steel Wall Mount**

**Rain Master Eagle-i *Plus*
In Stainless Steel Pedestal**

**Rain Master Eagle-i *Plus*
In Stainless Steel Wall Mount**

In addition to having Internet access from anywhere, iCentral customers have the ability to access their system using any smart phone. From a smart phone, customers can access their system in real-time, to retrieve flow, check alerts/alarms, run manual stations and programs, conduct communication tests, and put controllers into rain shutdown.

Operational Features

Rain Master's iCentral provides 5 ET source options for both its Eagle and Eagle Plus.

- Connect to a wired or wireless Rain Master Weather Center
- Receive daily ET wirelessly using Rain Master's ZipET, simply enter your ZIP code
- California customers can access any CIMIS station of daily ET
- Use historical ET, 12 monthly adjustments
- Enter your ET manually for a 7-day period.

When the Eagle/Eagle Plus programs are enabled for ET operation, station run times are adjusted automatically on a daily basis when connected to the Internet or a Rain Master Weather Center. (Eagle Plus can also operate with the Weather Center II, which can interface with a tipping bucket type rain gauge.) If daily ET is unavailable, the controller will intelligently use average monthly historic ET entered by the user to adjust its daily schedules. Historic ET data by ZIP code are available at Rain Master's Web site (www.rainmaster.com). The controller computes ET adjustment granularity to the nearest second, which eliminates rounding errors commonly found in

controllers that round on incremental minute basis (e.g., a 5-percent programming error can occur based on just a 10-minute run time).

Rain Master's ZipET is an ET data collection and dissemination service for Rain Master iCentral Internet customers. Rain Master collects raw weather information on a daily basis from thousands of Federal Aviation Administration and NOAA weather stations throughout the United States. The weather information is validated and converted, as necessary, to generate accurate, industry-accepted ET values. The ET values are interpolated by ZIP code using a three-dimensional surface regression model. Site-specific ET information then is delivered automatically to each controller via the two-way wireless communications card (iCard). Rain Master's iCentral Web site provides daily reports on all ET weather information that was successfully delivered to each controller (two-way confirmation).

An alternative to the ZipET service is available for users who require the accuracy of an onsite weather station. Rain Master's commercial grade, computer controlled, Weather Center measures wind, rain, temperature, solar radiation, and relative humidity and calculates ET at a frequency of 10 seconds. A contact closure signal is transmitted from the weather station to the controller by wired or wireless connection to signal accumulation of 0.01 inch of ET. The electrical signals are counted and stored in the memory of the controller, which uses the ET data to adjust the irrigation schedule. The Rain Master Weather Center is permanently mounted on a 10-foot-tall, vandal-resistant tower with all connections made within the tower's terminal block. The controller supplies power to the system. The graph in figure 4 shows Weather Center calculated ET versus that of a nearby CIMIS station.

The user also has the ability to manually enter daily ET information at any time. When used in conjunction with historic ET, manually input ET can mitigate for extreme conditions. Using manually entered ET data in conjunction with historical ET data can significantly improve irrigation efficiency. The controller will use the manually entered ET value for a period of 1 week and then automatically revert back to using the selected ET data source. Manual ET data can be entered at any time; each time it is entered, it will overwrite the last data value stored and supersede all other ET data sources.

When the Eagle or Eagle Plus controller is coupled with the optional two-way wireless communication card, irrigation control and monitoring may be performed via the iCentral Software. Activation of the wireless service to the controller is

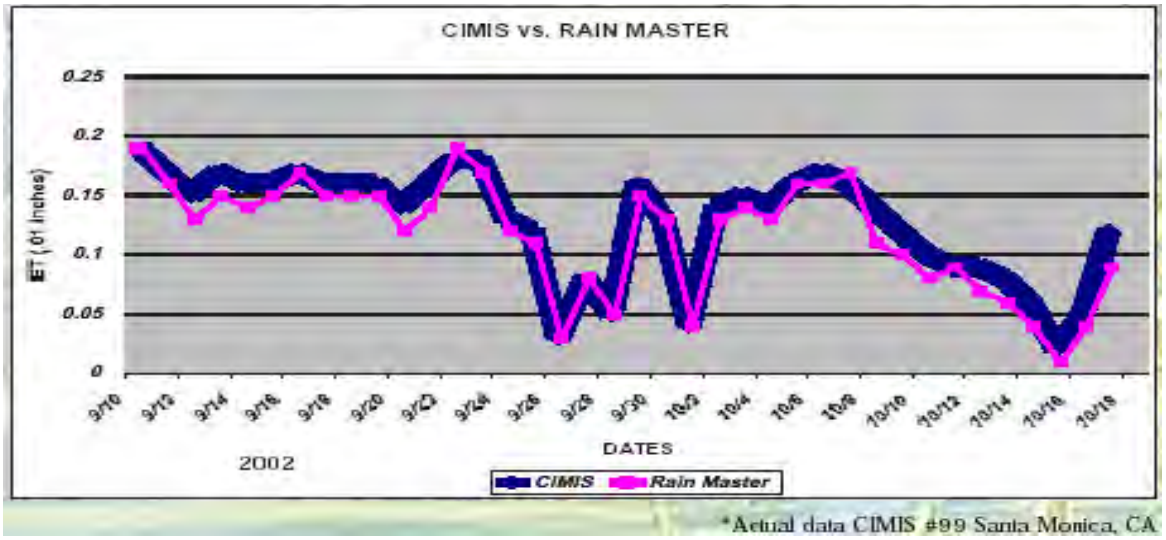


Figure 4 – Rain Master Weather Center versus CIMIS reference ET.

performed directly from the Rain Master Web site. Because it is wireless, installation is simple for either new or retrofit applications. A knockout at the bottom of the controller enclosure is provided for mounting the 3-inch antenna.

The iCentral Web site automatically informs the user anytime a field change has occurred, including controller alarms (sensors and wiring fault detection) that are also e-mailed or sent via text to the user in real-time. The Web site allows the user to command a rain shutdown, modify controller setup information, and manually turn on/off any station or program. The Web site also provides an automatic schedule generator so that users may generate representative irrigation schedules taking into consideration plant type, irrigation system design, and climatic conditions. Once the user enters all the scheduling constraints and station attributes for a controller, as described below, suitable programs are downloaded throughout the year in addition to the daily ET adjustments that are sent to the controller. The scheduler algorithms use the accepted Irrigation Association "Landscape Irrigation Scheduling and Water Management" equations.

The scheduling constraints define the irrigation season, the controller water window, the stations, programs, the allowable water days that are available for the scheduler, and any hydraulic constraints the system may have.

The station attributes include plant type, precipitation rate, soil type, root zone depth, slope, station efficiency, allowable soil moisture depletion, distribution uniformity, and seasonal landscape crop coefficients.

In the absence of the iCentral scheduler, the user programs the controller with a base schedule. The base schedule's total run times and soak/cycle times are adjusted automatically each day by the controller based on ET.

Descriptions, Prices, and Warranty

The RME Eagle controller is available in 6-, 12-, 18-, 24-, 30-, and 36-station configurations. It has four independent programs each with five start times. It is offered in both conventional and two-wire configurations.

The Eagle Plus is available in 8-, 16-, 24-, 32-, 40-, and 48-station configurations as well as a two-wire version that provides up to 200-station capabilities. Water days may be programmed on a 14-day weekly basis, by skip-by-day water day cycles with skip days ranging from 1 to 30 days, or by odd/even scheduling. Station run times may be programmed up to 10 hours in 1-minute increments and may be increased/decreased using the program percent feature from 0 to 300% in 1% increments. Programmable overlap protection provides for programs to be stacked or run concurrently, and provision is made for a separate master valve and/or pump. The controllers have nonvolatile memory, and the time and date are updated without backup batteries. Electronic overload protection is provided, with automatic reset (no fuses or circuit breakers). The Eagle and Eagle Plus standard water savings features are summarized in the bullets below.

- Programmable rain shutoff to delay the start of irrigation after a rain event (1–7 days).

- Manual rain switch (Automatic Watering – No Watering) provides a means of quickly turning off all irrigation programs without disturbing the stored program(s).

- Connectivity for any one of the following options: rain, moisture, or freeze sensor devices on a per program basis—when the sensor is "active," irrigation will stop; and the display will indicate that the sensor is active.

- The ability to select either odd or even day watering on a per-program basis.

- Selectable cycle-and-soak irrigation programming or conventional programming on a per-program basis.

- Programmable cycle run time, max cycle time, and soak time on a per-station basis

- Automatic minimization of the water window by intelligently scheduling station starts when other stations are satisfying their soak times.

- The controllers provide the ability to display total program duration, real time flow in gallons per minute (gpm), alarm information related to flow and station field wiring conditions, daily ET values, sensor status, and total water usage.

When connected to an optional Rain Master Flow sensor, the Eagle and Eagle Plus controller will suspend irrigation in the event of a line break (leak), catastrophic main line failure, or unscheduled flow. Station limits may be automatically "learned" by the controller, and irrigation will be suspended for any station that fails its limit checks while it irrigates. The controller display shows real-time flow measured in gpm as well as flow and station field wiring fault conditions.

The standard size RME Eagle controller dimensions are 13.1 by 10.4 by 4.4 inches, and the extended size cabinet is approximately 7 inches taller. The Eagle Plus enclosure is 15.5 by 10.75 by 6 inches. The enclosures are constructed of rolled steel with jet coat® or stainless steel and are suitable for outdoor installation. Various optional stainless steel pedestal enclosures are available. Eagle/Eagle Plus controllers are UL approved, Federal Communications Commission certified for emissions, and are SWAT tested and approved. Both controllers include an internal 24-VAC transformer, and the current capacity is 1.0 (1.5 Eagle Plus) ampere per station and/or master valve circuit(s). The controllers have terminal screw connections (quick connect for Eagle Plus) and will accept 12-gauge wires. Optional heavy-duty lightning and surge protection are available for the Eagle, and the Eagle Plus comes standard with lightning protection.

Rain Master's products are available throughout the United States at all major irrigation distributors. A distributor search engine can be accessed at Rain Master's Web site. The manufacturer's suggested retail price (MSRP) for the standard RME Eagle 6-station controller starts at $684. A 36-station price of $4,040 includes free online technical support, 1 year of free Internet service and 1 year of free ZipET. Individual Internet service plans for wireless two-way communications range from $9.95 to $14.95 per month. The MSRP for the Rain Master Weather Center is $4,266. All Rain Master Controllers come with a 5-year warranty. Nationwide product support is available by a network of Rain Master sales and service representatives. Toll free factory phone support is available from 7:00 a.m. through 5:00 p.m. Pacific Standard Time at 800-777-1477.

Installation

Rain Master reports installation of the controller is straightforward. The AC power, however, has to be hard-wired, and a contractor is recommended. Installation time and cost varies depending on site-specific conditions.

Track Record, Water Savings, and SWAT Testing

Rain Master reports that thousands of Eagle controllers have been installed throughout the United States and that the Rain Master RME Eagle controller has been recognized and accepted by more than 40 water purveyors/agencies across the Nation. A list of water agencies that accept Rain Master's products in their water saving incentive programs can be accessed at Rain Master's Web site.

Rain Master has several specific site case studies where customers have reported water savings up to 43%; however, Rain Master reports average water savings of 25 to 40%. These case studies can be found on their Web site. Rain Master's reputation and the controller's 5-year warranty are significant factors when considering the reliability and overall performance of their products. A SWAT performance report for the Eagle and Eagle Plus is posted on the Irrigation Association – SWAT – Web site. Rain Master currently is testing both the Eagle and Eagle Plus controllers against the new EPA WaterSense certification requirements.

Toro

This manufacturer did not provide updated information for this report and the following is unchanged from the previous 2009 edition.

The Toro Company, which was established in 1914, is a Fortune 1000 internationally recognized supplier of irrigation and landscape products. Toro's corporate headquarters are located in Bloomington, Minnesota, and its Irrigation Division resides in Riverside, California. Toro's Intelli-Sense™ series of residential and commercial controllers utilize the ET Everywhere™ data service and WeatherTRAK® Scheduling Engine™ irrigation software to update watering schedules at each landscape valve. Toro also manufactures Irritrol products and is

a partner with HydroPoint Data Services. Irritrol and HydroPoint controllers also utilize ET Everywhere and WeatherTRAK, as discussed in the HydroPoint and Irritrol sections of this report.

The Intelli-Sense series entered the market in 2005 and currently includes 11 controllers, comprised of residential and light commercial models (TIS-612/240) for 6, 9, 12, and 24 zones (plus a pump/master valve circuit) and commercial/professional models (TIS-PRO) for 12, 24, 36, and 48 zones (plus a pump/master valve circuit). All WeatherTRAK-enabled controllers integrate Scheduling Engine software that reportedly matches the Irrigation Association standard for "Best Water Management Practices" in calculating irrigation run times and schedules. This, combined with daily collection and modeling of local weather conditions, attempts to ensure that the controller applies the right amount of water when and where it is needed.

The WeatherTRAK system collects weather data each day from over 40,000 weather sources across the United States, including the NOAA network, State and county networks, and private weather stations. The WeatherTRAK system integrates advanced climatologic modeling techniques developed at Pennsylvania State University and proprietary software called WeatherTRAK *ET Everywhere*™, to determine site-specific weather conditions down to a 1-square-kilometer resolution across the entire continental United States. This methodology of data collection, modeling, and sending is reportedly the most independently studied and validated product offering within a standard deviation of .01 inch of daily ET.

The HydroPoint Data Center validates the weather data and transmits calculated ET through three paging servers providing overlapping coverage of the United States to ensure signal reception.

Operational Features

The Intelli-Sense controller calculates irrigation schedules for each valve station on a site independently. The controller does not require the use of preset irrigation schedules input by the user. Instead, it asks a series of questions to define the site-specific and environmental variables that influence watering requirements. The controller is programmed by entering the following station-specific information: sprinkler type, sprinkler efficiency, precipitation rate, plant type, root depth, soil type, microclimate (sun or shade), and slope (including if the valve is at the top, middle, or bottom of the slope. The schedule for each station is adjusted daily according to the local weather data received via the ET Everywhere service.

With these inputs, the Intelli-Sense controller calculates an irrigation schedule for each irrigation valve. Soil moisture depletion tracking, triggered at a 50% depletion level (adjustable), along with daily ET updates, allow the controller to

adjust schedules as the weather changes. The number of water days, minutes, and cycles (with appropriate soak times between cycles) are generated automatically and change as weather and water need fluctuates. The Intelli-Sense controller has an 8-week scheduling window. This allows for infrequent watering of low water use or native plants.

Programming options for all Intelli-Sense controllers include sequential stacking of overlapping start times or the ability to run multiple programs simultaneously depending on the product series. The Intelli-Sense controllers have a manual feature providing any amount of time setting for plant establishment or to check the irrigation system on a valve-by-valve basis. Independent master valve and pump start functions are also available on the commercial/professional series to address site-specific requirements including the type of master valve. A rain pause mode allows the user to shut off irrigation for up to 14 days during or after rain for the residential series and up to 200 days for commercial series. HydroPoint Data Center also can be contacted to automatically "rain pause" controllers and groups of controllers using the wireless data service. Nonwatering days can be selected.

Other features include inputs for crop coefficient values and community water restrictions (odd/even or selected watering days). The independent station adjust feature allows for individual station adjustments from -50 to +25% in 5% increments.

The controllers are compatible with Toro's wired and wireless rain and rain/freeze sensors, which eliminate irrigation during rainfall and freezing weather if added as an optional accessory.

The commercial/professional series include flow sensing for consumption reporting as well as monitoring, isolation, and alarm in the event of system issues (lateral and main line pipe breaks, stuck open valves, etc.) and are compatible with Toro flow sensors. Also included is compatibility with Toro's handheld maintenance remote.

Descriptions, Prices, and Warranty

For Residential and Light Commercial Units (TIS-612/240)

The indoor controller models' cabinet is constructed of polypropylene plastic, while the outdoor units are comprised of Lexan. The dimensions of the indoor models are 7.5 by 6.5 by 3.3 inches, and the dimensions of the outdoor models are 7.5 by 9.5 by 5.8 inches. The controllers have a large (3.5- by 0.8-inch) LCD information display, dial type controls, and a copy button for simplifying setup. All controllers include internal Underwriters Laboratories (UL)/Canadian Standard Association (CSA) listed transformers. The current capacity for each zone circuit is 0.5 amperes, and the current capacity for pump/master valve circuit is 0.375 amperes, with total controller capacity of 1.0 amperes for 6, 9, or

12 stations and 1.2 amperes for 24 stations. The controllers will accept wire sizes from 12 to 18 gauge. The nonvolatile memory maintains programming, and the backup battery maintains the date and time during power outages.

