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Evaluation of Smart Irrigation Controllers: Initial Bench Testing Results

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By
Charles Swanson, Extension Associate
Guy Fipps, Professor and Extension Agricultural Engineer

Rio Grande Basin Initiative
Irrigation Technology Center
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EVALUATION OF SMART IRRIGATION CONTROLLERS:

INITIAL BENCH TESTING RESULTS[1]

By
Charles Swanson and Guy Fipps, P.E[2]

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Irrigation Technology Center
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[2]Extension Associate, and Professor and Extension Specialist, Biological and Agricultural Engineering, 2117 TAMU, College Station, TX 77843-2117; http://itc.tamu.edu

SUMMARY

A smart controller testing facility has been established by the Irrigation Technology Center at Texas A&M University in College Station. Six manufacturers donated controllers for initial laboratory set-up and evaluation. For evaluation purposes, the controllers were programed for College Station, Texas using the virtual landscape as defined in the IA (Irrigation Association) SWAT (Smart Water Applicator Technologies) 7th draft testing protocol. However, the controllers could not be programmed with all the parameters required to defined these virtual landscapes.

The controllers were then run over an eight-week period. The results are compared to the actual ETo during the test periods and to the irrigation recommendations of the TexasET Network (http://texaset.tamu.edu). The irrigation amounts produced by the controllers varied significantly, even for the same zone. In addition, all exceeded the irrigation recommendations of TexasET. Four of the controllers produced irrigation amounts that were higher than the ETo (potential evapotranspiration) that occurred during the test period. Such high irrigation amounts may be related to the source and values for the ETo used by the controllers and/or in the methodologies used to account for rainfall. The results will be used to establish protocols for further testing.

INTRODUCTION

The term *smart irrigation controller* is commonly used to refer to various types of controllers that have the capability to calculate and implement irrigation schedules automatically and without human intervention. Ideally, smart controllers are designed to use site specific information to produce irrigation schedules that closely matche the day-to-day water use of plants and landscapes. In recent years, manufacturers have introduced a new generation of smart controllers which are being promoted for use in both residential and commercial landscape applications. The Irrigation Association (IA) has reported that in some studies, these controllers have reduced water usage by as much as 16% when compared to conventional controllers.

However, many questions exist about the performance, dependability and water savings benefits of smart controllers. Of particular concern in Texas is the complication imposed by rainfall. Average rainfall in the state varies from 56 inches in the southeast to less than eight inches in the western desert. In much of the state, rainfall commonly occurs during the primary landscape irrigation seasons. Some Texas cities and water purveyors are now mandating smart controllers. If these controllers are to become requirements across the state, then it is important that they be evaluated formally under Texas conditions.

In 2008, the Irrigation Technology Center (ITC) began a program to conduct bench testing and outdoor testing of smart controllers. Six controllers were donated from different manufacturers who are currently marketing these products in Texas. The controllers were used in the initial set-up and troubleshooting of the laboratory, and for evaluation over a eight-week period.

CLASSIFICATION OF SMART CONTROLLERS

Smart controllers may be defined irrigation system controllers that determine runtimes for individual stations (or "zones") based on historic or real time ETo and/or additional site specific data. We classify smart controllers into four (4) types (see Table 1): Historic ET, On-site Sensor, ET, and Central Control.

Most controllers use ETo (potential evapotranspiration) as a basis for computing irrigation schedules in combination with a root-zone water balance. Various methods, climatic data and site factors are used to calculate this water balance. The parameters most commonly used in the root-zone water balance include:

- ET (actual plant evapotranspiration)
- Rainfall
- Site properties (soil texture, root zone depth, water holding capacity)
- MAD (managed allowable depletion)

The IA SWAT committee has proposed an equation for calculating this water balance. For more information, see the IA's website: http://irrigation.org

Table 1. Classification of smart controllers by the basis of the ETo method used in the calculation of irrigation runtimes.

Historic ETo	Uses historical ETo data from a table stored in the controller
On Site Sensor	Uses one or more sensors (usually temperature and/or solar radiation) to adjust or to calculate ETo using an approximate method
ET	Real-time ETo (usually determined using a form of the Penman equation) is transmitted to the controller daily. Alternatively, the runtimes are calculated centrally based on ETo and transmitted to the controller.
On-Site Weather Station (Central Control)	A controller or a computer which is connected to an on-site weather station equipped with senors that record temperature, relative humidity (or dew point temperature) wind speed and solar radiation for use in calculating ETo with a form of the Penman equation.

MATERIALS AND METHODS

Testing Equipment and Procedures

Two smart controller testing facilities have been established by the ITC at Texas A&M University in College Station: an indoor lab for testing controllers which do not use an on-site sensor and an outdoor lab for controllers with on-site sensors. Basically, the controllers are connected to a data logger which records the start and stop times for each irrigation event and station (or zone). This information is transferred to a database and used to determine total runtime and irrigation volume for each irrigation event. The data acquisition and analysis process is illustrated Figure A-1 . Additional information and photographs of the testing facilities are provided in the Appendix.

Smart Controllers

Six (6) manufacturers provided us with complimentary controllers for initial lab set up and evaluation. The specific manufacturers and products are not identified in this report. Each controller was assigned an ID for testing purposes. Table 2 lists each controller's classification, communication method and on-site sensors, as applicable. The controllers were grouped by type for testing purposes. The ET controllers (A-D) were bench tested indoors, and Controllers E and F were tested outdoors.

Table 2. The testing ID, type, communication method and sensors of the six smart controllers evaluated in this study.

Controller ID	**Type**	**Communication Method**	**Sensors Utilized**
A	ET	Pager	None
B	ET	Internet	None
C	ET	Pager	None
D	ET	Pager	None
E	On-site sensor	None	Rain , Pyranometer
F	On-site sensor	None	Rain, Temperature, Pyranometer

Definition of Stations (Zones) for Testing

Each controller was assigned six stations, each station representing a virtual landscaped zone. These zones were based on those proposed in the SWAT testing protocol (Table 3). However, we made one change in the virtual landscape set-up. Since we do not recommend that schedules be adjusted for the DU (distribution uniformity), the efficiency were set to 100% where allowed by the controller.

Programing the smart controllers according to these virtual landscapes parameters proved to be problematical, as many of these parameters could not be set. Table 3 shows the parameters which could be selected for each controller. In addition, it was impossible to see the actual values used for each parameter or to determine how closely these followed SWAT.

Table 3. The virtual landscapes as defined in the 7th draft SWAT testing protocol.

	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
Soil Texture	Loam	Silty Clay	Loamy Sand	Sandy Loam	Clay Loam	Clay
Slope (%)	6	10	8	12	2	20
Exposure	75% Shade	Full Sun	Full Sun	50% Shade	Full Sun	Full Sun
Root Zone Working Water Storage (in)	0.85	0.55	0.90	2.00	2.25	0.55
Vegetation	Fescue	Bermuda	Ground Cover	Woody Shrubs	Trees & Ground Cover	Bermuda
Crop Coefficient (Kc)	0.8	0.6	N/A	N/A	N/A	0.6
Landscape Coefficient (KL)	N/A	N/A	0.55	0.40	0.61	N/A
Irrigation System	Pop-Up Spray Heads	Pop-Up Spray Heads	Pop-Up Spray Heads	Pop-Up Spray Heads	Surface Drip	Rotors
Precipitation Rate (in/hr)	1.60	1.60	1.40	1.40	0.20	0.35

Table 4. The parameters which could be set in each controller identified by the letter "x."

Controller	Soil Type	Soil Depth	Sun Exposure	Slope	Plant Type	Root Zone Depth	Precipitation Rate	Zip Code or Location
A	X		X	X	X	X	X	X
B	X	X	X		X		X	X
C					X		X	X
D	X		X	X	X	X	X	X
E					X		X	
F	X		X	X	X		X	

Testing Period

For comparison purposes, the controllers were set up and allowed to run for an eight-week period. The testing period for the bench-tested controllers was Aug. 3 - Sept. 27, 2008; and for the outdoor-tested controllers: Sept. 28 - Nov. 22, 2008.

ETo and Recommended Irrigation

Irrigation amounts produced by the six controllers were compared to the actual ETo which occurred during the testing periods and the irrigation recommendations of TexasET, http://texaset.tamu.edu. Figures 1 and 2 show the weekly recommended irrigation amounts for the bench tested and outdoor test controllers, respectively.

ETo was computed from weather parameters measured at the Texas A&M University Golf Course in College Station, TX. The weather parameters were measured with a standard agricultural weather station which records temperature, solar radiation, wind and relative humidity. The ETo was computed using the standardized Penman-Monteith method.

RESULTS AND DISCUSSION

The results are summarized in Table 5 and Figures 1-14 which show the total volume of irrigation for each controller and station during the testing periods. Table 5 also provides the recommended irrigation volumes from TexasET, as do Figures 1 and 2. Ideally, all controllers would produce about the same irrigation amount for the same station. However, there was significant variation between the irrigation amounts for the same station produced by these controllers.

ETo is defined as the water requirements of a cool season grass growing about 4 inches tall under well-watered conditions. Generally, most landscape plants (turfgrasses, ground cover, shrubs and trees) will require less water than ETo. However, the bench-tested controllers exceeded the total ETo 58% of the time. One likely explanation is the source and actual values that each controller uses for ETo. Table 6 shows ETo values that could be read on the controller during the testing period compared to the ETo values from TexasET.

Compared to the recommended irrigation volumes from TexasET, all the controllers produced irrigation amounts significantly higher. The bench-tested controllers exceeded recommended irrigation amounts 100% of the time, applying on average 6.73 inches more. The outdoor-tested controllers exceeded the recommended amount 75% of the time applying on average 1.88 inches more water.

Table 5. Summary of test results. Also shown are the total ETo recorded during each test period and the recommended irrigation amount from the TexasET Network and Website.

