DISCLAIMER

This project was conducted with financial assistance from a grant from the Metropolitan Water District of Southern California (Metropolitan), the U.S. Bureau of Reclamation, the Central Arizona Project, and the Southern Nevada Water Authority through Metropolitan's Innovative Conservation Program (ICP). The ICP provides funding for research to help document water savings and reliability of innovative water savings devices, technologies, and strategies. The findings of this project, summarized in this report, are solely from the project proponent.

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aqua CENTS
WATER MANAGEMENT LLC

"Quantifying Water-Savings and Sustained Results Utilizing Hydrogels Injected Below the Root Zone of Existing Turf"

Glen Bennett, Water Management Consultant
Certified Water Manager/Certified Turfgrass Professional, EPA WaterSense Partner
Jenn Downs, Water Management Consultant/Certified Water Manager

THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Southern Nevada Water Authority

CAP
CENTRAL ARIZONA PROJECT

RECLAMATION
Managing Water in the West

Metropolitan Water District of California
INNOVATIVE CONSERVATION GRANT PROGRAM

FRESNO STATE
Center for Irrigation Technology

FRESNO STATE
International Center for Water Technology

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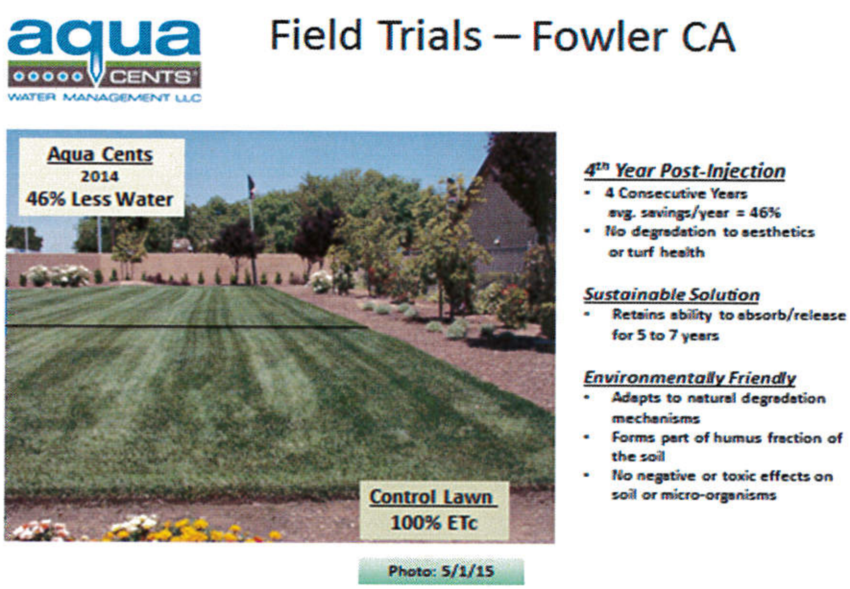
Abstract

Utilizing methodology developed by the Center for Irrigation Technology[1], a two-fold study took place, in conjunction with the C.I.T. at California State University Fresno, on the quantitative and qualitative benefits associated with the injection of Aqua Cents® hydrogels into turf. The goal was to determine the ability of water absorbing hydrogels to reduce water requirements and maintain vibrant turf, during both year four of an efficacy trial in Fowler, CA, and a 52 week 'proof of concept' trial on CSU Fresno's, Agricultural Sciences turf plots.

Test 1 used a process (machine and methodology) developed by Aqua Cents® Water Management, LLC to emulsify and directly inject water absorbing hydrogels into/below turf root zones has shown, over the course of a four year-running experiment in Fowler, CA, a 44-45% reduction in irrigation water application/use within Trial Plots (treated) while producing turf of comparable quality to that of the Control Plots (untreated).



Test 1 – Fowler, CA

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[1] *"A Procedure for Quantifying the Application Efficiency of Turfgrass Irrigation Systems", Edward Norum, CIT/CSUF, March 2012*

Abstract (continued)

Test 2 encompassed turf plots treated in similar fashion with the Aqua Cents® hydrogels during the 52 week trial in an extremely dry climate, in Fresno, CA, have shown the same ability to reduce water requirements by 42-44% plus, while maintaining quality comparable to that of the Control Plots. These same plots preserved turf quality despite cultural influences beyond the influences of the trial that affected water supply, maintenance practices, and irrigation application uniformity. Trial Plots show Aqua Cents® Water Management, LLC's 2012 findings[2] and minimized negative effects of sprinkler pattern loss, and facilitated turf preservation during California's historic drought.

Test 2 – CSU Fresno/C.I.T. Fresno, CA

[2] *"An Experiment Using Water Absorbing Hydrogels Injected into Turfgrass Root Zones as a Way to Improve Water Application Efficiency", Downs/Bennett, Aqua Cents® Water Management, LLC, March 2013*

Introduction

This presentation outlines the results and evaluates both trials conducted in conjunction with The Center for Irrigation Technology (CIT) at California State University Fresno, on water savings through the injection of water absorbing hydrogels into existing stands of turf. The study utilizes a water management strategy for the Control Plots developed by the CIT and Aqua Cents personnel. The CIT was responsible for determining irrigation intervals and application amounts, and Aqua Cents® Water Management, LLC was responsible for injecting the water absorbing hydrogels into the Trial Plots with their equipment, and for irrigation management on the treated plots.

The study validates significant water savings may be achievable by treating turf plots with water absorbing hydrogels. The injection of Aqua Cents® hydrogels beneath established turf plots has been proven to provide retention for water previously lost to deep seepage, and eliminate runoff. This stored water within the hydrogels is readily available to turf roots as they are trained to seek it out. ***Aqua Cents® hydrogels*** have allowed the use of 35-60% less water with no appreciable degradation to turf quality.

By storing water within the root zone, the hydrogels also reduced sprinkler distribution uniformity losses that would normally waste water, and made water available at much lower stress levels thereby enhancing the general health of the treated turf.

Procedure

Test 1 (Year 4 efficacy trial in Fowler, CA) irrigation intervals and application amounts for Control Plots were determined by the CIT from data collected from CIMIS Station 39 in Parlier, CA, using the calculated ETc value (ETc = Kc * ETo). Water was applied (application = ETc/**Effective Application Rate**[3]) at 100% of the calculated value to the Control Plots, and Aqua Cents® Water Management, LLC personnel were responsible for determining fractional percentages of that total to be applied to the Trial Plots, and documenting water savings and resulting turf quality.

- ***A crop coefficient (Kc) is the ratio of the crop evapotranspiration (ETc) to the potential evapotranspiration (ETo) that varies over time based upon growth, horticultural practices…***

[3] *"A Project to Develop a Protocol to Determine the Sprinkler Operating Efficiency of Turf Sprinklers", Edward Norum, CIT/CSU Fresno, June 2015*

Procedure (continued)

MONTH	NOT ADJUSTED FOR ALLOWABLE STRESS			ADJUSTED FOR ALLOWABLE STRESS		
	COOL SEASON	WARM SEASON	COMBINED GRASS	COOL SEASON	WARM SEASON	COMBINED GRASS
January	0.61	0.55	0.61	**0.49**	0.44	0.49
February	0.64	0.54	0.64	**0.51**	0.43	0.51
March	0.75	0.76	0.75	**0.60**	0.61	0.60
April	1.04	0.72	0.72	**0.83**	0.58	0.58
May	0.95	0.79	0.79	**0.76**	0.63	0.63
June	0.88	0.68	0.68	**0.70**	0.54	0.54
July	0.94	0.71	0.71	**0.75**	0.57	0.57
August	0.86	0.71	0.71	**0.69**	0.57	0.57
September	0.74	0.62	0.62	**0.59**	0.50	0.50
October	0.75	0.54	0.75	**0.60**	0.43	0.60
November	0.69	0.58	0.69	**0.55**	0.46	0.55
December	0.60	0.55	0.60	**0.48**	0.44	0.48

Crop Coefficient Values for California Turfgrass

Test 1 continued work previously started, and simply monitored applied versus anticipated water, and recorded resulting turf quality of Control Plots irrigated at 100% of ETc/EAR, and Trial Plots irrigated at fractional percentages thereof.

Test 2 (52 week 'proof of concept' trial at CSU Fresno) consisted of twelve (12) individual turf plots at approximately 1,800sf each. Prior to start of Trial, representative turf plots were selected from each of the four classifications (Water Only, Hydrogel Injection, No Treatment, and Control); a soil sample was collected from each and composited/analyzed for general nutrition. Additionally, using a random number generating program, 20 individual catchment locations within each representative plot were identified, and an irrigation uniformity audit was conducted to determine system efficiency per methodology established in Citation 1.

Plot 1 was to represent those plots injected with **Water Only** with Aqua Cents machinery, Plot 5 was to represent those treated by **Hydrogel Injection**, Plot 9 for those left **Untreated**, and Plot 11was to represent the true **Control Plots**. Collected data was analyzed, anomalies recorded, and both Effective and Average Application

Procedure (continued)

Rates were calculated to establish I85 and I50 quotients to be used in converting irrigation minutes to inches.

- ***i85 and i50 quotients use irrigation audit catchment data to account for pattern loss due to deep seepage from sprinkler non-uniformities and water management inadequacies.***

Plots 1, 2, and 3 were injected with water only (single event) to observe/rule out beneficial effect from introducing water to the root zones. Plots 4, 5, and 6 were injected with Aqua Cents® water absorbing hydrogels at 7lbs per 1,000sf of turf, and were monitored to demonstrate water savings and sustainable quality. Plots 7, 8, and 9 were not treated, and were monitored to demonstrate the inability of untreated turf to maintain quality, while conserving water. Plots 10, 11, and 12 were also not treated however these plots would be irrigated at 100% of the calculated ETc value, and were to be used as the Control Plots for quality relative to water use.

The CIT determined irrigation intervals and application amounts for Test 2 from data collected from CIMIS Station 80 on the campus of CSU Fresno, and results of multiple irrigation catchment tests performed by and Aqua Cents® Water Management, LLC personnel, and audited by CIT Agricultural Engineer, Ed Norum. Aqua Cents® Water Management, LLC personnel were responsible for initial soils test/analytical results, determining fractional percentages of calculated ETc to be applied to Plots 1, 2, and 3, Plots 4, 5, and 6, Plots 7, 8, and 9, and Plots 10, 11, and 12. Water savings and turf quality would be documented by and Aqua Cents® Water Management, LLC and all 12 plots would be maintained by CSU Fresno grounds personnel.