Other controller features include surge protection up to 6 kilovolts and valve malfunction detection. The irrigation schedule, irrigation history, and program review can be viewed with the LCD information display. In addition to the rain and rain/freeze sensors, pancake and bow tie antennas are available for sites with poor reception.

For Commercial/Professional Units (TIS-PRO)

The controller cabinet is powder-coated steel designed for wall mounting but with an optional stand on top pedestal. The wall mount cabinet dimensions are 10.75 by 15.75 by 5.75 inches. The controller has a preinstalled, top-mounted pancake antenna. The controllers have a large (3.5- by 0.8-inch) LCD information display, dial type controls, and a copy button for simplifying setup. All controllers include internal UL/CSA listed transformers. The current capacity for each zone circuit is 0.5 amperes, and the current capacity for pump/master valve circuit is 0.5 amperes, with total controller capacity of 1.5 amperes. The controllers will accept wire sizes from 12 to 18 gauge. The nonvolatile memory maintains programming, and the backup battery maintains the date and time during power outages.

The Intelli-Sense controllers may be purchased from authorized Toro distributors and retailers. The suggested 2009 list prices for controllers and accessories are summarized in table 13. Actual pricing may vary. Contact Toro at 1-877-345-8676 for current pricing. The Intelli-Sense controllers come with a 5-year warranty. To make an Intelli-Sense controller weather-based requires the ET Everywhere service, which is provided by WeatherTRAK. The ET Everywhere annual service agreement is $48 for the 6- to 12-station residential (TIS-612) controllers, $84 for the light commercial (TIS-240) 24-station controller, and $120 for the commercial/professional (TIS-PRO) 12-, 24-, 36-, and 48-station controllers as discussed in the “HydroPoint” section of this report.

Installation

The Intelli-Sense controllers do not require professional installation, although trained installation is recommended. Typical installation times range from 1 to 2.5 hours, depending upon the size of the landscape covered and mounting issues. Installation should include a site assessment and discussion with the user about the site’s irrigation system and how the controller operates. Installation and setup instructions are included in the owner’s manual. A *User’s Guide* with DVD is available upon request for the 6-, 9-, 12-, and 24-station residential/light

commercial models. Technical support is available from Toro by a toll free number (1-877-345-8676), or www.Toro.com, and through field certified contractors.

Track Record, Water Savings, and SWAT Testing

Intelli-Sense controllers have undergone SWAT™ testing; performance reports are posted to the Irrigation Association Web site. WeatherTRAK-enabled controllers have been tested in 22 public agency settings since 1998. HydroPoint reports the overall results from these tests indicate significant water savings (16– 58%) and reductions in runoff (64–71%). These studies are discussed in the "Hydropoint" section of this report.

Table 13 – Toro Intelli-Sense Controller and Accessories Prices

Description	Model	List Price
6-station, Indoor, Controller	TIS-06-ID	$325
9-station, Indoor, Controller	TIS-09-ID	$370
12-station, Indoor, Controller	TIS-12-ID	$417
6-station, Outdoor, Controller	TIS-06-OD	$365
9-station, Outdoor, Controller	TIS-09-OD	$412
12-station, Outdoor, Controller	TIS-12-OD	$458
24-station, Outdoor, Controller	TIS-24-OD	$909
12-station, Outdoor, Professional Controller	TIS-12P-MW	$2,250
24-station, Outdoor, Professional Controller	TIS-24P-MW	$2,500
36-station, outdoor, professional controller	TIS-36P-MW	$2,700
48-station, outdoor, professional controller	TIS-48P-MW	$3,050
Bow tie antenna	TIS-ANT	$52
Pancake antenna	TIS-ANT02	$124
Pedestal for professional controller	TIS-PED	$594
Wired rain sensor	TRS	$31
Wireless rain sensor	TWRS	$114
Wireless rain/freeze sensor	TWRFS	$134
Handheld maintenance remote kit	TMR-1-KIT	$740
0.5-inch-diameter flow sensor	TFS-050	$362
0.75-inch-diameter flow sensor	TFS-075	$362
1.0-inch-diameter flow sensor	TFS-100	$362
1.5-inch-diameter flow sensor	TFS-150	$614
2.0-inch-diameter flow sensor	TFS-200	$635
3.0-inch-diameter flow sensor	TFS-300	$677
4.0-inch-diameter flow sensor	TFS-400	$730

Tucor

This manufacturer did not provide updated information for this report and the following is unchanged from the previous 2009 edition.

Tucor, Inc., incorporated in 1995 and based in Wexford, Pennsylvania, was the first company to market residential and commercial two-wire, weather-based controllers. Tucor's controller now also is available for conventional, 24-VAC irrigation wiring, making it an option for water-saving retrofits to existing conventional wired systems.

Tucor's basic controllers include the RKD (two-wire) and RKS (conventional) controllers (hereinafter, RKx). Both controllers are capable of handling up to 100 valves, with up to 10 valves, a master valve, booster pump, and cut-off-valve running simultaneously. The RKx can run 10 unique programs with 12 daily start times.

Weather-based control is achieved with onsite or shared weather station data. Tucor offers a sophisticated solid-state wireless weather station (ET-500) and a more affordable, solar-powered, wireless device (ET-300-W). The weather station is installed in the field and is capable of communicating up to 1,000 feet line-of-sight to the RKx. The weather station data may be shared among multiple controllers—either through RealNet or by broadcasting the data directly to other nearby controllers. Provided software allows monitoring and sharing data using a Windows-based PC.

Operational Features

The RKD is a decoder-based two-wire system. Tucor's two-wire systems have been used for 14 years. The decoders are shipped "blank" and are programmed to the selected station by the user. Programming is done at the RKD or with an optional hand-held device. Diagnostics allow for testing of the decoders in the field or at the controller. Decoders may be reprogrammed to different stations.

Tucor reports typical two-wire benefits include: installation efficiencies, easy expansion, very long distances (3 miles with 16 AWG), simplified troubleshooting, quick repairs, and multiple valves running simultaneously.

The RKS, a conventional system, uses discrete wires to each valve, with a common to all valves. It has a 25-station physical capacity; additional 25-station capacities are added by using an RKXT (XT) module, allowing up to three XTs total, for 100 valves. The RKS controls the XT add-ons. An XT is connected to the RKS via a direct wire or wirelessly (up to 1,000 feet line-of-sight). Stations may be added individually, and stations may be spread individually over multiple XTs. That is, the RKS could have 12 stations, XT1 with 10 stations, XT2 with 16 stations, XT3 with 24 stations, for 62 total stations. Effectively, four conventional controllers could be replaced by one RKS.

Additional RKx features include remote real-time monitoring and control; inputs for ET, flow sensor, and rain alarm; program flow stacking; misting (timing in seconds); cycle-and-soak; learn flow (per station); water budget (0–250%). Alarm actions are based on short circuits and unexpected, high, deviation, and pump flows. Actions can optionally include sending of emails.

Both controllers may be accessed over the Internet in real time from any operating system's Web browser. Internet connections to the controllers—Tucor's "RealNet"—are made with either an AT&T wireless Internet module (stand-alone) or a serial-ethernet LAN module (for use with the end-user's LAN).

ET and rain data are supplied as pulses to the RKx, via front-panel terminals. Each pulse is defined by the user in the RKx to represent an increment of ET or rain. Accumulated ET is stored in the controller and may be adjusted by the user at the controller. ET adjustments to a given day's irrigation are made by automatically modifying the station run times of the chosen programs, based on the ET accumulated prior to that day. Base program and station run time scheduling is simplified using an Excel spreadsheet. Historic ET may be defined and stored in the RKx, based on 12 monthly values, which are then automatically subdivided into daily ET values, to be used either as the primary or fallback method.

Descriptions, Pricing, and Warranty

The RKx is housed in a NEMA 4, wall-mounted, painted steel, locking enclosure. Options include stainless steel pedestals and other enclosures. It is powered by an internal, Class 2, 50-voltampere (VA) transformer with a ½-inch NPT nipple mounting. Dimensions are approximately 12 by 12 by 5 inches. The RKx's firmware is nonvolatile and may be "flash" upgraded. Program memory is backed upped via a lithium cell with a lifetime rating of 10 years. The display is a 40-character/2-line backlit LCD.

Tucor products are available through certified distributors. A list of distributors is available from Tucor upon request (800-272-7472). Current retail prices for the

RKx, soil moisture sensors and popular accessories are summarized in table 14. Base warranty on the controller and decoders is 1 year and may be extended up to 5 years.

Table 14 – Tucor Pricing

Description	Model No.	Price
100-valve 2-wire decoder controller	RKD	$1,975.00
100-valve 2-wire decoder controller (stainless steel version)	RKD-SS	$2,590.00
100-valve 2-wire decoder controller (panel version)	RKDP	$1,480.00
Singe valve line decoder for use with the RKD	RKLD-050	$90.00
100-zone capacity, conventional output controller (must add zone count, individually priced). Includes 25 zone terminal connections.	RKS	$1,165.00
25-zone extension cabinet for zone count 26–50, 51–75, 76–100	RKS-EXT	$840.00
License Key for 1 zone	RKS-Z	$32.00
100-zone capacity, conventional output controller (stainless steel version)	RKS-SS	$1,875.00
100-zone capacity, conventional output controller (panel version)	RKSP	$865.00
25-zone extension cabinet for zone count 26–50, 51–75, 76–100 (panel only)	RKS-EXTP	$512.00
CSI (Irrisoft) WR7 Weather Reach Receiver	WR-T	$795.00
Solar powered, wireless weather station with ET and rain pulse	ET-300-W	$1,440.00
Solid state wireless weather station	ET-500	$12,875.00
Wireless logger receiver, includes output logger	ET-WLR	$678.00
Wireless logger receiver, includes output logger and outdoor enclosure	ET-WLRX	$776.00
Pulse output Tipping Spoon Rain Gage	TRB-100	$240.00

Installation

The RKx typically is installed by a certified professional.

Track Record, Water Savings, and SWAT Testing

A SWAT performance report for the RKS and Tipping Rain Bucket with Historical ET was posted in May 2009.

Weathermatic

Weathermatic®, established in 1945, is a worldwide manufacturing company of a full line of irrigation products. The company, headquartered in Dallas, Texas, began developing water conserving products in the 1950s when it used soil moisture sensors, which were later followed by its innovation of the industry's first rain sensor shutoff device in the 1970s. Weathermatic's SmartLine™ residential and commercial irrigation controllers operate based on weather conditions using onsite sensors.

Operational Features

The Weathermatic SmartLine controller technology patent was filed in 1998 and granted in 2000. SmartLine controllers accept user inputs by zone for sprinkler type, plant type, soil type, slope, and a zone fine-tune adjustment factor. The units then incorporate a ZIP code input (for solar radiation) and an onsite weather monitor (sensing temperature and rainfall) to calculate real time ET estimates that are used with user inputs to calculate proper zone run times, including cycle/soak, at user selected start times and watering days. The Weathermatic SmartLine controller/weather monitor package operates stand-alone and does not require communication with remote servers to obtain weather data or irrigation schedules, and no ongoing service costs are associated with the unit. After 8 years of development, testing, and field trials, the SmartLine controller line entered the market in November of 2004. Next Generation firmware entered the market in 2011. The Next Generation firmware allows users to exempt selected zones from ET watering and from shutdown for rain and freeze conditions. This feature is important for users with potted plants under cover that do not receive natural rainfall. Next Generation firmware also allows the users to select a minimum deficit for ET watered zones. The SmartLine will save water by skipping set watering days until the minimum deficit is reached. Next Generation also has an automatic change feature for daylight savings time. The feature is user resettable.

The Weathermatic controller platform is built around zone modules that allow expandability from 4 to 8 zones for their SL800 model and 4 to 16 zones for the SL1600 to accommodate various size residential and commercial landscapes. The SL1620 and SL1624 have fixed zone capacities of 20 and 24. A larger commercial model, the SL4800, provides module and wiring space for up to 48 zones. The SL1600, SL 1620, SL1624, and SL4800 are all suitable for indoor or outdoor installation. The SL800 is an indoor model.

Descriptions, Prices, and Warranty

The SL800 is a fixed four-zone unit that can be expanded to six or eight zones with two-zone modules (SLM2). The SL1600 controller is shipped standard with a 4-zone module and can be expanded to 8, 12, or 16 zones with additional 4-zone modules (SLM4). The SL1620 and SL1624 controllers are fixed 20-zone and 24-zone units. The SL4800 is shipped with 12 zones included. SLM12 modules are added to accommodate 24, 36, or 48 zones. The controller housing dimensions are: SL800 – 7 by 7.8 by 1.8 inches; SL1600 series – 9.1 by 10.1 by 4 inches; and SL4800 – 15 by 16.5 by 5.8 inches. The SL800 has an external transformer power supply with a barrel connector that plugs in to the side of the controller for fast installation. The SL1600 Series controllers have internal transformers with a prewired plug-in cord that will accept 120 or 240 volts (V). The SL4800 also will have a 120/240-V internal transformer but without a prewired plug-in cord (professional installation required). For the SL800 controller, either a 120-V power supply or a 240-V power supply with connectors for Europe or Australia

can be specified when ordering. The controller output circuit capacities are 1.0 amperes for the SL800; the SL1600 series, and the SL4800 is rated at 1.2 amperes. Weathermatic reports these capacities are adequate for running three-zone valves concurrently, including a master/pump valve for the SL800 and SL1600 series, and five valves concurrently including a master/pump valve for the SL4800. Accepted wire sizes range from 14 to 18 gauge.

The SmartLine controllers have advanced functions including zone-to-zone and master valve timing delays and a built-in valve locator as well as a unique diagnostic function that displays the electrical current by zone for troubleshooting. Additionally, the user can omit specific calendar event dates, days of the week, and times of the day when no watering is allowed. The SLRC remote control option is available for all SmartLines with firmware 3.0 or higher for the SL1600 Series and the SL4800 and 2.0 or higher for the SL800. The SLRC uses the same wireless HUB receiver as the SLW15 wireless weather station, eliminating the need for separate wireless receivers in the controller. The handheld has a 600-foot line-of-sight range. TRC Sidekick offers a professional remote package for commercial properties with greater distance requirements. The TRC receiver can plug in to the phone jack on the SmartLines.

Weathermatic introduced a Web site called SmartLink in 2011 that allows SmartLine users to access any number of sites and controllers and perform any function that can be performed in front of the controller. SmartLink requires a special modem that plugs in to the SmartLine controller. The annual fee for a subscription to the Web site is $199.95. SmartLink will be a major labor and water saver for property management companies, homeowner association managers, and other commercial users allowing immediate access with any smart device.

Weathermatic offers a two-wire option with the SL1600 series controllers. The SmartWire™ decoder module for two-wire systems (model SLM48DM) can be integrated into these controllers and is considered cost effective for 18 zones and larger systems. The SLM48DM includes connections for up to three different two-wire paths and includes an LED display and status lights for programming, operation status, and troubleshooting. The valve decoders used to decode the signals from the SLM48DM come in one-, two-, and four-valve capacity (models SLDEC-1, SLDEC-2, and SLDEC-4). Additional valve decoder features include: shock and freeze/heat resistant, 14-gauge wiring, surge protection, and functional distance up to 100 feet from the valve.

The onsite weather station includes a temperature sensor and rain sensor. The unit has a microprocessor to record and process measurements. The temperature-sensing unit is encased in a solar shield. The hygroscopic disc type rain sensor can be set to trigger rain delay at rainfall depths from 0.125 to 1 inch. Weather station models available are the SLW1-, SLW10-, and SLW20-wired units and the SLW15 wireless. The SLW15 wireless has line-of-sight operation up to 600 feet. The SLW1 has no onboard power requirement (battery) to replace. Operation limit is 200 wired feet from the controller. The SLW10, SLW15, and SLW20 require onboard battery power. Maximum wired distance for the SLW10 and SLW20 is 3,000 feet.

SmartLine Solar is a solar-powered package available in 24- and 48-zone models for operating standard 24-volt AC solenoids.

SmartLine controllers are distributed through Weathermatic's established wholesale suppliers (specialty irrigation suppliers) and installation professionals. The list prices for currently available, and planned residential controllers and components are listed in table 15.

Programming of the "Auto Adjust" ET portion of the controller requires inputs by zone for sprinkler type, plant type, soil type, and slope. Sprinkler type can be entered on a basic level by the user by selecting the type of sprinkler in a zone—SPRAY, ROTOR, or DRIP. A more advanced user can scroll past these basic inputs with default precipitation rates and prescribe an exact numerical precipitation rate for the zone from 0.2 to 3.0 inches per hour. Users will select STD setting for zones not included in ET Auto Adjust watering. Plant type works similarly to the sprinkler type input in that the user can simply select the type of plant life in the zone—COOL TURF, WARM TURF, ANNUALS, SHRUBS, NATIVE, or TREES. Again, a more advanced user can scroll past these basic inputs with default percentages and prescribe an exact numerical percentage for the zone from 10–300% based on the plant life in the zone and sun/shade consideration. The soil type—CLAY, SAND, LOAM—and slope (numerical degree of slope 1–25+ degrees) are used to automatically calculate the cycle/soak function by zone.

