Performance Evaluation of WeatherTRAK™ Irrigation Controllers in Colorado

AquaCraft

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EXECUTIVE SUMMARY

The Weather TRAK ™ ET based irrigation controller consists of an irrigation controller linked to a network of local weather stations via pager technology. This allows evapotranspiration (ET) data to be sent to the units on a periodic basis. The controller then adjusts the irrigation schedule as appropriate in order to insure the correct applications for the specific plant types in each zone of the system.

Beginning in 2000, the Cities of Boulder, Longmont and Greeley Colorado began a field study aimed at determining the performance of the WeatherTRAK system in actual field use within their service area. A total of 10 sites were selected for the study from a combination of volunteers and high water using accounts. A total of nine residential and 1 office account were included in the study. The actual irrigation applications of each system were tracked against the theoretical requirements for the 2001 season, and the results are summarized in this report.

- As a group, in 2001 the 10 sites applied 94% of the ET_o, or 28 inches of water to their landscapes.
- As a group the 10 sites saved an average of 26,000 gal of water per site compared to their historical use.
- If just the 5 participants who saved significant amounts of water were included, their average annual savings were 68,000 gal per site. This shows the greater savings potential if the program was marketed to only high users.
- The 5 participants that saved water with the Weather TRAK system also saved an average of $197 per year in water charges. This was based on weighted average water rates of $2.40 per kgal.
- Some of the volunteer participants in the study were historically under-irrigating. Consequently, it was not possible for the system to save them water. But, the WeatherTRAK system matched their historical performance.
- Most customers liked the way the WeatherTRAK worked, and the problems reported were minor. Most importantly, the system delivered the appropriate ET information to the controllers with a high degree of reliability.

A conclusion of this study is that the WeatherTRAK ET controller system is capable of utilizing ET information from local weather stations, and transmitting these data to the units in the field. The field units successfully converted the ET data into irrigation programs that matched applications to ET based requirements. The system performance was increased slightly with rain sensors and obtaining measurement of actual zone-by-zone precipitation rates. Customer satisfaction was good, but customers were hesitant about paying directly for the suggested annual signaling fee for the system. Most customers were willing to allow the utility to use the system to curtail their irrigation for short periods to help shave peak demands.

INTRODUCTION

In the spring of 2000 the cities of Boulder, Longmont, and Greeley, Colorado began a small pilot study of the reliability and effectiveness of the WeatherTRAK™ ET signal controller. The purpose of this study was to document the performance of the system in actual field conditions at homes of volunteer customers. Due to delays in receiving the controllers little data were collected during the 2000 irrigation season and the test was extended through the 2001 season. A total of 10 customers had a WeatherTRAK unit installed by the middle of June 2001, and water use data were collected throughout the 2001 irrigation season. The purpose of this report is to provide the results of this study. This document focuses on water use, reliability, customer acceptance, and monetary savings of the system. It is hoped that this will assist with evaluation of this potentially useful water management system.

STUDY DESCRIPTION

Participants

Three Colorado cities: Boulder, Greeley and Longmont participated in the WeatherTRAK irrigation controller study. Each City distributed fliers to targeted neighborhoods in their service areas describing the study and asking for volunteers to participate. Individuals who wanted to participate were asked to contact the utility or consultant. The exceptions to this were a school district building in Longmont and two residences in Boulder. All of these parties were requested to participate in the study because of their historical water use patterns. Consequently, this study group consisted of seven volunteers and three solicited participants. It does not represent a standard or random sample, and judgement must be used in interpreting the results.

As a requirement of participation, each customer had to have an irrigation controller with 12 zones or less. These customers also had to agree to have their present irrigation controller replaced for the 2001 irrigation season. Nine of the ten participants were single family residential customers. The School District's administration building was the one institutional customer in the study. The City of Boulder had four residential customers in the study; Greeley three residential customers and Longmont had two residential customers and an institutional customer. A map showing the three study cities is shown in Figure 1.

Northern Colorado Water Conservancy District Test

In parallel with this study, but not part of it, a WeatherTRAK controller was installed in Loveland, Colorado, by Mr. Brent Mecham at the offices of the Northern Colorado Water Conservancy District. The purpose of this installation was to compare a series of sensor and ET based controllers. At the end of the 2001 irrigation season Mr. Mecham reported to us that the WeatherTRAK unit applied 19.63 inches of water to the test turf, compared to the estimated plant requirement of 19.84 inches, which represents 99% of the requirement. Mr. Mecham also reported that the default application rates in the program overestimated the precipitation rates (and consequently, under-irrigated the landscape) at the beginning of the season. It was not until he programmed the actual precipitation rates into the unit that the system was optimized.

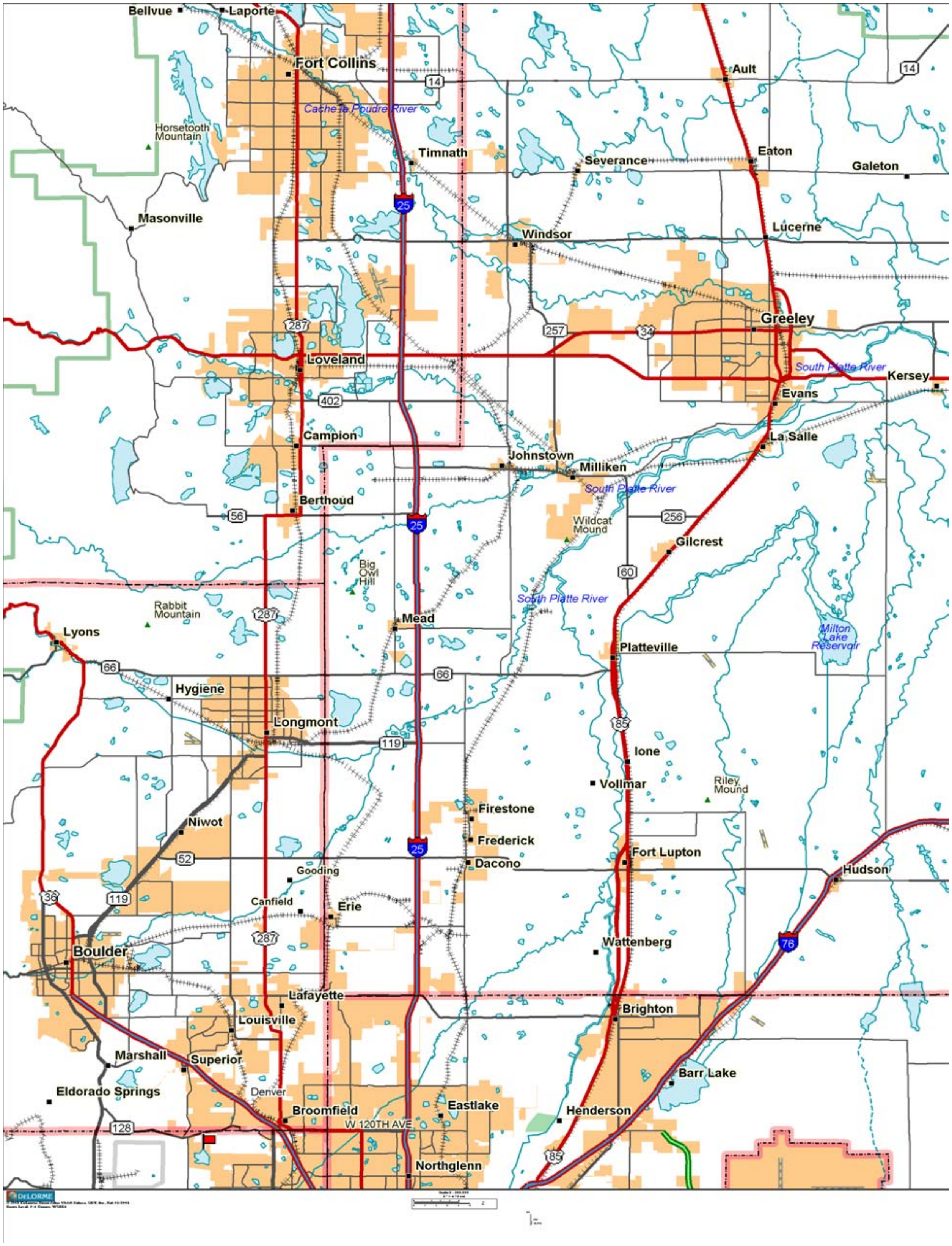


Figure 1: Location of Study Sites

Overview of WeatherTRAK Evaluation

The WeatherTRAK™ system consists of three elements: a network of weather stations that can be remotely down-loaded, a central data processing and communications hub, and the WeatherTRAK™ field controllers (ET signal controllers). These controllers are capable of receiving evapotranspiration (ET) data via satellite. The network utilizes pager-like technology to send a signal pulse that can be broadcast to any number of WeatherTRAK controllers. Each controller can be addressed in several ways. Controllers in the same utility, or linked to the same weather station, or zip code can all be sent the same message. Specific messages can also be sent to individual controllers by their serial number. The information typically transmitted to a field unit is the ET_o for the past 7 days, which is used by the controller to develop an irrigation schedule for the current week. The WeatherTRAK controllers have crop coefficients built in to modify the ET_o for the predominant vegetation in each irrigation zone. In this way, the controllers are continuously making up the soil moisture depletion from the previous time period in current time. In addition, signals can be sent out to initiate a rain pause or to update the date and time information on the controller.