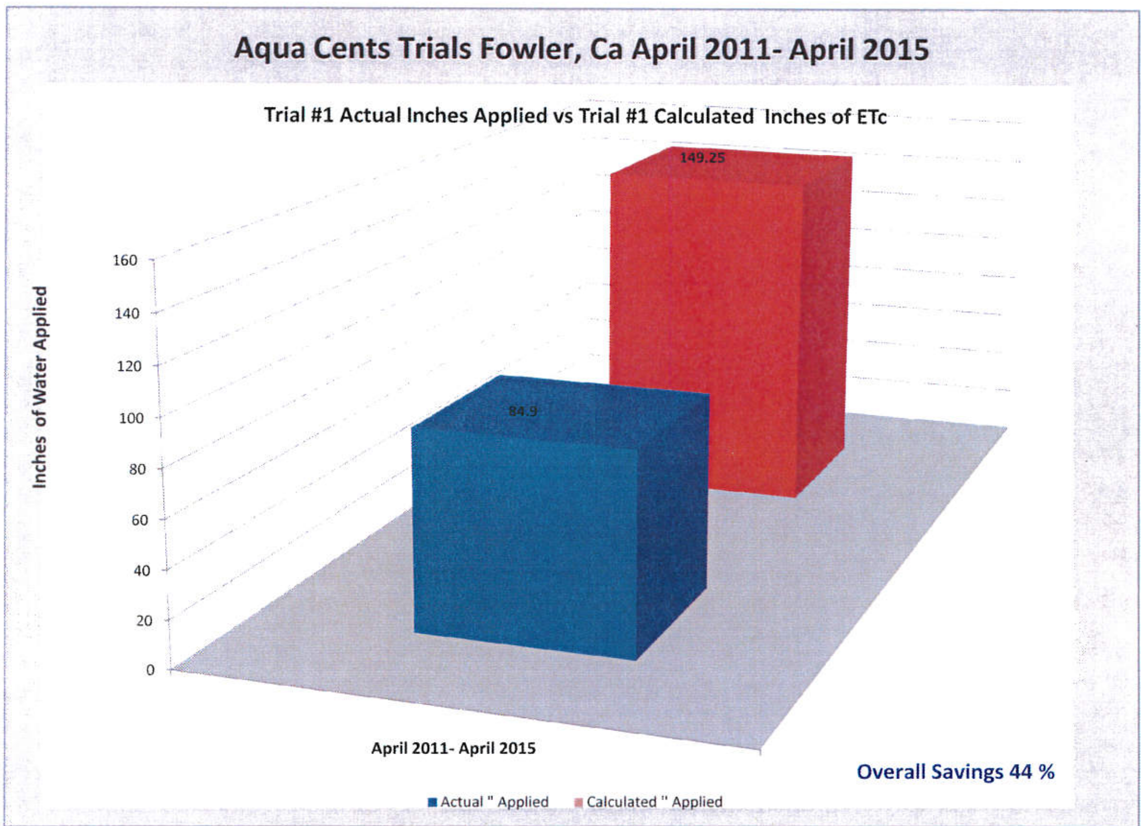
One week post injection, the water applied to Trial Plots (1 – 9) was reduced to fractional percentages of the calculated ETc, and monitoring/documentation of results commenced. Throughout the 52 week trial, application amounts to the Trial Plots would be reduced to demonstrate the ability of those plots treated with hydrogels to sustain viable stands of turf, relative to those treated with water only or nothing at all, and save water in comparison to Plots 10, 11, and 12. The Control Plots (10, 11, and 12) would only have irrigation increased, when necessary, to preserve the quality standard for the Trial Plots.

Testing of soil moisture content, documentation of turf quality, irrigation and turf management would continue throughout the 52 week trial period. Testing would also incorporate actual, as installed, environmental and cultural variables during California's historic drought period.

Results

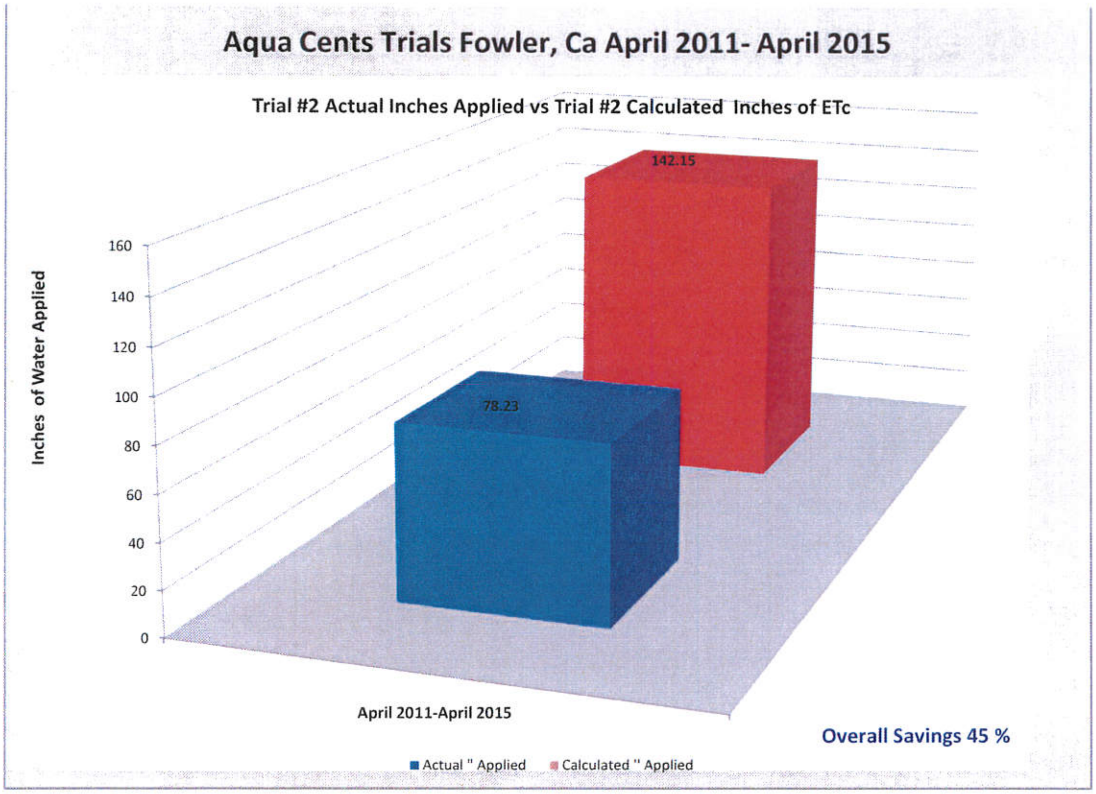
Test 1, over the course of the 52 week period, irrigation/turf manager was able to reduce applied irrigation by **43%** on Trial Plot 1, and ***46%*** on Trial Plot 2 (versus anticipated irrigation as established by calculated ETc) while maintaining comparable quality (no appreciable difference per NTEP Standards) as that of Control Plots 1 and 2 which received 100% of anticipated irrigation.

Turf root zones were also observed in both Trial Plots, and continued to exhibit vigorous growth at greater depths than those of the Control Plots. Overall, applied irrigation savings, compared to calculated ETc, were ***44%*** for Trial Plot 1 and ***45%*** for Trial Plot 2 for the running, four-year efficacy trial.



Test 1/Trial 1 Results – Fowler, CA

Results (continued)



Test 1/Trial 2 Results – Fowler, CA

Test 2 results collected for will illustrate the Trial Plots' ability, when treated with Aqua Cents® hydrogels, to withstand extreme water conservation efforts and sustain quality when compared to Trial Plots treated with water only, or those left untreated.

The results will also document the Trial Plots' ability to maintain turf quality during these water conservation efforts when compared to Control Plots receiving 100% of anticipated irrigation, per calculated ETc.

Trial Plots 1, 2, and 3, treated with ***water only***, were irrigated at fractional percentages of ETc, as were their partner Trial Plots treated with ***Aqua Cents® hydrogels*** 4, 5, and

Results (continued)

6, and those ***left untreated***, 7, 8, and 9 throughout the initial 12 weeks of the 52 week Test. Irrigation to Plots 1, 4, and 7 was reduced from 100% of calculated ETc to 65%, Plots 2, 5, and 8 were reduced from 100% to 70%, and applied irrigation for Plots 3, 6, and 9 was reduced from 100% to 85% of ETc. Irrigation to Plots 10, 11, and 12 remained constant at 100% of calculated ETc.

Turf quality was evaluated and documented throughout **Weeks 1 – 12**; overall, the quality of turf within Plots 1, 2, and 3, as well as those within Plots 7, 8, and 9 had begun to suffer from both lack of applied water, as well as physical inefficiencies within the project's irrigation system and environmental variables.

Weeks 13 through 26 encompassed what are traditionally the warmest/driest within the Test 2 locale; irrigation to the Control Plots (10, 11, and 12) was increased to 130% of ETc/EAR to maintain quality while irrigation to Trial Plots 4, 5, and 6 (treated with hydrogels) was maintained at 50, 45, and 45% of ETc respectively, and turf quality remained equal to or greater than that of the Control Plots. Trial Plots 1, 2, and 3 **and** Trial Plots 7, 8, and 9 were unable to match the water savings/turf quality index established by Plots 4, 5, and 6 (treated w/ Aqua Cents hydrogels).

Week 27 irrigation to Plots 4, 5, and 6 (hydrogels) was suspended, Plots 10, 11, and 12 (Control) continued to receive 100% of ETc to maintain baseline quality standard. Plots 4, 5, and 6 were monitored, and irrigation applied only as quality demanded. Plots 1, 2, and 3, and Plots 7, 8, and 9 continued to receive irrigation at 50, 45, and 45% of calculated ETc respectively. Turf quality did not meet acceptable standards, per NTEP, on Plots 1, 2, 3, and Plots 7, 8, 9.

Weeks 28 – 31 continued, per week 27 however Plots 1, 2, and 3 and Plots 7, 8, and 9 had their percentage of calculated ETc further reduced to 40, 40, and 30% respectively. Plots 4, 5, and 6 continued to receive no irrigation, and Plots 10, 11, and 12 received 100% of ETc.

Week 32 brought about the removal from the formal trial of Plots 1, 2, and 3 (treated with water only), and Plots 7, 8, and 9 (untreated); further deprivation would simply kill the turf within each plot that had survived which would necessitate complete renovation to these plots. It was concluded, at Week 32, that the plots treated with water only, and those left untreated were incapable of both conserving water and maintaining quality of an acceptable standard. Moreover, it appears that the aeration process on Plots 1, 2, and 3 actually increased atmospheric exchange and further exacerbated moisture loss within these root bearing zones.

Results (continued)

Weeks 33 through Week 41 continued, per Week 32, and Plots 4, 5, and 6 continued to go without irrigation, and Plots 10, 11, and 12 received 100% of calculated ETc or 50 minutes per week in total. Quality of turf within Plots 4, 5, and 6 was comparable to that of turf within Plots 10, 11, and 12.

Weeks 42 and 43 received unseasonably warm temperature, and no precipitation; turf within Plots 4, 5, and 6 received 80 minutes of a calculated ETc total of 169 (53% water savings), and Plots 10, 11, and 12 received 120 minutes of a calculated ETc total of 117 (100% +).