Table 15 – Weathermatic SmartLine Controllers and Component Prices

Description	Model	Availability	Price
4- to 8-zone indoor controller[1] (with 2 zones included in base price)	SL800	Currently available	$104.95
4- to 16-zone residential controller[1] (with 4 zones included in base price)	SL1600	Currently available	$194.95
20-zone commercial controller[1]	SL1620	Currently available	$549.95
24-zone commercial controller[1]	SL1624	Currently available	$649.95
48-zone commercial controller[1] (with 12 zones included in base price)	SL4800	Currently available	$649.95
2-zone module for SL800	SLM2	Currently available	$34.95
4-zone module for SL1600	SLM4	Currently available	$54.95
12-zone module for SL4800	SLM12	Currently available	$199.95
2-wire decoder module	SLM16DM	Currently available	$299.00
2-wire decoder module	SLM24DM	Currently available	$399.00
2-wire decoder module	SLM48DM	Currently available	$749.00
2-wire decoder for one valve	SLDEC1	Currently available	$120.00
2-wire decoder for two valves	SLDEC2	Currently available	$240.00
2-wire decoder for four valves	SLDEC4	Currently available	$340.00
Wired residential weather monitor	SLW1	Currently available	$149.95
Wireless residential weather monitor	SLW10	Currently available	$249.95
Wired commercial weather monitor	SLW15	Currently available	$349.95
Hand-held remote control for SL1600	SLW20	Currently available	$349.95
Hand-held remote control for SL1600	SLRC-HH	Currently available	$124.95
SLRC-KIT-HUB remote control with SLHUB-RF		Currently available	$249.95

[1] Weather Monitor required for weather-based irrigation scheduling not included in price.

In addition to these inputs by zone, the user programs the ZIP code of the site, or primarily for locations outside the United States, the latitude of the site. This input and the calendar day of the year are used to determine the solar radiation at the site, which is a variable in ET calculation. These static inputs are combined with the dynamic onsite weather monitor inputs to perform the overall equation that determines proper zone run times.

The SmartLine user has the ability to fine tune the zone run times by zone through a MORE/LESS function. This allows the user to increase watering by zone up to 25% or decrease watering by up to 50%.

The controller's irrigation schedule is based on the user-prescribed irrigation days, start times, and omit times (dates, days, and times of day) so as to conform to local watering restrictions and also accommodate site-specific hydraulic issues, which vary by time of day. Once programmed, the controller calculates ET for the period beginning at the end of the last irrigation cycle, or measurable rainfall, and ending at the next prescribed irrigation day. Irrigation will occur if the calculated deficit exceeds the minimum deficit setting. If sufficient demand has not been reached, irrigation will not occur, and the controller will carryover the accumulated ET to the next prescribed irrigation day and time. This accumulation threshold, which prevents ineffective irrigation, is calculated based on a default accumulation factor. Swat testing on SmartLine is available for viewing at www.irrigation.org.

Installation

Installation and programming of SmartLine controllers are designed to be simple and intuitive for both the novice homeowner and the advanced professional who are familiar with the unit's industry standard programming dial. Advanced user functions are located in an "Advanced Menu" position on the programming dial so as to not complicate the setup for novice users. While programming the unit is simple, Weathermatic recommends installation by a professional who will give the site the highest rate of success, not only for controller programming but also for complete system operations with an emphasis on water conservation. Based on Weathermatic's solid reputation and well-established support network, it appears the SmartLine controllers' technical support system is outstanding. Installation and programming instructions are available on Weathermatic's Internet site (weathermatic.com), and a programming video and DVD are available to supplement the standard user manual.

Track Record, Water Savings, and SWAT Testing

Weathermatic tested its Hargreaves equation based ET calculation algorithm and controller functionality extensively for 8 years. For comparing ET calculations, CIMIS weather station reference ET values were compared to those using the Weathermatic controller/weather monitor methodology at 10 geographically diverse sites over a 7-year period for 70 years of combined data. Weathermatic reports good correlation between the CIMIS and Weathermatic ET data at all sites. The graph shown in figure 5 is one example that is representative of the study.

In addition to comparing the ET calculation, the Weathermatic SmartLine controllers were included in a field study performed by a Rocky Mountain Region Water Conservancy District. This 3-year study analyzed the Weathermatic controller's accumulated water output in comparison to actual ET (as measured by lysimeter), reference ET (ET calculated with onsite weather station data), and

net plant watering requirements (PWR). The study results sample graph of figure 6 shows the Weathermatic unit watered consistent with plant demand.

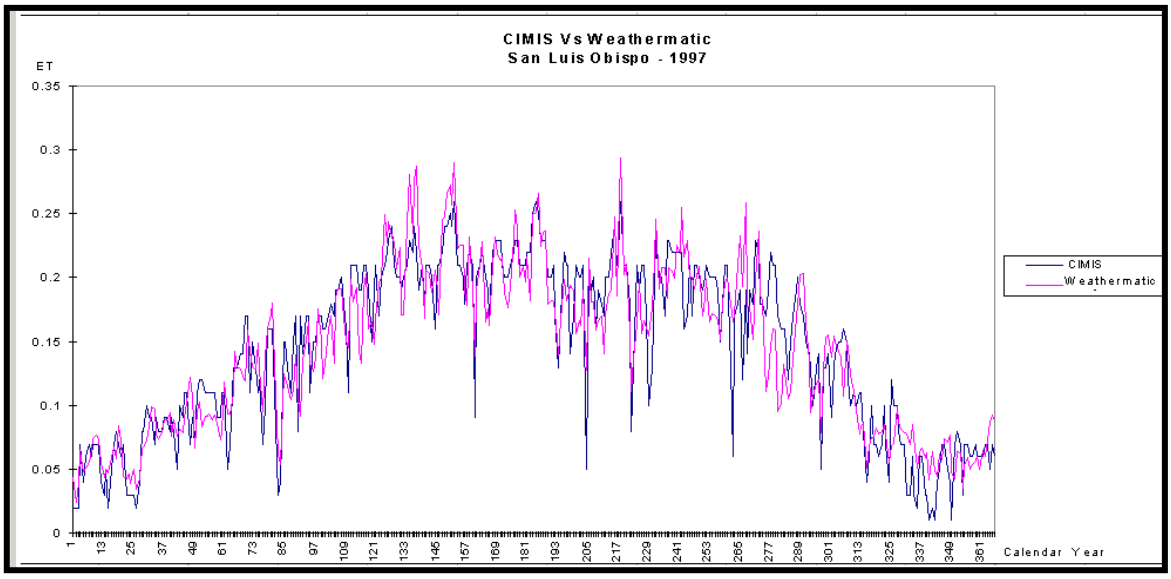


Figure 5 – Comparison of Weathermatic ET to CIMIS ET.

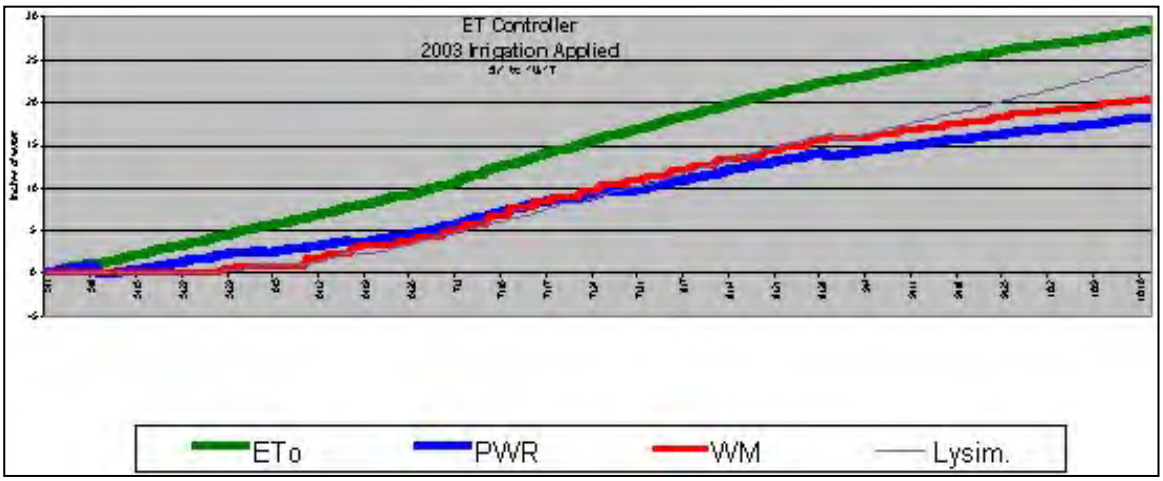


Figure 6 – Sample of Weathermatic field study results.

The Weathermatic SmartLine controllers were also part of a field pilot program conducted by the Marin Municipal Water District. In this study, 13 controllers were installed at 7 sites to compare water usage in 2002 and 2003 to the base year usage in 2001. Weathermatic reports that, in 2002, sites installed with the Weathermatic ET controller saved 26%. In 2003, the water savings climbed to

32%. Based on documentation from this program submitted by Weathermatic, it appears that the Weathermatic controller performs well and yields significant water savings.

A SWAT performance summary and technical report for the Weathermatic SL1600 was posted at http://www.irrigation.org/swat/control_climate/ in 2007. Weathermatic plans to submit its products for EPA WaterSense certification.

Soil Moisture-Based Irrigation Control System Principles

All of the soil moisture-based products reviewed operate on the principal of scheduling irrigation as a function of soil moisture conditions measured onsite with one or more soil moisture sensors. The concept is for an appropriate amount of irrigation to occur when needed to maintain adequate soil moisture levels.

Landscape soil moisture conditions should be maintained such that root zone moisture levels are between field capacity and the wilting point. Field capacity conditions occur following irrigation or precipitation when the maximum amount of water is retained in the soil after seepage and surface drainage ceases. The wilting point occurs when soil moisture is depleted to the point at which plants wilt without recovery during the night. The soil moisture levels at which field capacity and wilting point occur are a function of soil characteristics.

Soil moisture is typically reported in terms of volumetric soil water content, or as soil tension. Soil moisture content is the ratio of the volume of water in the soil to the volume of void spaces between the soil particles, and is reported as a percentage value. Soil tension is a measure of the negative pore pressure that occurs in the void spaces (increasingly negative as the moisture level drops), and is reported as a negative pressure reading.

Most of the soil moisture-based products reviewed function such that a preset irrigation quantity is applied when the measured soil moisture level drops to a threshold point set by the user. Ideally, the irrigation quantity applied replenishes the soil moisture to field capacity with minimal surface runoff and seepage below the root zone (over-watering). Some of the products reviewed begin and end irrigation based on two preset thresholds; the first is set at a moisture level well above the wilting point and the second is set at near field capacity. One product adjusts run times based on soil moisture data. Most of the devices, however, do not automatically calculate total run times or cycle and soak times.

As with the weather-based products, some of the soil moisture-based systems include a stand-alone controller and others include an add-on device that works with an existing clock-type controller. Regardless of stand-alone versus add-on controller type, some of the devices control the irrigation of all zones based on measurements from one soil moisture sensor. Others control individual zones or groups of zones based on measurements from multiple sensors placed in representative zones.

In general, all of the soil moisture-based systems' operate similarly and comparison is more straight-forward relative to that of the weather-based systems.

Most of the products possess similar components and features. All of the systems reviewed provide potentially effective methods for scheduling irrigation based on soil moisture sensing, which should result in water savings.

Several different types of soil moisture sensors are used with the systems reviewed. In recent years, significant technological advances have been made in the field of soil moisture sensors. In general, the accuracy of all types of sensors has improved and costs have gone down significantly for some types of sensors. However, all types of soil moisture sensors possess one or more inherent deficiencies that should be considered. Several types of sensors function based on the dielectric properties of the soil, which vary depending on the soil type. Hence, calibration of these devices is soil specific to varying degrees depending on the specific type of device. Specifically, a factory-calibrated sensor may not function accurately for certain soil types and should be field calibrated. Salinity or fertilizer content, as well as temperature, affect the measurement accuracy of some sensors. Certain tensiometer type sensors will not tolerate freezing temperatures and or require maintenance anytime the soil becomes exceedingly dry.

Soil Moisture-Based Control Product Features and Comparison Criteria

Significant product components and features are discussed below. The discussion identifies different methods used to achieve similar results by the various products and associated advantages and disadvantages.

Soil Moisture Sensor Types

Soil moisture sensors have been used for laboratory and outdoor testing purposes and for agricultural applications for over 50 years. There are many types of sensors, but only those used in the present generation of landscape irrigation scheduling systems are discussed.

Electrical Resistance Granular Matrix

This type of sensor consists of two electrodes embedded in a reference matrix material, which is confined within a corrosion-proof and highly permeable case. The matrix material includes gypsum to buffer against the effects of salts and fertilizer, but these sensors do not dissolve like gypsum block sensors. Soil moisture is constantly absorbed or released from the sensor as the surrounding soil moisture conditions change. As the soil moisture changes, the sensor moisture reacts as reflected by the change in electrical resistance between the electrodes. Reaction time, however, is relatively slow compared to some other types of sensors. As the moisture level increases, conductivity increases, and the sensor is calibrated to output the moisture level in terms of soil tension. Calibration is temperature and soil type dependant. This type of sensor has been used in agricultural and landscape applications for approximately 20 years, and their performance is well documented. They are relatively inexpensive, and their manufacturer reports a minimum useable life of 5 to 7 years.

Electrical Conductivity Probes

This type of sensor measures soil moisture by how well a current of electricity is passed between two probes (electrodes) that are inserted directly into the soil. As the soil moisture changes, the sensor moisture reacts as reflected by the change in electrical resistance between the electrodes. Reaction time is relatively fast. As the moisture level increases, conductivity increases, and the sensor is calibrated to output the moisture level in terms of volumetric soil water content by percentage. Since the probes have direct contact with the soil, there is no buffer against salt; and fertilizer affects on the measured conductivity. These devices are very

sensitive to the spacing of the probes as well as being influenced by soil type, salts, and fertilizers. Specifically, bent probes and improper calibration for soil type can result in poor performance. Also, fluctuations in salt and fertilizer levels can affect measurement accuracy/consistency.

Time Domain Transmissometry (TDT)

This type of sensor measures the time required for an electromagnetic pulse to travel a finite distance along steel rods or length of wire (wave guide), and the travel time is dependent of the dielectric properties of the soil surrounding the wave guide. As moisture increases in the soil, the pulse travel time decreases; and the sensor's time signal is converted into a volumetric soil water content measurement by percentage. This technology, which evolved from and is similar to time domain reflectometry, provides high accuracy that is independent of low and moderate salt and fertilizer levels in the soil. The original time domain reflectometry type sensors were expensive and difficult to use. The recently developed time domain transmission devices are less expensive and more suitable for landscape irrigation applications. The manner in which a TDT signal is processed is unique to its manufacturer, and at least one manufacturer has patented its digital signal analysis process. The significance of the signal processing method, with regard to accuracy and consistency, is beyond the scope of this review; and it is recommended the reader research this matter as warranted.

Frequency Domain Reflectometry (FDR or Capacitance)

This type of sensor contains a pair of electrodes (either an array of parallel spikes or circular metal rings) which form a capacitor with the soil acting as the dielectric in between. The electrodes are inserted into the soil or in an access tube in the soil. An oscillating frequency is applied to the electrodes, which results in a resonant frequency, the value of which depends upon the dielectric constant of the soil. The moisture content changes the dielectric constant of the soil, thereby changing the resonant frequency. The change in frequency then is converted to a soil moisture measurement. FDR sensors, which operate at high frequency (greater than 20 megahertz), are relatively independent of soil salt and fertilizer levels. This type of sensor is especially sensitive to undisturbed soil contact. (See discussion of undisturbed soil contact under the "Installation" heading below.)

Tensiometers

This type of sensor measures the soil moisture tension, or negative pore pressure, as it changes with soil moisture content. Tensiometers operate by allowing the soil solution to come to equilibrium with a reference pressure indicator through a permeable ceramic piece that is in contact with the soil. A vacuum gauge measures the soil moisture tension, and high tension reflects low soil moisture. Tensiometers accurately measure wet soil moisture levels independent of salt and fertilizer levels but are less accurate for dry soils. They can require maintenance

to refill the tensiometer with liquid and maintain the integrity of the soil/ceramic tip interface. (This typically occurs only when the soil dries beyond the wilting point.) Some tensiometers must be removed from the soil during winter months in northern climates where the soil freezes.