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Average Excess Per Station***
Plant Type	Cool Season	Warm Season	Ground Cover	Shrubs	Trees	Warm Season	
Bench Controller ID	**Total Irrigation (inches) for the Testing Period Aug 3 - Sept 27**						
A	13.74	12.1	10.59	6.38	12.67	11.39	8.66
B	6.13	6.20	12.17	10.73	9.08	6.05	5.92
C	6.40	9.60	9.80	9.80	9.60	9.45	6.67
D	7.61	9.81	6.53	5.66	8.0	11.29	5.68
Recom-mended*	3.66	2.69	2.24	2.24	1.33	2.69	
ETo**	9.31 inches						
Rainfall	7.36 inches						
Outdoor Controller ID	**Total Irrigation (inches) for the Testing Period Sept. 28 - Nov. 22**						
E	4.16	4.08	4.97	3.15	0.45	0.89	1.84
F	2.26	3.26	5.0	1.36	3.33	3.54	1.92
Recom-mended*	3.02	2.25	1.87	1.87	1.08	2.25	
ETo**	5.97 inches						
Rainfall	3.26 inches						

* Recommended irrigation amount from the TexasET Website: http://texaset.tamu.edu

** Total ETo calculated using the standardized Penmen-Monteith method using weather data collected at the the Texas A&M University Golf Course, College Station, Texas.

*** Average excess irrigation per controller based on TexasET recommendation

Table 6. Potential Evapotranspiration (ETo, inches per day) received by controllers and taken from TexasET.

Date	Controller A	Controller C-1	Controller C-2	Controller D	TexasET
8/29/2008	.21	.17	.19	.21	.18
9/1/2008	.21	.21	.20	.21	.21
9/3/2008	.12	.20	.21	.12	.19
9/4/2008	.16	.20	.20	.16	.20
9/5/2008	.20	.20	.20	.20	.19
9/8/2008	.20	.20	.20	.20	.16
9/9/2008	.20	.20	.20	.18	.18
9/11/2008	.19	.17	.17	.19	.17
9/14/2008	NA	.16	.17	NA	.13
9/16/2008	NA	.16	.16	NA	.13
9/17/2008	.13	.15	.16	.19	.11
9/18/2008	.13	.17	.16	.19	.11
9/19/2008	.13	.15	.13	NA	.13
9/21/2008	.20	.16	.16	.21	.14
9/24/2008	.20	.17	.19	.20	.15
9/25/2008	.20	.18	.23	.18	.14
9/28/2008	.12	.11	.11	.17	.13
10/6/2008	.15	.14	.13	.15	.13
10/7/2008	.14	.18	.22	.19	.14

Due to rainfall, no irrigation was needed for four weeks during the bench testing period, and three weeks during the outdoor testing period. However, as shown in Figures 3 - 18, generally, most of the controllers did not adequately adjust irrigation schedules for rainfall. The outdoor-tested controllers did a much better job of accounting for rainfall and reduced irrigation 56.25% of the time, while the bench-tested controllers decreased irrigation 48.53% of the time as direct response to rainfall events.

CONCLUSIONS AND FUTURE PLANS

Based on the findings of this study, all six smart controllers evaluated produced excessive irrigation amounts. There are several possible causes of this over-irrigation, which may include improper ETo values, and insufficient accounting for rainfall. These results indicate that the use of on-site sensors reduces the amount of excess irrigation compared to ET controllers.

Additional testing is needed in order to verify these initial results. During the next phase, we plan on working cooperatively with manufacturers in designing the testing protocol and on evaluating the values used for definition of site parameters, particularly plant type, the ETo values computed or transmitted to the controller, and other factors which could improve the irrigation schedules and promote landscape water conservation. In addition, the analysis will also include evaluation of the day to day root zone soil water balance, and muti-cycling that is performed to prevent runoff. Since this study was started, newer versions of two of the controllers have been placed on the market, thus on-going testing and evaluation is needed. Further phases of testing are recommended before wide-spread mandating of smart controllers occurs in Texas.

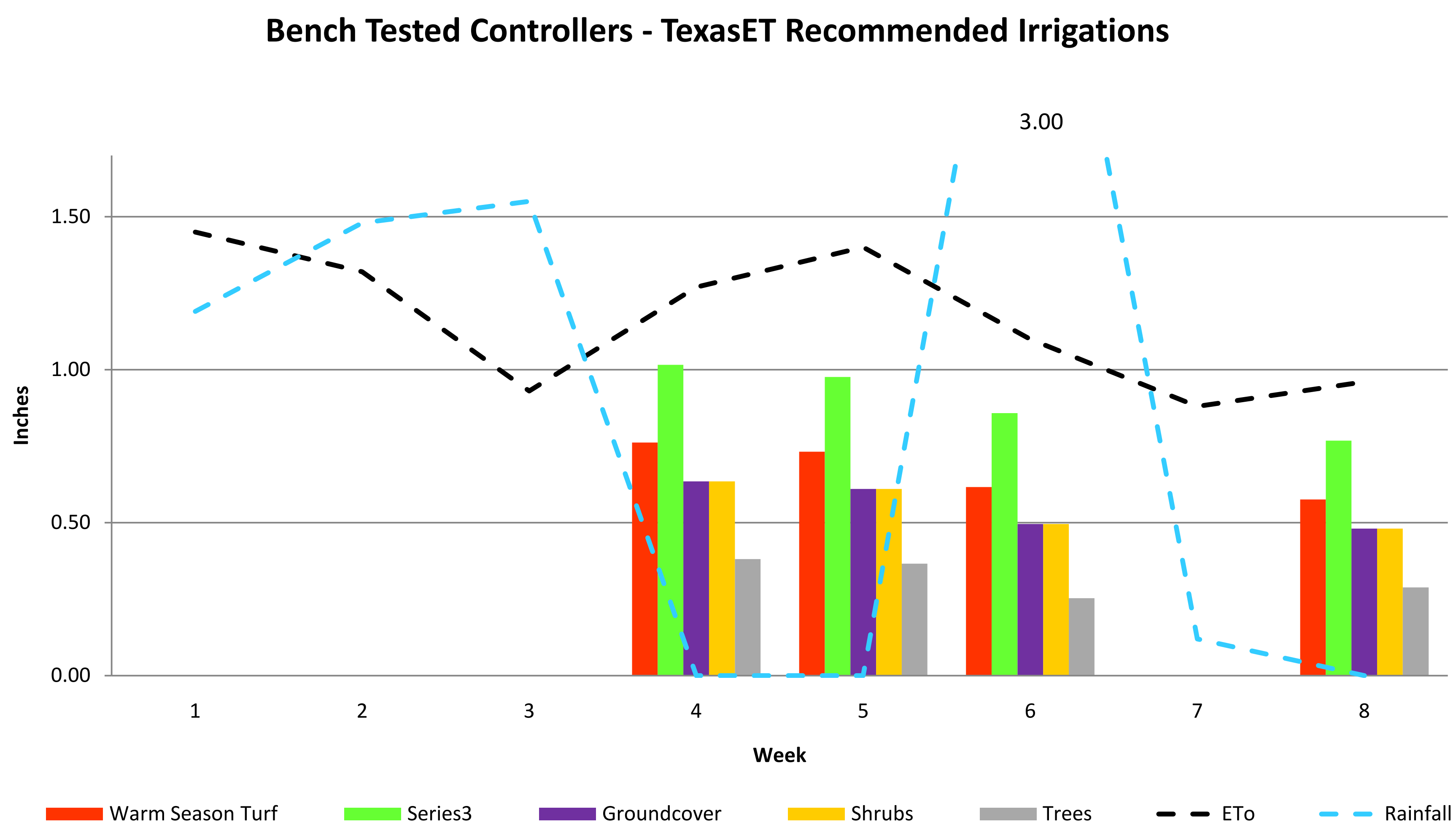

Figure 1 – Weekly irrigation volumes recommended by Texas ET recorded rainfall and the ETo during the period of August 3 to September 27, 2008.