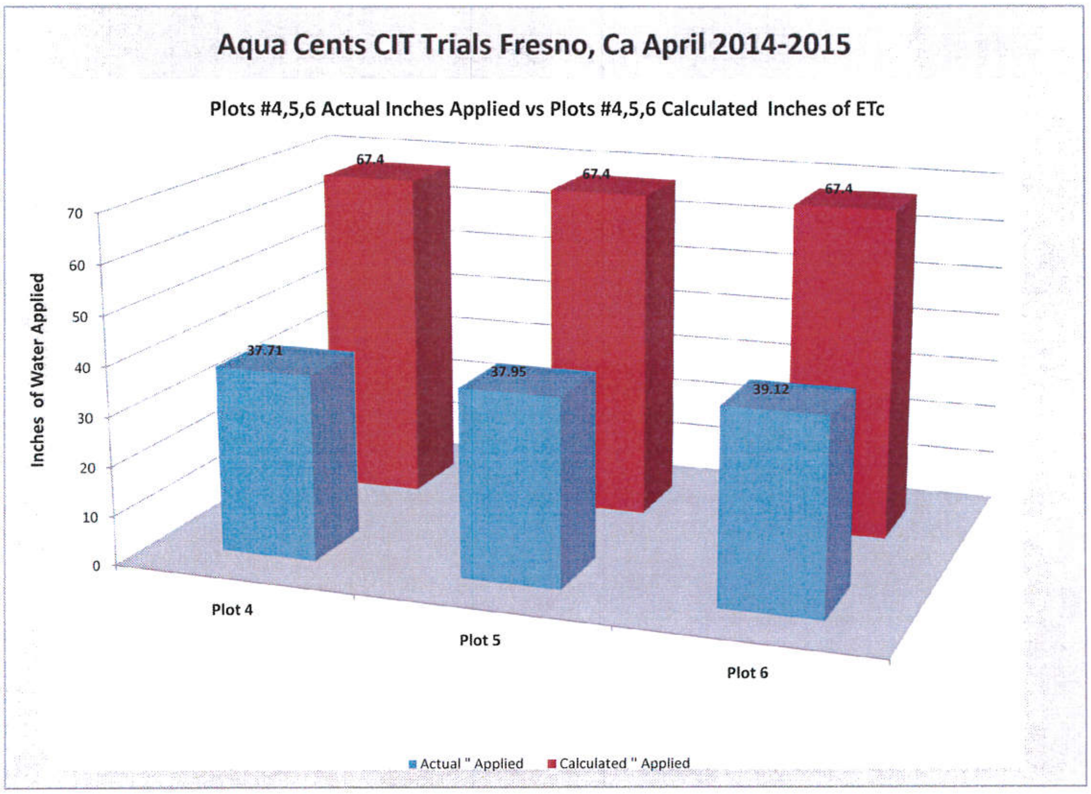
Week 44 conditions were more typical of seasonal averages and irrigation to Plots 4, 5, and 6 was again suspended while Plots 10, 11, and 12 received ~100% of calculated ETc.

Weeks 45 through 50 were again drier and warmer, and irrigation resumed on Plots 4, 5, and 6. These plots received 300 minutes of a calculated ETc of 1,200 total minutes (~75% water savings). Plots 10, 11, and 12 received 840 minutes of a calculated ETc of 833 total minutes (100% +). Comparable turf quality between Plots 4, 5, and 6, and Plots 10, 11, and 12 was noted/recorded.

Week 51 irrigation to Plots 4, 5, and 6 was suspended, and Plots 10, 11, and 12 received 70 minutes of the calculated total of 69, or 100% + of ETc.

Week 52 (final trial week) irrigation to plots 4, 5, and 6 resumed during and those plots received 60 minutes of a calculated total ETc of 420 minutes (85% water savings). Plots 10, 11, and 12 received 300 of the calculated total 292, or 100% + of ETc. The final turf evaluation found no significant qualitative differences within Plots 4, 5, and 6, and Plots 10, 11, and 12.

Results (continued)



Test 2 Results – CSU Fresno

Conclusion

Test 1 demonstrated the ***Aqua Cents® hydrogels'*** ability, over a four year efficacy trial period, to save water and preserve quality within established stands of treated turf. Irrigation to Trial Plot 1 was reduced by 42%, and irrigation to Trial Plot 2 was reduced by a total of 46% of anticipated irrigation, when compared to their corresponding Control Plots.

The hydrogels, when injected beneath established turf, provide catchment for water previously lost to deep seepage. This water is stored, made available to turf, and

Conclusion (continued)

appears to have demonstrated the ability to significantly reduce applied irrigation, and preserve quality, especially when coupled with proper irrigation management.

Test 2 affirmed the ***Aqua Cents® hydrogels'*** water savings capabilities (**42 – 44% of calculated ETc**), and again, when coupled with proper irrigation management, demonstrated an ability to preserve turf quality while saving water. When compared to comparable stands of turf, and their ability to maintain quality while saving like amounts of irrigation, the Plots treated with ***Aqua Cents® hydrogels*** (Plots 4, 5, and 6) performed at, or near, the same level as those Plots left untreated and irrigated at 100% + of calculated ETc (Control Plots).

Plots treated with ***water only*** (Plots 1, 2, and 3) and those ***left untreated*** (Plots 7, 8, and 9) failed to show an ability to save comparable or significant water, and maintain acceptable quality. Moreover, these Plots also failed to successfully weather the same "as installed" specifics (wind, broken/damaged rotors, inconsistent irrigation pressure and/or volume…) as did Plots 4, 5, and 6. The catchment provided by the hydrogels injected beneath the trial turf stored/released water to treated turf roots, as needed, and appear to have reduced the negative effects of sprinkler pattern non-uniformities associated with both cultural and environmental variables

Potential Benefits

Water use, especially landscape water use, is scrutinized more closely than ever in California; the functional, recreational, and qualitative benefits of turf need to be assessed and honored prior to arbitrary removal/replacement as it is both possible and achievable to conserve water while maintaining healthy turf. The non-plant alternatives to turf do not provide positive ecosystem results[4] to the same degree, as do properly managed stands of urban turfgrass; turf captures run-off that can result in 'urban drool'[5], it mitigates fugitive dust and erosion, documented to lessen the heat island effect[6], captures and stores more carbon than its maintenance equipment produces[7], and it boosts one's oxygen footprint.

Aqua Cents® hydrogels, when injected beneath the root zones of existing turf, can be incorporated into a responsible irrigation/turf management program[8] and produce

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[4] *"Think Before You Remove Your Lawn! – The Benefits of Turfgrass", Dr. Ranajit (Ron) Sahu, California Institute of Technology*

[5] *"Preventing Runoff of Pesticides and Nutrients", Loren Oki, UC Davis, February 2012*

[6] *http://www.epa.gov/heatisland/index.htm*

[7] *"Technical Assessment of the Carbon Sequestration Potential of Managed Turfgrass in the United States", Dr. Ranajit (Ron) Sahu, California Institute of Technology*

Potential Benefits (continued)

healthy stands of urban turfgrass capable of providing sustainable, positive benefits to urban ecosystems[9], while honoring water conservation mandates regardless of climate, species or use of targeted turf, or root zone conditions of existing turf.

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[8] *"Water Management on Turfgrass", Richard L. Dibble, Turfgrass Specialist, Texas Cooperative Extension, Texas A&M*

[9] *"Hydrogel and Its Application in Agriculture", Roqieh Barihi, Ebram Panahpour, Masoud Hossein, and Mizaree Beni, World of Sciences Journal 2013 Volume 1, Issue 15, Pages 223 – 228*

Test 1 and 2 Appendix

Daily Report

Page 1 of 1

April 2015

California Irrigation Management Information System (CIMIS)

CIMIS Daily Report

Rendered in ENGLISH Units.
Monday, March 30, 2015 - Sunday, April 05, 2015
Printed on Wednesday, April 15, 2015

Parlier - San Joaquin Valley - Station 39

Date	ETo (in)	Precip (in)	Sol Rad (Ly/day)	Avg Vap Pres (mBars)	Max Air Temp (°F)	Min Air Temp (°F)	Avg Air Temp (°F)	Max Rel Hum (%)	Min Rel Hum (%)	Avg Rel Hum (%)	Dew Point (°F)	Avg Wind Speed (mph)	Wind Run (miles)	Avg Soil Temp (°F)
3/30/2015	0.20	0.00	522	10.5	87.0 Y	50.6	69.5 Y	87	21	43 Y	45.9 Y	3.9	94.4	66.4
3/31/2015	0.23	0.00	536	9.3	77.1	51.4	64.7	74	28	44	42.6	8.0 Y	191.2 Y	65.5
Tots/Avgs	0.43	0.00	529	9.9	82.1	51.0	67.1	81	25	44	44.3	6.0	142.8	66.0

Actuals
Trial #1
100 mins
.72"
Trial #2
90 mins
.83"

Parlier - San Joaquin Valley - Station 39

Date	ETo (in)	Precip (in)	Sol Rad (Ly/day)	Avg Vap Pres (mBars)	Max Air Temp (°F)	Min Air Temp (°F)	Avg Air Temp (°F)	Max Rel Hum (%)	Min Rel Hum (%)	Avg Rel Hum (%)	Dew Point (°F)	Avg Wind Speed (mph)	Wind Run (miles)	Avg Soil Temp (°F)
4/1/2015	0.18	0.00	518	7.2	72.1	44.2	58.6	75	20	43	36.2	5.3	126.2	63.9
4/2/2015	0.17	0.00	539	7.3	71.2	38.4	56.4	88	21	47	36.5	3.4	82.5	62.9
4/3/2015	0.19	0.00	544	7.2	77.7	42.6	60.4	86	15	40	36.0	3.6	87.0	65.0
4/4/2015	0.20	0.00	549	7.0	77.7	40.5	60.5	87	15	39	35.3	4.1	98.1	64.1
4/5/2015	0.18	0.00	526	7.9	70.8	44.1	58.0	74	24	48	38.3	5.9	141.8	62.5
Tots/Avgs	0.92	0.00	535	7.3	73.9	42.0	58.8	82	19	43	36.5	4.5	107.1	63.7

Total Avg = 1.35

Flag Legend		
A - Historical Average	I - Ignore	R - Far out of normal range
C or N - Not Collected	M - Missing Data	S - Not in service
H - Hourly Missing or Flagged Data	Q - Related Sensor Missing	Y - Moderately out of range
Conversion Factors		
Ly/day/2.065=W/sq.m	inches * 25.4 = mm	(F-32) * 5/9 = c
mph * 0.447 = m/s	mBars * 0.1 = kPa	miles * 1.60934 = km

ETc
1.35
x .83
1.12

Trial #1
i_{90} = .334 in/hr
$T = \frac{1.12}{.334} = \frac{3.35 (60)}{10}$ = 200 mins
i_{50} = 3.35 x .431 = 1.44" calculated

Trial #2
i_{90} = .456 in/hr
$T = \frac{1.12}{.456} = \frac{2.46 (60)}{10}$ = 150 mins
i_{50} = 2.46 x .550 = 1.35" calculated

Control #1
i_{90} = .382 in/hr
$T = \frac{1.12}{.382} = \frac{2.93 (60)}{10}$ = 170 mins

Control #2
i_{90} = .513 in/hr
$T = \frac{1.12}{.513} = \frac{2.18 (60)}{10}$ = 130 mins

http://www.cimis.water.ca.gov/UserControls/Reports/DailyReportViewer.aspx 4/15/2015

[10]

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[10] *Example: CIMIS ETo Data Used to Calculate ETc and Anticipated vs. Actual Irrigation Minutes – Test 1*