The Northern Colorado Water Conservancy District (NCWCD) operates a network of remote, solar powered, automated weather stations throughout its service area. The weather station network is currently composed of 16 stations, 10 in alfalfa fields and six on urban turf grass. The urban turf grass stations are located at large, well-irrigated areas. Stations are approximately 25 to 30 miles apart to provide the best practical coverage for the District's 1.5 million-acre service area. The three stations used for the study were turf grass sites and each was located in one of the participating cities (Boulder, Greeley, and Longmont).

Each station records air temperature, relative humidity, wind speed and solar radiation. The data are used daily to calculate standardized reference evapotranspiration (ET_o) using the 2000 Standardized ASCE Penman-Monteith equation for turf grass. Stations automatically transmit data via modem and cell phone twice daily to district headquarters. This ET_o information was downloaded by Aquacraft from the NCWCD's web pages.

The Colorado Front Range region has numerous microclimates that can dramatically affect the calculation of ET from one city to another. To account for this, Aquacraft created a distinct ET zone for each city in the study and there was at least one weather station in each ET zone. All WeatherTRAK controllers were coded to receive signals for the appropriate ET zone. This allowed individual WeatherTRAK irrigation controllers to receive an ET signal that closely represented the specific local microclimate.

The specific ET data used adjust the ET signals for the WeatherTRAK irrigation controllers were faxed to Network Services Inc. initially on a weekly basis. Weekly signals were sent from April 1 to May 15, 2001. After May 15, 2001 it was determined that due to the variability of Colorado weather, which includes locally intense rainstorms storms and sudden temperature changes, the best approach for transmitting the ET signals was to transmit signals three days a week, on Monday, Wednesday and Friday. If local weather conditions changed dramatically between these periods, a signal was sent adjusting the ET_o or initializing the rain pause feature of the WeatherTRAK irrigation controller.

As shown in Table 1 five of the WeatherTRAK controllers were installed toward the end of the 2000 irrigation season and the other five were installed in 2001. The final install was on June 19th, 2001. Units that were installed during the course of the irrigation season were tracked starting from the date of installation, which should be kept in mind when comparing the results.

Over the course of the 2001 irrigation season the water use at each site was tracked so that the application rate of the system as controlled by the WeatherTRAK units could be compared to the ET_o. In addition, each site was visited at least once during the year to check on the operation of the irrigation system and controller. A log was kept of all problems reported by the owners and what measures were taken to resolve them.

At the end of the season the water use data was tabulated and the owner's were sent a survey to complete. Once all of the survey responses were returned, all of the information was summarized and this report was prepared for presentation to the sponsors, participants and other interested parties.

Table 1: Irrigated Area and Landscape

Site #	City	Weather TRAK Install Date	# of Irrigation Zones	Approximate Areas		
				Total Landscape Area (sf)	Cool Season Grass (sf)	Shrubs,Trees Flowers and Garden (sf)
ADA	Boulder	6/5/01	5	4,500	3,825	675
BOG	Boulder	06/19/01	6	4,100	2,665	1,435
KER	Boulder	9/12/00	6	8,230	4,527	3,704
LEW	Boulder	8/7/00	6	5,860	4,395	1,465
AND	Greeley	9/13/00	7	11,000	6,050	4,950
CER	Greeley	9/11/00	7	4,000	3,800	200
SAR	Greeley	9/18/00	10	13,000	9,750	3,250
HAR	Longmont	04/27/01	12	15,780	11,835	3,945
SOU	Longmont	04/27/01	9	17,500	10,500	7,000
SVS	Longmont	05/11/01	7	6,665	5,665	1,000

Irrigated Area and Historical Water Use

The 10 study participants had an average irrigated area of 9,065 square feet (sf). The maximum irrigated area in the study was 17,500 sf and the minimum irrigated area was 4,000 sf. The total irrigated area for the ten study sites was 90,635 square feet and of this irrigated area approximately 63,010 sf or 70% percent was cool season grass and 27,625 sf or 30% percent was shrubs, trees, flowers and garden. Table 1 shows the information on the landscaped areas for each of the 10 sites.

The historical water use and application rate data for the sites are shown in Table 2. It is important to note that this table shows that many of the participants in this study were irrigating well below ET *before* the installation of the WeatherTRAK controller. In fact, while the average application rate was 105% of ET_o, 6 out of the 10 sites were applying significantly less than ET. The 95% confidence interval of the data was 47% so the true average could lie anywhere between 58% and 152% of ET_o. The wide range in historical applications is shown graphically in Figure 2 which is a histogram showing the number of sites falling into 10% bins ranging from 30% to 270% of ET_o.

Table 2: Historical irrigation application rates for study sites

Site #	City	Irrigated Area (sf)	Historical Outdoor Use		
			kgal	Historical (inches)	Percent of ET_o
ADA	Boulder	4,500	64	22.8	64%
BOG	Boulder	4,100	112	43.8	122%
KER	Boulder	8,230	65	12.7	35%
LEW	Boulder	5,861	50	13.7	38%
HAR	Longmont	15,780	323	32.8	103%
SVS	Longmont	6,665	350	84.3	265%
SOU	Longmont	17,500	296	27.1	85%
AND	Greeley	11,000	220	32.1	96%
CER	Greeley	4,000	121	48.5	145%
SAR	Greeley	13,000	256	31.6	95%
Average (±95% Conf. Int.)		9,064	186 ± 83	34.9±14.9	105% ± 47%

It is fairly typical for volunteers in water efficiency studies to be people who already were concerned about irrigation and efficient use of water. So, it is not surprising that so many of these people were efficient irrigators to start with. On the other hand, some of the persons who had higher application rates were requested to join the study, so in a sense they could be called conscripts, and their motivation may have been mainly to please the utility rather than a desire to take advantage of this technology.

The exact attitudes and motivations of the participants while important, were not a critical element for this study. The primary goal was to determine whether or not the technology *works*. From this perspective, then, the real critical elements were:

- To observe if the WeatherTRAK controllers were reliable in receiving the ET signals
- To determine if the WeatherTRAK controllers converted the ET signals into appropriate irrigation schedules
- To observe how users might modified the operation of the WeatherTRAK controllers (using the instruction sheets provided) to increase or decrease the programmed applications
- To measure the actual application rate after the installation of the WeatherTRAK controller and to compare this to the ET requirement
- To determine how frequently failures or errors occur in the field