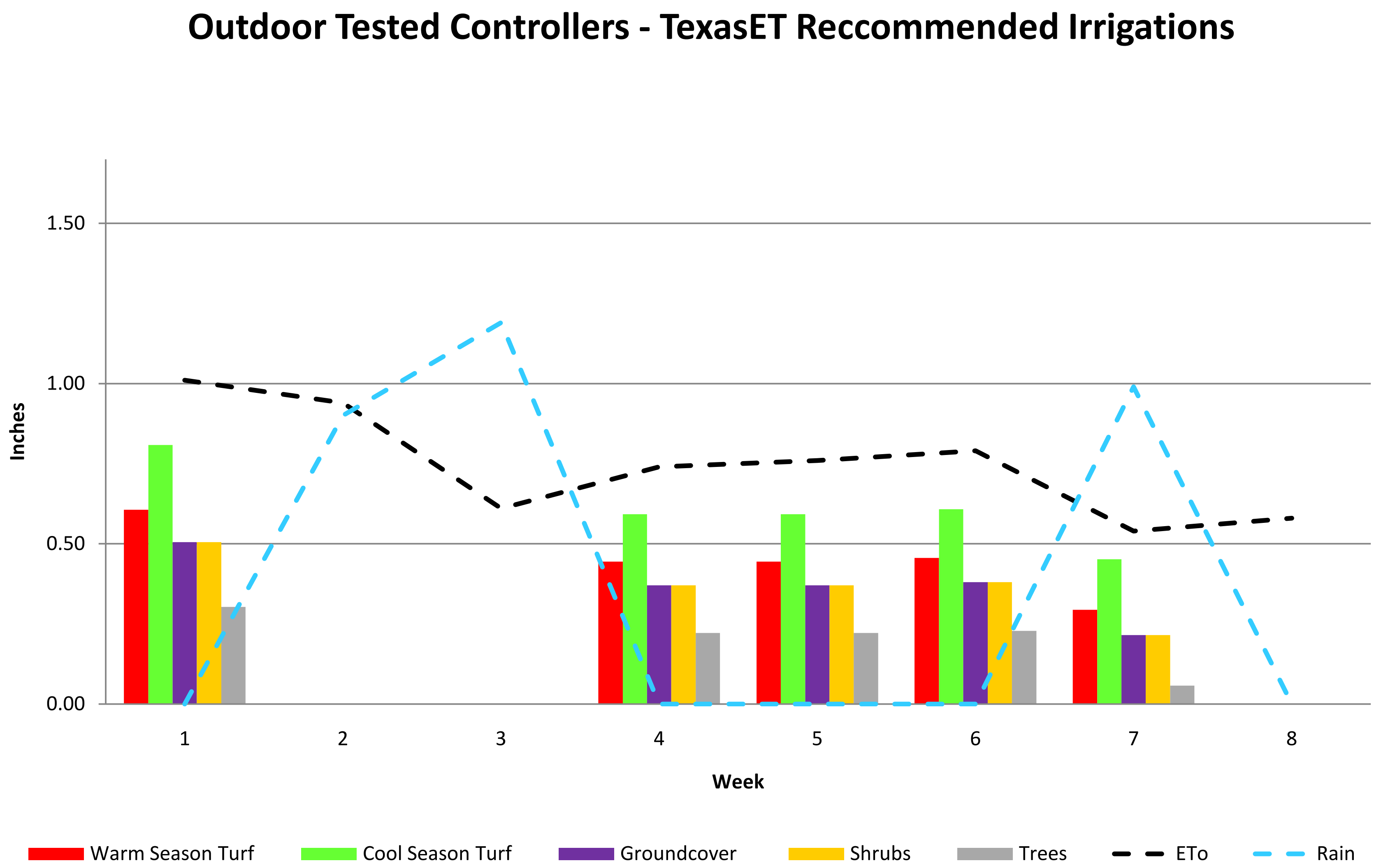

Figure 2 –Weekly irrigation volumes recommended by Texas ET, recorded rainfall and the ETo during the period of September 28 to November 22, 2008.

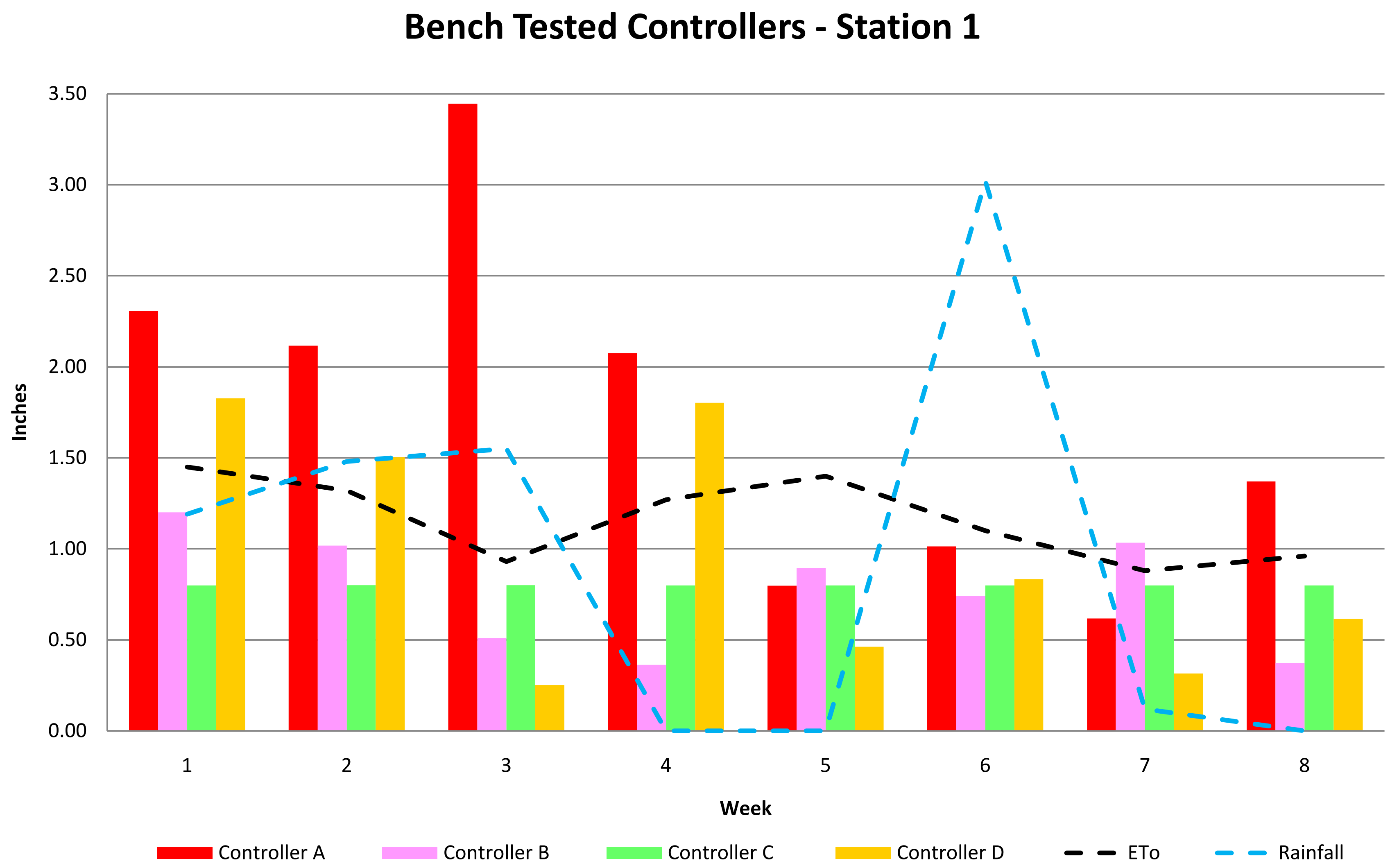

Figure 3 - Weekly irrigation volumes from four smart controllers for station 1 ET_o and recorded rainfall for the period of August 3 to September 27, 2008.

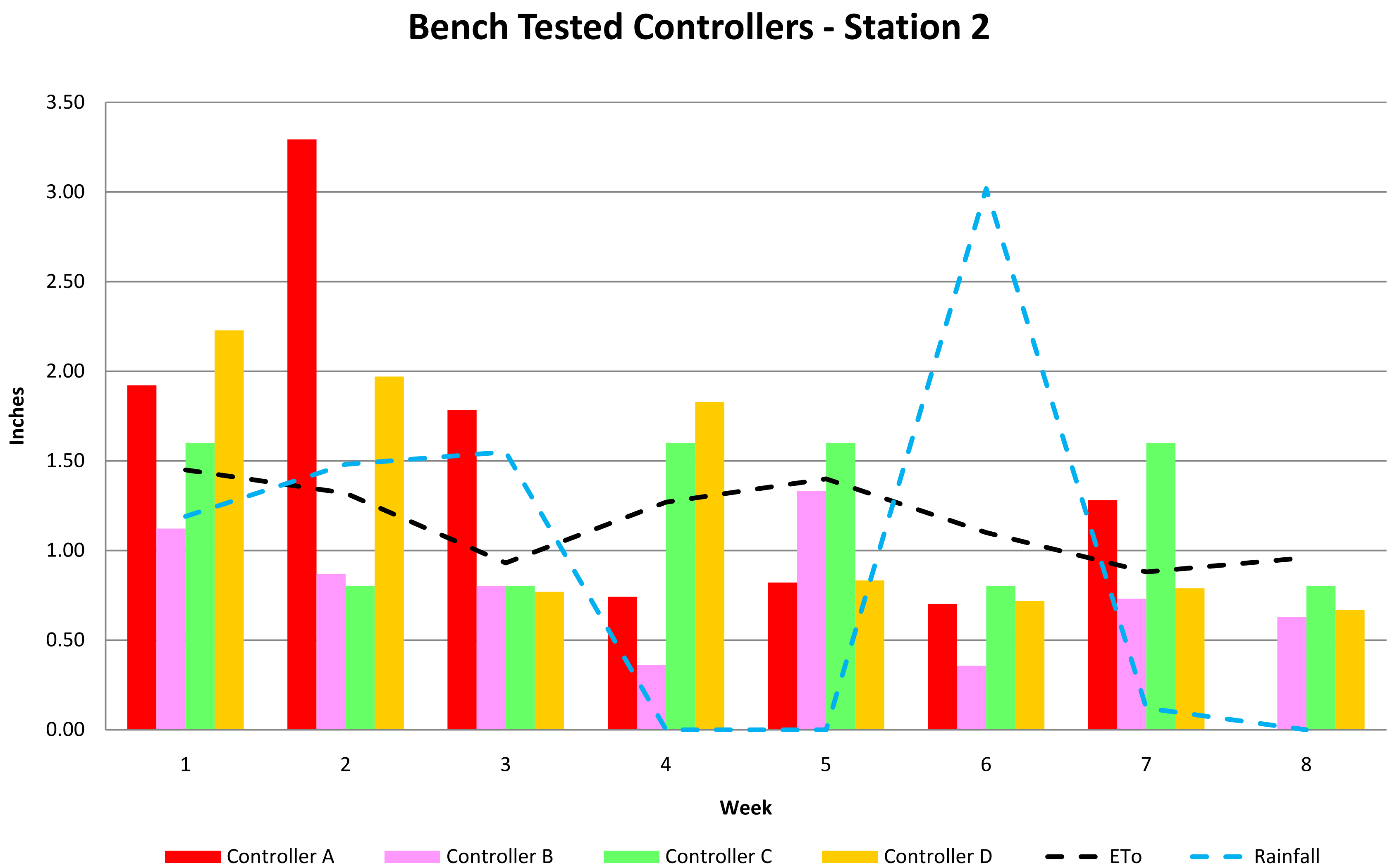

Figure 4 - Weekly irrigation volumes from four smart controllers for station 2 ET_o and recorded rainfall for the period of August 3 to September 27, 2008.

