PREDICTING WATER SAVINGS WITH WEATHER-BASED IRRIGATION CONTROLLERS

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Introduction

Much of the Southwest and Western United States has experienced several years of drought, a burgeoning population, and a growing awareness that long-term water conservation is more effective than short-term restrictions. These factors have resulted in the need for tools to assist landscape designers, irrigation contractors, and homeowners and business owners with ways to reduce water used for irrigation while still maintaining attractive landscapes. Municipalities need tools that will insure that they will continue to have sufficient water supplies to meet their customers' demands.

Weather based irrigation controllers (WBIC) appear to be one of several promising tools currently available for reducing water waste by municipal irrigators. Manufacturers tend to make very optimistic claims about their performance, but there is a need to consider these claims in a critical manner, and evaluate exactly what their real savings potential might be, and under what conditions these savings can be achieved. This paper uses data from the Discovery House, a demonstration house in Loveland, Colorado, to show the role that a *properly installed* WBIC plays in water savings at a residential landscape when used in combination with a water efficient landscape and a good irrigation design.

The combination of water efficient landscape design and properly installed and programmed real-time weather based irrigation control combined with a site-specific theoretical irrigation requirement can be used to achieve significant and reliable water savings over the typical residential landscape. In the paper the authors discuss:

- That water efficiency can be optimized with a weather based irrigation controller only by combining it with a water efficient landscape design and a good irrigation system installation.

- The process of establishing a theoretical irrigation requirement; i.e. a water budget for the site, is essential and will provide a target for irrigation applications.
- The three essential factors (design, installation, and control) that must be considered in order to achieve reliable water savings from a water efficient landscape design.
- The irrigation controller is only one element in a water efficient landscape design, and must be combined with both a good landscape plan and a good system installation to be effective.

The authors worked with a local landscape designer to establish a water budget based on the theoretical irrigation requirement for the landscape, installed a weather based irrigation controller (WBIC) at the site, and tracked water use on a new residential property in the Colorado Front Range during the irrigation season of 2004. The site was used as a case study to evaluate the efficacy of a water budget tailored to the landscape which was calculated with site-specific landscape factors and historic evapotranspiration (ET) data. Irrigation application was adjusted with an onsite, weather-based irrigation controller, using real-time ET.

The Test Home

The home used for this study was named the Discovery House and was built by a homebuilder as part of a demonstration of a range of water and energy efficiency devices. The homebuilder[1] is well known for being innovative and with a strong incentive to offer buyers homes that are as efficient as possible. As one element of the demonstration home the builder hired a landscape architect to design a water efficient landscape.[2] Aquacraft installed a WBIC at the site, programmed it with the proper parameters,[3] and tracked the water used for irrigation over the 2004 irrigation season.

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[1] McStain Neighborhoods, Lafayette, CO, contact Justin Wilson, 303-449-5900.
[2] Nature's Design, Jamestown, CO, contact Becky Martinek, 303-459-3333
[3] WeatherTRAK controller, HydroPoint Data Systems, Petaluma, CA, contact Chris Manchuck, 707-769-9696.

The Landscape Design

The design was aimed at producing a water efficient landscape through the use a variety of trees, shrubs, vines and low water use plants on the majority of the area. Turf was used only in the area where it was most useful for play and aesthetics. The site has an irrigated area of 3,990 square feet with four separate irrigation zones. The two turf zones total 480 square feet (12% of the landscape) and are irrigated with conventional spray heads; the non-turf zones total 3,510 square feet (88% of the landscape) and are irrigated with drip irrigation. The landscape was designed to follow the principles of Xeriscape with careful attention paid to plant selection and placement as well as soil preparation and efficient irrigation design.

Irrigation System Installation

A professional irrigation contractor installed the irrigation system. The system was then evaluated by a trained irrigation auditor for compliance with the design and to insure the proper coverage and distribution uniformity of the spray zones. In addition, the contractor installed a rain sensor that was attached to the irrigation controller.