Installation

All of the soil moisture system manufacturers recommend professional installation and programming of their commercial products and report that installation and programming of their residential models can be done by a nonprofessional. Based on discussions with third-party individuals with experience installing most of the reviewed residential models, it appears homeowner installation may not be a realistic option with certain products. The degree of difficulty to install any of the products can vary significantly depending on site-specific conditions. A significant factor is the soil moisture sensor wiring configuration. Some sensors are connected to the existing nearby valve wiring, and some must be connected to the controller with potentially long runs of new wiring. Wiring the sensors to the irrigation valves should be easy in most cases, but the ease of connecting to the controller depends on site-specific conditions (distance, obstacles, etc.). It is difficult to determine what percentage of homeowners successfully install and program the various residential products. Installation and programming instructions are available for some of the products at their Web sites. All potential customers should review this information when shopping for a device regardless of whether they plan to do their own installation and programming.

Additional installation issues to be considered are associated with the placement of the soil moisture sensor(s) in the root zone. A soil moisture sensor should be in contact with relatively undisturbed soil that is representative of the irrigated landscape. Contact with disturbed soil with a higher void space ratio may result in soil moisture readings that are not representative of the landscape. Some sensor types are more sensitive to this than others. Therefore, the sensor shape and method of placing the sensor with regard to undisturbed soil contact should be considered when comparing systems. Installation of the sensor may also result in disturbance of the turf root system and affect the health of the turf for a period following installation. This may cause the soil moisture in the vicinity of the sensor to be higher than typical due to reduced ET by the disturbed turf until it "heals."

Stand-Alone Versus Add-On Controller

The controller component for most of the soil moisture products reviewed is an add-on device that works with an existing clock type controller. The other

products include a stand-alone controller with many of the features of typical clock type controllers. In some cases, the cost of the add-on device is a significant attraction. Regardless of cost, the quality of an existing controller should be a factor when considering replacement with a stand-alone control device. If the existing controller is a high quality unit with adequate features, an add-on device may be an attractive alternative.

The primary stand-alone controller features which should be considered include: automatic scheduling, number of programs and start times, cycle and soak, master valve circuits, compatibility with other sensors (rain, flow, temperature, wind, etc.), remote control, and system testing capabilities.

Irrigation Schedules and Run Time Calculation and Adjustment

Most of the devices reviewed do not automatically calculate irrigation run times, although some adjust user-entered run times based on soil moisture measurement data or control run times with on and off soil moisture thresholds. None of the soil moisture sensor devices automatically calculate cycle and soak times. Some manufacturers (stand-alone and add-on) provide guidelines or computer programs to assist the user in calculating total run times and cycle and soak times. The product descriptions identify the manufacturers that provide guidelines or computer programs for determining appropriate run times and cycle and soak times.

Single Versus Multiple Soil Moisture Sensors

Most of the residential systems reviewed use one soil moisture sensor to control operation of the entire system, and varying zone conditions are accommodated for by adjusting run times. For complex residential landscapes and commercial systems, some systems have the capacity to use multiple sensors to control a single valve or groups of valves. For complex systems, the user should consider the sensor capacity of the controller. In some cases, multiple controllers with single sensor capacity can be used to build a multiple sensor system. Some of the multiple sensor controllers allow for bypassing the soil moisture control mode and running in clock mode by station. All of the products reviewed will allow for system-wide clock mode operation.

Soil Temperature and Conductivity Measurement and Display

Some of the sensors included with the products reviewed measure soil temperature and conductivity in addition to soil moisture. Soil temperature is necessary for calibration of the soil moisture measurement by certain types of sensors. Some of the controllers allow for display of the temperature and conductivity measurements. Display of the conductivity measurements is a significant feature for users irrigating with wastewater effluent or water that contains high levels of salts in order to know when to flush the soil. When the user is informed that the salt levels in the soil have reached a critical point based on the conductivity readings, the landscape should be irrigated heavily to leach (flush) the salts to below the root zone.

Soil Moisture Sensor Accuracy and Calibration

As previously discussed, the measurement of soil moisture by some sensors is affected by soil type, temperature, and salinity. All of the sensor products reviewed are factory calibrated to measure moisture content for a spectrum of soil types. The manufacturers typically report a level of accuracy that is good for a range of soil types. In some cases, the accuracy may vary significantly for the different soil types. Also, the accuracy may be inconsistent for different moisture, temperature and salinity levels.

For the purpose of landscape irrigation scheduling, the consistency of a sensor is as important as, or more so than , its accuracy. For practical purposes, the user of a sensor-based landscape irrigation control system typically performs a quasi-calibration of the sensor during setup. This is accomplished when the user observes the moisture level reading that occurs with the soil at field capacity. Regardless of the accuracy of the reading, the user typically sets the irrigation trigger moisture level as a percentage of the field capacity reading. If the sensor does not read consistently, the percentage relationship between field capacity and the irrigation trigger will be affected. As an example, if a sensor reads 36% at field capacity and the user wants to set the irrigation trigger at 50% of field capacity, the controller would be set to irrigate at a reading of 18% if the sensor reads consistently. If the sensor does not read consistently, the controller would need to be set to irrigate at a reading higher or lower than 18%.

Power Supply and Surge and Lightning Protection

Most of the controllers and devices operate on 24 VAC, and few are battery powered. The stand-alone devices typically include a power transformer that converts 110-120 VAC to 24 VAC. The transformers are either hardwired inside

the controller cabinet (internal) or plugged into a power outlet (external). The add-on scheduling devices that operate on 24 VAC either receive power from the existing clock/controller or from an external transformer. Most of the transformer devices include some type of current overload protection such as a fuse or breaker switch. Some of the controllers include lightning and/or surge protection or offer these as an optional feature. Surge and lightning protection limits damage to the controller's circuitry from transient voltage and current from the power source (surge) and from the valve circuits (lightning).

Station Circuit Rating, Wiring, and Terminal Wire Sizes

The compatibility of the existing electrical circuits (wiring from the controller to the station valves) should be considered in selecting a stand-alone controller. If the station wire terminals on the controller will not accept the existing wire, adapters must be used. Also, the circuit current capacity required for an existing system should be checked prior to installing a new unit. Installation problems associated with insufficient circuit capacity to operate some irrigation valves with high circuit resistance are a possibility.

The traditional wiring system (circuitry) used for most controllers consists of a common and a dedicated wire from the controller to each valve and sensor. Some controllers utilize "twore" circuitry that consists of a single pair of wires connected to all of the valves and sensors in the system. These systems require the installation of a decoder device for each valve and sensor. Applications include large systems and linear systems (e.g., highway corridors) with large quantities of wiring required for traditional circuitry.

Warranties and Reliability

All of the products reviewed include a warranty. Warranty details are discussed in the product descriptions section. In some cases, the manufacturers' warranty periods vary for its different products. Although the warranty periods may or may not be indicative of the life expectancy of the products, some cases there appears to be a correlation between the cost and overall quality of the product to the warranty period. It is assumed the cost of a product somewhat reflects the quality of the construction materials and electronic components. Hence, the less expensive residential devices should not be expected to last as long and function as reliably as the more expensive residential and commercial products. Since most of the devices are relatively new products, it is difficult to speculate on how long they should last.

Soil Moisture-Based Product Descriptions

The following product descriptions address operational characteristics and features and include discussions of available information from demonstration and pilot studies relative to documented water savings and operation. Each of the manufacturers was provided copies of the product descriptions for input prior to being incorporated into this report.

Acclima

Acclima, Inc., of Meridian, Idaho, manufactures soil moisture sensor-based landscape irrigation control systems. Acclima began developing its system components in 1997, and Acclima products entered the market in 2003. Acclima's sensor technology is sold throughout the United States, Europe, South Africa, Asia, and Australia.

Acclima Closed Loop Irrigation® systems are governed by real-time root zone soil moisture content as measured by its patented Digital TDT® absolute soil moisture sensor. The Acclima sensor is the industry's only digital process time domain transmissometry soil moisture sensor. University studies (available on acclima.com) report that Acclima digital process sensors measure the absolute soil moisture content regardless of changing soil types, electrical conductivity, and temperature. All systems accommodate one or more soil moisture sensors. Controllers suitable for all residential and commercial applications are available.

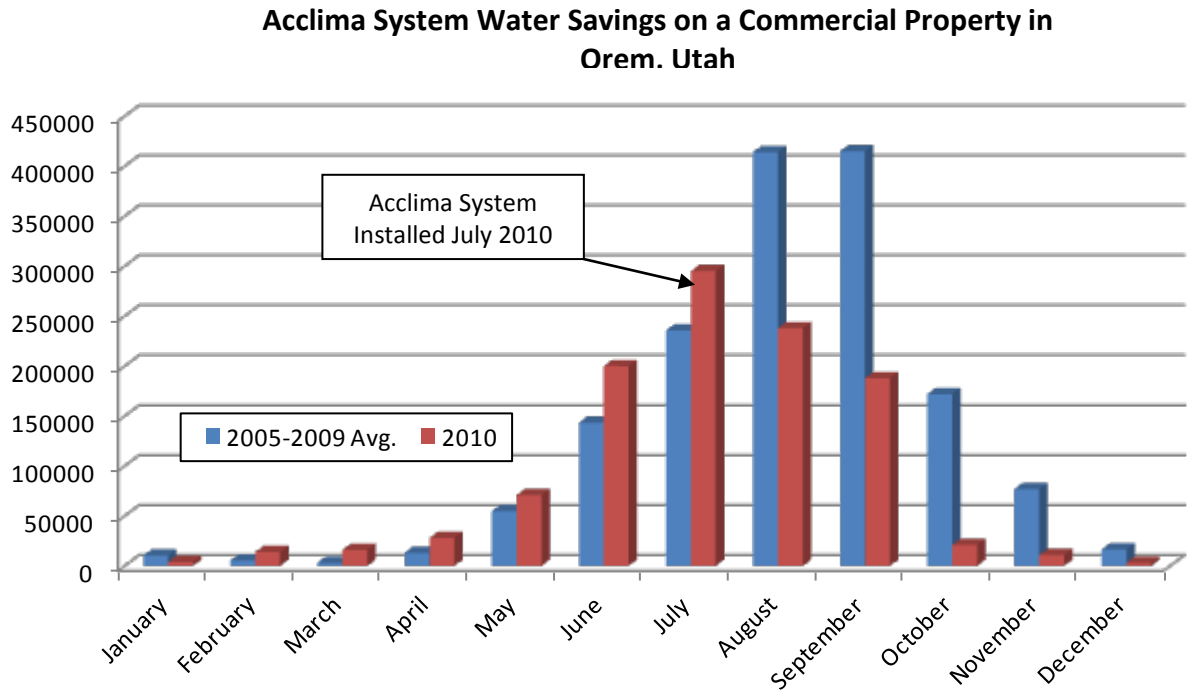
Sensor Description and Operation

The heart of all Acclima irrigation systems is the patented digital TDT soil-moisture sensor. The sensor dimensions are 8 by 2 by 0.5 inches, and the sensor is constructed of Type 316 stainless steel rods and electronic components embedded in moisture-resistant epoxy resin, molded in heavy duty plastic. Sensor rods are electrically isolated from the circuit board to prevent galvanic corrosion, and each sensor includes lightning protection. Sensors are buried in the soil among the active rootlets of turf, trees, and shrubs. The sensor reports the

moisture content to the controller via the same wiring used for valve control in resolution of tenths of 1%. A typical residential installation employs one to two sensors. Commercial systems typically use multiple sensors—one for each microclimate or landscape vegetation type. Various zones may be programmed to track any sensor.

Acclima reports that its patented Digital TDT sensor is unique because it provides *absolute* percentage volumetric water content whereas other sensors provide only *relative* moisture data. The sensor generates a unique high frequency pulse along the sensor rods with a sampling interval of 5 picoseconds—the time required for light to travel 1.5 millimeters. This high speed sampling minimizes the dielectric relaxation properties found in clay soils. Acclima reports this characteristic, combined with its patented digital analysis process, produces superior stability and accuracy in all soil types. The Acclima sensor can detect the addition of 0.002 inch of water to 4 inches of soil, yielding maximum water savings.

Upon installation, the soil surrounding the sensor is doused to saturation and then allowed to percolate to field capacity. A sensor reading is taken at this time to determine the unique field capacity of the microclimate, and the irrigation threshold is calculated.



All Acclima irrigation controllers use the Digital TDT sensor as a "closed loop" feedback mechanism in controlling the irrigation process. The controller polls the sensor for accurate soil moisture readings; if the sensor returns a reading below the irrigation threshold, the system will intelligently replace only the amount of

moisture lost through ET since the last irrigation cycle. Thus, root zone moisture levels are perpetually maintained at user-specified levels, resulting in optimized economy and healthier landscapes.

Controller Description, Prices, and Warranty

Acclima offers a variety of control devices suitable for any application. All stand-alone Acclima controllers allow multiple sensors with highly flexible programming. On all models, volumetric soil moisture content is displayed from 0 to 100%. Soil temperature is displayed in degrees Fahrenheit or Celsius, and soil conductivity in 10^{-1} siemens per meter (dS/m).

Acclima's Suspended Cycle® systems are programmed just as a standard irrigation clock. When the programmed time arrives, the system polls the sensor to see if irrigation is allowed. If not, the cycle is suspended; if water is required, irrigation takes place. Acclima's Water on Demand® systems require no programming whatever. The user enters the irrigation threshold, specifies times when irrigation is *not* allowed, and the system irrigates only as needed without any programming.

The Acclima SC6, SC12, SC6+, SC12+, SC24, and SC36 controllers are stand-alone suspended cycle control units for up to 36 zones. These units are available in 6-, 12-, 24-, and 36-zone configurations with three different cabinet models. These controllers employ standard zone wiring with typical programming processes.

The Acclima SC6/12 controller is designed for residences and light commercial applications with up to 12 zones. The 6-station controller is sold with 1 sensor, and the 12-station controller is sold with 2 sensors. The controller has an LCD display and accepts as many sensors as there are zones. The controller's programming features include timer or sensor control; simple push-button control; preset factory default schedules including, sod, new seed, rotors, and spray popups; three independent programs with six start times each; automatic threshold setup; nonvolatile program memory that preserves programming during power and battery failures; program and circuit test modes; zone error reporting; master valve/pump start capability; rain sensor/accessory terminal; and enhanced surge protection.

This controller has an exterior 24-V transformer and is designed for interior use. The SC6+ and SC12+ controllers include interior transformers with a locking cabinet and are suitable for outdoor mounting.

The Acclima SC24/36 controller uses traditional valve wiring with four available nonsensor programs and six start times for each program. Each controller accommodates as many sensors as it has zones, and each sensor adds a new program to the controller. For multiple sensor setup, each sensor is connected to

the valve for each reference zone; and sensor readings are transmitted to the controller via the valve wiring. Zones without sensors are assigned to a reference zone, and irrigation occurs based on the soil moisture measured in the reference zone. Unique soil moisture thresholds may be programmed for each reference zone.

The controller may be operated in automatic soil moisture-based, timed, or manual modes. Up to four zones, plus a master valve circuit, may run concurrently, dependent on system water volume capacity. Multizone watering may be configured per zone based on the water usage of that zone versus available water. This may be done automatically when a flow meter is attached to the system, or the configuration can be adjusted manually at any time. These controllers support rain, wind, and freeze sensor inputs to shut off the water when weather does not permit irrigation. Flow meter support checks for broken pipes and valves. Connection of a flow meter requires an interface device manufactured by Acclima.