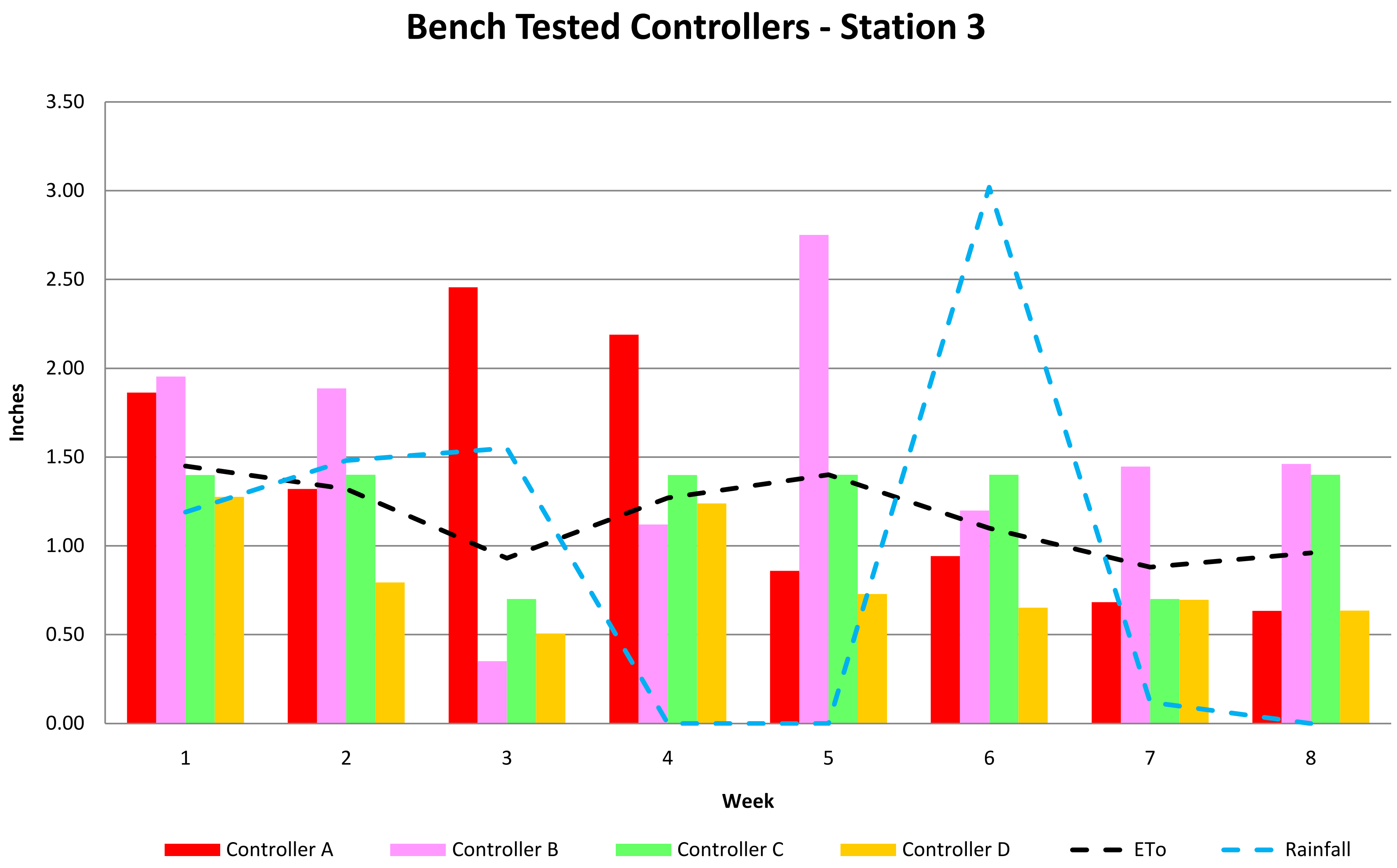

Figure 5 - Weekly irrigation volumes from four smart controllers for station 3 ET_o and recorded rainfall for the period of August 3 to September 27, 2008.

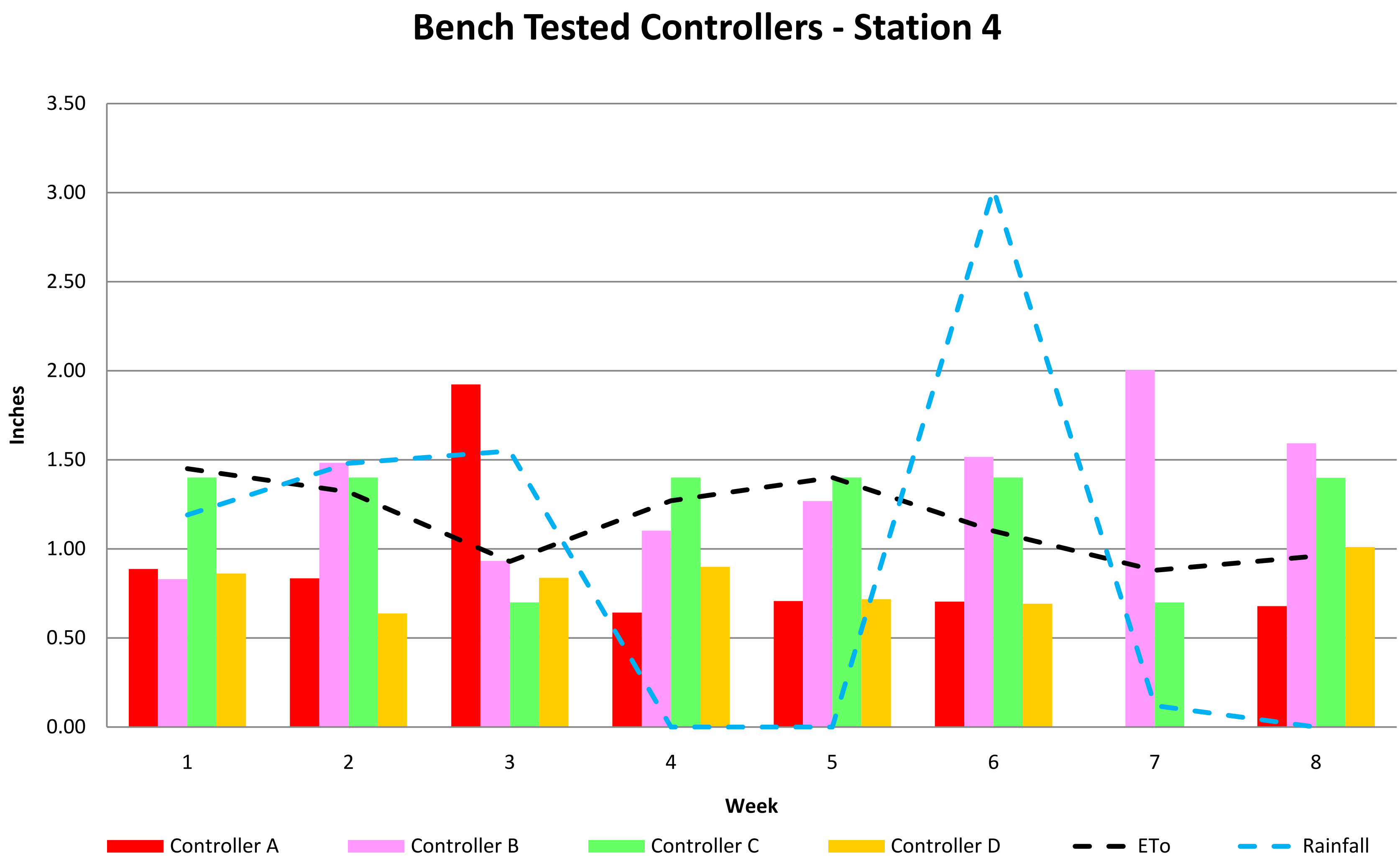

Figure 6 - Weekly irrigation volumes from four smart controllers for station 4 ET_o and recorded rainfall for the period of August 3 to September 27, 2008.