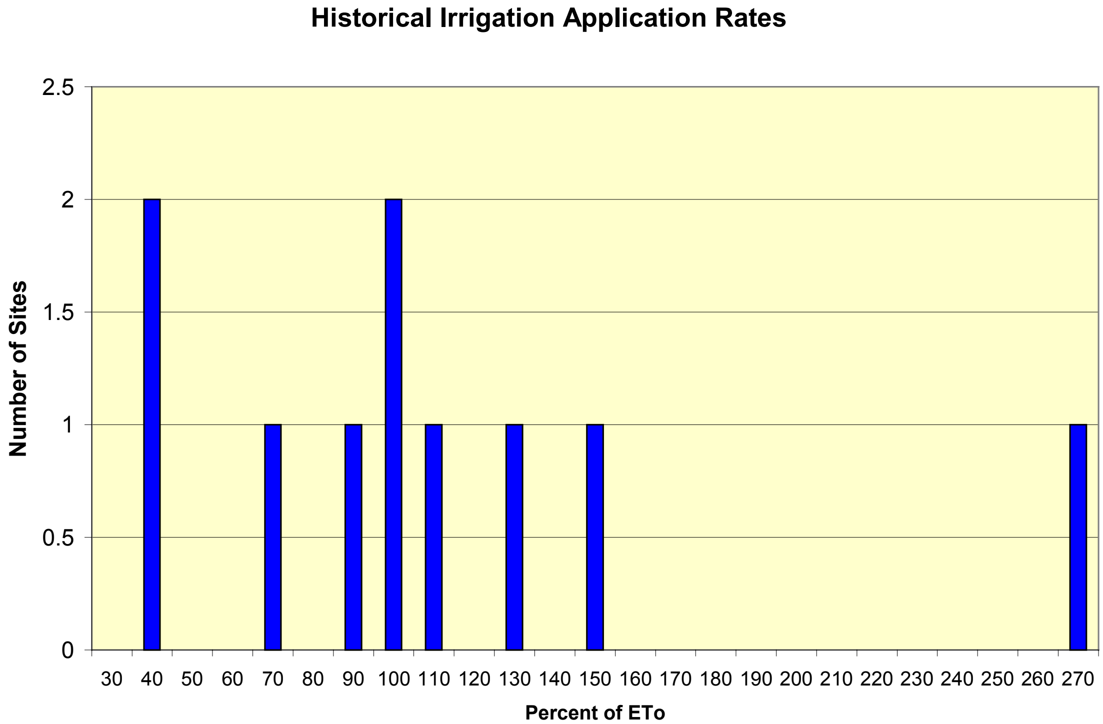


Figure 2: Historical irrigation applications as percent of Eto

Installation

For this study the old irrigation controller was either left mounted to the wall or taken down and given to the participant to store. Each participant was given the option of have the old controller re-installed at the end of the study if he/she didn't want to continue operating the WeatherTRAK unit. One man using hand tools installed all of the WeatherTRAK controllers. Installation typically consisted of attaching the controller to the wall, plugging it in and connecting the zone wires. If the installation also included a rain shut off device it was always more complicated because this involved running a wire from the controller, which might be in a basement or garage, outside to a place where a clear spot for the shut-off was available. This typically involved drilling holes in walls, climbing on ladders, and stapling wire to the walls.

At each site a careful zone by zone evaluation of the system was conducted to determine the proper settings for the controller. This evaluation was the most complex element of the installation. Proper programming of the WeatherTRAK controller requires information on the plant type, soil type, exposure, slope, precipitation rate, and irrigation efficiency of each zone in the system.

In order to obtain the necessary system information, after the WeatherTRAK irrigation controller was installed the function selector was set to manual, and all zones were run for two minutes. During the testing of the irrigation system the application rates and efficiencies were estimated. Sprinkler heads that needed repair were identified on the installation sheet and the participant was informed of any problems with the understanding that the participant would correct these. The participant was also informed of other potential problems, such as over/under spray areas, non-uniform coverage and blocked sprinkler heads, again, so that the problems could be remedied.

The average time of installation for the WeatherTRAK irrigation controller was 1.25 hours.[1] If a rain sensor shut off device was installed the installation time increased to 1.75 hours. The average landscape audit to determine the square footage of the irrigation zones and the landscape composition was 1.0 hour bringing the total time at the site to an average of 2.25 hours. The longest install took four hours. The majority of problems that occurred during the installation of the WeatherTRAK irrigation controller occurred when the previous controller's zone wiring was not identified and anytime the installer had to go through the wall of a house and any installation on block or concrete walls.

Each WeatherTRAK irrigation controller follow up audit took less than one hour to perform. The audit checked that the WeatherTRAK irrigation controller was operating correctly, identified any changes the owner had made to the controller, the condition of the landscape, problems with the sprinkler system that may be contributing to landscape conditions, and the current ET and zone configurations.

RESULTS

Comparison of Irrigation Applications

Evapotranspiration (ET) gives a measurement of the amount of water (in inches) required to replace evaporation and transpiration for maximum plant growth. The reference ET_o is 12 cm (4.7") for cool season turf grass. ET_o is calculated by measuring the energy from various sources that impact plant growth. These energy sources are solar radiation, wind, and air temperature as moderated by relative humidity. Standard instruments on weather stations measure these parameters, and the energy equation converts them into inches of evapotranspiration. ET_o includes rainfall only indirectly through its effect on relative humidity. It also does not include water requirements for flushing salts from the soil and irrigation system inefficiencies.

During the primary irrigation season, from April through October, for the years 1998-2000 the average ET_o for Boulder, Longmont and Greeley was 34.3 inches. In 2001 the ET_o for Boulder, Longmont and Greeley was quite similar, at 34.8 inches. As shown in Table 2, during the 1998-2000 irrigation seasons the participants averaged 34.9 inches of irrigation application, while, as shown in Table 3, in 2001 the application rates for all 10 sites dropped to 28.2 inches, a reduction of 19%.

Results varied considerable from site to site as are shown in Figure 3, but it is evident that all of the 2001 application rates were much closer to the ET_o values than were the historical application rates. In addition, it can be seen that those customers who historically over-irrigated tended to make adjustments to the WeatherTRAK that increased their application rate and those

[1] Excluding travel time.

that were under-irrigators made the opposite changes. As shown in Table 3 the post WeatherTRAK applications were 94% of ETo with a margin of error of ±20%.

The two types of adjustment most often made by the customer were percent increases or decreases which were applied to the signal generated applications, or simple manual operation of one or more zones on an as needed basis.

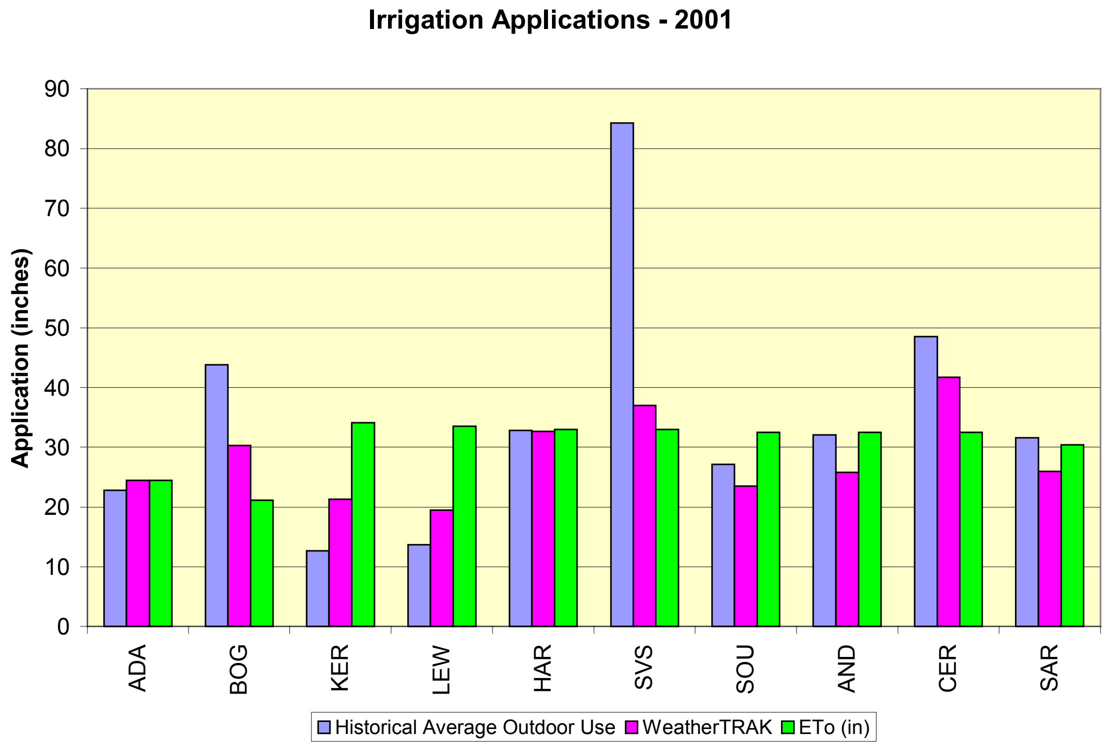


Figure 3: Irrigation application rates before and after WeatherTRAK installation

Cumulative Application Comparisons

Appendix A shows graphs for each of the ten sites that compare the cumulative irrigation applications of each against the ET_o and historical applications for the 2001 irrigation season or the date of install for the unit.