The Irrigation Controller

Aquacraft installed and programmed the WBIC thereby insuring that all of the program information: soil type, plant type, precipitation rates, and microclimate, were measured correctly and entered separately for each zone. Default values for the precipitation rate were not used; rather the precipitation rates for the spray zones were measured with catch cans and verified by flow rate tests. The precipitation rates for the drip zones were calculated by measuring the flow rate and number of emitters and determining the area of coverage of each emitter.

The WBIC controller used at this site received local ET information via a pager network on a daily basis. The ET data were calculated using a proprietary model developed by the manufacturer that predicts ET at any location. This broadcast ET information was used in conjunction with the horticultural data programmed for the system that then created a real time irrigation schedule and application rate for each zone.

The authors obtained similar data from the nearest ET weather station, operated by the Northern Colorado Water Conservation District to determine the ET_o for the site. These data were used in calculating the water budget as well as the theoretical irrigation requirement that was use to compare the performance of the WBIC discussed later in this paper.

The Tools – Determining Landscape Water Use

Many residential landscapes consist of large areas of cool season turf bordered by shrubs and interplanted with trees. Irrigation systems are often scheduled to run 15 minutes per zone with only minor adjustments to the schedule throughout the season. By comparing the typical irrigation application to this type of site with the theoretical irrigation requirement of a water efficient landscape and irrigation system, predicting the potential water savings from any landscape becomes straightforward.

Developing the Theoretical Irrigation Requirement

The amount of water required to maintain a particular landscape is known as the theoretical irrigation requirement, and over the course of the irrigation season it is used to determine the water budget for the site. There are numerous factors that influence the water requirements for the landscape and these factors must be considered when determining the theoretical irrigation requirement. These factors have been found to have a very significant affect on the amount of replacement water that needs be applied to maintain a healthy landscape. They include:

- Microclimate (K_{mc}),
- Species factor (K_s), and
- Density factors (K_d)

The microclimate can vary significantly from one irrigation zone to the next in a landscape and is affected by wind, shade, reflected heat, and a variety of localized conditions. The species factor represents the rate at which various plant species lose water (transpire) through their leaf and stem surfaces and therefore the amount of replacement irrigation required to maintain the health of the plant. Finally, the density factor refers to the percent of ground covered by plants in a particular irrigation zone. This will tend to increase as the landscape matures.

Once each of these factors is determined for each zone and they are multiplied together to calculate a zone factor, K_z.[4] It is then a simple matter to multiply the historic annual reference ET_o for the site by the zone factor, and divide by the efficiency of the irrigation zone to calculate the theoretical irrigation requirement for each zone. For example, Zone 1 at the Discovery House was a turf zone newly planted with cool season grass. The density factor for turfgrass is 1.0, the microclimate for this zone is 0.95 due to some light shading from some small trees and a fence, and the species factor used was 0.95[5] yielding a zone factor or 0.86. The ET_o (18.7 gpsf) was based on historic weather data obtained from a local weather station for cool season turfgrass. Multiplying the ET_o by the zone factor (K_z) of 0.86 and dividing the result by the irrigation efficiency of 70 percent results in a seasonal water budget for Zone 1 of 5,479 gallons. This process was repeated for each zone and the results are shown in Table 1. The annual theoretical irrigation requirement determines the water budget for the landscape over the course of the entire irrigation system when the zone coefficient K_z is applied to historic ET. The total theoretical irrigation requirement or water budget for this site was 28,178 gallons.

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[4]For the purposes of this paper, K_z is equivalent to the landscape factor, K_L, defined by the Irrigation Association as $K_s \times K_d \times K_{mc} = K_L$ for each zone. We refer to the landscape coefficient of the overall site as the ratio of the theoretical irrigation requirement to the reference irrigation requirement.

[5]This is higher than the species factor recommended for "high turfgrass" by the Irrigation Association but was chosen due to the fact that the landscape had just been recently installed and was in the establishment period.