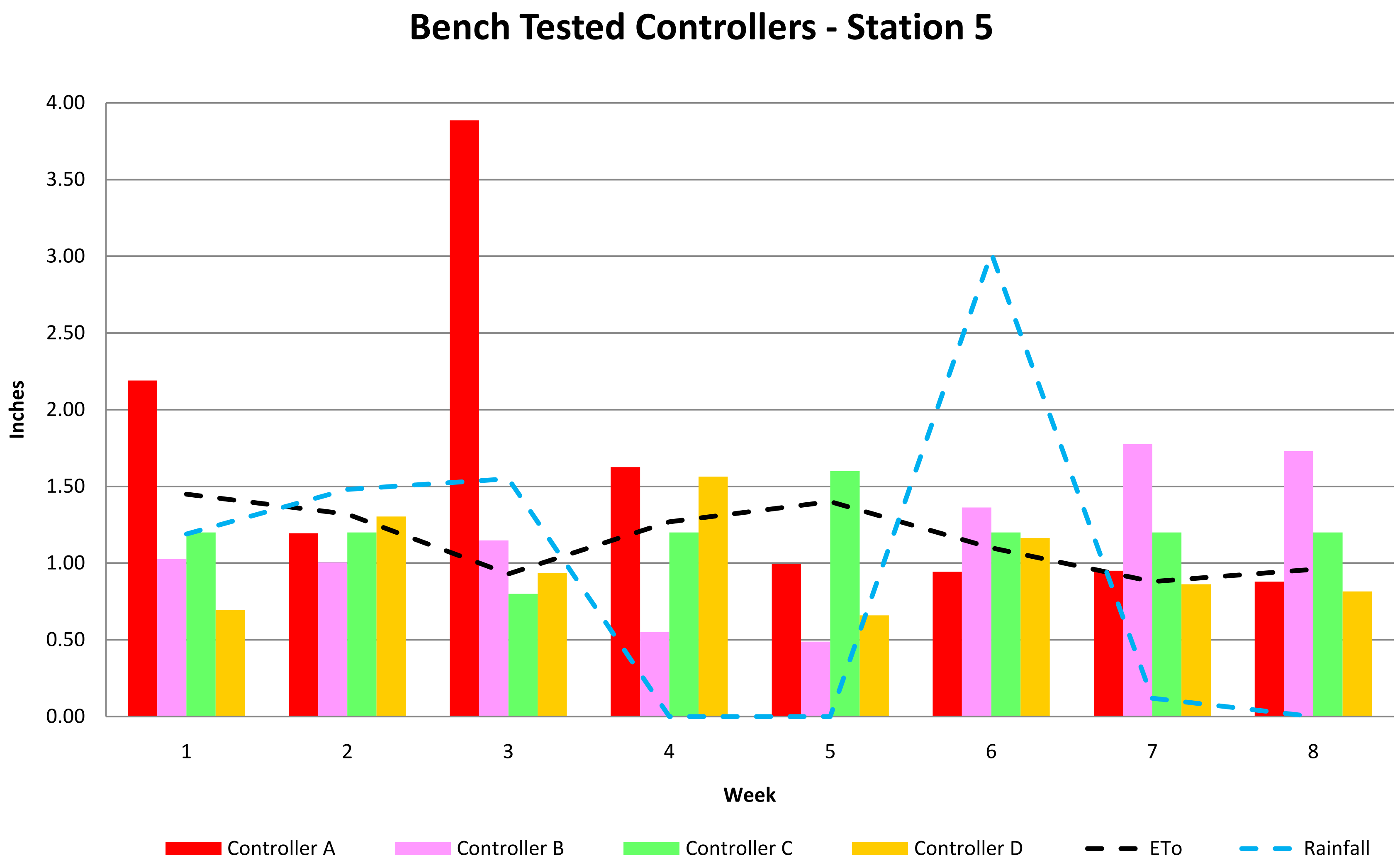

Figure 7 - Weekly irrigation volumes from four smart controllers for station 5 ET_o and recorded rainfall for the period of August 3 to September 27, 2008.

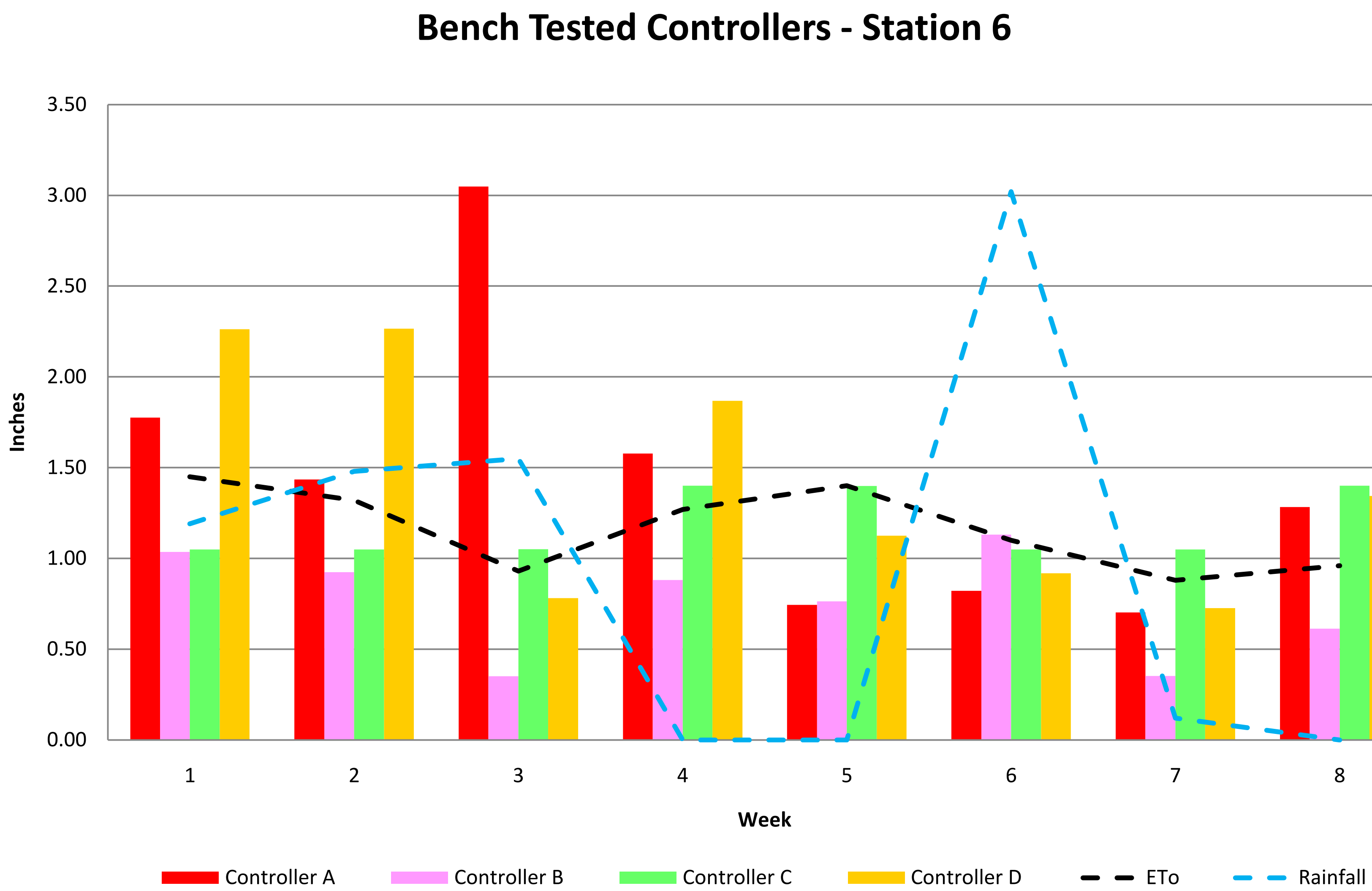

Figure 8 - Weekly irrigation volumes from four smart controllers for station 6 ET_o and recorded rainfall for the period of August 3 to September 27, 2008.

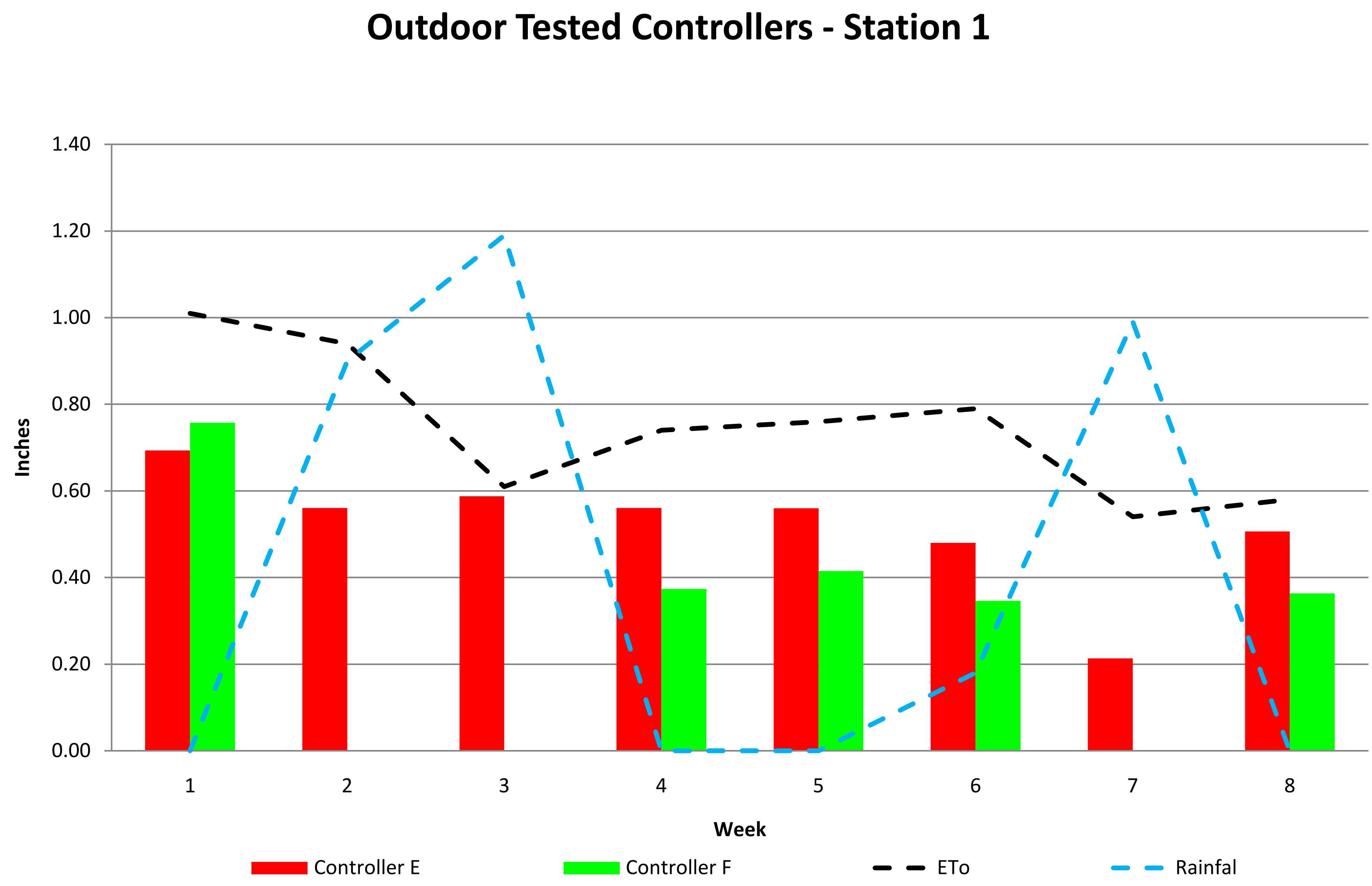

Figure 9 - Weekly irrigation volumes from two smart controllers for station 1 ET_o and recorded rainfall for the period of September 28 to November 22, 2008.