The 10 figures show how well the system tracked ET for the entire irrigation season. In some cases the applications lie above or below the ET line, but in all cases they tend to mirror the shape of the line from the beginning to the end of the season. They start out slowly, accelerate through the middle of the season and the taper off at the end of the season, which is precisely what the study was looking to find.

Table 3: Irrigation application with WeatherTRAK

Site #	Precipitation during Irrigation Season (in)	Irrigation Application with WeatherTRAK (in)	Irrigation Application as Percent of ET_o
ADA	11.9	24.5	100%
BOG	11.9	30.3	143%
KER	11.9	21.3	63%
LEW	11.5	19.5	58%
HAR	11.0	32.6	99%
SVS	11.0	37.0	112%
SOU	11.0	23.5	72%
AND	9.4	25.8	79%
CER	9.4	41.7	128%
SAR	9.4	25.9	85%
Average (± 95% Confidence Interval)		28.21 ±5	94% ± 20%

With three major (ADA, CER and BOG) and one minor exception (SVS), all of the irrigation application lines lie below the ET_o line and run parallel to it. The SVS site started out just below the line but was adjusted to a slightly higher position in order to maintain a more lush appearance desired by the staff and also to compensate for a broken water line that interrupted irrigation in September. The remainder of the sites showed applications that parallel and run at 60-80% of ET_o. The three sites that come closest to the ideal application are those of AND, SAR and SOU.

Percent of Potential Savings Captured

The applications with the WeatherTRAK dropped from 34.9” down to an average of 28.2” – a 19% reduction. A full turf landscape should be able to do well with an application of 30” after effective rainfall and plant coefficients are considered, and with mixed landscapes the overall applications should easily drop to 25”. Using these guidelines the WeatherTRAK system appears to have captured around 88% of the potential savings on these 10 sites.

Impact of Rain Interrupts

Rain interrupt devices (Mini-Clicks™) were installed on four of the sites as an add-on to the WeatherTRAK. Five were left with no interrupts, and one had one at the start of the project, so the group was evenly split between those with and without rain interrupts. The five sites with rain interrupts achieved an application of 84% of ET_o while those without had applications averaging 104% of ET_o. It is not correct to attribute this change totally to the rain interrupts, but the data do suggest that adding a rain interrupt increases the efficiency of the system by preventing operation after local rain showers.

Water and Cash Savings

The WeatherTRAK system clearly was able to regulate irrigation in order to match $ET_{o.}$ But how does the system perform in terms of simple water and money savings. Figure 4 shows the net savings for each of the 10 sites. Savings for the group as a whole averaged 26 kgal for the year, including both increased and decreased uses. The data show that four of the sites used more water in 2001 than they did historically. These include the BOG site which is difficult to analyze since their system was installed in the middle of June, 2001, and over 50 kgal of outdoor use had already occurred. The KER and LEW sites used more water in 2001, but this was compared to very sparse historical irrigation practices. The ADA site used slightly more water, but as with the HAR site their historical use was right at ET as was their WeatherTRAK use, so their numbers are essentially a break even situation.

If we look just at the sites where savings were achieved, and if we assume these sites could be targeted for participation in large-scale projects, then the potential savings appear more favorable. All of the sites with savings were in either Longmont or Greeley. Table 4 shows that for those customers that achieved water savings their average savings amounted to 68 kgal. At the water rates shown in the Table this resulted in savings of $197 per site, on average. At higher water rates these savings would be greater.

Table 4: Results from Sites Showing Savings

Site	City	Water Rate ($/kgal)	Savings (kgal)	Savings ($)
SVS	Longmont	3.41	196.17	$ 668.95
SOU	Longmont	3.41	39.92	$136.12
AND	Greeley	1.73	43.10	$ 74.55
CER	Greeley	1.73	16.94	$ 29.30
SAR	Greeley	1.73	45.84	$ 79.30
Average			68.39	$197.65

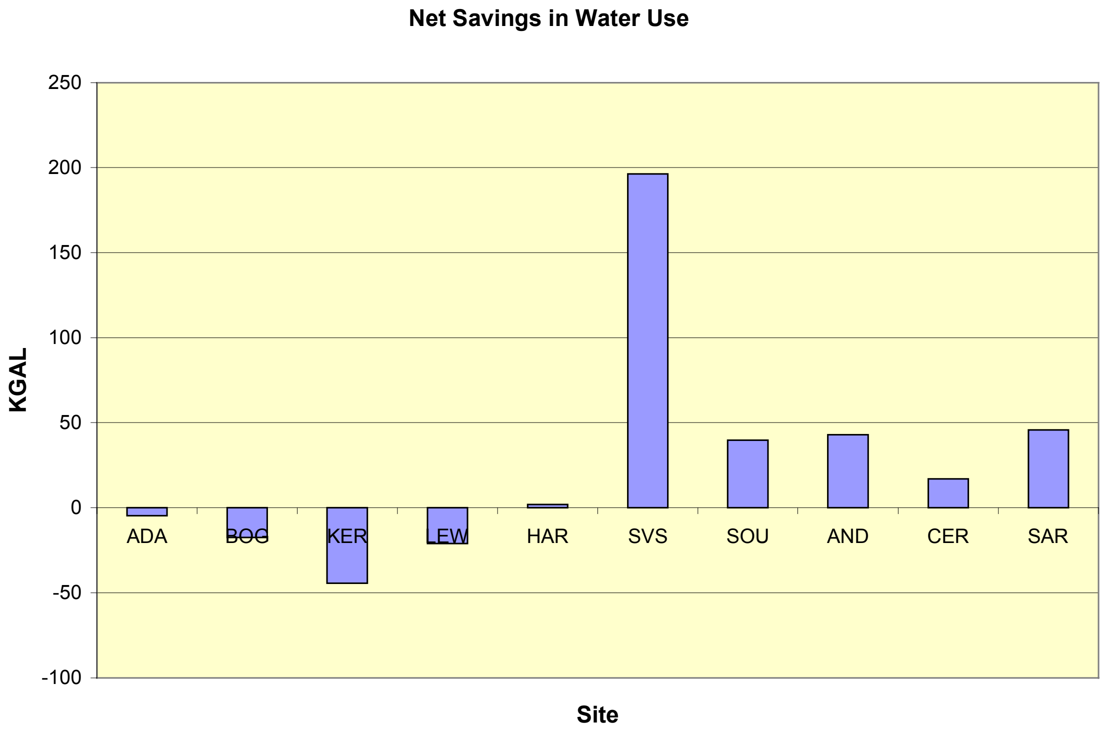


Figure 4: Net water savings for 10 study sites

Survey Results

A 32 question survey form was mailed to each of the participants at the end of the 2001 irrigation season. This questionnaire solicited the opinions of the user's on the operation of their irrigation system and whether or not they would continue to use the WeatherTRAK in the future if a fee were charged for sending the signal. All participants were provided information on the water use at their home and the impact of the WeatherTRAK controller, so each had the information on how well the WeatherTRAK managed the irrigation application in 2001. A summary of the most relevant responses to the survey is provided here.

Appearance of Landscape

At the end of the 2001 season most users rated their landscapes between average to good. One user rated the appearance poor and one rated it very good. The appearance was about the same as the previous year, in their opinion.

Water Use

Most people believed there was some decrease in water use with the WeatherTRAK system, and thought they had spent between $300 and $400 per year prior to the WeatherTRAK installation for irrigation water.

Problems

Four users reported noting a problem during the study. The most common problems were loss of signal and having a wrong ET value or date appear on the controller. These problems were all successfully resolved. With the exception of the two controllers replaced from the 2000 installation in order to update the software, none of the controllers needed replacement for operational reasons in 2001. Most of the problems were corrected by sending new signals to the units.