Table 1: Determining the plant water requirement for each zone of test home

	Irrig Area	Plant Type[6]	K_d	K_{mc}	K_s	K_z	ET_o (gpsf)	Irrigation Efficiency	Water Budget (gal)
Zone 1	240	CSG	1.0	0.90	0.95	0.86	18.69	70%	5,479
Zone 2	240	CSG	1.0	0.90	0.95	0.86	18.69	70%	5,479
Zone 3	1,755	HWUS	0.50	0.75	0.63	0.24	18.69	90%	8,610
Zone 4	1,755	HWUS	0.50	0.75	0.63	0.24	18.69	90%	8,610
Total	**3,990**								**28,178**

Reference Water Requirement and Potential Water Savings

The reference water requirement is based on the irrigation requirement for a similar size property planted in cool season turf grass or other plants with a similar K_s. As noted above, the ET for this type of landscape is approximately 30 inches per irrigation season or 18.7 gallons per square foot. This results in a reference water requirement for this 3,990 square foot test site of 74, 573 gallons. Taking difference between the reference water requirement and the theoretical irrigation requirement shows the potential savings that can be achieved from a water efficient landscape. In the case of the Discovery House the potential savings amounts to 74,573 – 28,178 = 46,395 gallons of water per year. Because the reference water requirement is based on the amount of irrigation required on a square foot basis it is possible to predict the savings for an entire landscape or on a zone-by-zone basis. Table 2 shows the information that must be known or calculated in order to predict the water savings for any landscape.

Table 2: Reference ET_o and theoretical irrigation requirements for test site

Reference ET_o	ET_o	Inches	30
ET Application Rate	ET_o	Gpsf	18.69
Irrigated Area	A_i	square feet	3,990
Reference Water Requirement	ET_{req}	Gallons	74,573
Theoretical Irrigation Requirement	V_t	Gallons	28,178
Predicted Savings		Gallons	**46,395**

[6] CSG – cool season grass; HWUS – high water use shrubs

Landscape Coefficient

The landscape coefficient is the *ratio* of the theoretical irrigation requirement to the reference requirement. In other words, the landscape coefficient is the percentage of the water used by a standard bluegrass lawn required to maintain the particular landscape at the site. The landscape coefficient of the Discovery House yields was 0.38. The landscape coefficient can be calculated for any site using this method and provides municipalities with an excellent predictive tool of water needed for landscape irrigation in relation to a standard value.

Weather Based Irrigation Control

When a landscape is irrigated efficiently the application of water should match the requirements of the plants in the landscape over the entire irrigation season. Since ET varies over the season, so will the irrigation requirement. By looking at the historical ET over several years one can develop seasonal water requirements. Calculating the theoretical irrigation requirement on a real-time basis serves several purposes:

- It takes into consideration fluctuations in historic ET_o which is simply an average of the ET data gathered over a period of several years.
- It can provide a tool for making percent adjustments to the irrigation controller on sites that are not equipped with a WBIC
- It provides a means of monitoring the irrigation application throughout the season

responded to changes in ET. The actual application rate was lower because the WBIC was programmed for to match the actual landscape not cool season grass. The high application rate early in the season took place during the installation of the new landscape and was the result of a manual override on the WBIC.

Figure 1 is a graph of the actual water applied at the discovery house over the 2004 irrigation season. The bottom line shows the actual application and the top line shows the reference requirement based on cool season grass. With the exception of the start of the season when the system was catching up, the figure shows how closely the WBIC responded to changes in ET. The actual application rate was lower because the WBIC was programmed for to match the actual landscape not cool season grass. The high application rate early in the season took place during the installation of the new landscape and was the result of a manual override on the WBIC.