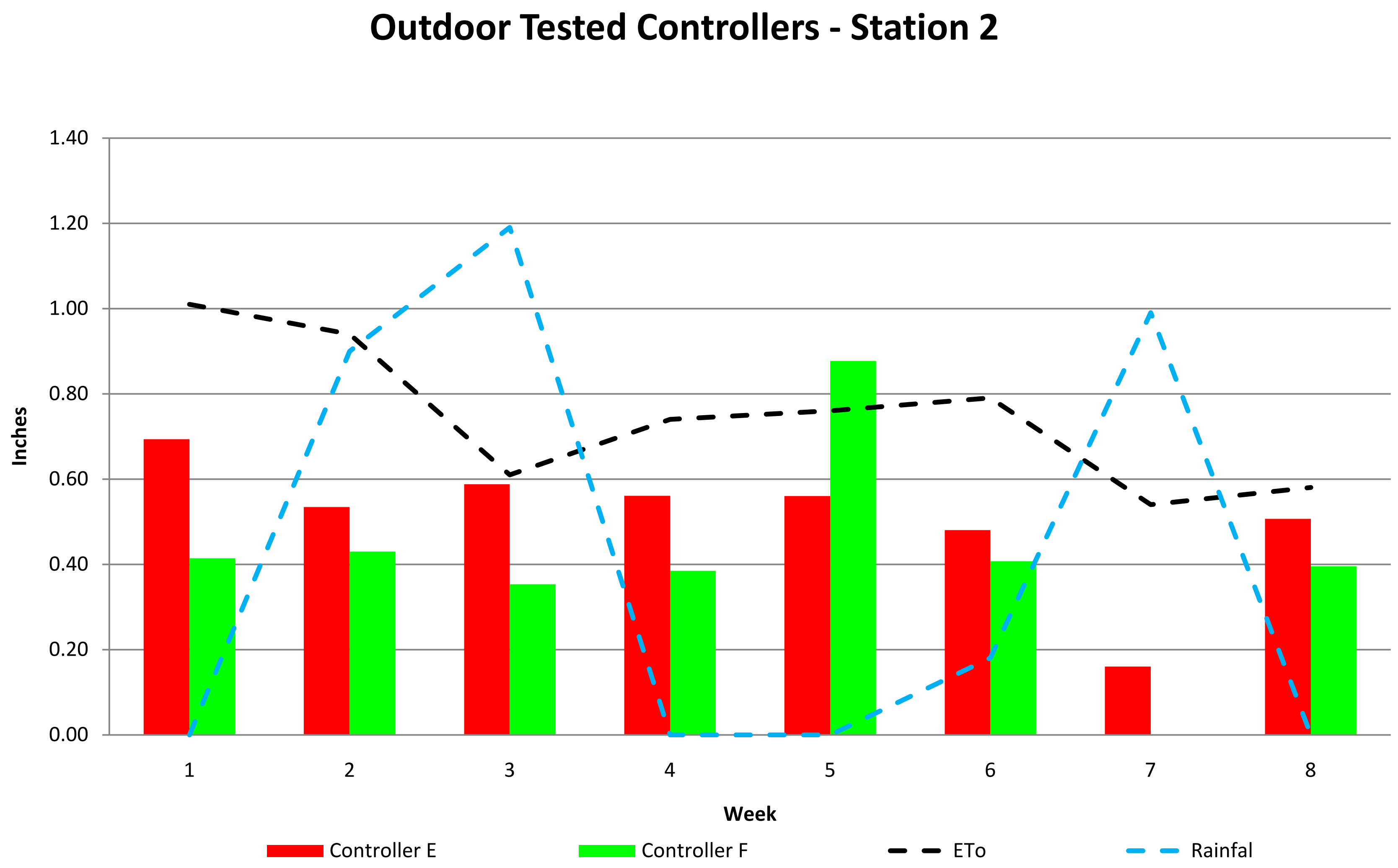

Figure 10 - Weekly irrigation volumes from two smart controllers for station 2 ET_o and recorded rainfall for the period of September 28 to November 22, 2008.

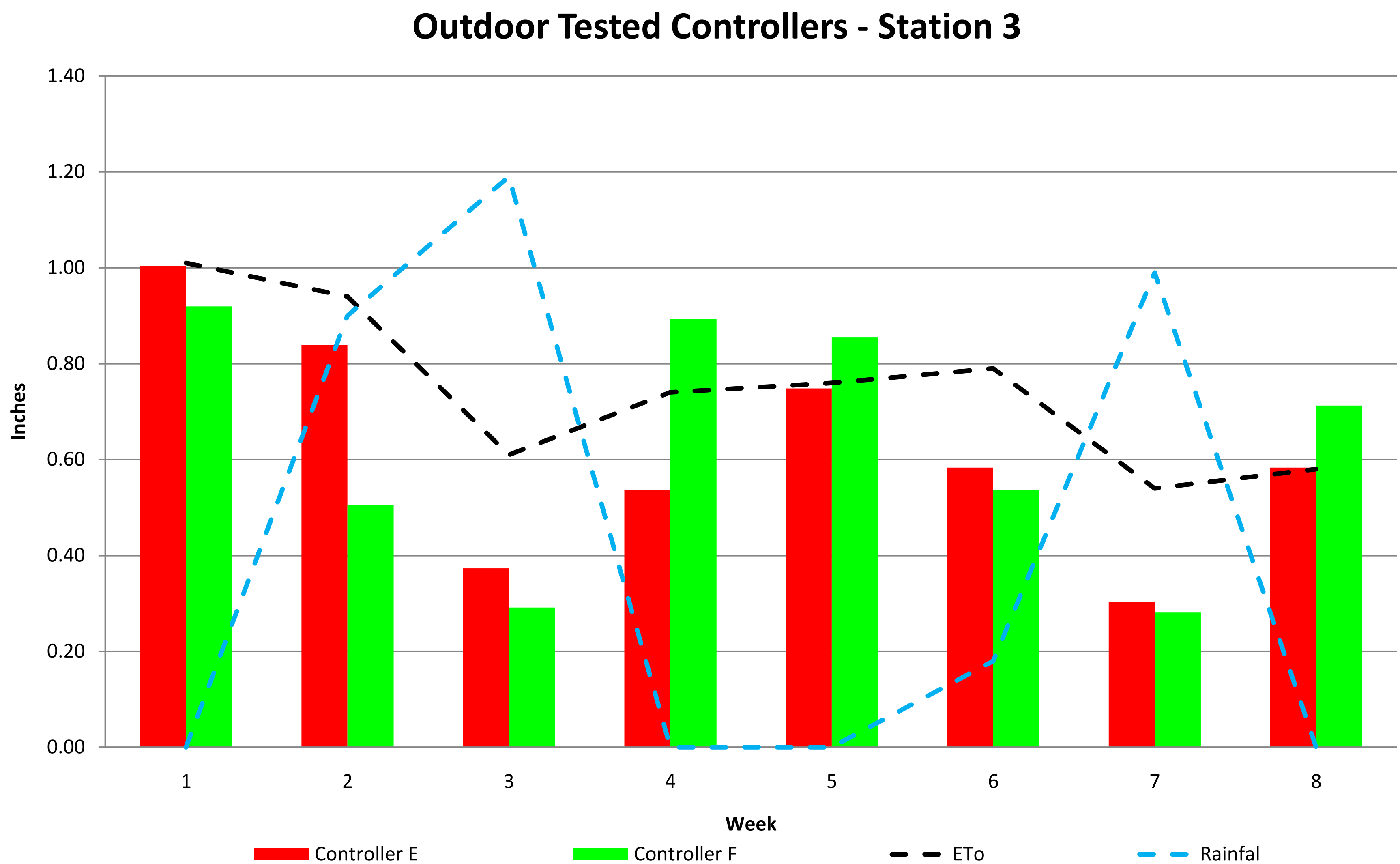

Figure 11 - Weekly irrigation volumes from two smart controllers for station 3 ET_o and recorded rainfall for the period of September 28 to November 22, 2008.