Overall Performance

This was rated at "good+" by the group with responses ranging from adequate to very good.

Compared to Old Controller- 5 users rated the WeatherTRAK as better, 2 as less, and 4 as the same. Six users would recommend the system to a friend.

Adjustments

Each of the 10 participants made some sort of adjustment to their system during the year, and they rated these as easy to very easy. The most common adjustment was the rain pause, which was used an average of 3 times per season. The percent increase adjustment was used by 7 users, while only 3 users made a decrease percent adjustment. Five users reprogrammed specific stations, 3 made changes to the default application rates and 2 changed either the start time or non-water day. Most people thought the changes they made increased the performance of the system.

Manual Watering

Most users took advantage of the manual watering feature of the system between two times per season and once per week.

Payment for Signal

Only 1 out of 10 users indicated a willingness to pay a fee to continue receiving the signal, and three users were uncertain. The rest indicated that they would not pay a fee of $49/year to continue to receive the signal. However, 7 of the users indicated that if the utility paid the signal fee they would like to continue using the system.

Use by Utility to Interrupt Irrigation

Eight out of ten users indicated that if they were using this system they would be willing to allow the utility to interrupt their irrigation during peak periods to avoid system peaking problems.

Decision Factors

The participants rated the ability of the system to save water as most important in deciding if they should continue to use WeatherTRAK. The convenience of the system and the appearance of the landscape were rated next.

Given the fact that only one person was willing to pay a fee, it appeared as a somewhat contradictory surprise to learn that the cost of the WeatherTRAK and the annual fee was rated low as a factor in deciding whether or not to use the system.

Other Comments

Five users made other comments. As was mentioned by Brent Mecham, of NCWCD, one user reported that adjusting the precipitation rate based on site measurements increased the performance of the system. One user said he was changing back to his old controller even though he liked the concept of the WeatherTRAK, because he felt the old system was more flexible. This user also mentioned that he liked the ability of the WeatherTRAK to make adjustments while he was out of town. Several users commented that they like the WeatherTRAK and the concept of how it operated.

System Problems

During the study, which started in August of 2000, minor errors were noted with the operation of the Weather Trak units in the field, but none of these created serious problems with the landscapes on which they were sited. On occasion, a problem was reported by a user that was traced to problems unrelated to the controller.

1. During the early phase of the study some controllers locked up and would not receive a signal. This was a software problem, and was resolved with a software updates.
2. On two occasions units showed a wrong date and time caused by errors in signal transmission. These were resolved by resending the signal or performing a manual setting.
3. It was noticed that some units tended to lock up in the office, but not in the field. This was thought to be due to static electricity from the carpets.
4. One user reported the system had totally failed to irrigate at least twice, but these problems were tracked to either loss of power at the controller or breaks in the irrigation system caused by excavation and were unrelated to the controllers.
5. A user reported that the system appeared to be under irrigating his yard. He was given instructions on how to set the precipitation rates manually, which he did. After this adjustment he was happy with the performance.

SUMMARY

The results of this study offer useful information about the performance the WeatherTRAK system and the willingness of users to accept it. Technically, the system appeared to perform quite well. The WeatherTRAK controllers successfully received signals with rare exceptions, and when problems did occur they were easily corrected. Not only did the WeatherTRAK receive signals, it made a reasonably good translation of these ET data into actual irrigation schedules. Even using the default settings the systems tracked the ET_o lines at appropriate levels. From the standpoint of water savings, for the group as a whole, savings averaged 26 kgal per year. When accounts that saved no water were excluded, savings of 68 kgal per year were observed. Monetary savings on those sites which reduced their water use ranged from $29 of $668, and averaged $197 per site, and these were based on relatively low water rates.

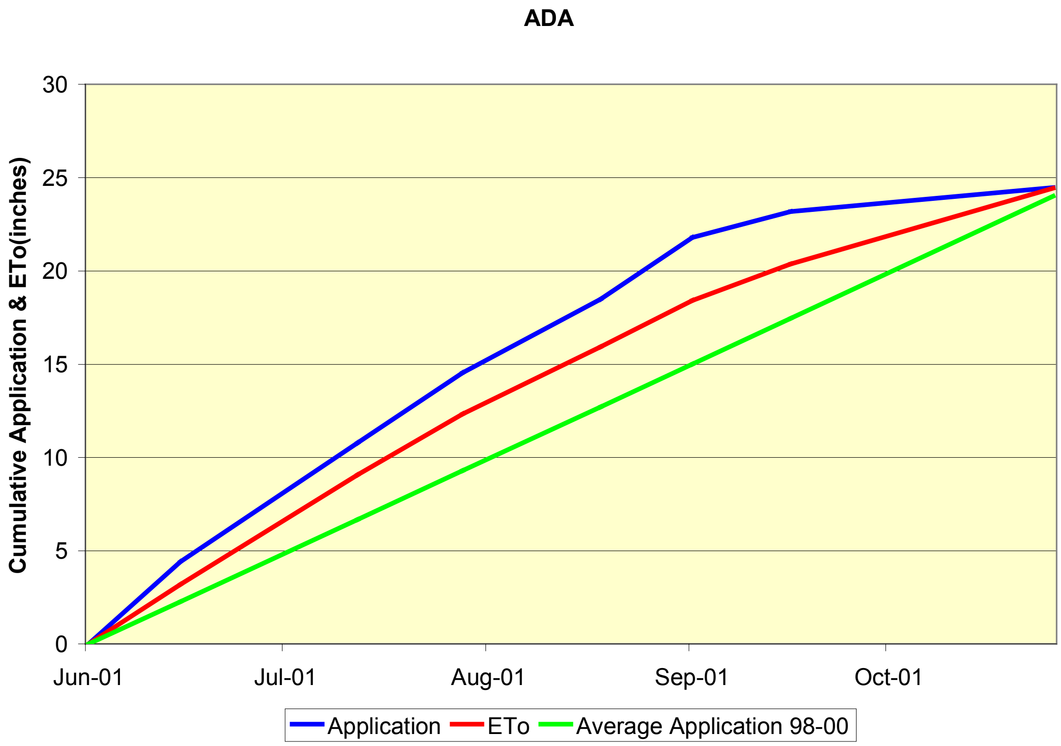
Most of the users liked the system and appreciated its ability to make adjustments automatically, especially when they were out of town. A couple of people, however, felt the system was not as flexible as it could have been. This is a typical trade-off between automation and control. Also, some users interpreted the fact that the system sometimes watered during the middle of the day as a problem, even though this was an intentional feature. Additional experience with the units would correct these misperceptions.

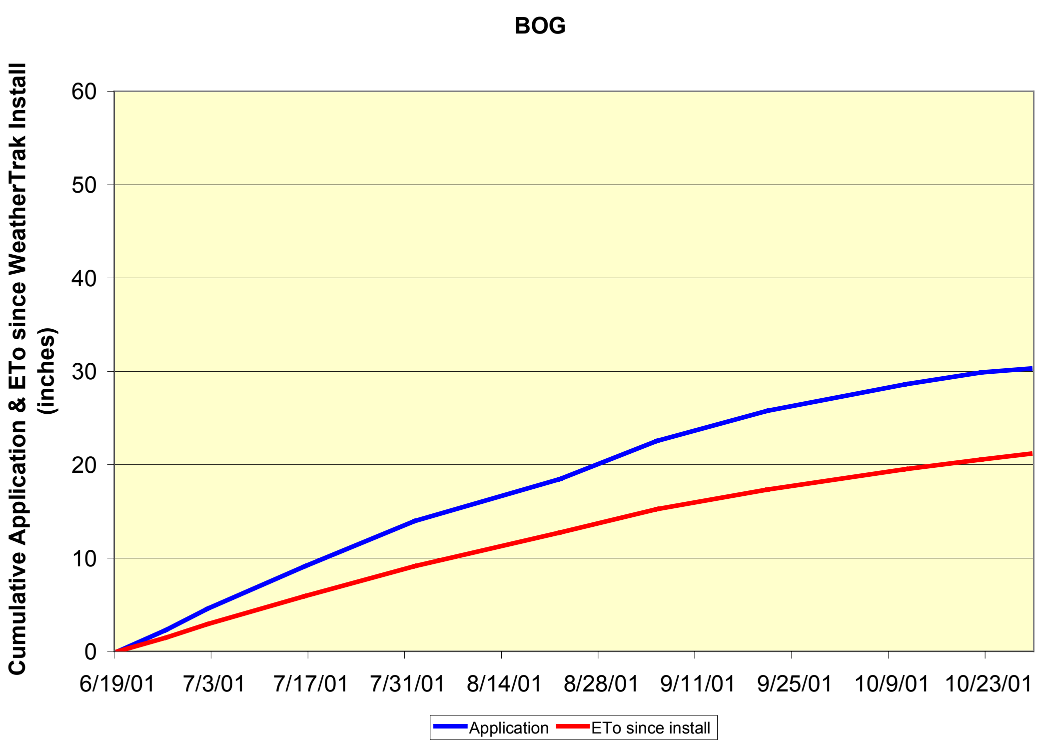
The users showed very little willingness to pay for this system, at least directly and at $49/yr. While only 1 user said they would be willing to use the system if they paid $49/yr for it, 7 users said they would use the system if the utility paid for it. This implies that if utilities wish to use this approach to water management, they need to build the signaling fees into their rates, and perhaps negotiate a single fee to the company that would cover signals for the entire district. The fact that 80% of the users were willing to allow the utility to interrupt their irrigation during peaking times shows that this system could be quite useful for peak demand reduction.