Trial #1 April 2014 - April 2015 Fowler, Ca					
Month	Minutes (Calculated)	Minutes (Actual)	Inches (Calculated)	Inches (Actual)	% Savings
April	790	490	5.62"	3.28"	42%
May	1,190	780	8.58"	5.61"	35%
June	1,030	660	7.43"	4.18	43%
July	990	760	7.11"	5.44"	23%
August	1,070	840	7.75"	6.02"	22%
September	560	405	3.95"	2.90"	27%
October	450	200	3.26"	1.44"	56%
November	140	0	1.05"	0"	100%
December	90	0	.66"	0"	100%
January	110	0	.71"	0	100%
February	180	0	1.33"	0	100%
March	510	120	3.62"	.86"	76%
April	1,000	490	7.22"	3.51"	51%

April 1 2014- April 30th 2015 Total Calculated Inches= 58.29"
April 1 2014- April 30th 2015 Total Actual Inches= 33.24"

April 2014- April 2015 $\frac{58.29''-33.24''}{58.29''}$ 43 % Savings

Trial #2 April 2014- April 2015 Fowler, Ca					
Month	Minutes (Calculated)	Minutes (Actual)	Inches (Calculated)	Inches (Actual)	Savings
April	570	295	5.27"	2.72"	48%
May	870	446	8.02"	4.09"	49%
June	750	440	6.95"	4.02"	47%
July	720	480	6.65"	4.4"	34%
August	780	588	7.28"	5.37"	26%
September	400	285	3.67"	2.62"	29%
October	330	180	3.03"	1.66"	45%
November	120	0	.86"	0"	100%
December	60	0	.72"	0"	100%
January	90	0	.80"	0"	100%
February	130	0	1.24"	0"	100%
March	430	0	3.49"	.91"	74%
April	730	390	6.75"	3.59"	47%

April 1, 2014- April 30, 2015 Total Calculated Inches= 54.73"
April- March 31st Total Actual Inches= 29.38"

April 2014- April 2015 $\frac{54.73''-29.38''}{54.73''}$ 46 % Savings

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[11] *Anticipated vs. Actual, Test 1 – Fowler, CA*

Report of Soil Analysis

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Chemists and Consultants

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Fresno CA 93727
7961
09

ID: Turf Existing

Lab No. 199370
Sampled Date
Submitted Date 1/30/2014
Submitted by Jenn Downs
Reported Date 2/7/2014
Location/Project Fresno State
Copy To
Fax (559) 453-3259
E-mail jdowns@acls.bz

Rec's

No.	Description	%	units	dS/m	meq/l	meq/l	meq/l	meq/l	%	T/ac-6"	+\-	lbs/ac-6"	mg/l	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
		SP	pH	EC	Ca	Mg	Na	Cl	ESP	GR	Lime	Lime	B	NO_3-N	PO_4-P	K	Acid K	Zn
	RL--->	0.50	1.0	0.01	0.1	0.1	0.1	0.1	0.1	0.1		500	0.1	1.0	2.0	2.0	40.0	0.1
	NAPT Methods--->	S1.00	S1.10	S1.20	S1.60	S1.60	S1.60	S1.40	Calc.	Hndbk 60-22d	Hndbk 60-23a	S2.50	S1.50	S3.10	S4.10	S5.10	SSSA,p56 1 mod	S6.10
	Handbook 60--->																	
1	Turf Plots	38	8.0	1.06	4.7	3.3	3.7		1.5		-		<0.1	<1	72	221		8.7

Landscape Soil	"Texture"	"Acidity"	Total Salts	Calcium	Magnesium	Sodium	Chloride	"Alkali"	Gyp Req	Lime Pres	Lime Req.	Boron	Nitrate-N*	Phosphate-P*	Potassium*		Zinc*
Low 	Sand<20	< 6.4	< 0.5	< 4	-	-	-	-		-		< 0.2	< 7	< 12	< 110		< 0.8
Normal	Loam 25-45	6.7-7.7	0.7-2.0	6-25	2-15	< 8	< 8	<4		++		0.3-0.5	12-25	20-30	125-250		1.0-3.0
High	Clay>50	8.0+	2.2 **	35 +	25+	Na>Ca	12+	11 +		++++		1.0 +	40	40	350 +		5.0

*Tissue analysis can be used to track nutrient use during the growing season.
** = EC up to 4.0 not a problem if primarily calcium
SP levels with a significant textural interface (>6) are indicated with a separator line.
*** = High & Low color levels may be differ based on consultant interpretation of the situation, including location, drainage, soil type, weather, irrigation system, etc.

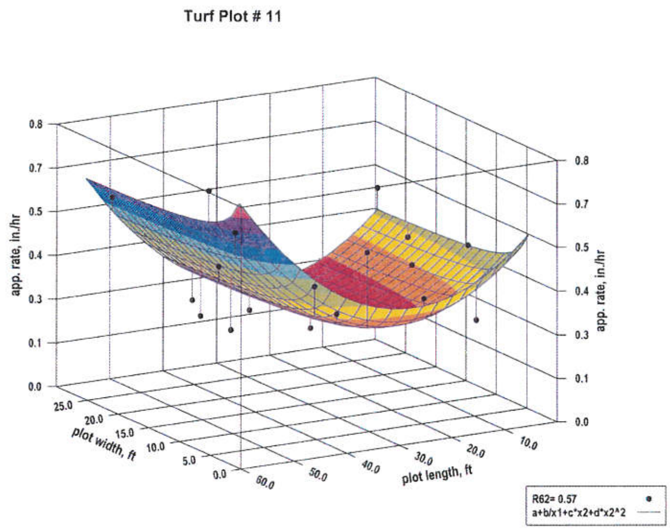
(mg/kg is equivalent to ppm)

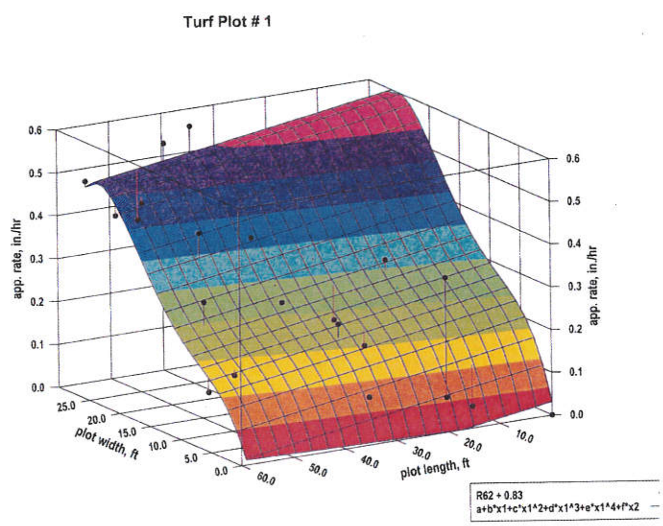
Black = Normal	***
Red = High	Green = Sl.Low
Orange = Sl. High	Blue = Low

Page 1 of 1

12

12 *Analytical Results, Composited Soil Samples, Plots 1, 5, 9, and 11, CSU Fresno – Test 2*





[13]

Computer Generated Model of Irrigation Distribution
(Red = Area of Lightest/Pink Area of Heaviest Application of Water)

[13] *Example: Distribution Uniformity in 3D, CSU Fresno – Test 2*

Daily Report Page 1 of 1

California Irrigation Management Information System (CIMIS)

CIMIS Daily Report

Rendered in ENGLISH Units.
Monday, September 22, 2014 - Sunday, September 28, 2014
Printed on Monday, September 29, 2014

Fresno State - San Joaquin Valley - Station 80

Date	ETo (in)	Precip (in)	Sol Rad (Ly/day)	Avg Vap Pres (mBars)	Max Air Temp (°F)	Min Air Temp (°F)	Avg Air Temp (°F)	Max Rel Hum (%)	Min Rel Hum (%)	Avg Rel Hum (%)	Dew Point (°F)	Avg Wind Speed (mph)	Wind Run (miles)	Avg Soil Temp (°F)
9/22/2014	0.17	0.00	471	15.5	88.1	60.2	74.2	84	32	54	56.4	3.5	84.5	73.4
9/23/2014	0.18	0.00	502	15.2	91.4	60.7	75.3	84	26	51	55.5	2.9	69.0	73.7
9/24/2014	0.18	0.00	502	15.6	92.9	61.0	74.9	88	24	53	55.4	3.9	94.7	73.1
9/25/2014	0.17	0.00	441	16.8	80.0	61.9	69.0	97	53	69	56.5	7.1 Y	170.7 Y	73.1
9/26/2014	0.16	0.00	371	12.8	77.7	60.4	67.2	77	32	56	51.0	7.4 Y	177.0 Y	71.9
9/27/2014	0.15	0.00	465	12.3	78.5	55.6	64.6	81	31	59	50.0	4.9	117.4	71.0
9/28/2014	0.12	0.07 R	349	14.1	73.5	57.0	65.2	90	42	67	53.8	3.9	93.2	70.7
Total/Avgs	1.13	0.07	443	14.6	83.5	59.5	70.1	84	34	58	54.6	4.5	115.2	72.4

Flag Legend		
A - Historical Average	I - Ignore	R - Far out of normal range
C or N - Not Collected	M - Missing Data	S - Not in service
H - Hourly Missing or Flagged Data	Q - Related Sensor Missing	Y - Moderately out of range
Conversion Factors		
Ly/day/2.065=W/sq.m	inches * 25.4 = mm	(F-32) * 5/9 = c
mph * 0.447 = m/s	mBars * 0.1 = kPa	miles * 1.60934 = km

http://wwwcimis.water.ca.gov/UserControls/Reports/DailyReportViewer.aspx 9/29/2014

WK 22

WEEKLY IRRIGATION SCHEDULE
C.I.T. - CSU Fresno

Period	9/23 - 9/29/14
ETo ("/week)	1.41
Crop Coefficient (Kc)	0.59
ETc ("/week)	0.8319

	H2O	AC	NONE	CONTROL
Plot Number	1	5	9	11
Effective Application Rate ("/hr)	0.181	0.194	0.199	0.280
Average Application Rate ("/hr)	0.280	0.335	0.340	0.379
Required Run Time (hr/wk)	4.596	4.288	4.180	2.971
Minutes Per Week	275.768	257.289	250.824	178.264
Cycles Per Week: 10				
M				
T	55.15	51.46	50.16	35.65
W	55.15	51.46	50.16	35.65
TH	55.15	51.46	50.16	35.65
F	55.15	51.46	50.16	35.65
SAT	55.15	51.46	50.16	35.65
SUN				
TOTAL	275.768	257.289	250.824	178.264

276	252	251	
138/1	126/4	126/7	50%
124/2	113/5	113/8	45%
124/3	113/6	113/9	45%

14/1	13/4	13/7	19/10
12/2	11/5	11/8	19/11
12/3	11/6	11/9	19/12

10 cycles/wk

MIN/PLOT

14

[14] *Example: CIMIS ETo Data Used to Calculate ETc and Anticipated vs. Actual Irrigation Minutes – Test 2*


15


16

[15] *Plots 1, 2, 3 (Water Only) Week 1 – Test 2 CSU Fresno April 21 – 28, 2014*
[16] *Plots 4, 5, 6 (Aqua Cents Hydrogel) Week 1 – Test 2 CSU Fresno April 21 – 28, 2014*