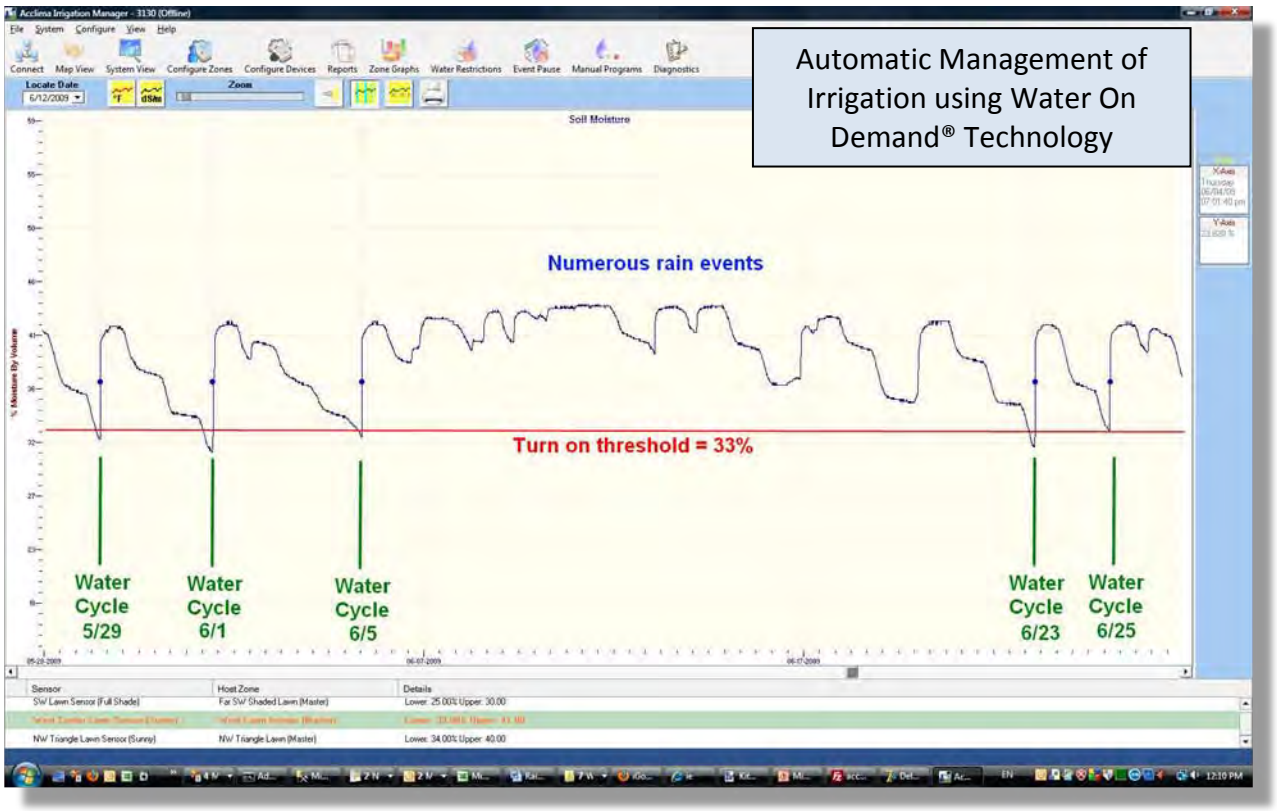
The controller's calendar/clock automatically compensates for leap years. The clock can be maintained for up to 2 months without power using 2-AA alkaline batteries. The nonvolatile program memory maintains configuration information even if the power fails and the batteries are dead. Watering day schedules include Custom, Every Day, Odd Day, Even Day, Every nth Day watering (where n may range from 3 to 31). Zone stacking ensures that all zones eventually will be watered even though program start times may overlap. Other features include soak/cycle, valve circuit test, programmable pause, rain delay (0–14 days) and water budget adjustment (5–500%). Remote control is available with optional hand-held radio and interface devices.

The controller cabinet measures 12.3 by 10 by 5.9 inches and is weather resistant extruded ABS plastic, suitable for outdoor installation. The internal power transformer includes over-under detector that automatically detects loads exceeding 2.1 amperes and over-load backup fuse (slow-blow, self-healing fuse of 2.5 amperes). Station circuit capacity is 0.6 amperes. The controllers possess surge and lighting protection consisting of the following:

Input:	Transient voltage suppressor (TVS)
Common Wires, Signal Ground:	5,000 Amp gas discharge tube to earth ground
Each Terminal:	Metal oxide varistor
Earth Ground Terminal:	Up to #6 copper wire to divert surges to ground

The Acclima CS 3500 controller is a Water on Demand® device, operating over a two-wire communications line, saving copper and allowing flexibility for system modification. Up to 60 sensors may be used with this 64-zone system. The controller operates without programming. The user identifies blocks of time when irrigation is restricted and sets an upper and lower

irrigation threshold. Water is applied when the sensor reports moisture below the lower threshold and will irrigate until the upper threshold is reported.



The two-wire circuit requires valve adapters (decoders) to establish the two-wire communications bus to valve interface. These adapters contain electronic switches that apply power to the solenoid valves upon command from the controller. Acclima sensors also contain a single electronic switch so there is no need for a valve adapter when a sensor is installed in the valve circuit.

The CS3500 offers features similar to the Acclima SC Series and has central control capabilities using the Acclima Irrigation Manager™ software and advanced communications capabilities through serial cable, dial-in modem, cell phone, or radio communications. The clock can be maintained for up to 10 years without 24-volt power using a CR2032 battery. The CS3500 cabinet is the same size and material as the SC24/36 and is suitable for exterior mount. Surge and lightning protection are also similar to the SC24/36.

Prices for selected Acclima products are summarized in table 16. Acclima products may be purchased through distribution by referring to the Acclima Web site, www.acclima.com. Acclima products carry a 2-year warranty.

Table 16 – Acclima Product Prices

Description	Model No.	Price
SC6 Indoor Residential Controller[1]	ACC-SYS-SC6	$277
SC6+ Outdoor Residential Control[1]	ACC-SYS-SC6P	$327
SC12 Indoor Residential Controller[2]	ACC-SYS-SC12	$457
SC12+ Outdoor Residential Control[2]	ACC-SYS-SC12P	$507
SC24 Commercial Controller	ACC-SYS-SC24	$1,097
SC36 Commercial Controller	ACC-SYS-SC36	$1,497
CS 3500 Commercial Controller	ACC-SYS-WD64	$2,997
Digital TDT Soil Moisture Sensor	ACC-SEN-TDT	$197
Flow Meter Interface	ACC-FPM-015	$600

[1] Includes one Digital TDT Soil Moisture Sensor.
[2] Includes two Digital TDT Soil Moisture Sensors.

Installation

Detailed installation instructions, manuals, and videos are available on the Acclima Web site, www.acclima.com. Acclima reports that the SCX, SC6, SC6+, SC12, and SC12+ controllers may be installed by homeowners but recommends professional installation of the SC24, SC36, and CS3500 control systems.

Track Record and Water Savings

The accuracy of Acclima's Digital TDT soil moisture sensor is well documented by independent laboratories, and their patented irrigation systems have been tested and researched by numerous academic institutions. Acclima's sensor technology was first evaluated by the Center for Irrigation Technology in 2003. Since then, dozens of independent university studies have validated unprecedented savings of water and fertilizer. Acclima reports average water savings are approximately 30–40% in arid climes; savings increases with higher annual rainfall. Acclima submitted their technology for independent verification before placing their products on the market. Testing entities include the following:

University of Arkansas
Oregon State University
New Mexico State University
University of Tennessee

University of Florida
Utah State University
Brigham Young University
California State University, Fresno

Information on the above testing and research and certain study report documents are available on Acclima's Web site.

Baseline

Baseline, LLC, located in Boise, Idaho, designs and manufactures soil moisture sensor-based landscape irrigation control systems. Baseline began business in 1998, and its first soil moisture sensing products entered the market in 2002. Its systems include add-on and stand-alone controllers, as well as centralized control systems. Baseline reports its products are easy to use and require minimal administration time.

The Baseline irrigation control systems are based on real-time soil moisture content as measured by Baseline's patented biSensor™ TDT soil moisture sensor. All systems (noncentralized) function with one or more soil moisture sensors that are offered with three controller options: a stand-alone controller, an add-on controller that interfaces with an existing clock type controller, or a computerized system of multiple stand-alone satellite controllers. Baseline manufactures systems that are suitable for both residential and commercial applications.

Sensor Description and Operation

The biSensor™ comes in three models: a 6-inch rigid sensor used with the S100 controllerand 1.5-foot rigid sensor for all the other Baseline products. All measure the volumetric soil moisture content near the sensor. The sensors are buried in the root zone and transmit soil moisture and temperature information to the controller via the same wiring used for valve control. A single sensor can control multiple irrigation zones. A typical residential system includes just one sensor. A commercial system may use numerous sensors associated with various microclimates or landscape types. Baseline recommends installation in a V-shaped trench to minimize soil disturbance where contact is made to the sensor. The biSensor is constructed of corrosion-resistant fiberglass.

The biSensor functions by sending an electronic pulse along an imbedded wire path. The wire is embedded in fiberglass providing desired characteristics by not being in contact with the soil, but the speed of the pulse is delayed by the soil's water content. The higher the water content, the slower the pulse moves around the biosensor. The biSensor measures the pulse speed to determine the amount of water in the soil. biSensors reportedly can resolve the travel time in increments as small as 10 picoseconds. Baseline's biSensors measure distortion caused by salts and temperature changes and adjust moisture readings accordingly. All sensor-related electrical components are insulated from the soil, including the actual sensing elements.

Baseline systems can be linked to a computer network through a variety of wired and wireless communications. Baseline's BaseManager software allows administration of thousands of sites. Irrigation managers can even use the Web to control irrigation through BaseManagerWeb.

Controller Descriptions, Prices, and Warranty

Baseline's controllers include one add-on model and four stand-alone models. Three of the stand-alone controllers use two-wire valve control wiring, and the other supports conventional valve wiring. The add-on model is designed for use with a single biSensor and functions with any clock/controller. The stand-alone models can be connected to multiple biSensors. All of Baseline's controllers are rain sensor compatible and have a bypass feature that disables the soil moisture-based control. The soil moisture reading for all controllers is displayed as volumetric water content from 0–100%. The stand-alone models include an internal power transformer, and the add-on models power supply is from the clock/controller or from an external transformer. The stand-alone controllers operate on Baseline's Time/biSensor™ control system allowing for several smart watering strategies from fully automatic to timer type controls and many options in between. The four stand-alone models all have central control options. This allows the user to access and manage the system from a computer, iPad, or even a phone. The central control features mapping functions that allow the user to turn a zone on and off by the touch of a button from anywhere in the world.

The Baseline WaterTec™ S100 controller is an add-on device for use with an existing clock/controller and a single biSensor. The S100 cabinet is constructed of heavy-duty plastic and is available in an indoor model. Its

dimensions are 5.8 by 2.6 by 1.5 inches, and it has a three-character, one-line LCD display and touch pad type controls. The S100 comes with a 6-inch biSensor soil moisture sensor.

Guidelines for performing a site audit and determining appropriate total run times and soak and cycle times are available from Baseline for programming the clock/controller connected to the Watertec S100.

The BaseStation 3200R is a stand-alone commercial controller supporting new or existing conventional irrigation wiring and scales from 12 to 200 zones. Baseline biosensor moisture sensors may be connected directly to existing valve lines for existing (or new) sites. The BaseStation 3200R also includes a two-wire expansion port, which allows system expansion using either conventional wiring or two-wire. The 3200R offers 20 programs with 8 start times for each program. The user programs a base schedule, and then the total run times are adjusted by the controller based on its evaluation of soil moisture data. (Guidelines are provided for determining an appropriate base schedule.) Other features include day interval calendar, event scheduling, self-test diagnostics, and adjustable soak cycles. The 3200R is remote access capable with Baseline's BaseManager™ computer software package.

The 3200R is available in lockable indoor wall mount and outdoor pedestal models. The wall mount cabinet is constructed of powder-coated steel, and its dimensions are 12 by 10 by 4 inches. The pedestal cabinet is constructed of stainless steel, and its dimensions are 36 by 17.5 by 12.5 inches. The controller face includes a dial and touch pad controls. The controller's 3.5-inch LCD display provides an entire week of watering schedule at once.

The BaseStation 3200 is a stand-alone commercial controller with two-wire biLine™ valve wiring configuration. The two-wire system requires the use of biCoder™ devices at each valve to convert the two-wire signal to power and control the valve. The 3200 has 200-zone and 25-biSensor capacities. This controller offers the same features of the 3200R including 20 programs with 8 starts and an event scheduling feature that allows for restrictions of future events. Also, the user has the option of setting the controller to adjust run times or run frequency. The 3200 is available in wall mount or pedestal cabinets of the same construction and sizes as the 3200R. The control and display features are also the same.

Current suggested retail prices for Baseline products are summarized in table 17. Baseline products are available from its distributors, and a distributor list is available at the Baseline Web site (www.baselinesystems.com). All Baseline products have a 5-year warranty.

Table 17 – Baseline Product Suggested Retail Prices

Description	Model No.	Price
Indoor Add-on Controller	S100	[1]$149
200-Zone Stand-alone Wall Mount Controller	3200C	$1,800
200-Zone Stand-alone Wall Mount Controller	3200X	$1,900
200-Zone Stand-alone Pedestal Controller	3200P	$3,600
12-Zone Expandable to 200 Wall Mount Controller	3200C-R12	$2,040
24-Zone Expandable to 200 Wall Mount Controller	3200C-R24	$2,280
36-Zone Expandable to 200 Wall Mount Controller	3200X-R36	$2,620
48-Zone Expandable to 200 Wall Mount Controller	3200X-R48	$2,860
12-Zone Expandable to 200 Pedestal Controller	3200P-R12	$3,840
24-Zone Expandable to 200 Pedestal Controller	3200P-R24	$4,080
36-Zone Expandable to 200 Pedestal Controller	3200P-R36	$4,320
48-Zone Expandable to 200 Pedestal Controller	3200P-R48	$4,560
biSensor Soil Moisture Sensor (1.5-foot)	5315B	$249
biCoder Two-wire Valve Adapter (single zone)	5201	$137.50
biCoder Two-wire Valve Adapter (two-zone)	5202	$192.50
biCoder Two-wire Valve Adapter (four-zone)	5204	$270.00

[1] Price includes biosensor.

Installation

Although Baseline recommends installation by a landscape professional, it reports that the S100 can be installed by most homeowners. The reported average homeowner installation time is about an hour. The 3200 series is reported to be less labor intensive to install than the majority of industry smart controllers. Baseline recommends that these systems be installed by a landscape professional.

Track Record and Water Savings

Although no information was submitted for this report on formal studies and testing, Baseline submitted documentation from numerous customers reporting significant water savings (30–70%) resulting from installation of Baseline systems.

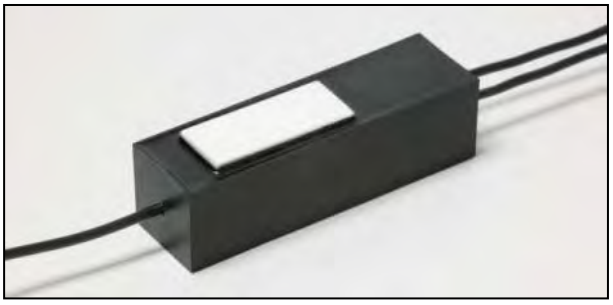
Calsense

As discussed in the “Weather-Based Product Descriptions” section, Calsense manufactures water management systems for large commercial customers. The Calsense Model 1000-S soil moisture sensor measures and transmits soil moisture readings to a Calsense ET2000e irrigation controller to provide efficient

landscape irrigation. The ET2000e will automatically suspend irrigation when the soil moisture level is above the threshold set by the user. A full description of the ET2000e and its features is included in the Calsense discussion in the "Weather-Based Product Descriptions" section.

Sensor Description and Operation

The 1000-S is a solid-state tensiometer type soil moisture sensor that provides consistent long-term soil moisture readings to the Calsense irrigation controller. The moisture sensor electronics are encased in epoxy, and the sensor is constructed of heavy-duty plastic. No maintenance or calibration are required for the life of the sensor. The 1000-S readings are unaffected by temperature, salinity, or changes in soil pH. The sensor's dimensions are 6.4 by 1.9 by 1.6 inches.



The 1000-S is installed in the root zone and is connected to the valve that controls the area where the sensor is located. Soil moisture data are transmitted to the irrigation controller via the valve control wiring. Special wire runs between the irrigation controller and the sensor are not necessary. The only additional wiring required is between the valve and the 1000-S sensor. The total combined maximum wire run between the moisture sensor and the irrigation controller is 3,000 feet. Calsense reports that maintenance of the 1000-S is only required when the soil becomes extremely dry, requiring the device be removed and soaked and then placed into moist soil. If the soil freezes, removal is not required.

The Calsense ET2000e controller, using the sensor to measure available water in the pore space of the soil, makes a decision before the start of each cycle/soak run whether or not to apply water. This decision is based on the actual moisture reading compared to the user-input moisture set point. Total run times and cycle and soak times are included in the base program entered by the user, based on field knowledge and soil moisture content for the time of year.

A 1000-S is connected to a representative station for each different climatic and plant material zone, which is defined as a master station. Slave stations are stations without sensors and are assigned to a master station that shares similar water requirements. The user chooses groups of stations controlled by the same sensor during initial setup. Stations can be easily changed or moved from one sensor to another through user friendly programming. Calsense recommends a general guideline of one moisture sensor per four active valves to cover varying moisture needs. Up to one soil moisture sensor per every valve may be connected using the ET2000e controller.

Controller Description, Prices, and Warranty

The 2000e features are discussed in more detail under the Calsense portion of the "Weather-Based Products" section.