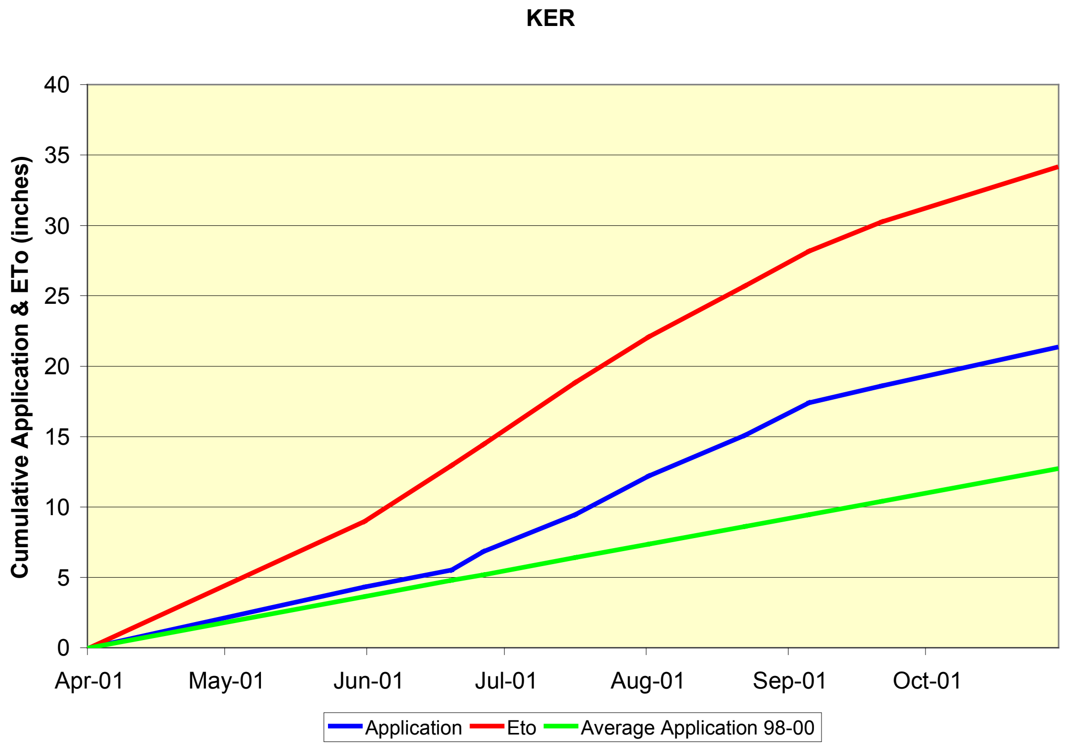
The overall conclusion of this study is that this system works technically, and can accurately match irrigation applications to plant requirements. Over time, as users learn to make appropriate adjustments (such as setting proper precipitation rates) performance should improve. The fact that this system allows utilities to manage irrigation on a real time basis, including curtailing systems in order to reduce peak demands, should be a major advantage. Customers have also shown a willingness to permit this type of management.

The major impediment to the use of this system is the issue of how to structure the payments for installation and ongoing operations and signaling. The survey indicates that users in the Northern Colorado area would do not want to pay for this service separately, but prefer the utility to make the payments. (Presumably, these could be built into the utility rate structure or included on a customer's bill.) It is also possible that customers would be willing to pay for the signals directly if annual fees were lower.