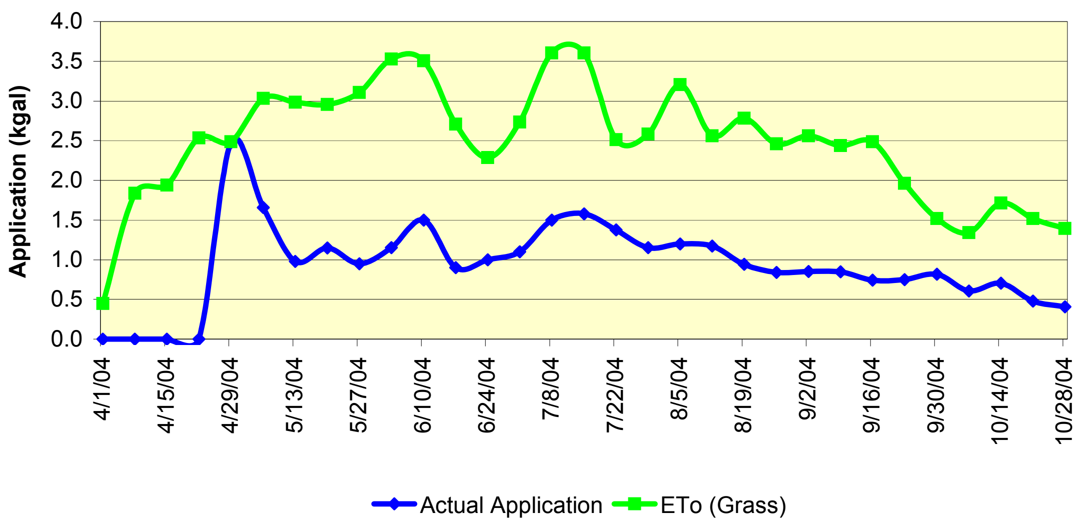

Figure 1: Weekly application versus ET_o for the Discovery House

The Savings – Analysis of the Results

Of particular interest to municipalities is whether or not predicted savings are achievable. In order to avoid or at least reduce the need for severe restrictions during times of drought, water suppliers can more readily predict residential water demand during the peak irrigation season if a water budget has been developed for a site.

Tracking Water Use

The theoretical irrigation requirement was calculated for the Discovery house site over the entire irrigation season on a weekly basis. This was the water budget for the site and was calculated by multiplying the landscape coefficient of the site (38%) by the weekly

ET_o. Weekly meter readings obtained by the builder were used to determine the actual application. Irrigation at this site began on April 22 and continued through October 28, 2004. Tracking water use at this site was simplified due to the fact that the house was unoccupied during the period of this study and therefore all metered water could be attributed to irrigation. The fact that the house was unoccupied also insured that no changes were made to the programming of the WBIC. Also, the water meter data were provided by the builder, there were no occupants to perform manual "adjustments" to the system, and Aquacraft never visited the site during the irrigation season. This provided us with a good test case of how the system ran in an unsupervised mode.

In Figure 2 the weekly theoretical irrigation application for the test site was plotted against the actual application. This shows a very close correlation between the predicted water use for the site and the water that was actually applied. The only period where the actual application was significantly different than the theoretical requirement was during the start up phase at the beginning of the season. At this time it was assumed that the soil moisture was depleted and additional irrigation was needed to meet the plant requirements.