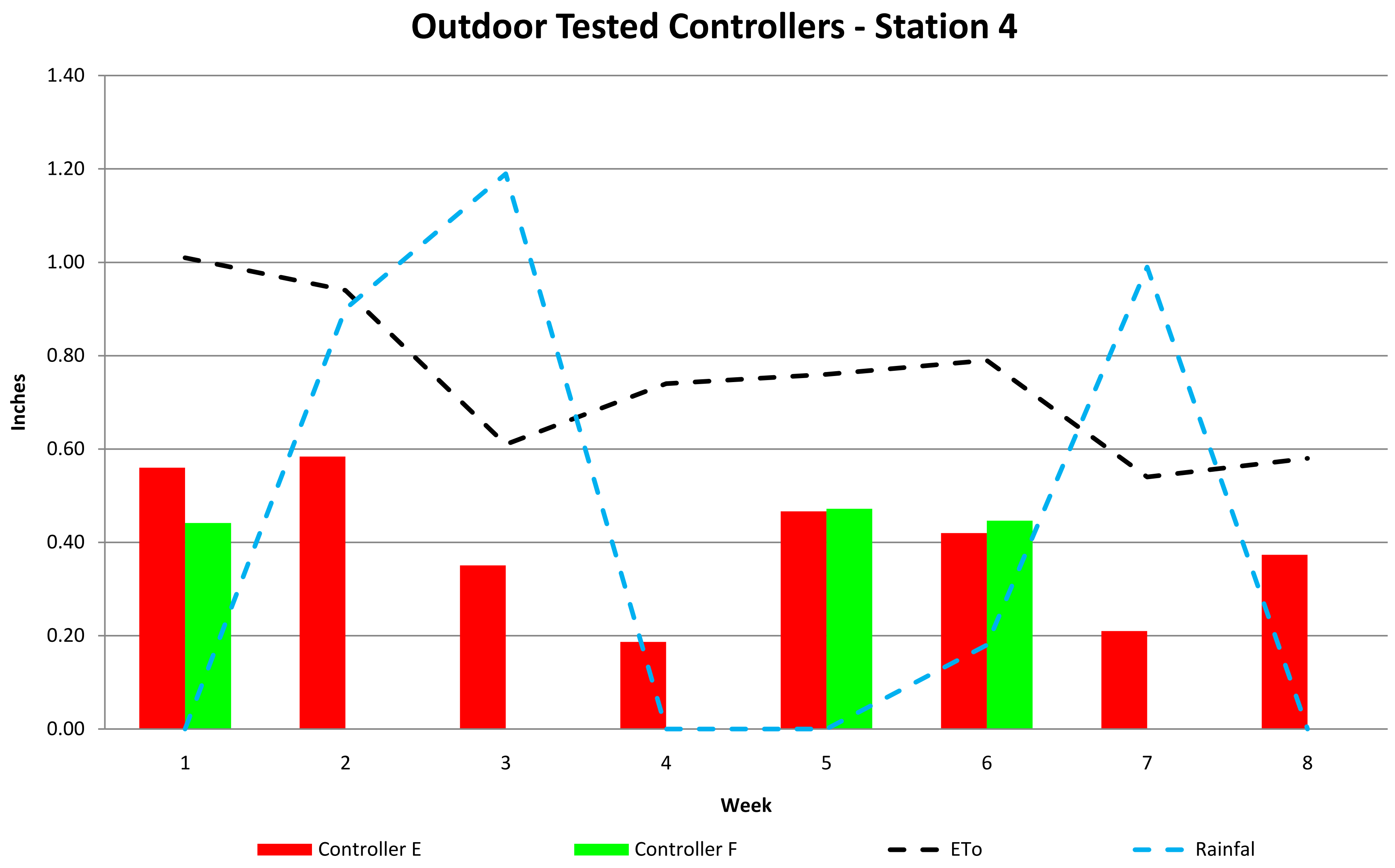

Figure 12 - Weekly irrigation volumes from two smart controllers for station 4 ET_o and recorded rainfall for the period of September 28 to November 22, 2008.

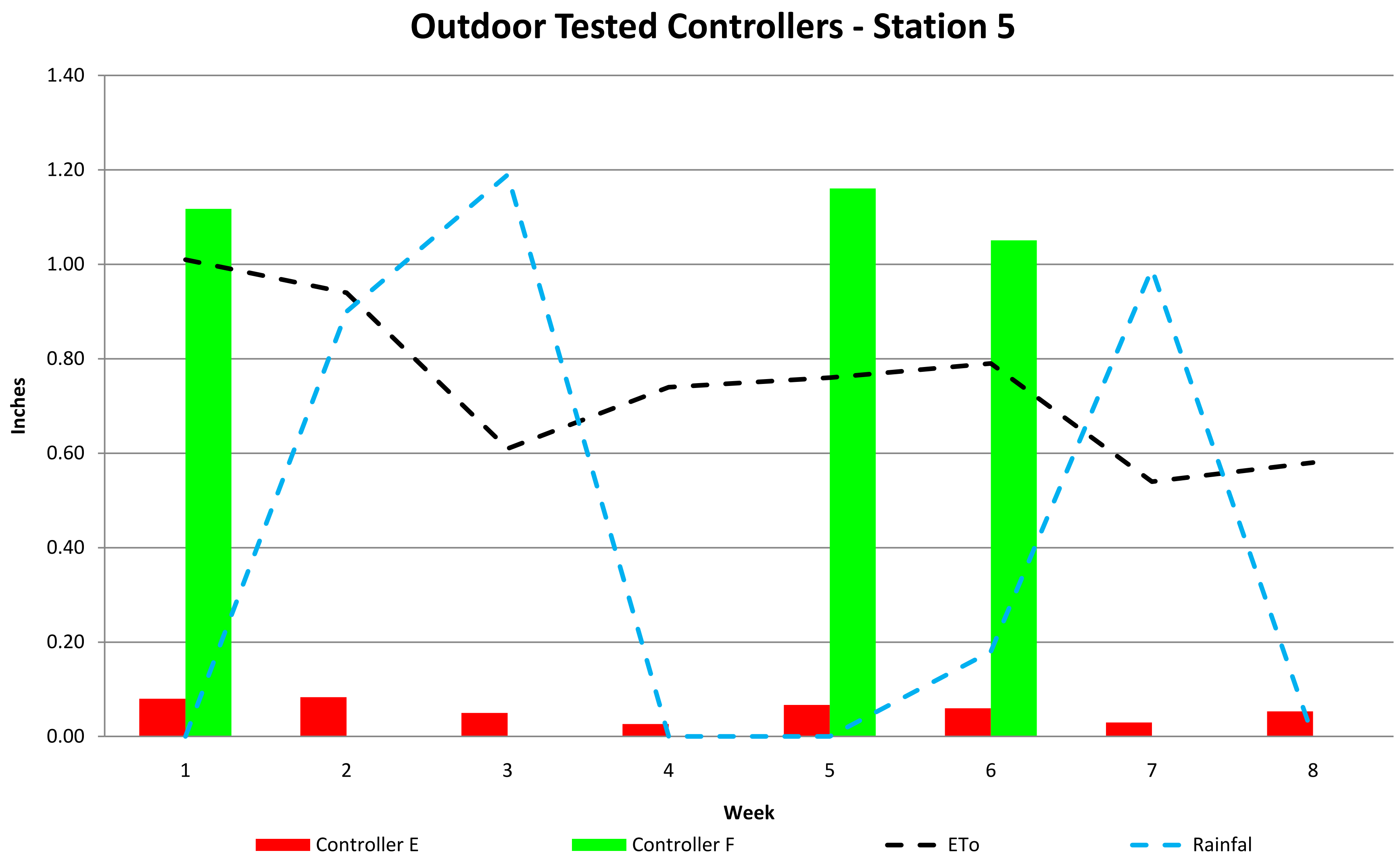

Figure 13 - Weekly irrigation volumes from two smart controllers for station 5 ET_o and recorded rainfall for the period of September 28 to November 22, 2008.

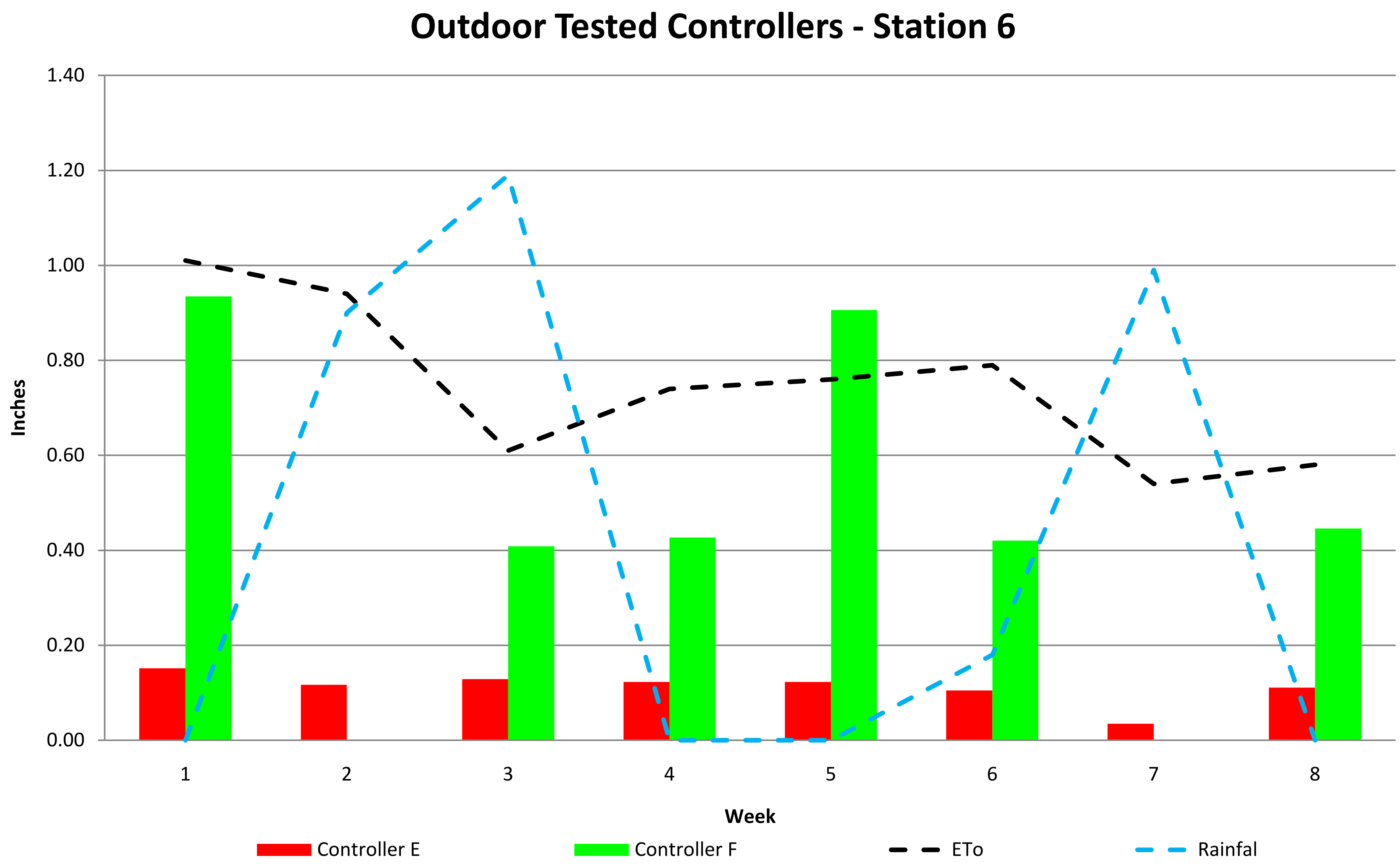

Figure 14 - Weekly irrigation volumes from two smart controllers for station ET_o and recorded rainfall for the period of September 28 to November 22, 2008.