Appendix A: Cumulative Applications vs. ET_o's



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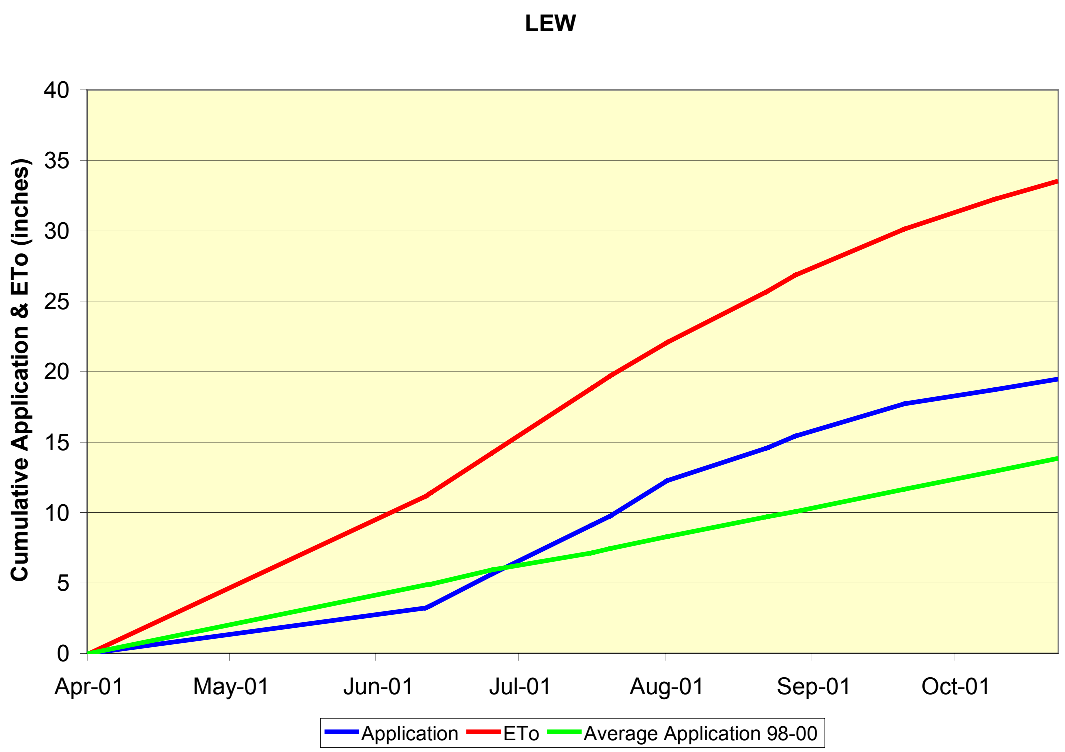
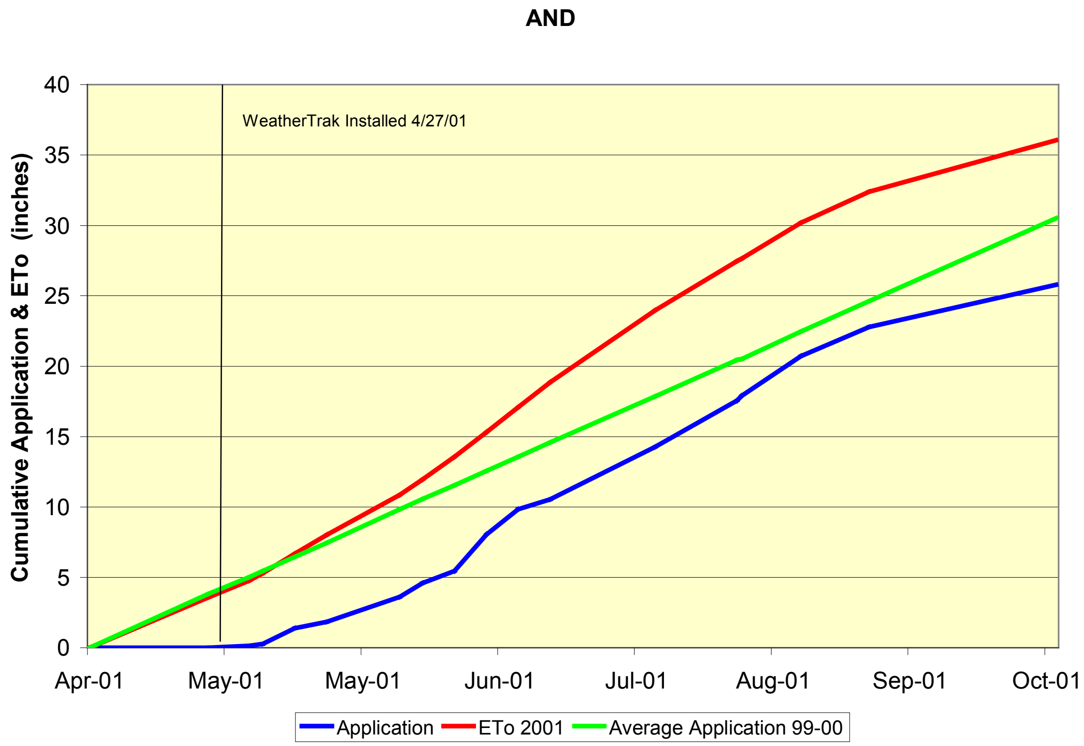
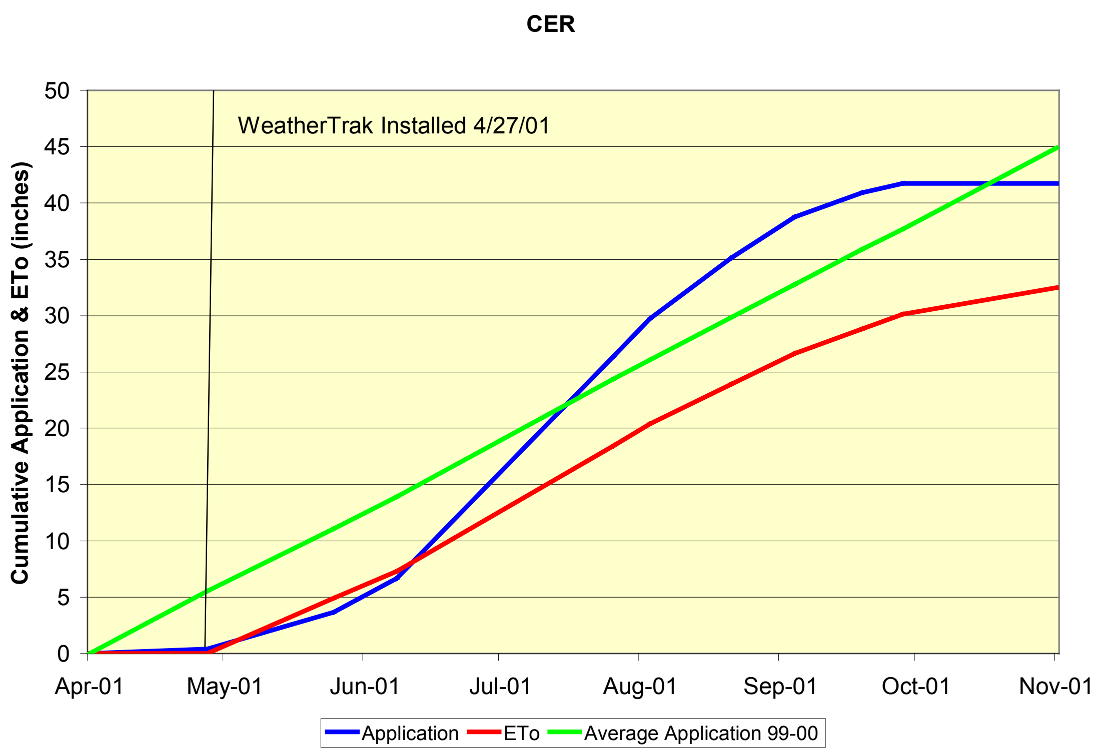
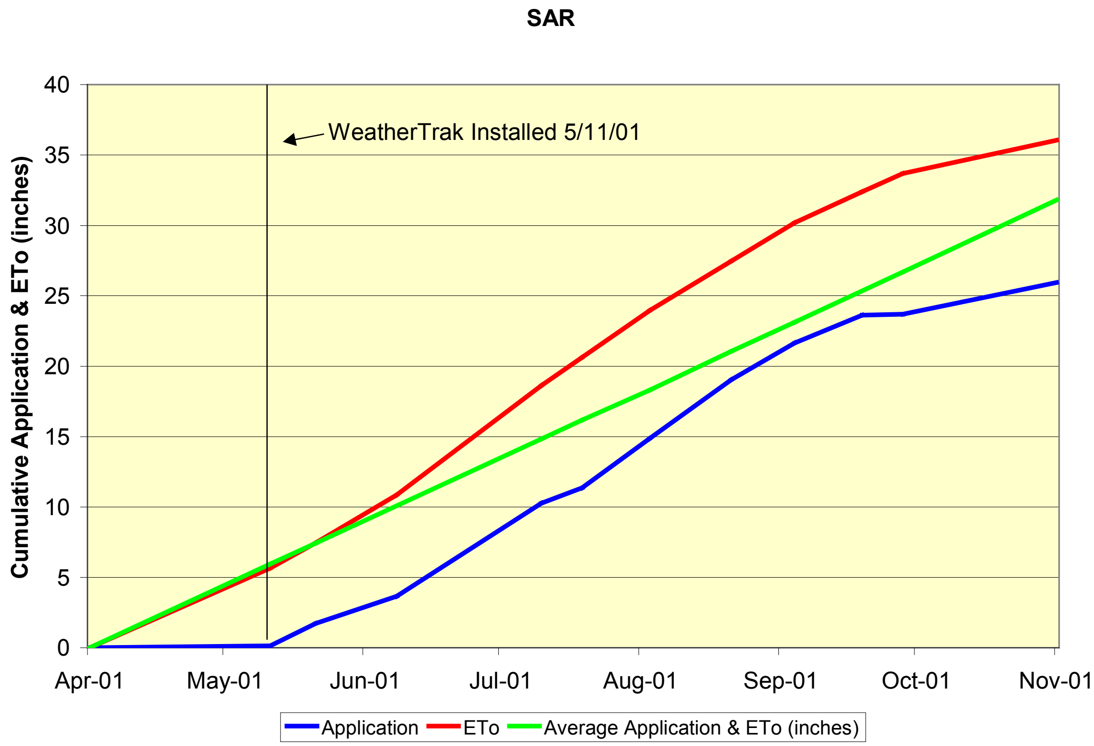
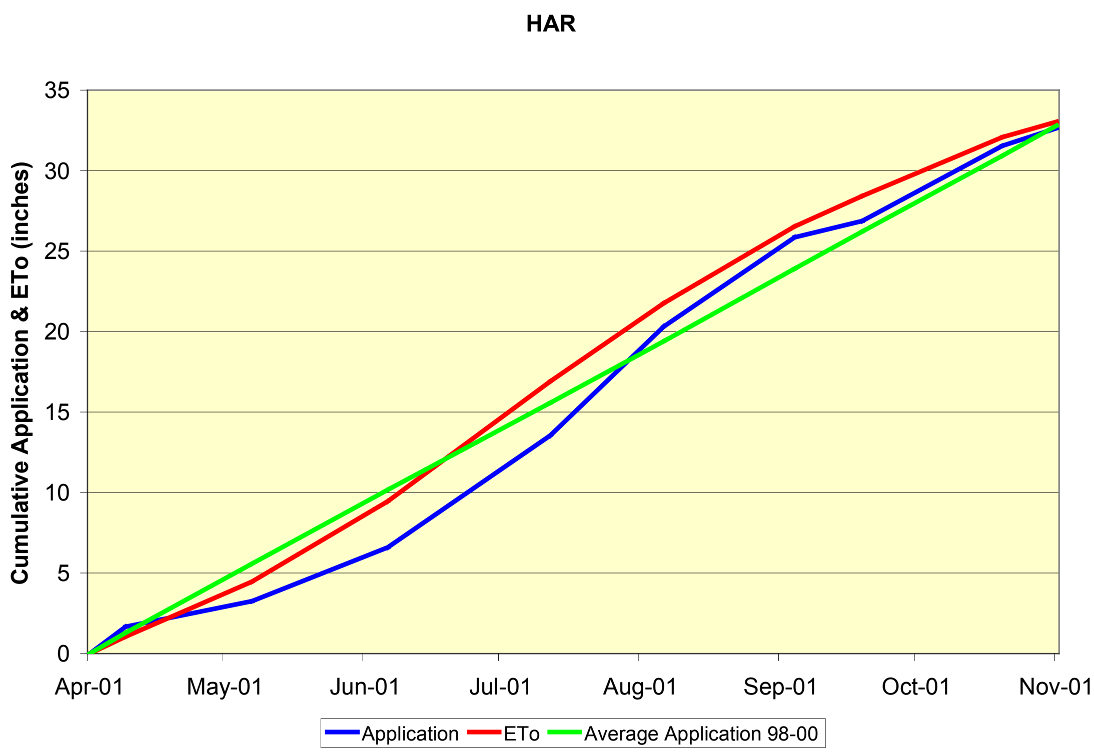
Eto
Average Application 98-00