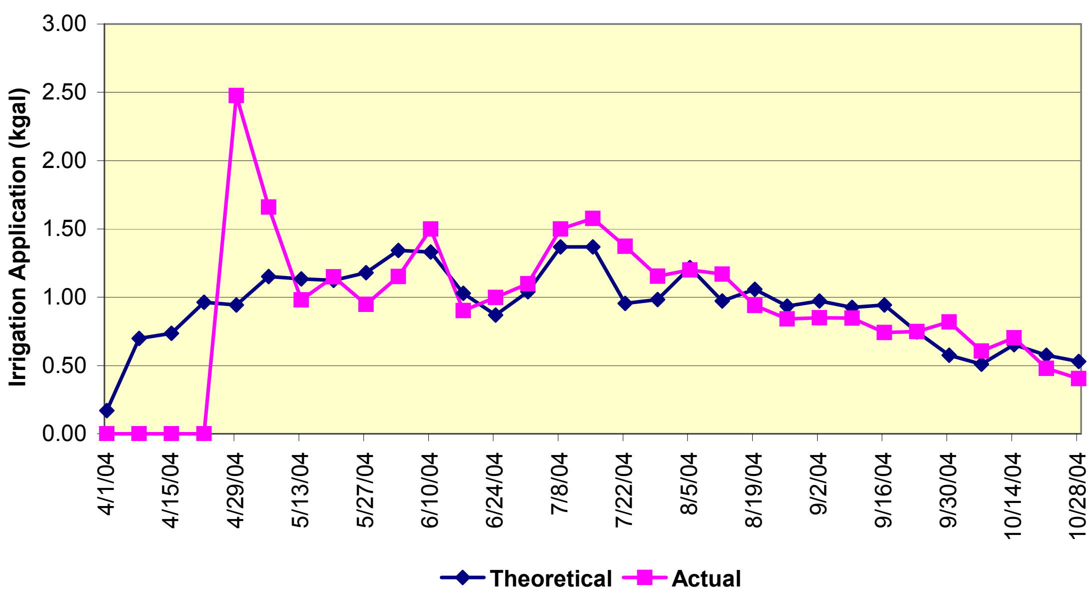

Figure 2: Theoretical requirement based on real-time ET_o versus actual irrigation application

At the end of the irrigation season the actual irrigation application for the site was 28,820 gallons and the theoretical requirement was 29,010 gallons – a difference of less than one percent. A standard landscape would have required over 75,000 gallons, so the Discovery home saved over 46,000 gallons of water (0.14 af).

Conclusion

Increasingly, it is becoming the responsibility of landscape and irrigation professionals to provide homeowners with water efficient landscapes, good irrigation systems and intelligent irrigation controllers. Minimizing water use for irrigation, while maintaining a high quality landscape appearance, is a good way for conserve urban water supplies. Both the demand and supplies problems can be addressed by use of new technology.

Weather based irrigation technology is a promising tool for increasing efficient irrigation. The results of this study make it clear, however, that a weather based irrigation controller is fully capable of applying the appropriate amount of water for irrigation when properly programmed. It is less clear that simply installing and programming a WBIC will necessarily result in significant savings unless it is used in conjunction with a good water efficient landscape design and an appropriate irrigation budget. In fact, in many cases a WBIC may result in water use increasing.

The Discovery House used only 38% of the irrigation water that a comparable house with a standard blue grass lawn would have used. This represents a savings of 62% from a standard design, or over 46,000 gallons of water per year. These saving could be used to support other development or maintain a storage reserve in the system reservoirs.

Creating a water budget for a landscape is essential to manage water use. Factors such as plant type, microclimate, and plant density must be considered an integral part of the calculating the water budget (or theoretical irrigation requirement) for the landscape.

Developing a landscape water budget will help homeowners, landscape and irrigation professionals, and utilities gauge the amount of water that is needed to maintain a healthy landscape, and how well their irrigation systems are performing in matching the actual applications to the theoretical requirements.

Using the landscape coefficient and theoretical irrigation requirement to develop a water budget provides homeowners with a way to gauge and track water use on their landscape and is an excellent way of alerting them to potential problems with their irrigation system.

The fundamentally fact must be emphasized that no technology, no matter how elegant, can optimize irrigation water use. Only when all of the components of efficient irrigation are used together will we be able to maximize the savings from landscape irrigation. Without a water efficient design the system will never be able to make major savings from reference requirements. A poorly constructed system, with poor distribution uniformity will force owners to choose between efficiency and a attractive appearance. A controller that does not adjust irrigation applications to match actual requirements will just represent a liability. On the other hand, a water efficient design in combination with a good irrigation system and an intelligent controller can achieve major saving, like those demonstrate in this case study.