Calsense products are available from many distributors located throughout the United States. A list of these distributors is available from Calsense upon request (800- 572-8608 or www.calsense.com). The current retail price for the 1000-S is $210. It has a 5-year warranty. The price range for the various ET2000e models is from $1,075 to $3,950, as detailed in the Calsense discussion in the "Weather-Based Products" section. Calsense provides technical support at no charge to assist in the proper installation of the moisture sensors for the most efficient system.

Installation

Calsense recommends professional installation of the ET2000e, and installation time varies significantly depending on site conditions.

Track Record and Water Savings

Although Calsense has not participated in any outside studies or demonstration projects, its track record speaks for itself. During Calsense's 23 years of existence, they have developed a large database on its products' performance and customer success. A SWAT calibration report for the 1000-S was not available at the time of this report.

Dynamax

Dynamax, Inc. manufactures a wide variety of products used for water status applications, water cycle measurement, plant-water relations, carbon flux instruments, as well as weather stations. Dynamax is located in Houston, Texas, and has been in business for 20 years. Distribution of its soil moisture-based landscape irrigation control systems began in 1999.

Dynamax offers two add-on systems and a third system that works as an add-on or stand-alone device. The Moisture Clik™ (IL200-MC) and the Moisture Switch™ (IL200-MS) are add-on only devices that function with newer model, nonmechanical clock type controllers. Dynamax's Data Logger/Irrigation Monitor (GP-1) can function as a stand-alone controller or as an add-on device. All three systems use the Dynamax SM200 soil moisture sensor.

Sensor Description and Operation

The SM200 is a frequency domain reflectometry type of dielectric sensor that measures volumetric soil moisture content from 0–60% with a Dynamax reported 3.0% accuracy. The SM200 soil moisture sensor consists of a waterproof housing that contains the electronics and two sharpened stainless steel rods that are inserted into the soil. The rods are threaded and may be removed from the housing for replacement if damaged or bent. Each SM200 is adjusted during manufacture to provide a consistent output when measuring media of known dielectric constant, making them readily interchangeable without system recalibration. Specifically, Dynamax reports soil temperature effects and low to moderate salt and fertilizer (conductance levels below 2,000 microsiemens) effects are negligible. The overall length of the sensor is 5.4 inches, and the housing diameter is 1.6 inches. It comes with 85 feet of four-wire cable. The SM200 is installed into the root zone by pushing the rods into the wall of a shallow trench, resulting in contact with relatively undisturbed soil. The sensor cable is connected to the irrigation scheduling device.

The SM200 is designed to measure volumetric soil water content using a novel technique that the manufacturer reports matches other methods, such as time-domain reflectometry, for accuracy and ease-of-use, while reducing the complexity and expense. A simplified standing wave measurement is used to determine the impedance of a sensing rod array and, hence, the volumetric water content of the soil matrix.

The SM200 applies a 100-megahertz sinusoidal signal via a specially designed transmission line to a sensing array whose impedance depends on the dielectric constant of the soil matrix. Because the dielectric constant of water (80) is significantly greater than that of the other soil matrix materials (3–4) and of air (1), the dielectric constant of the soil depends primarily on soil water content. The signal frequency has been chosen to minimize the effect of ionic conductivity.

Controller Descriptions, Prices, and Warranty

The Dynamax add-on only systems (Moisture Clik and Moisture Switch) regulate irrigation by continuously monitoring the soil condition at the sensor and interrupting the clock controller schedule when enough water is available in the root zone. As soon as the soil dries out below the user programmed set point, an internal switch closes the signal to the clock controller to irrigate. The clock controller to which the device is connected operates as programmed by the user to replenish the depleted soil moisture. The Dynamax owner's manuals include information regarding appropriate run, cycle, and soak times. The GP- 1 Irrigation Monitor controls irrigation frequency and run times automatically with on and off soil moisture triggers that are programmed by the user.

The Moisture Clik and Moisture Switch devices come with normally open, and separate hot or neutral outputs providing for several connection options. Specifically, a single Moisture Clik or Moisture Switch controller may be connected to the existing clock controller such that one Dynamax controller and soil moisture sensor will control all stations or multiple Dynamax controllers and sensors may be used to control groups of stations, or individual stations.

The Moisture Clik is recommended for residential and smaller commercial applications. It typically is connected to a clock controller to control and regulate all valves, and up to three valves may operate simultaneously. The Moisture Clik controller also may be used where multiple sensors are desired for individual soil moisture control of one or more stations. However, only one SM200 soil moisture sensor may be attached to each individual Moisture Clik. The Moisture Clik may be programmed using its dial settings based on soil type and the desired allowable soil moisture depletion level. Alternatively, advanced users may verify sensor settings and measure soil moisture field capacity with a voltage meter to improve performance.

The Moisture Clik controller cabinet is constructed of polycarbonate and ABS plastics and is rated for indoor or outdoor installation. Its dimensions are 4.6 by 4.6 by 2.4 inches. The 24-VAC, 3-ampere power supply is either from the clock controller or from an external transformer. (Dynamax recommends using its optional external transformer.) It possesses a 3-ampere input fuse and 0.5-ampere internal fuse. Approximately 6 feet of minimum 12-gauge wire is required to connect the Moisture Clik to the existing controller.

The Moisture Switch controller features are suited for large landscape applications where simultaneous control of multiple valves is necessary. It typically is connected to a clock controller to control and regulate all valves, and up to 10 valves may operate simultaneously. Multiple Moisture Switch controllers may be used where multiple sensors are desired for individual soil moisture control of stations. However, only one SM200 soil moisture sensor may be attached to each individual Moisture Switch. The Moisture Switch requires the use of a standard voltage meter for installation and programming.

The Moisture Switch controller cabinet is constructed of fiberglass-reinforced polycarbonate plastic and is rated for indoor installation only. Its dimensions are 5 by 3.5 by 3 inches. The 24-VAC, 10-ampere power supply is either from the clock controller or from an external transformer. (Dynamax recommends using its optional external transformer.) The Moisture Switch possesses a 10-ampere input fuse and 1.0-ampere internal fuse. Approximately 6 feet of minimum 12-gauge wire is required to connect the Moisture Switch to the existing controller. The Moisture Switch includes an alarm display and a terminal for connection of an external alarm mechanism. As discussed above, installation of the Moisture Switch requires the use of a voltage meter to determine the irrigation set point.

Dynamax GP-1 Data Logger/Irrigation Monitor is a more sophisticated commercial product with numerous applications, including use as a stand-alone or add-on landscape irrigation-scheduling device. One to four SM200 soil moisture sensors may be connected to it, and it has terminals for up to two temperature sensors, a flow sensor and a rain gauge. It also has a terminal for connection of an external alarm mechanism. The GP-1 has several unique features, including two soil moisture level thresholds for irrigation on and off.

As a stand-alone controller, the GP-1 can be programmed to initiate continuous irrigation at a prescribed soil moisture level and then discontinue irrigation at a second soil moisture level. This is best suited for precision irrigation applications and/or drip irrigation systems. As an add-on device, irrigation frequency and total run times are controlled automatically by using the two soil moisture level set points. When the soil moisture drops to the first trigger, irrigation run and soak cycles are initiated. The cycles are discontinued when the second soil moisture level is measured. With the GP-1 connected to a clock controller, it will control and regulate all valves with one SM200 sensor or two groups of valves with two to four sensors. Up to 10 valves may operate simultaneously, and multiple GP-1 units can be used to control individual valves or groups of valves as with the other devices.

The GP-1 is constructed of polycarbonate and ABS plastics and is suitable for outdoor installation. Its dimensions are 5.5 by 4.1 by 1.8 inches. The GP-1

operates on 11- to 24-VDC power from batteries (alkaline or lithium) or an external transformer. Approximately 6 feet of minimum 12-gauge wire is required to connect the GP-1 to the existing controller. The GP-1 is programmed using a personal computer or a personal digital assistant (PDA) device. Programming software is included with the GP-1, and an optional PDA and PDA kit is available.

Current retail prices for Dynamax soil moisture sensor-based irrigation control products are summarized in table 18. (Moisture Clik, Moisture Switch, and GP-1 prices include one SM200 soil moisture sensor, cable, and owner's manual.) Dynamax products may be ordered directly by contacting the sales department through their Web site (www.dynamax.com) or toll free telephone (800-896-7108), and through its distributors and irrigation design consultants. A distributor search engine is also available at its Web site. Dynamax provides a 1-year warranty with its soil moisture sensor control systems.

Table 18 – Dynamax Products Retail Prices

Description	Model No.	Price
Moisture Clik Add-on Controller	IL200-MC	[1]$525
Moisture Switch Add-on Controller	IL200-MS	[1]$625
Data Logger Irrigation Monitor	GP-1	[1]$1045
Moisture Sensor	SM200	$290
Temperature Sensor	ST3	$98
Tipping Bucket Rain Gauge	TR4-L25	$425
Pocket PC (HP iPAQ® hx2190 or hx2200)	PDA PPC-1	$990
Pocket DeltaLINK Kit	PDLK1-M8	$225
24-VAC Power Transformer	IL200-ADP	$40

[1] Price includes one soil moisture sensor, 82-feet of cable, and owner's manual.

Installation

Dynamax recommends installation by irrigation professionals; however, it reports installation and programming of the Moisture Clik is relatively easy and may be accomplished by some homeowners. Dynamax reports installation time reportedly varies from 1 to 1½ hours.

Track Record and Water Savings

The Macaulay Land Use Research Institute, Aberdeen, United Kingdom, and Delta-T Devices, Cambridge, developed Theta Probe soil moisture sensors jointly. Since its development and release, Delta-T has sold over 17,500 of its Theta Probe ML2 units into the scientific and research community. The SM200 is very similar to the ML2, but is constructed to meet a slightly less stringent

specification. Copies of several published reports from studies, including the Theta Probe ML2, were submitted as part of this review—all reporting favorably on the ML2. A list of Web sites with product comparisons, technical reports, and completed studies pertaining to Dynamax products are available from Dynamax. Dynamax also will provide a list of their SM200 customers upon request.

Irrometer

The Irrometer Co., Inc., located in Riverside, California, has been in business since 1951. Irrometer manufactures irrigation optimization equipment including soil moisture sensors and control devices, soil solution access tubes for nutrition management, and pressure gauges. Their original tensiometer type soil moisture sensing products have been on the market since 1951. The Watermark resistance type sensor was introduced in 1985.

Irrometer offers four different add-on control devices for soil moisture-based residential and commercial landscape irrigation control. The controllers use one or more of the Watermark soil moisture sensors to interrupt the existing clock/controller schedule until the soil moisture reaches the user-prescribed level. Included with the purchase of an Irrometer control system is its WaterPerfect turf and landscape irrigation scheduling and water management software. This software program aids the user in the proper scheduling of irrigation utilizing Watermark soil moisture sensors, including calculation of total run times and cycle and soak times based on site conditions.

Sensor Description and Operation

The Watermark is a solid-state electrical resistance type sensor, which Irrometer reports provides accurate readings from 0 to 200 centibars. T his covers the entire soil moisture range required in irrigated landscapes, including heavy clay soils. The sensor is installed by placing it into a hole made with a 7/8-inch-diameter rod to the desired sensor depth. If a larger diameter hole is made, then a “grout” of the soil and water is poured into the hole.

The sensor consists of two concentric electrodes embedded in a reference matrix material, which is surrounded by a synthetic membrane for protection against deterioration. The exterior surface is of ABS plastic and a stainless steel mesh. The internal matrix includes gypsum, which provides some buffering for the effects of salinity levels normally found in irrigated landscapes. The sensor is 7/8 inch in diameter by 3 inches long. The original Watermark (model 200) was improved in 1993 to the current model 200SS, which has improved its soil moisture response characteristics. The sensors are maintenance free and are not damaged by freezing. The reported minimum life span for a Watermark sensor is 5 to 7 years.

Irrometer's soil moisture sensor based control devices include the WaterSwitch (WS1), Watermark Electronic Module (WEM), Battery WEM (WEM-B), and Watermark Multiple Hydrozone System (MHS). A s mentioned above, all of these devices use the Watermark sensors and interrupt the common power supply to the clock/controller or interface with the controller's sensor circuit, and the WEM may be used to control individual valves. The sensor wiring is connected directly to the control module, which is connected to either the clock/controller or the valve(s). The maximum run between the sensor and controller is 1,000 feet using 18-gauge wire. Larger wire sizes can be used for longer distances.

Controller Descriptions, Prices, and Warranty

The Watermark Electronic Module is Irrometer's flagship controller. It is a versatile device that can be used in multiple connection scenarios and in combination with the Multiple Hydrozone System as discussed below. The WEM can be used to control an individual valve, a group of valves watering areas of similar water demand, or all the valves on any clock/controller. In a typical residential application, a pair of Watermark sensors is connected to the WEM; and the wiring configuration for the connection to the clock/controller provides for interruption of the power supply common connection. Alternatively, a pair of sensors and a WEM may be installed and connected to a single valve at the valve box. When a new system is being installed for a large landscape with a need for multiple sensor pairs, multiple common wires can be installed to provide for using multiple WEMs and sensors. For a retrofit of an existing system where multiple sensors are needed, a Multiple Hydrozone System device should be used rather than installing the needed additional common wiring.

The WEM's cabinet is constructed of heavy duty plastic, and it can be installed indoors or outdoors. It may be installed at the controller or at the valve. The

WEM's dimensions are 3 by 2 by 1.5 inches. The WEM is adjustable from 10 to 120 centibars by a simple dial that has an OFF position to allow for overriding the sensors. The WEM's indicator light comes on when the clock/controller is powering a valve controlled by the WEM, and the soil moisture conditions are drier than the selected setting indicating irrigation is allowed. It is powered by a 24-VAC supply from the clock/controller.

The WaterSwitch and the Battery WEM are designed for use with clock/controllers that possess switch terminals (rain, freeze, flow, etc.). This provides for a simple wiring configuration and easy installation. Both function similar to the WEM and possess the same features. The WaterSwitch is constructed of heavy duty plastic and is suitable for indoor or outdoor installation. Its cabinet dimensions are 2 by 2 by 1.25 inches that make it small enough to mount inside many controller cabinets. The WaterSwitch is powered by the 24-VAC supply from the clock/controller.

The Battery WEM is designed for use with a DC-powered clock/ controller. It is constructed of heavy duty plastic and is suitable for outdoor installation. Its cabinet dimensions are 2.5 by 1.5 by 2 inches. The Battery WEM is powered by a 9-volt battery housed inside its waterproof battery compartment.

The Multiple Hydrozone System device functions with multiple WEMs and is designed for commercial applications where numerous sensor pairs are used, or retrofit of an existing system with a need for more than one sensor pair. The MHS can control valves for up to eight separate moisture sensing areas. Each area is monitored using a WEM and Watermark sensors allowing for individual adjustment of the soil moisture threshold, and a manual override feature is included. This device communicates with the clock/controller such that individual valves or groups of valves can be controlled without the need for multiple power supply common connections.

The MHS is constructed of heavy duty plastic and is suitable for indoor installation. A weatherproof stainless steel enclosure (shown in photograph) is available for outdoor installations. Its dimensions are 11 by 16 by 2 inches, and the stainless steel enclosure dimensions are 18 by 18 by 7 inches. A weatherproof nonmetallic cabinet is also available for outdoor installations. Its dimensions are 11.5 by 15 by 4.25 inches. The MHS is powered by a 24-VAC supply from the clock/controller.

Current retail prices for Irrometer soil moisture sensor based irrigation control products are summarized in table 19. Irrometer products are available through irrigation equipment distributors, some of which are listed at its Web site (www.irrometer.com). Irrometer provides a 1-year warranty with its soil moisture sensor control systems.

Table 19 – Irrometer Product Retail Prices

Description	Model No.	Price
WaterSwitch Add-on Controller	WS1	[1]$100
WEM Add-on Controller	WEM	[2]$200
Battery WEM Add-on Controller	WEM-B	[2]$250
MHS Device	MHS-_-_	$869 and up
MHS Stainless Steel Enclosure	-SE	$870
MHS Nonmetallic Enclosure	-PE	$40
Watermark Soil Moisture Sensor	200SS-5	$34

[1] Price includes one Watermark soil moisture sensor.
[2] Price includes two Watermark soil moisture sensors.

Installation

Irrometer recommends professional installation, but it reports a typical residential system can be installed by some homeowners in approximately 2 to 4 hours.

Track Record and Water Savings

Irrometer's Watermark sensors have been used in soil science research by universities, as well as in production agriculture and landscape applications, worldwide for over 16 years. Their use in landscape applications has been documented for the longest period of time by a study that originated in 1993 for the city of Boulder, Colorado. The consulting firm conducting the study, Aquacraft, Inc., published numerous papers from 1995 to 2001 for the Irrigation Association, the American Society of Agricultural Engineers, the American Water Resources Journal, and the American Water Works Association. The graph shown in figure 7 is from one of these papers and the following is an excerpt from one of the papers:

"The results of this study were quite encouraging from the standpoint of both irrigation efficiency and cost effectiveness. On a seasonal basis, the systems limited applications to an average of 76% of theoretical requirement when all sites are combined."