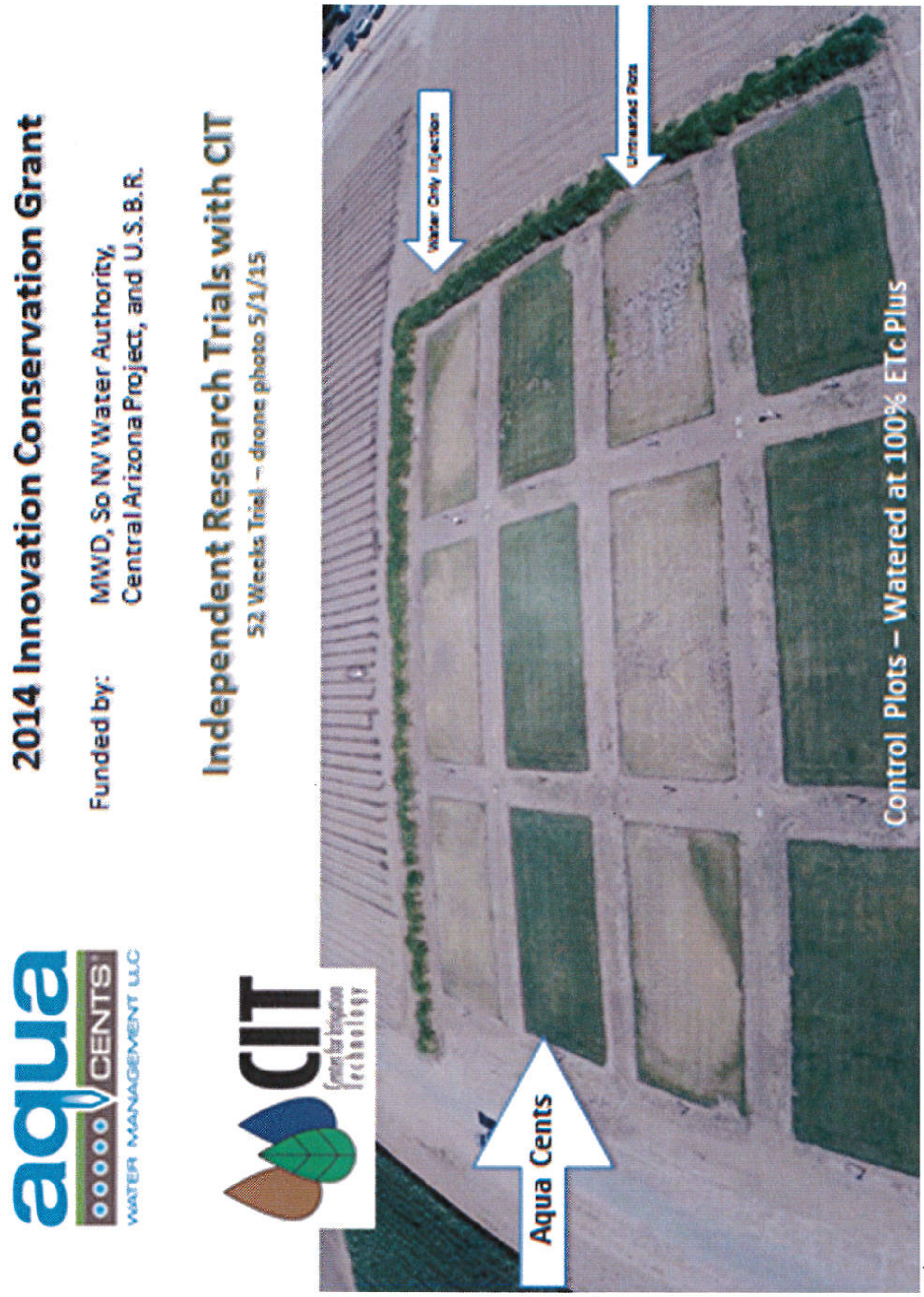
17

[17] *Plots 7, 8, 9 (Untreated) Week 1 – Test 2 CSU Fresno April 21 – 28, 2014*

[18]

[18] *Test 2 Week 26 – CSU Fresno October 20 – 27, 2014*

aqua CENTS WATER MANAGEMENT LLC



[19]

[19] *Trial Results, Test 2 Week 52 – CSU Fresno April 27– 30, 2015*

Plot #4				
Month	Minutes (Calculated)	Minutes (Actual)	Inches (Calculated)	Inches (Actual)
May	1,655	1324	10.76	8.61
June	1,520	1039	9.05	6.19
July	1908	1240	10.65	6.92
August	1,524	991	8.51	5.53
September	1082	596	6.04	3.33
October	206	392	4.42	2.19
November	452	0	2.52	0
December	160	0	1.04	0
January	229	0	1.49	0
February	332	80	2.16	0.52
March	744	200	4.84	1.3
April	911	480	5.92	3.12

April 1 2014- April 30th 2015 Total Calculated Inches=	67.40"
April 1 2014- April 30th 2015 Total Actual Inches=	37.71"

April 2014- April 2015 $\frac{67.40-37.71}{67.4}$ 44 % Savings

20

[20] *Anticipated vs. Actual, Test 2, Plot 4 – CSU Fresno*

Plot #5

Month	Minutes (Calculated)	Minutes (Actual)	Inches (Calculated)	Inches (Actual)
May	1,655	1324	10.76	8.61
June	1,520	1091	9.05	6.51
July	1908	1328	10.65	7.41
August	1,524	991	8.51	5.53
September	1082	554	6.04	3.09
October	206	333	4.42	1.86
November	452	0	2.52	0
December	160	0	1.04	0
January	229	0	1.49	0
February	332	80	2.16	0.52
March	744	200	4.84	1.3
April	911	480	5.92	3.12

April 1 2014- April 30th 2015 Total Calculated Inches=	67.40"
April 1 2014- April 30th 2015 Total Actual Inches=	37.95"

April 2014- April 2015 $\frac{67.40-37.95}{67.4}$ 44 % Savings

21

[21] *Anticipated vs. Actual, Test 2, Plot 5 – CSU Fresno*

Plot #6				
Month	**Minutes (Calculated)**	**Minutes (Actual)**	**Inches (Calculated)**	**Inches (Actual)**
May	1,655	1324	10.76	8.61
June	1,520	1319	9.05	7.87
July	1908	1522	10.65	8.5
August	1,524	838	8.51	4.68
September	1082	476	6.04	2.66
October	206	333	4.42	1.86
November	452	0	2.52	0
December	160	0	1.04	0
January	229	0	1.49	0
February	332	80	2.16	0.52
March	744	200	4.84	1.3
April	911	480	5.92	3.12

April 1 2014- April 30th 2015 Total Calculated Inches=	67.40"
April 1 2014- April 30th 2015 Total Actual Inches=	39.12"

April 2014- April 2015 $\frac{67.40-39.12}{67.4}$ 42 % Savings

22

[22] *Anticipated vs. Actual, Test 2, Plot 6 – CSU Fresno*

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FRESNO STATE
International Center
for Water Technology

MEMO TO: Glen Bennett, Water Management Consultant
Jenn Downs, Water Management Consultant
Aqua Cents Water Management, LLC

FROM: Edward Norum, Agricultural Engineer
Center for Irrigation Technology

DATE: August 26, 2015

SUBJECT: Results of Aqua Cents® hydrogels field study on turf plots located on the University Agricultural Laboratory (UAL) at Fresno State

NOTE: The project was a cooperative effort by Aqua Cents Water Management personnel and the Center for Irrigation Technology staff at Fresno State

SUMMARY

The study was an effort to evaluate the effects on water management by injecting Aqua Cents® water-retaining gels into the root zone of turfgrass. The turf plots were located east of the Center for Irrigation Technology (CIT) office on the University Agricultural Laboratory (UAL) at Fresno State. For comparative purposes, three types of research plots were studied: 1) injecting water only; 2) injecting hydrogels; and 3) no injection. The study was conducted over a growing season period of 27 weeks coinciding with the turf irrigation season in central California. The study was extended to include the off-season period of 25 weeks then providing a 52-week study.

Study methodology utilized a protocol that was developed for predicting the irrigation water needed to produce acceptable grass quality (Norum, 2013. See Appendix "A Procedure for Quantifying the Application Efficiency of Turfgrass Irrigation Systems."). The goal of the research then was to compare the grass quality in the plots subjected to deficit irrigation to the quality anticipated if the plots were deficit free. The results are summarized in Table 1.

Table 1. Summary statistics for the 52-week project period starting April 21, 2014 to April 20, 2015

PLOT #/DESCRIPTION	ET_C -BASED REQUIRED RUN TIME [1] *hours*	ACTUAL RUN TIME *hours*	DEFICIT *hours*	DEFICIT *percent*
ON-SEASON RESULTS (27 weeks)				
#1 cult w/o hydrogels	161.7	115.1	46.6	28.8
#5 cult with hydrogels	148.1	99.98	48.1	32.5
#9 w/o cult or hydrogels	155.1	112.2	46.4	29.9
OFF-SEASON RESULTS (25 weeks)				
#5 cult with hydrogels	56.8	12.7	44.2	77.7
ANNUAL RESULTS (52 weeks)				
#5 cult with hydrogels	204.9	112.6	92.3	45.0

1. Calculated using the protocol and weather information from CIMIS station #80 located at Fresno State.

Plot #1. Cultivated by Aqua Cents® without hydrogels failed to provide satisfactory turf quality with 28.8 percent on-season (27 weeks) deficit.

Plot #5. Cultivated by Aqua Cents® injected with hydrogels provided satisfactory turf quality with 32.5 percent deficit during on-season (27 weeks) irrigation.

During the 52-week period of the project, the Aqua Cents® hydrogels treated Plot #5 demonstrated an overall reduction of 45.0 percent in water use while maintaining a satisfactory turf quality.

Plot #9: Received no Aqua Cents® treatment or hydrogels and failed to provide satisfactory turf quality with 29.9 percent on-season (27 weeks) deficit.

Toward the end of the on-season test period, the grass quality on plots #1 and #9 had deteriorated to a permanent wilt condition as a result of the continuing irrigation water deficit. The grass on plot #5 continued to grow at an acceptable quality in spite of a continuing irrigation water deficit totaling 32.5 percent during the on-season period.

The Aqua Cents® treatment with injected hydrogels then had the effect of overcoming the influence of the water deficit estimated from conventional irrigation protocol. In practical terms, acceptable grass quality appears to be attainable with about one-third less irrigation water. The water savings is due to the combined effect of the hydrogels and scientific water management. It appears that the hydrogels act to increase water storage in the root zone and improve water distribution. This is especially true during the off-season irrigation period.