Appendix A

Figure A-1. System Set-Up and Data Flow

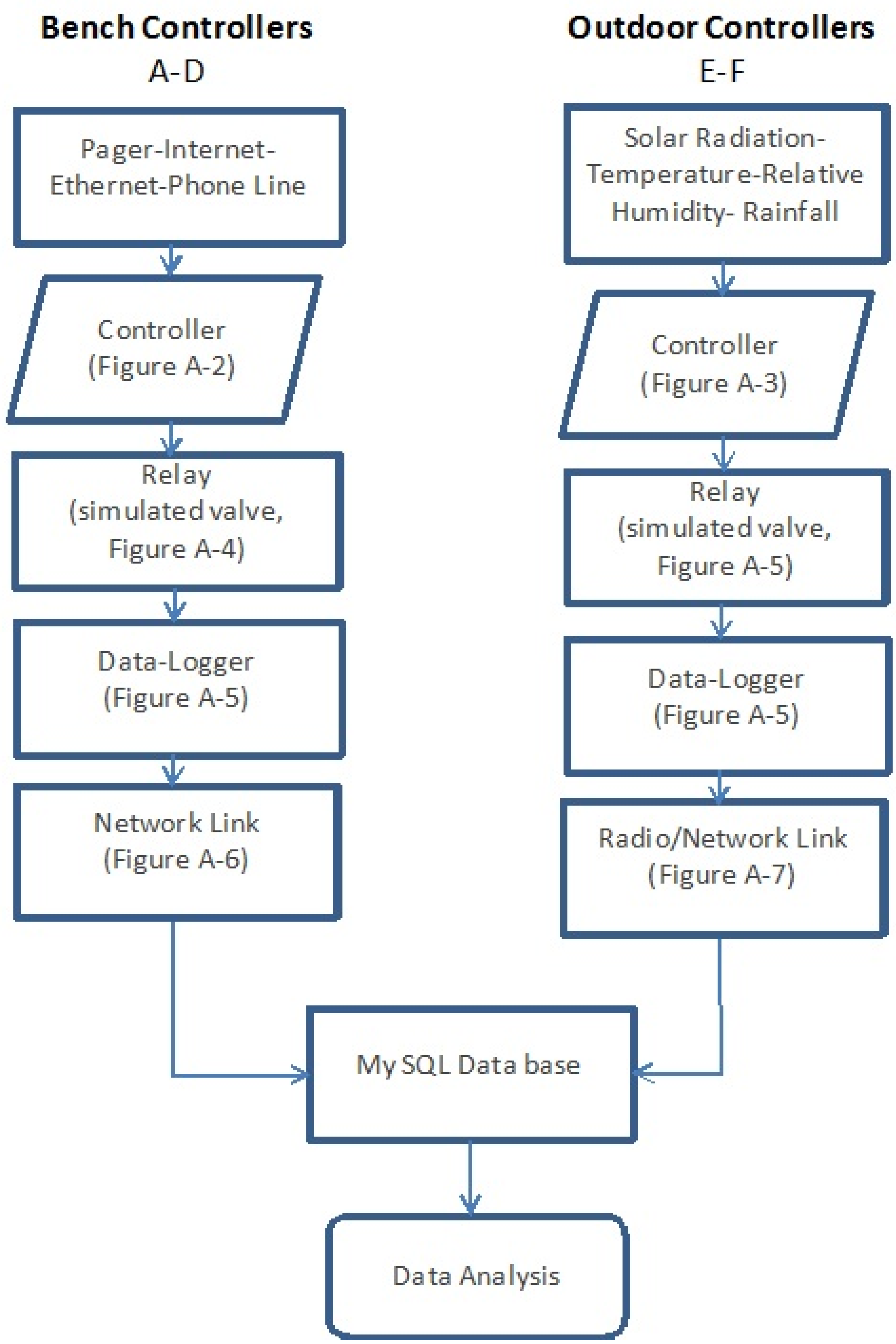

Figure A-2. Bench Tested Controllers

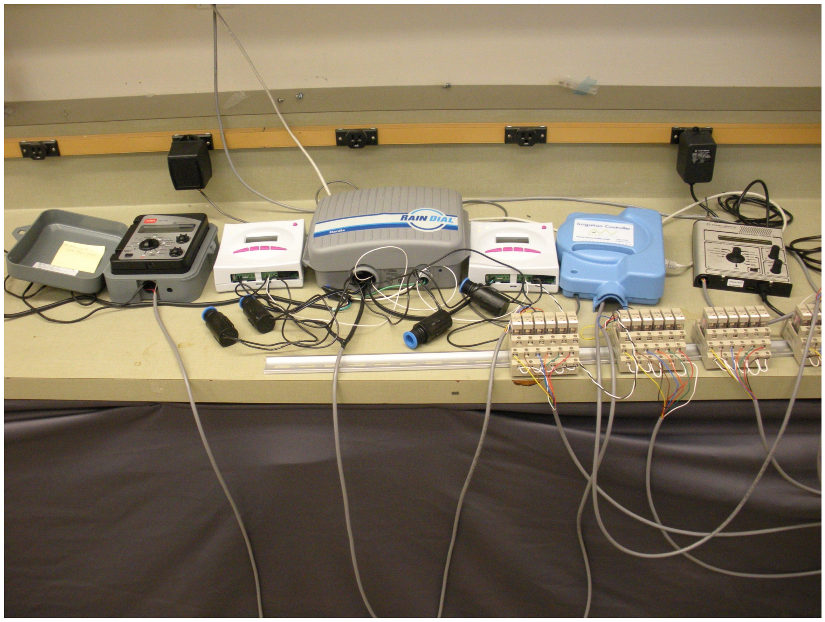

Figure A-3. Outdoor Tested Controllers

Figure A-4. Relays

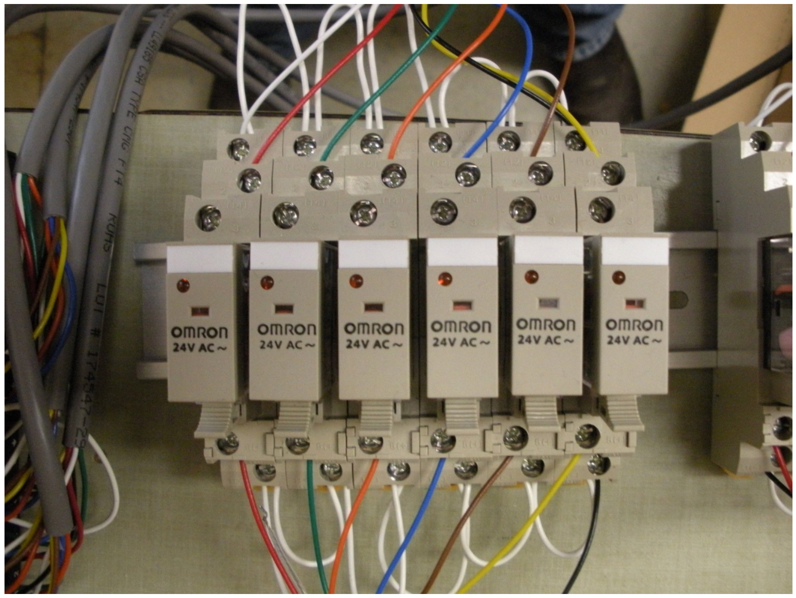

Figure A-5. Datalogger

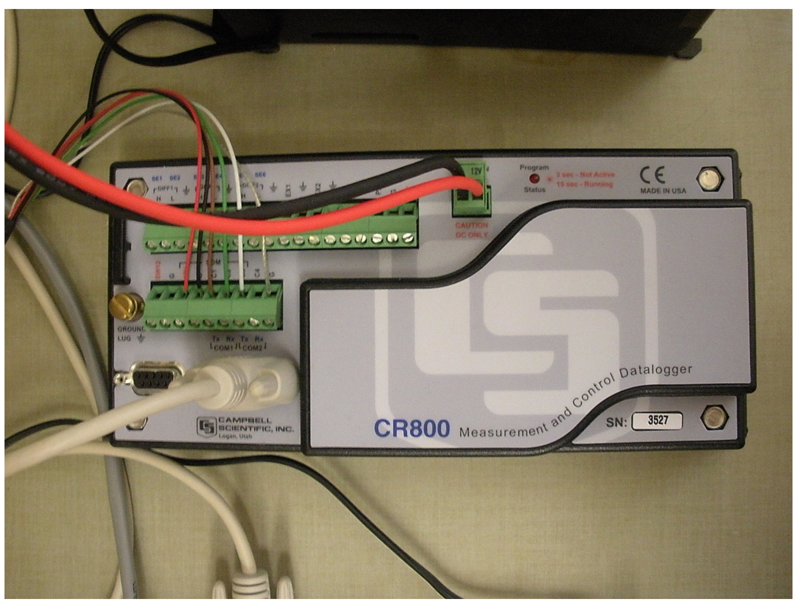

Figure A-6. Network Link

Figure A-7. Radio/Network Link

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This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement No. 2008-45049-04328 and Agreement No. 2008-34461-19061. For program information, see http://riogrande.tamu.edu.