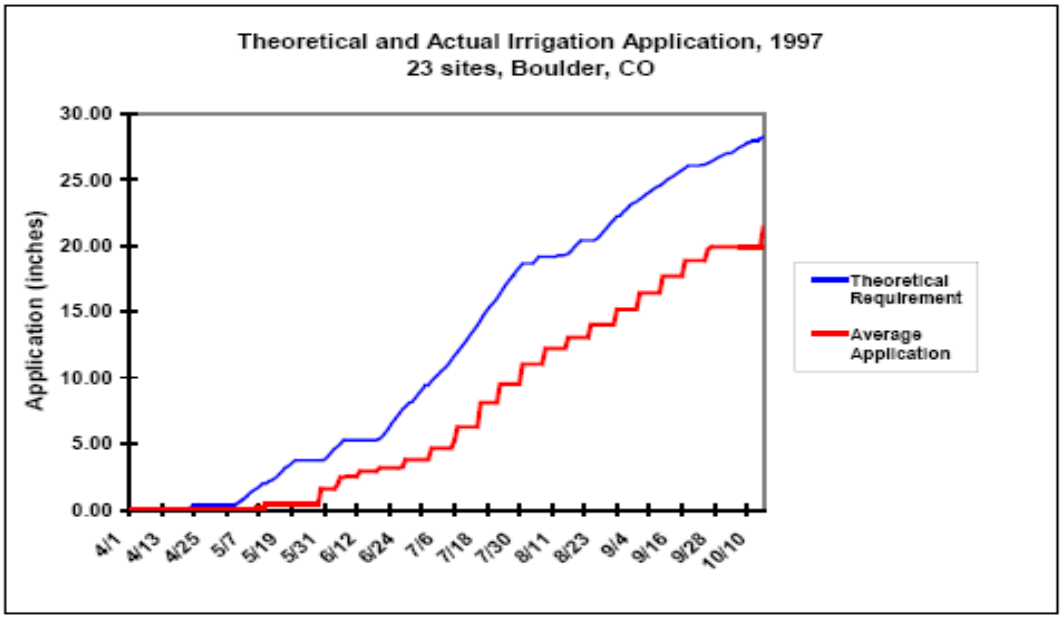


Figure 7 – Watermark performance compared to turf water requirement.

Irrometer's Watermark control products have also received the *Smart Approved WaterMark* designation**,** Australia's water saving labeling program for products to reduce outdoor water use.

AquaSense Inc. (formerly MorpH2O)

AquaSense Inc., located in Ogden, Utah, since 2006, is a manufacturer of soil moisture-based landscape and agricultural irrigation products and other agricultural irrigation and microclimate monitoring instruments.

MorpH20's AguaMiser and Aguamiser II (wireless) landscape irrigation systems include an add-on control device and an ECH2O soil moisture sensor.

The AguaMiser and Aguamiser II (wireless) systems interrupt programmed irrigation events when soil moisture is at or above a predetermined level or trigger point. The trigger point is automatically determined using a self-calibrating procedure that calculates field capacity of the soil and then sets an upper soil moisture limit. Once the trigger point is determined, the AguaMisers will stop scheduled irrigation events until watering is needed. When the irrigation timer/controller opens the 24-volt circuit to the remote valve, the AguaMisers take a soil moisture measurement, compare it to the trigger point, and interrupt the common power supply if the soil moisture level is at or above the trigger point.

Each AguaMiser will control up to four valves and can be installed at either the controller or valve box. Each Aguamiser II (wireless) can control up to eight valves, with up to eight solar powered transmitters (including sensors). Valve box installation can be advantageous if sensor wiring obstacles exist between the existing controller and sensor location. The AguaMiser is battery powered, and the battery is recharged via the valve circuits during operation.

Sensor Description and Operation

The AguaMisers use the Decagon Devices ECH2O EC-5 soil moisture sensor. The EC-5 is a capacitance/frequency domain type sensor that calculates volumetric water content by measuring the dielectric constant of the soil. The EC-5 incorporates a high frequency oscillation, which reportedly allows the sensor to measure soil moisture in any soil with minimal salinity and textural effects. Its reported accuracy is ± 3% for most soils, and its functional temperature range is -40 °C to +50 °C. The dimensions of the EC-5 are approximately 3.5 by 0.7 inches. It comes with a 16-foot cable that can be extended up to 250 feet as an extension kit.

Controller Description, Prices, and Warranty

The AguaMisers' cabinets are over-molded with a special water-resistant plastic material (Macromelt® OM687) and are suitable for indoor and outdoor installation or can be completely submerged in the valve box.

They have a 1.1- by 0.66-inch LCD display, various LED indicator lights, and control buttons. The AguaMisers' rechargeable battery is a 3-volt lithium type.

The AquaMiser can be purchased online at www.morph2o.com or from the local distributors provided on the Web site. The price for an AguaMiser, including sensor, is $250.00, and the sensor wiring extension kit is $0.75 per foot plus $4.00 per splice kit.

The Aguamiser II requires a $185.00 receiver per eight-valve control and can be used with up to eight transmitters (including sensors) at $200.00 ea. Each transmitter has an approximate range of 400 feet.

The manufacturer warranty on the AguaMiser and EC-5 is 1 year and includes replacement or repair to correct material or workmanship defects.

Installation

AquaSense recommends professional installation but reports most homeowners can perform installation using the installation guide included on its Web site. The installation guide includes brief instructions on wiring, calibration, sensor placement, trouble-shooting, and setting appropriate run times.

Track Record and Water Savings

AquaSense has conducted multiple tests at sites in Utah, Nevada, and California. Published test results are available at www.morph2o.com. The Magna City, Utah, test showed an average savings of as much as 68% from normal water use. A test was performed at Brigham Young University in Utah that reportedly showed an average savings of 40% on a previously calibrated existing system.

A SWAT calibration report for the ECH2O EC-5 soil moisture sensor was posted in November 2008.

Tucor

This manufacturer did not provide updated information for this report and the following is unchanged from the previous 2009 edition.

As discussed in the "Weather-Based Products" section, Tucor, Inc. is a manufacturer of two-wire and conventional wired irrigation controllers that possess weather-based control features. Tucor's RKD and RKS (subsequently referred to as RKx) controllers also operate with soil moisture sensor input, and up to 10 sensors may be used with a controller.

Sensor Description and Operation

Tucor's soil moisture sensors come in five styles, one being a "Fin" Sensor that has one sensor embedded, and four being "Probes," which have multiple embedded sensors. The Probes contain 6-15 sensors, spaced over 12 to 60 inches. All Tucor soil moisture sensors are capacitance or FDR type sensors.

Within the Probes, one sensor can be chosen by the user to affect the RKx's programs. Each program in the RKx can be adjusted by data from the selected sensor, and each sensor can affect one or more programs. That is, since the RKx can run ten unique programs, each program can be controlled by any one of ten sensors; or one sensor can control all programs; or any combination thereof.

The RKx is either programmed manually or automatically with weather-based features (historical ET, weather station, etc.), and then irrigation may be interrupted based on soil moisture input. The soil moisture sensors interrupt irrigation based on a percent measured moisture level for a specific sensor. The soil moisture percent value is defined by the user. When a selected sensor's moisture level is triggered—indicating that the soil moisture at that depth is sufficient—the program assigned to that sensor, if running, will continue to run for the duration of all valves scheduled within the program (the program will not be interrupted midway through the cycle). If the trigger is enabled before the program begins, the entire program will be disabled until the next scheduled run time.

The RKx monitors all sensors, and up to 150 sensors may be monitored (maximum of 10 probes with each having 15 sensors). Data feedback consists of soil moisture percentage and temperature values. Data feedback per sensor may be viewed at the controller or, optionally, via a Web interface. Alarms based on selected criteria may be generated from the sensor data, and email notification may be sent based on the alarms.

The connections from the sensors to the RKx are by dedicated, four-conductor, direct-burial wire, which is connected to the RKx's serial input. Multiple sensors may be on the same wire, and total wire length may be up to 2,000 feet.

A soil moisture sensor may be used in conjunction with the Tucor Weather Station to ensure valid soil moisture when using ET. Since ET only ensures replenishment of lost moisture, using a soil moisture sensor validates the initial moisture levels and monitors the accuracy of the ET data.

Controller Descriptions, Prices, and Warranty

The RKx is housed in a NEMA 4, wall-mounted, painted steel, locking enclosure. Options include stainless steel pedestals, and other enclosures. It is powered by an internal, Class 2, 50-VA transformer with a ½-inch NPT nipple mounting. Dimensions are approximately 12 by 12 by 5 inches. The RKx's firmware is nonvolatile and may be "flash" upgraded. Program memory is backed upped via a lithium cell with a lifetime rating of 10 years. The display is a 40-character/ 2-line backlit LCD.

Additional discussion of the RKD and RKS features are included under the Tucor discussion in the "Weather-Based Products" section.

Base warranty on the controllers and sensors is 1 year and may be extended up to 5 years.

Table 20 – Tucor Pricing

Description	Model No.	Price
100 Valve 2-wire Decoder Controller	RKD	$1,975.00
100 Valve 2-wire Decoder Controller (Stainless Steel Version)	RKD-SS	$2,590.00
100 Valve 2-wire Decoder Controller (Panel Version)	RKDP	$1,480.00
Single Valve Line Decoder for use with the RKD	RKLD-050	$90.00
100-zone capacity, conventional output controller (must add zone count, individually priced). Includes 25 zone terminal connections.	RKS	$1,165.00
25-zone extension cabinet for zone count 26–50, 51–75, 76–100	RKS-EXT	$840.00
License Key for 1 zone	RKS-Z	$32.00
100 zone capacity, conventional output controller (Stainless Steel Version) includes	RKS-SS	$1,875.00
100 zone capacity, conventional output controller (Panel Version) includes Trans	RKSP	$865.00
25 zone extension cabinet for zone count 26–50, 51–75, 76–100 (panel only)	RKS-EXTP	$512.00
Single Soil Moisture and Temperature Sensor with 13 feet of cable	SMS-100	$180.00
12-inch Turf Soil Moisture and Temperature Probe with 6 sensors and 13 feet of cable	SMP-12	$1,040.00
20-inch Soil Moisture and Temperature Probe with 5 sensors and 13 feet of cable	SMP-20	$820.00
40-inch Soil Moisture and Temperature Probe with 10 sensors and 13 feet of cable	SMP-40	$1,395.00
60-inch Soil Moisture and Temperature Probe with 15 sensors and 13 feet of cable	SMP-60	$1,975.00
Soil Moisture Interface	SMI-232	$195.00
Tucor 18/4 Sensor wire with ground	TW18/4-G	$0.44

Installation

The RKx typically is installed by a certified professional.

Track Record, Water Savings and SWAT Testing

A SWAT calibration report for Tucor soil moisture sensors was not available for this report.

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Weather-Based Irrigation Technologies – Summary of Product Information and Features

Company Name		Accurate WeatherSet	Alex-Tronix	Aqua Conserve	Calsense	Cyber-Rain	ET Water Systems	Hunter (ET System)	Hunter (Solar Sync)	HydroPoint WeatherTRAK
Telephone		(818) 993-1449	(888) 224-7630	(877) 922-2782	(800) 572-8608	(818) 585-7178	(415) 945-9383 ext. 208	(760) 591-7344	(760) 591-7344	(800) 362-8774
Contact Person		Andrew Davis	George Alexanian	Bill Bounds	Rick Capitanio	Reza Pourzia	Katherine Wing	Dave Shoup	Dave Shoup	Tracey Bradley
Web Site		www.weatherset.com	www.alex-tronix.com	www.aquaconserve.com	www.calsense.com	www.cyber-rain.com	www.etwater.com	www.hunterindustries.com	www.hunterindustries.com	www.hydropoint.com
Number of Residential Model Types		2	2	2	0	2	2	1	4	1
Number of Commercial Model Types		1	2	2	1	1	3	1		1
Date Product(s) Entered Market		1994	2005	1998	1993	2007	2005	2006	2009	1997
Method of Operation and Water Savings										
Basis for Schedule	Historical Data		●	●	●	Back-up			●	Back-up
	Onsite Sensor(s)	●	●	●	● [1]	●	● [1]	●	●	● [1]
	Remote Weather Station(s)/Sensors						●			●
	Weather Forecasts					●				
Weather Data Source		Onsite solar and rain sensors	Onsite temperature sensor and solar radiation estimated based on geographic location	16 preprogrammed ET curves with onsite temperature/rain sensor	Historic ET data, evaporative atmometer type ET sensor, weather station or CIMIS data	Weather forecasts automatically from Internet and historic weather data	Public and ETWS weather stations and/or optional onsite weather statiion	Onsite weather station with full set of sensors	Onsite temp, solar, & rain sensors	Public and private weather stations managed by central computer and wireless delivery
Manufacturer Reported Water Savings (Percent)		25	10 to 30	21 to 28 [2]	20 to 40 [2]	30 to 40	20 to 50	30	30	16 to 58 [2]
Product Features										
Stand-alone Controller or Add-on to Existing		Stand-alone	Stand-alone and Add-on	Stand-alone	Stand-alone	Stand-alone	Stand-alone & add-on	Add-on	Add-on	Stand-alone
Station or Zone Capacity		8-48	4-24	6-66	8-48	8-24, unlimited	8-48	1-48	Not Applicable	6-48
Master Valve or Pump Circuit(s)		1	1	1-4	2	1	2	Not Applicable	Not Applicable	1
Internal Power Transformer		Outdoor Models Only	Not Applicable	Commercial Only	●	●	●	Not Applicable	Not Applicable	●
Battery Powered - DC			●					Not Applicable	Not Applicable	
Station Circuit Current Rating (Amperes)		0.75 and 1.5	5.0 (DC pulse)	1.0	1.5	1.0	1.1	Not Applicable	Not Applicable	0.375 and 0.5
Terminal Wire Size Range (Gauge)		12-20	12-18	12-18	14	Max 14 solid & 16 stranded	12 and smaller	Not Applicable	Not Applicable	12-20
Outdoor Installation		●	●	All Comm. & 2 Res.	●	●	●	●	●	●
Onsite Rain Gauge or Sensor w/ Rain Shutoff/Delay		Hygroscopic Rain Sensor	Hygroscopic Rain Sensor [1]	Hygroscopic Rain Sensor	Tipping Bucket Rain Gauge [1]	Hygroscopic Rain Sensor [1]	Rain Sensor or Gauge [1]	Electronic Rain Sensor	Electronic Rain Sensor	Hygroscopic Rain Sensor [1]
Rain Shutoff/Delay by Remote Sensor or Rain Forecast						●				●
Rainfall Irrigation Schedule Compensation		●			●		●	●		●
Onsite Wind Gauge w/ High Wind Shut-off					● [1]	● [1]	● [1]	● [1]		● [1]
High Wind Shut-off by Remote Sensor							● [1]	● [1]		● [1]
Onsite Temperature Sensor w/ Freeze Shut-off			●	●		●	● [1]	●	●	● [1]
Onsite Temperature Sensor w/ High Temp On or Off						●	● [1]	●		
Freeze or High Temp Shut-off by Remote Sensor							● [1]			●
Onsite Evaporative Atmometer Type "ET Sensor"					● [1]					
Onsite Solar Radiation Sensor		●			● [1]		● [1]	●	●	
Onsite Humidity Sensor					● [1]		● [1]	●		
Flow Sensor(s) Connectivity		5 models		12 models	●	●	●			● [1]
Additional Sensor Terminals				With adaptor [1]	●		●	●		●
Internet or Computer Interface					●	●	●			
Remote Control Device(s) for Controller					● [1]		●	● [1]		● [1]
Two-way Communication Between Server and Receiver						●	●	Not applicable	Not applicable	Commerical model
Station Circuit Testing		5 models	●		●	●	●	Not applicable	Not applicable	●
Surge and/or Lightning Protection		5 models	●	Etu & ET-SP models	● [1]	●	●	●		●
SWAT Test Performance Report Available			●		●	●	●	●	●	●
Scheduling Features										
Fully Automatic Schedule (No Base Schedule Required)						●	●	●		●
Base Irrigation Schedule Required		●	●	●	●	●			●	
User May Define Non-Irrigation Days		●	●	●	●	●	●	●	●	●
Operable in Manual Clock Mode		●	●	●	●	●	●	●	●	●
Manual Operation by Station or Program		●	●		●	●	●	●	●	●
Variable Total Run Times		●	●	●	●	●	●	●	●	●
Irrigation Schedule Period(s)		Weekday or daily to 40 days	Week or up to 99 days	Week or odd/even	7-, 14-, 21- or 28-day	Week	Unlimited days	Weekday,1-31 day, odd/even	Not applicable	8 Weeks, Odd/Even & Weekday
Available Start Times		10	4 per program	4-8	6 per manual program	4	9			8 starts with 20 repeat cycles
Cycle/Soak Manual Input		●	●	●	●	●	●			Optional
Cycle/Soak Periods Automatically Calculated						●	●	●		●
Runs Concurrent Stations		●	●		●		●			●
Number of Programs		5	4	4	7	4	Unlimited	Not applicable	Not applicable	Unlimited
Percent Irrigation Adjust Feature			●	●	% of ET Adjust per station		●	●		●
Station Distribution Uniformity/Efficiency Setting							●			●
Syringe Cycle or Program		●		●	●		●			●
New Landscape Establishment/Fertilizer Program				●	●	●	●	●		
Review of Weather Information					●	●	●	●		●
Review of Irrigation or Water Use Information		●	●	●	●	●	●	●		●
English and Spanish Langauges Display					●	●				
Product Support and Warranty										
Warranty		3 years	2 years	3 years	10 years	**3 (Res) and 5 (Comm) years**	3 years	2 years	2 years	3 (Res) and 5 (Comm) years
Support	Onsite Service Technicians	In Southern California	●		●		●			●
	Telephone Technicians	●	●	●	●	●	●	●	●	●
	Local Distibutors	In Southern California	●	●	●	Selected areas	●	●	●	●
Installation and Maintenance Requirements										
Professional Installation and Programming Recommended			Recommended for 2 models	Commercial models	●		●	●	●	●
Ongoing Maintenance Required					Clean sensors			Clean sensors	Clean sensors	
Battery Replacement Required			●	●			●	●	●	
Cost										
Suggested Retail Price		$222 - $1,440	$249 - $2,112	$250 - $3,525	$1,075 - $3,950	$850 - $2,100	$850 - $3,000	$475	$110 - $235	$398 - $4,299
Annual Service Cost		0	0	0	0	0	$75 - $199	$0	$0	$48 - $225