METHODOLOGY

The turf plots are located in a field east of the Center for Irrigation Technology (CIT) office on the University Agricultural Laboratory (UAL) at Fresno State. Nine individual 30 ft by 60 ft plots were established and planted to tall fescue – a cool season grass commonly used in local turf areas. The plots were sprinkler irrigated using Hunter I-20 sprinklers. A field audit was conducted before the study began to determine the system irrigation efficiency. Figure 1 shows an aerial view of the plots taken on May 1, 2015. The plots were designated as follows:

1) Plots #1, #2 and #3 were injected with water only
2) Plots #4, #5 and #6 were injected with Aqua Cents® hydrogels
3) Plots #7, #8 and #9 were not treated

In order to calculate the "required run time," a pattern uniformity study was conducted on Plots #1, #5 and #9 using the protocol described in the paper "A Procedure for Quantifying the Application Efficiency of Turfgrass Irrigation Systems" (attached). These three plots are individually representative of the three treatments with plot #5 as the plot receiving the Aqua Cents® hydrogels treatment. No data analysis was done on plots #2, #3, #4, #6, #7 and #8 in this report. The pattern uniformity study is required in order to calculate the required run time.

The results of these studies are summarized in Table 2.

Table 2. Summary statistics from pattern loss studies

ITEM	DESCRIPTION	PLOT #1	PLOT #5	PLOT #9	COMMENTS
1	Rootzone treatment	Aqua Cents® w/o hydrogels	Aqua Cents® with hydrogels	None	
2	Grass quality	Unsatisfactory	Satisfactory	Unsatisfactory	See Figure 1
3	Effective app rate, in./hr[1]	0.191	0.194	0.199	
4	Average app rate, in./hr	0.280	0.335	0.340	
5	App efficiency, %	62.1	69.6	53.7	
6	Pattern loss, %	37.9	30.4	46.3	

1. Allows for 85 percent of the area adequately irrigated.

The actual run time was set by the Aqua Cents Water Management personnel on a weekly basis. The values shown in Tables 3, 4, 5 and 6 were divided equally from one to five days per week. Operation of the plots involved the weekly setting of the run times by the vendor's technicians. They were assisted in this task by the CIT engineer.

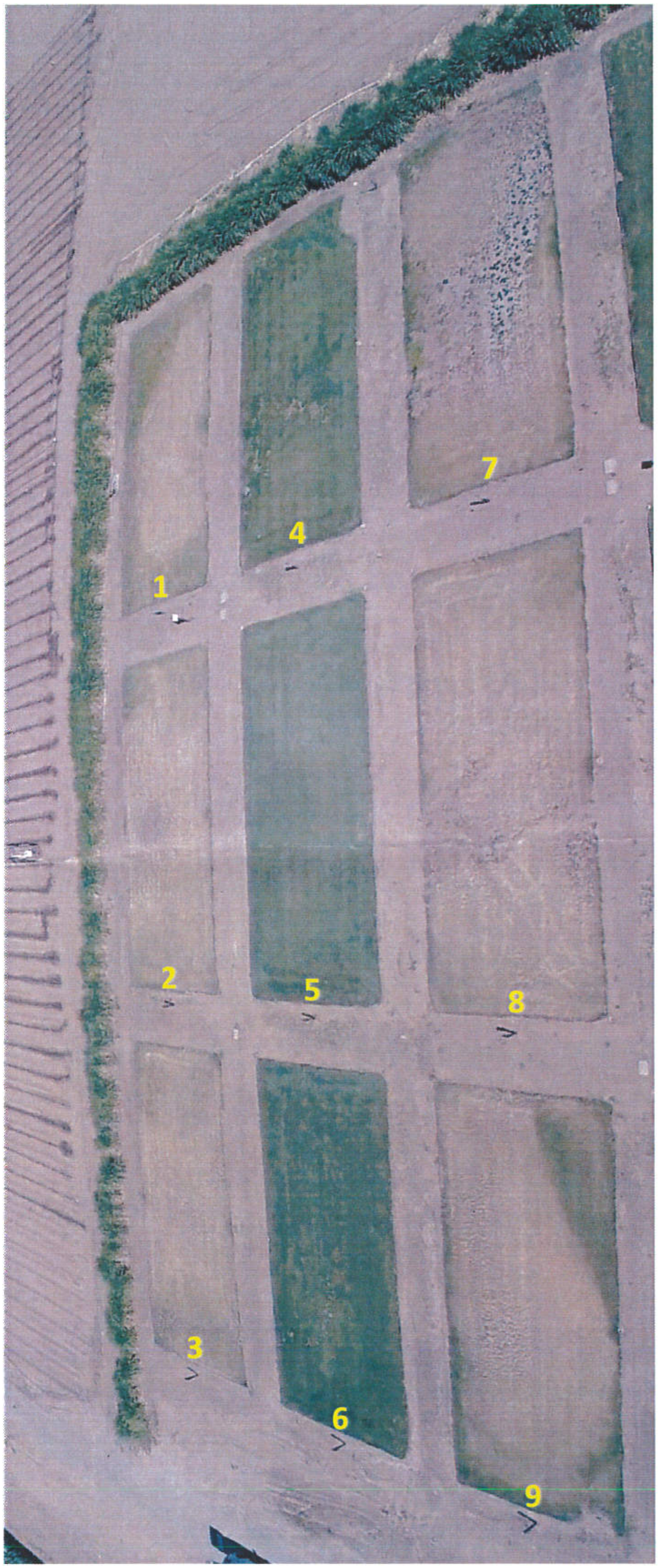

Figure 1. Aerial view of the test plots. From the top to the bottom:

Plot #1 – water injection only (top left)

Plot #5 – Aqua Cents® hydrogels treated (center plot)

Plot #9 – untreated plot (bottom right)

Photo taken May 1, 2015 courtesy Aqua Cents®

Tables 3, 4, 5 and 6 show the data and calculated values for Plot #1, Plot #5 and Plot #9. The following steps were involved to generate these calculations using Week 10 (6/23-6/29) for plot #5 as an example.

1. **Date, weekly Tuesday through Monday – column #2**

2. **Obtain a weekly ET_O value – column #3**

   ET_O, in./wk = 2.05 in./wk from CIMIS station #80 located on Fresno State farm (for previous seven days)

3. **Obtain a K_C value for the grass at its current age – column #4**

   K_C = 0.70 (crop coefficient for cool season grass, June (from Norum, 2013 Table 1 in Appendix A paper).

4. **Obtain an ET_C value – column #5**

   $ET_C = (K_C)\ (ET_O) = (0.70)\ (2.05) = 1.44$ in./wk

5. **Obtain an effective application rate value – column #6**

   This value was obtained from the actual pattern loss study for plot #5 which was determined to be 0.194 in./hr.

6. **Obtain a required run time – column #7**

   Required run time = ET_C / effective app rate = 1.44 / 0.194 = 7.42 hr

7. **Determine the actual run time – column #8**

   The actual run time of 5.18 hours for the week of June 23-29, 2014 was based on the judgement of the vendor's technicians. This judgement is a function of the grass quality assessment.

If the grass quality is to be maintained, this runtime will be needed to replace the root zone moisture removed the previous week. Aqua Cents Water Management personnel set the actual runtimes at values less than the calculated required runtime to observe the effect of the deficit. During the on-season project period, the deficit averaged about 30 percent. The effect on Plots #1 and #9 was to virtually kill the turfgrass. With plot #5, the Aqua Cents® hydrogels-treated plot, the root zone deficit was compensated for by the hydrogels and the grass quality remained satisfactory over the project period.

APPENDIX A

Norum, Edward M. (2013) A Procedure for Quantifying the Application Efficiency of Turfgrass Irrigation Systems. The Center for Irrigation Technology (CIT). California State University, Fresno. March 2013. (attached)

Table 3. On-season Plot #1 for period April 21, 2014 to October 27, 2014

WEEK	PERIOD 2014	ET_o *in./wk*	K_c	ET_c *in./wk*	EFF APP RATE *in./hr*	REQ'D RUN TIME *hr*	ACTUAL RUN TIME *hr*
1	4/21 – 4/27	1.61	0.83	1.34	0.25	5.36	4.16
2	4/28 – 5/4	1.31	0.83	1.08	0.248	4.17	4.16
3	5/5 – 5/11	1.77	0.76	1.35	0.248	5.44	5.41
4	5/12 – 5/18	1.60	0.76	1.22	0.248	4.92	4.17
5	5/19 – 5/25	2.00	0.76	1.55	0.248	6.25	5.30
6	5/26 – 6/1	1.85	0.76	1.41	0.248	5.67	4.82
7	6/2 – 6/8	2.10	0.70	1.47	0.248	5.93	4.15
8	6/9 – 6/15	2.11	0.70	1.48	0.248	5.96	4.07
9	6/16 – 6/22	2.13	0.70	1.49	0.181	8.23	7.42
10	6/23 – 6/29	2.05	0.70	1.44	0.181	7.96	5.20
11	6/30 – 7/6	2.14	0.75	1.61	0.181	8.90	5.81
12	7/7 – 7/13	2.13	0.75	1.60	0.181	8.83	5.71
13	7/14 – 7/20	1.87	0.75	1.40	0.181	7.73	5.13
14	7/21 – 7/27	1.87	0.75	1.40	0.181	7.73	5.58
15	7/28 – 8/3	2.06	0.75	1.55	0.181	8.56	5.58
16	8/4 – 8/10	1.78	0.69	1.23	0.181	6.79	4.42
17	8/11 – 8/17	1.76	0.69	1.21	0.181	6.69	4.35
18	8/18 – 8/24	1.89	0.69	1.30	0.181	7.18	4.68
19	8/25 – 8/31	1.75	0.69	1.21	0.181	6.69	4.35
20	9/1 – 9/7	1.43	0.59	0.84	0.181	4.64	2.80
21	9/8 – 9/14	1.63	0.59	0.96	0.181	5.31	2.93
22	9/15 – 9/21	1.48	0.59	0.87	0.181	4.82	2.67
23	9/22 – 9/28	1.13	0.59	0.67	0.181	3.68	1.85
24	9/29 – 10/5	1.17	0.59	0.69	0.181	3.81	1.90
25	10/6 – 10/12	1.15	0.60	0.69	0.181	3.81	1.90
26	10/13 – 10/20	1.15	0.60	0.69	0.181	3.81	3.8
27	10/20 – 10/27	0.87	0.60	0.52	0.181	2.87	2.8
						161.74	**115.12**