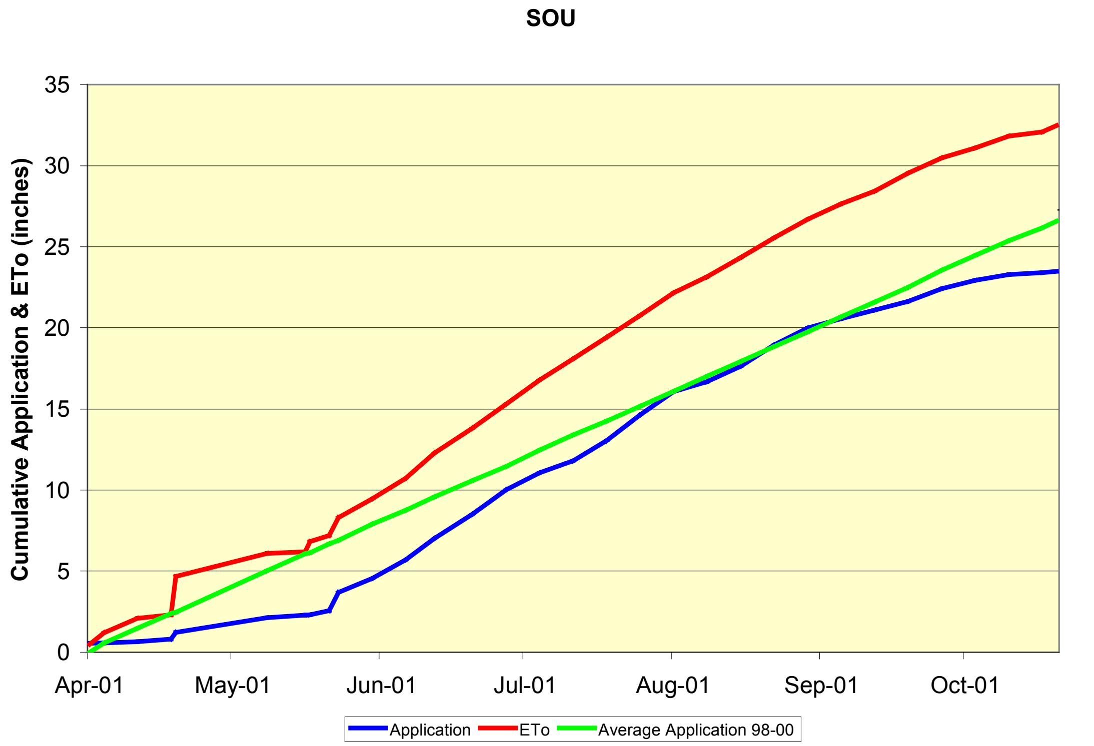

LEW
Cumulative Application & ETo (inches)
0
5
10
15
20
25
30
35
40
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Application
ETo
Average Application 98-00

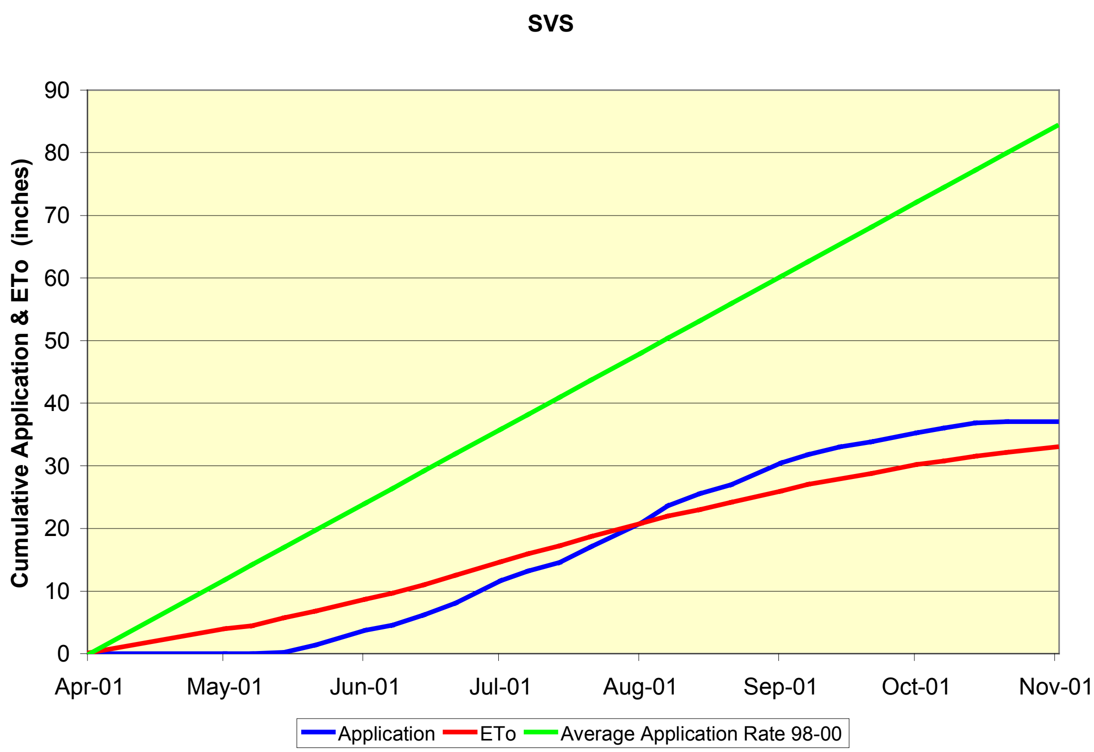

AND
Cumulative Application & ETo (inches)
40
35
30
25
20
15
10
5
0
WeatherTrak Installed 4/27/01
Apr-01
May-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Application
ETo 2001
Average Application 99-00


CER
Cumulative Application & ETo (inches)
50
45
40
35
30
25
20
15
10
5
0
WeatherTrak Installed 4/27/01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Application
ETo
Average Application 99-00


SAR
WeatherTrak Installed 5/11/01
Cumulative Application & ETo (inches)
0
5
10
15
20
25
30
35
40
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Application
ETo
Average Application & ETo (inches)


HAR
Cumulative Application & ETo (inches)
0
5
10
15
20
25
30
35
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Application
ETo
Average Application 98-00


SOU
Cumulative Application & ETo (inches)
35
30
25
20
15
10
5
0
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Application
ETo
Average Application 98-00


SVS
Cumulative Application & ETo (inches)
90
80
70
60
50
40
30
20
10
0
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Application
ETo
Average Application Rate 98-00