1 - Optional add-on feature not included in controller price(s) shown
2 - Reported water savings documentation is published or publically available
3 - Scheduling guidelines or assistance provided with purchase
4 - Complete pricing information was not available for this report
5 - Controller backup schedule based on recent ET good for 21 days without network connectivity that can be modified by user
6 - Includes remote monitoring of irrigation operation and tracks meter usage for savings reports

Weather-Based Irrigation Technologies – Summary of Product Information and Features (cont.)

Company Name		HydroSaver	Irrisoft Weather Reach	Irritrol	Raindrip	Rain Bird (ETMi & ETC)	Rain Bird (ESP-SMT)	Rain Master	The Toro Company[7]	Tucor[7]	Weathermatic
Telephone		1-562-494-8686	(435) 755-0400	(951) 785-3512	(559) 431-2003 x3014	(800) 724-6247	(800) 724-6247	(951) 785-3573	(877) 345-8676	(800) 272-7472	(972) 278-6131
Contact Person		Tom Carr	Steven Moore	Keith Shepersky	Dan Nourian	Sean Azad	Sean Azad	Bill Wolfe	Brian Ries	Larry Sarver	Brodie Bruner
Web site		www.hydrosaver.net	www.irrisoft.net	www.irritrol.com	www.raindrip.com	www.rainbird.com/etmanager	www.rainbird.com/ESP-SMT	www.rainmaster.com	www.toro.com	www.tucor.com	www.smartline.com
Number of Residential Model Types		0	1	1	2	2	3	0	1	1	2
Number of Commercial Model Types		1	1	1	0	2	0	2	2	3	1
Date Product(s) Entered Market		1994	2002	2011	2009	2006	June 2009	2002	2005	1995	2004
Method of Operation and Water Savings											
Basis for Schedule	Historical Data	●	Backup	●	●	Backup	●	●		●	
	Onsite Sensor(s)	●	●[1]	●	●	●[1]	●	●[1]	●[1]	●	●
	Remote Weather Station(s)/Sensors		●			●		●[1]	●	●	
	Weather Forecasts										
Weather Data Source		Historic ET data and onsite "ET sensor"	Public & private weather stations data managed by centralized computer server	Onsite temp, solar and rain sensors and historic weather data	Onsite temp and rain (tipping bucket) and historic weather data	Public & private weather stations data managed by centralized computer server	solar + solar radiation, & solar -- historic wind & humidity data	Automatic, historic or manually entered ET or with optional onsite weather station	Public and private weather stations managed by central computer and wireless delivery	Automatic, historic or manually entered ET or with optional onsite weather station	Onsite temp & rain sensor and solar radiation estimated based on date & location
Manufacturer Reported Water Savings (Percent)		Not Available	20 to 70	Not available	up to 30	30-80	20-50	25 to 50	16 to 58[2]	25-50	20 to 50
Product Features											
Stand-alone Controller or Add-on to Existing		Stand-alone	Add-on	Add-on	Stand-alone	Add-on	Stand-alone	Stand-alone	Stand-alone	Stand-alone	Stand-alone
Station or Zone Capacity		12-56	Not Applicable	Not applicable	6	Not Applicable	13	6-200	6-48	1-100	4-48
Master Valve or Pump Circuit(s)		1				Not Applicable	●	40,910	1-2	3	1
Internal Power Transformer		●		Controller powers receiver	●		●	●	●	●	Some models
Battery Powered - DC				DC powered sensor							
Station Circuit Current Rating (Amperes)		2.0	4	Not applicable	0.45	1.0 (ETC)	1.0	1.0	0.5	Not reported	1.5
Terminal Wire Size Range (Gauge)		12-20	14 to 26	Not applicable	16 to 24	14 to 26	14 to 20	12-14	12-18	18,16,14	14-18
Outdoor Installation		●	●	●		● (ETC)	●	●	Some models	●	●
Onsite Rain Gauge or Sensor w/ Rain Shutoff/Delay		Electronic rain sensor	Tipping bucket rain gauge[1]	Hygroscopic rain sensor	Tipping bucket rain gauge	Tipping bucket rain gauge[1]	Tipping bucket rain gauge	Tipping bucket rain gauge[1]	●[1]	●	●
Rain Shutoff/Delay by Remote Sensor			●	●		●		●[1]	●	●	
Rainfall Irrigation Schedule Compensation			●	●	●	●	●	●[1]	●	●	●
Onsite Wind Gauge w/ High Wind Shut-off								●[1]		●	
High Wind Shut-off by Remote Sensor			●			●	●	●[1]		●	
Onsite Temperature Sensor w/ Freeze Shut-off		●		●	●			●[1]	●[1]	●	●
Onsite Temperature Sensor w/ High Temp On or Off								●[1]			
Freeze or High Temp Shut-off by Remote Sensor			●			●		●[1]			
Onsite Evaporative Atmometer Type "ET Sensor"								●[1]			
Onsite Solar Radiation Sensor		●		●				●[1]		●	
Onsite Humidity Sensor		●						●[1]		●	
Flow Sensor(s) Connectivity		●	●			● (ETC)		●	●[1]	●	
Additional Sensor Terminals						● (ETC)		●		●	●
Internet or Computer Interface			●[6]					●		●	
Remote Control Device(s) for Controller				●[1]		● (ETC)	Planned for 2010	●[1]	●[1]	●	Planned for 2010
Two-way Communication between Server and Receiver			●					●[1]		●	
Station Circuit Testing					●	● (ETC)	●	●	●	●	●
Surge and/or Lightning Protection		●	●				●	●[1]	●	●[1]	●
SWAT Test Performance Report Available				●	●	●	●	●	●	●	●
Scheduling Features											
Fully Automatic Schedule (No Base Schedule Required)							●	●[1]	●		●
Base Irrigation Schedule Required		●	●[3]	●	●	●[3]		●		●	
User May Define Non-Irrigation Days		●	●	●	●	●	●	●	●	●	●
Operable in Manual Clock Mode		●	●	●	●	●	●	●	●	●	●
Manual Operation by Station or Program		●		●	●	● (ETC)	●	●	●	●	●
Variable Total Run Times				●		● (ETC)	●	●	●	●	●
Irrigation Schedule Period(s)		7, 14, & 28 days, odd/even	Custom, cyclical, odd/even, restricted	Not applicable	interval		Days of week, odd/even, cyclical	7- or 30-day	interval,weekday	14 day & odd/even	Up to 31 days & odd/even
Available Start Times		12		●	4	8 (ETC)	2 watering windows	5-8	●	12	8
Cycle/Soak Manual Input					●	● (ETC)		●	Optional	●	●
Cycle/Soak Periods Automatically Calculated		●		●			●	●	●		●
Runs Concurrent Stations		3		●		● (ETC)	●	●	●	●	●
Number of Programs		6	4	Determined by controller		4 (ETC)	Up to 13	4-16	3-4	10	4
Percent Irrigation Adjust Feature		●		●	●	● (ETC)	●	●	●	●	●
Station Distribution Uniformity/Efficiency Setting							●	●	●		
Syringe Cycle or Program						● (ETC)	●	●	●	●	
New Landscape Establishment/Fertilizer Program						● (ETC)	●				●
Review of Weather Information		●	●	●	●	●	●	●	●	●	●
Review of Irrigation or Water Use Information		●	●	●	●	●	●	●	●	●	●
English and Spanish Langauges Display		●				● (ETC)	●				Planned for 2010
Product Support and Warranty											
Warranty		3 and 5 years	1 year	5 years	1 year	3 years	3 years	5 years	5 years	5 years	2 years
Support	Onsite Service Technicians	In Southern Califonia						●			
	Telephone Technicians	●	●	●	●	●	●	●	●	●	●
	Local Distibutors		●	●		●	●	●	●	●	●
Installation and Maintenance Requirements											
Professional Installation & Programming Recommended		●	●	●		●	●	●	●	Recommended	●
Ongoing Maintenance Required				Clean solar sensor				Clean sensors (if applicable)		Clean sensors	
Battery Replacement Required				●	●						●
Cost											
Suggested Retail Price		$1,800 - $2,800[4]	$420 - $595	$229	$69-$109	$658 - $845	$325 - $450	$684 - $4,040	$325 - $3,050	$1,290 - $1,980	$255 - $900
Annual Service Cost		0	0 - $250	0	0	0 - $350	0	$120 - $180	$48 - $120	$72 - $360	0

1 - Optional add-on feature not included in controller price(s) shown
2 - Reported water savings documentation is published or publically available
3 - Scheduling guidelines or assistance provided with purchase

4 - Complete pricing information was not available for this report
5 - Controller backup schedule based on recent ET good for 21 days without network connectivity which can be modified by user
6 - Includes remote monitoring of irrigation operation and tracks meter usage for savings reports

7 - All information and prices are from June 2009 since manufacturer did not provide updated information for this report

Soil Moisture-Based Irrigation Technologies – Summary of Product Information and Features

Company Name	Acclima	AquaSense	Baseline	Calsense	Dynamax	Irrometer	Tucor[4]
Telephone	(866) 887-1470	(801) 388-9111	(208) 323-1634	(951) 352-3891	(800) 896-7108	(951) 689-1701	724-935-6850
Contact Person	Brad Nuffer	Scott Martin	Nick Toyn	Rick Capitanio	Gary Woods	Tom Penning	Larry Sarver
Web Page	www.acclima.com	www.morph2o.com	www.baselinesystems.com	www.calsense.com	www.dynamax.com	www.irrometer.com	www.tucor.com
Number of Residential Model Types	2	1	1	0	1	1	
Number of Commercial Model Types	2	1	3	1	2	3	2
Date Product(s) Entered Market	2003	2008	2002	1986	2006	1985	2008
Method of Operation and Water Savings							
Interupts Operation of All Stations	●		●		●	Residential models	●
Interupts Operation of Individual or Groups of Stations	●	●	●	●	Requires multiple controllers	Commercial models	●
Manufacturer Reported Water Savings (Percent)	30 to 40[1]		30 to 50	20 to 40[1]	Not available	24 to 60[1]	
Product Features							
Stand-alone Controller or Add-on to Existing	Stand-alone		Both	Stand-alone	Both	Add-on	Stand- alone
Type of Soil Moisture Sensor(s)	Digital time domain transmission	Frequency domain reflectometry	Time domain transmission	Tensiometer	Frequency domain reflectometry	Electrical resistance	Frequency domain reflectometry
Multiple Soil Moisture Sensors May Be Used	●		Commercial models	●	Requires multiple controllers	Commercial models	●
Soil Moisture Sensor Capacity	1-36	1	6 & 25	48	1 or 2	1 to 16	10
Sensor(s) or Controller Connects to Existing Valve Wiring	●	●	●	●		Commercial models	
Number of Soil Moisture Settings	1,000		Unlimitted	Unlimitted	51 and 0-60%	4, 9 and 11	Unlimitted
Measures and Adjusts for Soil Conductivity	●			●		"Internally compensated"	
Controller Displays Soil Conductivity	●						
Measures and Adjusts for Soil Temperature	●		●				
Controller Displays Soil Temperature	●		Commercial models				●
Controller Station Capacity	6,12, 24, 36, & 64	4	12-200	8-48	Unlimited	Unlimited	1-100
Master Valve or Pump Circuit(s)	Commercial models		Commercial models	2		Not applicable	3
Internal Power Transformer	Commercial models	Not applicable	Commercial models	●		Not applicable	●
Battery Powered - DC	Commercial models				Option available	1 model	
Station Circuit Current Rating (Amperes)	0.7	Not applicable	Not reported	1.5	3 & 10	Not applicable	
Outdoor Installation	●	●	●[2]	●	●[2]	All models, commercial option	●[2]
Rain Gauge or Sensor Compatible w/ Rain Shutoff/Delay	●		●	●		●	●
Flow Sensor Compatible	Commercial models		Commercial models	●	●	●	●
Additional Sensor Terminals	●		Commercial models	●	●	●	●
Remote Control Device for Controller	Commercial models[2]		Commercial models	●[3]	●		●
System Testing and Diagnostics	●		●	●			●
Surge and/or Lightning Protection	●		●	●[3]		●	●
SWAT Test Performance Report Avaialble	●	●	●		●	●	
Scheduling Features							
Fully Automatic Schedule (No Base Schedule Required)	Commercial models		Commercial models		Commercial models		
Variable Total Run Times	●		Commercial models	●	Commercial models		
User May Define Non-Irrigation Days	●	Not applicable	Commercial models	●		Not applicable	●
Operable in Manual Clock Mode	●	Not applicable	●	●		Not applicable	●
Manual Operation by Station or Program	●	Not applicable	Commercial models	●		Not applicable	●
Irrigation Schedule Period(s)	Odd/even, Nth day & custom	Not applicable	All options available	7, 14, 21 or 28 day		Not applicable	●
Cycle/Soak Manual Input	●	Not applicable	●	●		Not applicable	●
Cycle/Soak Periods Automatically Calculated		Not applicable				Not applicable	Not applicable
Available Start Times	Up to 6 or on demand	Not applicable	8	6		Not applicable	12
Irrigation Pause/Resume	●	Not applicable	Commercial models	●		Not applicable	●
Runs Concurrent Stations	●	Not applicable	Commercial models	●	●	Not applicable	10
Number of Programs	Up to 40	Not applicable	Up to 10	7	2	Not applicable	12
Syringe Cycle or Program	●	Not applicable	Commercial models	●		Not applicable	●
Review of Recent Irrigation Information	●		Commercial models	●			●
English and Spanish LanGauges Display	Commercial models			●			Universal display
Product Support and Warranty							
Warranty	2 years	2 years	5 years	10 years	1 year	1 year	2 years
Support – Onsite Service Technicians	Some locations			●	Some locations	Some locations	
Support – Telephone or InternetTechnicians	●	●	●	●	●	●	●
Support – Local Distibutors	●			●	Some locations	●	●
Installation and Maintenance Requirements							
Professional Installation & Programming Recommended	Commercial models		Commercial models	●	Commercial models	Commercial models	●
Battery Replacement Required	5 to 10 years	●			Optional		
Cost							
Suggested Retail Prices[3]	$277 - $2,997	$250 and up	$149 - $4,560	$1,285 - $4,160	$525 - $1,045	$100 - $3,146	$1,470 - $2,160

1 - Reported water savings documentation is published or publically available
2 - Optional add-on feature not included in controller price(s) shown
3 - Prices include controller and soil moisture sensor(s)

4 - All information and prices are from June 2009 since manufacturer did not provide updated information for this report

For copies of this report contact
Reclamation's Southern California Area Office at 951-695-5310
or download at
http://www.usbr.gov/waterconservation/docs/SmartController.pdf.