Table 4. On-season Plot #5 for period April 21, 2014 to October 27, 2014

WEEK	PERIOD 2014	ET_O *in./wk*	K_C	ET_C *in./wk*	EFF APP RATE *in./hr*	REQ'D RUN TIME *hr*	ACTUAL RUN TIME *hr*
1	4/21 – 4/27	1.61	0.83	1.34	0.287	4.62	3.75
2	4/28 – 5/4	1.31	0.83	1.08	0.287	3.76	3.73
3	5/5 – 5/11	1.77	0.76	1.35	0.287	4.70	3.73
4	5/12 – 5/18	1.60	0.76	1.22	0.287	4.25	3.40
5	5/19 – 5/25	2.04	0.76	1.55	0.287	5.40	4.33
6	5/26 – 6/1	1.85	0.76	1.41	0.287	4.91	3.93
7	6/2 – 6/8	2.10	0.70	1.47	0.287	5.12	3.81
8	6/9 – 6/15	2.11	0.70	1.48	0.287	5.16	4.13
9	6/16 – 6/22	2.13	0.70	1.49	0.194	7.68	5.36
10	6/23 – 6/29	2.05	0.70	1.44	0.194	7.42	5.18
11	6/30 – 7/6	2.14	0.75	1.61	0.194	8.30	5.75
12	7/7 – 7/13	2.13	0.75	1.60	0.194	8.25	5.75
13	7/14 – 7/20	1.87	0.75	1.40	0.194	7.22	5.03
14	7/21 – 7/27	1.87	0.75	1.40	0.194	7.21	5.58
15	7/28 – 8/3	2.06	0.75	1.55	0.194	7.99	5.60
16	8/4 – 8/10	1.78	0.69	1.23	0.194	6.34	4.41
17	8/11 – 8/17	1.76	0.69	1.21	0.194	6.23	4.23
18	8/18 – 8/24	1.89	0.69	1.30	0.194	6.70	4.02
19	8/25 – 8/31	1.75	0.69	1.21	0.194	6.24	3.71
20	9/1 – 9/7	1.43	0.59	0.84	0.194	4.33	2.60
21	9/8 – 9/14	1.63	0.59	0.96	0.194	4.96	2.50
22	9/15 – 9/21	1.48	0.59	0.873	0.194	4.50	2.25
23	9/22 – 9/28	1.13	0.59	0.67	0.194	3.44	1.60
24	9/29 – 10/5	1.17	0.59	0.69	0.194	3,56	1.60
25	10/6 – 10/12	1.15	0.60	0.69	0.194	3.56	1.60
26	10/13 – 10/20	1.15	0.60	0.69	0.194	3.56	1.60
27	10/20 – 10/27	0.87	0.60	0.52	0.194	2.69	0.80
						148.1	**99.98**

Table 5. On-season Plot #9 for period April 21, 2014 to October 27, 2014

WEEK	PERIOD 2014	ET_o *in./wk*	K_c	ET_c *in./wk*	EFF APP RATE *in./hr*	REQ'D RUN TIME *hr*	ACTUAL RUN TIME *hr*
1	4/21 – 4/27	1.61	0.83	1.34	0.230	5.83	3.62
2	4/28 – 5/4	1.31	0.83	1.08	0.226	4.78	4.75
3	5/5 – 5/11	1.77	0.76	1.35	0.226	5.96	6.00
4	5/12 – 5/18	1.60	0.76	1.22	0.226	5.40	4.87
5	5/19 – 5/25	2.04	0.76	1.55	0.226	6.86	6.83
6	5/26 – 6/1	1.85	0.76	1.41	0.226	6.24	5.65
7	6/2 – 6/8	2.10	0.70	1.07	0.226	6.50	5.85
8	6/9 – 6/15	2.11	0.70	1.48	0.226	6.55	5.26
9	6/16 – 6/22	2.13	0.70	1.49	0.199	7.48	6.36
10	6/23 – 6/29	2.05	0.70	1.44	0.199	7.23	6.07
11	6/30 – 7/6	2.14	0.75	1.61	0.199	8.09	6.98
12	7/7 – 7/13	2.13	0.75	1.60	0.199	8.04	6.80
13	7/14 – 7/20	1.87	0.75	1.40	0.199	7.04	5.25
14	7/21 – 7/27	1.87	0.75	1.40	0.199	7.04	5.85
15	7/28 – 8/3	2.06	0.75	1.55	0.199	7.79	5.85
16	8/4 – 8/10	1.78	0.69	1.23	0.199	6.18	4.38
17	8/11 – 8/17	1.76	0.69	1.21	0.199	6.08	3.05
18	8/18 – 8/24	1.89	0.69	1.30	0.199	6.53	2.41
19	8/25 – 8/31	1.75	0.69	1.21	0.199	6.08	3.05
20	9/1 – 9/7	1.43	0.59	0.84	0.199	4.22	1.28
21	9/8 – 9/14	1.63	0.59	0.96	0.199	4.83	2.41
22	9/15 – 9/21	1.48	0.59	0.87	0.199	4.39	2.22
23	9/22 – 9/28	1.13	0.59	0.87	0.199	3.35	1.51
24	9/29 – 10/5	1.17	0.59	0.69	0.199	3.46	1.56
25	10/6 – 10/12	1.15	0.60	0.69	0.199	3.47	1.56
26	10/13 – 10/20	1.15	0.60	0.69	0.199	3.47	1.57
27	10/20 – 10/27	0.87	0.60	0.52	0.199	2.62	1.16
						155.51	**112.15**

Table 6. Off-season Plot #5 for period October 28, 2014 to April 20, 2015

WEEK	PERIOD 2014-2015	ET_O *in./wk*	K_C	ET_C *in./wk*	EFF APP RATE *in./hr*	REQ'D RUN TIME *hr*	ACTUAL RUN TIME *hr*
28	10/28 – 11/3/14	0.60	0.60	0.36	0.194	1.86	0
29	11/4 – 11/10/14	0.60	0.55	0.36	0.194	1.87	0
30	11/11 – 11/17/14	0.38	0.55	0.21	0.194	1.08	0
31	11/18 – 11/24/14	0.29	0.55	0.16	0.194	0.82	0
32	11/25 – 12/1/14	0.45	0.55	0.25	0.194	1.28	0
33	12/2 – 12/8/14	0.33	0.48	0.16	0.194	0.82	0
34	12/9 –12/15/14	0.15	0.48	0.07	0.194	0.37	0
35	12/16 – 12/22/14	0.24	0.48	0.74	0.194	2.47	0
36	12/23 – 12/29/14	0.33	0.48	0.16	0.194	0.82	0
37	12/30 – 1/5/15	0.30	0.48	0.63	0.194	3.22	0
38	1/6 -1/12/15	0.30	0.49	0.15	0.194	0.76	0
39	1/13 – 1/19/15	0.20	0.49	0.98	0.194	5.05	0
40	1/20 – 1/26/15	0.17	0.49	0.083	0.194	0.43	0
41	1/27 – 2/2/15	0.43	0.49	0.21	0.194	1.09	0
42	2/3 – 2/9/15	0.50	0.51	0.26	0.194	1.31	0
43	2/10 – 2/16/15	0.61	0.51	0.31	0.194	1.60	0.67
44	2/17 – 2/23/15	0.32	0.51	0.16	0.194	0.84	0
45	2/24 – 3/2/15	0.67	0.51	0.34	0.194	1.76	0.67
46	3/3 – 3/9/15	0.89	0.60	0.53	0.194	2.75	0.83
47	3/10 – 3/16/15	0.91	0.60	0.55	0.194	2.81	0.67
48	3/17 – 3/23/15	1.04	0.60	0.62	0.194	3.22	0.83
49	3/24 – 3/30/15	1.29	0.60	0.77	0.194	3.99	1.0
50	3/31 – 4/6/15	1.36	0.60	0.82	0.194	4.21	1.0
51	4/7 – 4/13/15	1.26	0.83	1.05	0.194	5.39	0
52	4/14 – 4/20/15	1.63	0.83	1.35	0.194	6.97	7.0
						56.79	**12.67**

Appendix A
A Procedure for Quantifying the Application Efficiency of Turfgrass Irrigation Systems❖

by
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This evaluation procedure characterizes the performance of the irrigation systems "as installed." It quantifies the effects of design, installation, and operation. It does not deal with the effects of component leakage on water use.

Water is lost by irrigation systems in three ways:

1. Spray drift and evaporation
2. Surface runoff caused by:
   - Overfilling the root zone
   - Applying water at rates higher than the soil surface can absorb
   - Allowing insufficient soak time between rounds
3. Deep seepage that results from:
   - Sprinkler system non-uniformities
   - Water management inadequacies

This protocol deals with water lost through surface runoff and deep seepage considerations. The protocol assumes that the objective of the system is to provide a high level of vegetative quality (see Morris and Sherman).

Steps in the evaluation are as follows:

Step #1: Develop a sketch of the vegetated area to be irrigated. Figure 1 gives an example of an existing hydrozone planted to a cool season grass. Details of the irrigation system design including sprinkler location are not germane to the evaluation protocol.

❖ The Center for Irrigation Technology (CIT) is one of three water programs at California State University, Fresno. Visit www.californiawater.org for more information about CIT, the International Center for Water Technology (ICWT) and the California Water Institute (CWI).

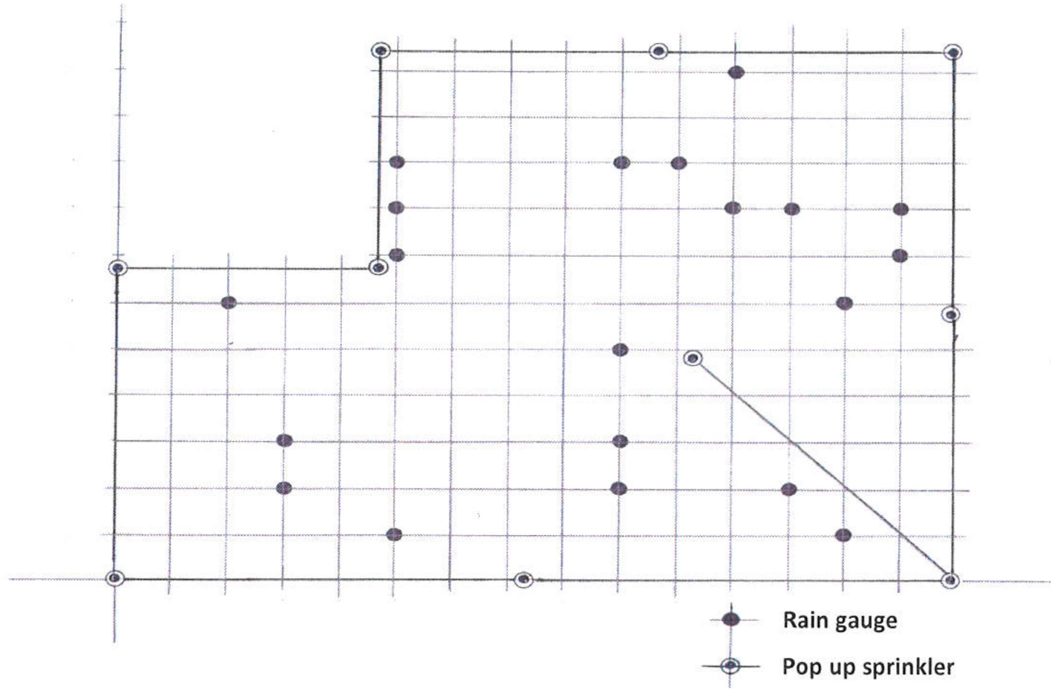

Figure 1. Hydrozone showing randomly located rain gauges and sprinkler locations.
(Note: Grid spacing, 2 ft X 2 ft)

Step #2: Operate the system for 10 minutes with the randomly located rain gauges in place (see Figure 2). The results are shown in Figure 3. A curve fit routine was used to characterize the data.

Figure 2. Rain gauge catchment (DWR/Cal Poly)

Catchment Data (ml)

1 =	35
2 =	30
3 =	30
4 =	26
5 =	25
6 =	25
7 =	25
8 =	25
9 =	25
10 =	23
11 =	20
12 =	20
13 =	20
14 =	20
15 =	20
16 =	16
17 =	15
18 =	15
19 =	15
20 =	10

Average: 22.8 ml **90.0%: 15.2 ml** **Pattern Loss: 32.3%**

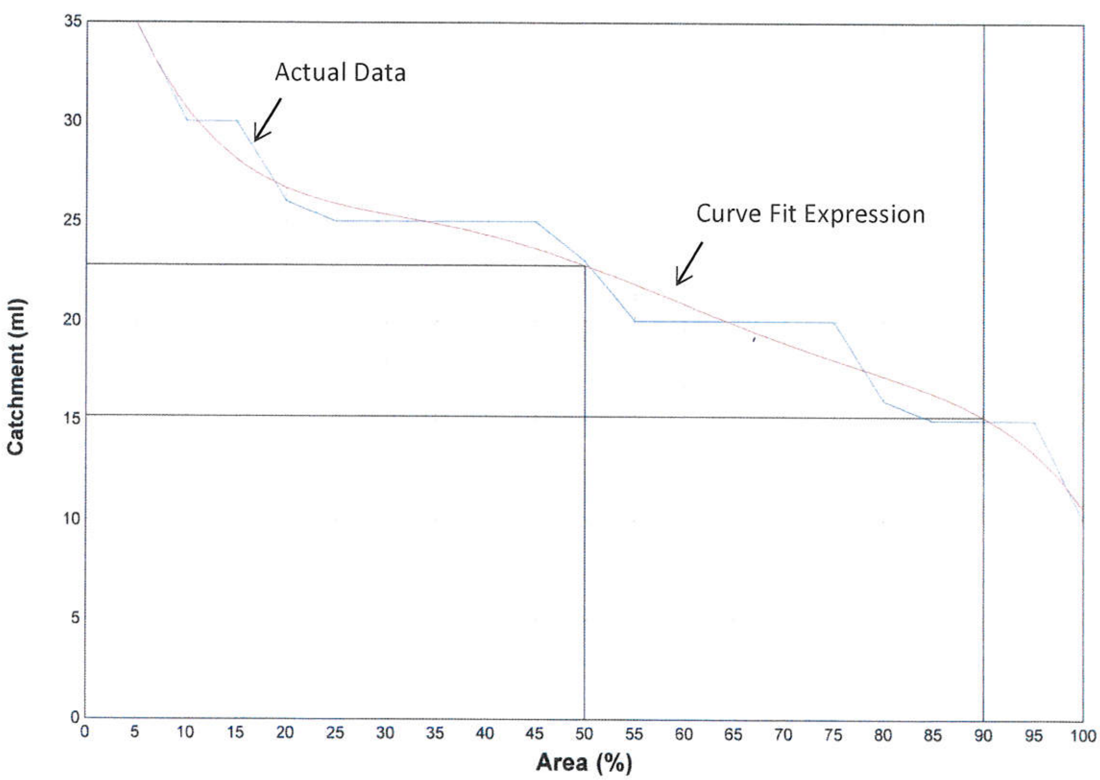

Figure 3. Hydrozone catchment characterization, (ml vs area, %)

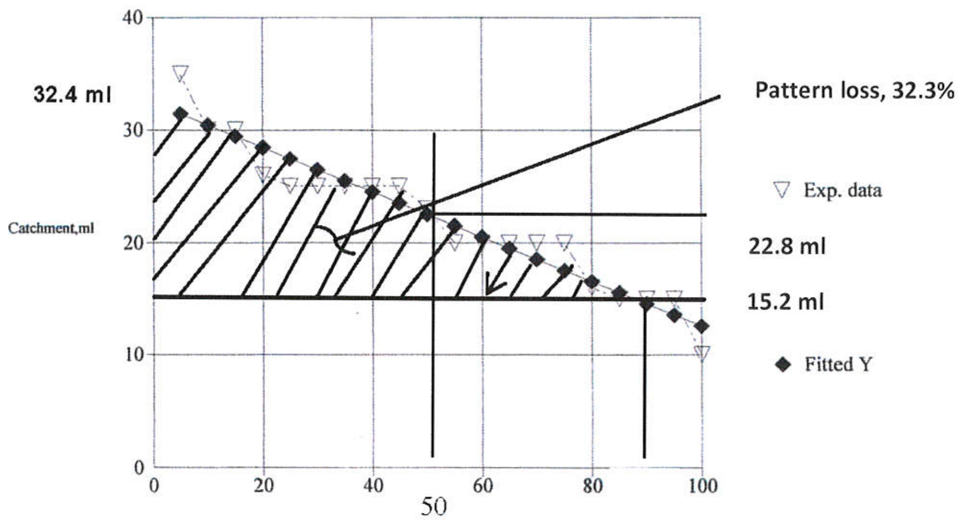

Figure 4. Control #1 pattern loss analysis (See Norum, 2004)

Using the rain gauge catchment throat area of 15.9 square inches, the hydrozone effective application rates for 90 percent coverage are calculated as 0.350 in./h. The graphical definition of pattern loss is shown in Figure 4. This calculation shows a pattern loss to deep seepage for the hydrozone of 32.3 percent. This represents the potential water savings that would result from products or processes that avoid deep infiltration losses.

Step #3: Set the system controller runtime to meet the requirements of the vegetation and consider any limitations imposed by soil type. Vegetative irrigation requirements are determined by the following formula:

$$ET_C = K_S (ET_O)$$

Where:

ET_C = crop evapotranspiration

K_S = crop coefficient (see Table 1 Crop Coefficient Values for California Turfgrass)

ET_O = reference crop evapotranspiration (from CIMIS, see Table 2 Daily CIMIS Report)

Table 1. Crop Coefficient Values for California Turfgrass

MONTH	NOT ADJUSTED FOR ALLOWABLE STRESS			ADJUSTED FOR ALLOWABLE STRESS		
	COOL SEASON	WARM SEASON	COMBINED GRASS	COOL SEASON	WARM SEASON	COMBINED GRASS
January	0.61	0.55	0.61	0.49	0.44	0.49
February	0.64	0.54	0.64	0.51	0.43	0.51
March	0.75	0.76	0.75	0.60	0.61	0.60
April	1.04	0.72	0.72	0.83	0.58	0.58
May	0.95	0.79	0.79	0.76	0.63	0.63
June	0.88	0.68	0.68	0.70	0.54	0.54
July	0.94	0.71	0.71	0.75	0.57	0.57
August	0.86	0.71	0.71	0.69	0.57	0.57
September	0.74	0.62	0.62	0.59	0.50	0.50
October	0.75	0.54	0.75	0.60	0.43	0.60
November	0.69	0.58	0.69	0.55	0.46	0.55
December	0.60	0.55	0.60	0.48	0.44	0.48

Table 2. Daily CIMIS Report

CIMIS Report Parlier – San Joaquin Valley – Station 39														
DATE	CIMIS ETO (in.)	PRECIP (in.)	SOLAR RAD (Ly/day)	AVG VAP (mBars)	MAX AIR TEMP (°F)	MIN AIR TEMP (°F)	AVG AIR TEMP (°F)	MAX REL HUMIDITY (%)	MIN REL HUMIDITY (%)	AVG REL HUMIDITY (%)	DEW POINT (°F)	AVG WIND SPEED (mph)	WIND RUN (miles)	AVG SOIL TEMP (°F)
07/01/2011	0.25	0.00	654	19.9	92.0	60.7	77.0	93	43	63	63.3	3.8	90.6	77.3
07/02/2011	0.27	0.00	660	21.6	99.0	65.2	82.1	91	36	58	65.7	3.9	94.0	80.0
07/03/2011	0.27	0.00	653	21.7	100.0	67.2	84.0	88	34	54	65.8	3.9	94.3	80.0
07/04/2011	0.27	0.00	650	22.6	102.4	69.4	85.8	89	28	54	67.0	3.9	92.9	80.9
07/05/2011	0.19	0.00	450	22.9	98.8	70.4	83.8	87	34	58	67.4	3.7	89.5	80.5
07/06/2011	0.28	0.00	630	21.9	101.9	71.0	86.4	87	30	51	66.1	4.7	112.4	80.9
07/07/2011	0.28	0.00	624	18.2	99.9	68.9	85.3	74	29	44	60.9	4.4	106.3	80.6
Total/Avgs.	1.81	0.00	617	21.3	99.1	67.5	83.5	87	33	55	65.2	4.0	97.1	80.0

The following example shows the runtime required for the first week of July 2011. Assuming a cool season turfgrass adjusted for allowable stress:

$$ET_C = (0.75)(1.81)$$

$$= 1.36 \text{ in/week}$$

The actual runtimes required are determined by the following formula:

$$\text{Runtime} = \frac{ET_C \text{ in./wk}}{\text{Effective application rate, in./h}}$$

$$= \frac{1.36}{0.350}$$

$$= 3.89 \text{ h/wk}$$

$$= 233 \text{ mins./wk}$$

These calculations were repeated weekly during the irrigation season and the controller runtimes adjusted accordingly.

Cycle runtimes must be limited to allow for adequate soak time between cycles in order to avoid surface runoff. Reference is made to the Irrigation Associations SWAT Testing Protocols for "Climatologically-based Controllers" [8th testing protocol (September 2008)]. The location of the example has a sandy loam soil and zero slopes. From Table 3 in the testing protocol, the "allowable surface accumulation (ASA) for these conditions is 0.33 in. and the basic soil intake rate (IR) is 0.4 in./h. The formula for maximum allowable runtime is:

$$R_{t(max)} = \frac{60(ASA), \text{ minutes}}{(PR-IR)}$$

Using the catchment data the average precipitation rate (PR) is 0.525 in./h. The formula for $R_{t\,(MAX)}$ gives the following result:

$$R_{t(max)} = \frac{60(0.33), \text{ minutes}}{(0.525 - 0.40)}$$

$$R_{t(max)} = 158 \text{ minutes}$$

It can be concluded then that for this site, surface runoff will not be an operational concern. Given for this example, the irrigation schedule is set at two cycles per day, five days per week. The runtime per cycle is calculated as follows:

$$\text{Runtime per cycle} = \frac{233}{10}$$

$$= 233 \text{ minutes}$$

Assuming a spray drift loss of 5.0 percent[1] and a pattern loss of 32.3 percent (see Figure 3), the overall application efficiency is calculated as follows:

$$\text{App. Efficiency} = 100[1.00 - 0.05][1.000 - 0.323]$$

$$= 64.3\%$$

In order to verify the efficacy of the calculation, periodically a series of photographs of the hydrozone were taken during the summer of 2012. Figure 5 shows a representative photo.

[1] A spray loss of 5.0 percent is assumed for illustrative purposes. Studies are required to provide actual data.

Figure 5.

References

1. Irrigation Association SWAT 8th Testing Protocol. September 2008. "Climatologically based Controllers
2. Morris, Kevin N. and Robert C. Shearman. NTEP Turf Grass Evaluation Guidelines, NTEP, Beltsville, Maryland.
3. Norum, Edward. 1961. "A Method of Evaluating the Adequacy and Efficiency of Overhead Irrigation Systems." Paper No. 61-206 presented at the Annual Meeting of the American Society of Agricultural Engineers at Ames, Iowa, June 1961.
4. Norum, Edward. 2004. "A New Method of Characterizing Sprinkler Distribution Patters". Paper presented at the Irrigation Association Annual meeting, Tampa, Florida. November.