IMPROVING GOLF COURSE IRRIGATION UNIFORMITY: A CALIFORNIA CASE STUDY

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The author wants to thank the golf course superintendents who cooperated in this study and their willingness to share information and experiences. Also we want to recognize the California Department of Water Resources for providing the support to conduct this study. We hope the information provided in this report will encourage other golf course superintendents to look closely at the uniformity of their irrigation system and determine if improvements are warranted.

Abstract

Golf courses located near cities and towns are a major competitor for urban water and energy supplies. As California faces the reality of 15 million new residents in the next 25 years, the pressure to extend existing water supplies will be unprecedented. This study was conducted to evaluate the experience of golf course superintendents who re-nozzled existing sprinkler systems to improve irrigation uniformity. Five golf courses participated in this study; there was a total of 606 irrigated acres representing 108 holes of golf (six-18 hole courses). The time span of data collection was one year prior to the nozzle change and one year of operation post nozzle change.

The estimated total gross water savings for all the participants was 99.8 acre feet of water (32,519,304 gallons) or 6.5% of the applied water. Individual golf course gross water savings ranged from positive 21.4% to a negative <11.3%>. Adjusting for useful rainfall, the estimated savings falls to 82.9 acre feet (27,012,799 gallons) or 5.7% of the applied water. Individual golf course-adjusted water savings ranged from a positive 14.7% to negative <3.1%>. Assuming the actual savings is somewhere in between, the total savings experienced may be nearer 91.4 acre feet (29,782,507 gallons) and an average savings of 6.1% per golf course of the applied water. Since all of the water on the participating golf courses is pumped, there is significant energy savings as well.

The average estimated gross water savings per golf course in this study (for 18 holes) is 16.6 acre feet per year. For the purpose of illustration, let's assume the one-time cost of nozzle replacement is $12,000. The cost of water and energy would need to be $361 an acre-foot to achieve an estimated two-year payback period to recover the cost of re-nozzling based on the assumptions listed above. Water and energy costs higher than $361 would provide a shorter payback period, while lower water and energy costs would require a longer payback period to recoup the investment. Also higher or lower initial re-nozzling costs would effect this estimate, either positively or negatively.

Additionally, the golf course superintendent will likely put a dollar value on any perceived improvement in turf quality, reduction in hand-watering, and/or playability of the course. This

would favorably impact or shorten the payback period. Finally, each golf course that participated in this study had water savings either higher or lower than the average used in the example used, so individual savings varied. The ultimate determination of whether re-nozzling is a viable option will be based on local economics, and must include all relevant conditions.

Introduction

Golf course irrigation is estimated to use more than 476 billion gallons of water annually in the US. Water consumption is highest in the southwest, with a reported average use of 88 million gallons annually per course. The Irrigation Association reports that of all fresh water used in the US for the purpose of irrigation, 79.6% is in agriculture, 2.9% is in landscape, and golf courses consume 1.5%. The remaining 16% is consumed by humans, animals, or industry.

These figures can be misleading as to the significant role of water used in golf course irrigation. Many golf courses are located within urban areas, and use potable water supplies for the purpose of irrigation. This water is highly treated, and is among the most expensive water available. Reducing consumption of water through improved irrigation uniformity can provide enormous benefits to local water purveyors.

Purpose of the Study

This study was conducted to identify potential water savings through improved sprinkler application uniformity. Additionally, we focused on a relatively simple and cost-effective method of changing sprinkler nozzles to improve uniformity. Replacement nozzles are typically provided as an upgrade from the sprinkler manufacturer or by a third party vendor. To be included in this study, the golf course must have sought to improve sprinkler uniformity through a change of nozzles. Additionally, the golf course needed to have relatively good records to account for changes in applied water. The time span of data collection was one year prior to the nozzle change and one year of operation post nozzle change.

The superintendent's decision to re-nozzle was based on the perceived or measured poor performance of the existing sprinkler systems coverage. Information was gathered in each case by the superintendent to select the "right" nozzle to effectively improve sprinkler uniformity. In some cases the superintendent started by replacing nozzles in the poorest coverage areas. Upon satisfactory results, the entire course would be re-nozzled.

The purpose of this case study review was to highlight the need for understanding the current uniformity of an existing sprinkler irrigation system, and what actions may be available to improve uniformity. Industry surveys have indicated the average tenure of a golf course superintendent is approximately five years. Thus, in a thirty-year career, a superintendent may work on six or seven different courses. The sprinkler uniformity of these courses is likely to run from excellent to poor. It is critical that the superintendent evaluate the system's performance, and understand what corrective options are available, if needed and understand the end results these improvements will have on budgets, total water use, and labor requirements.

Management Issues- There are three other issues closely related to water use efficiency. One is energy use. California is currently experiencing some of the highest electrical energy costs in the nation. Reducing the amount of applied water through improved irrigation uniformity will directly reduce energy costs associated with applying excess water, since practically all water is pumped and thus has come energy component.

A second important benefit of improved sprinkler uniformity is environmental. The reduction or elimination of runoff and/or deep percolation of irrigated areas can reduce the movement of fertilizers and chemicals that have been applied to the plants. In many urban settings, the runoff water ends up at waste water treatment plants. The processing of fertilizers and chemicals are a serious problem for waste water treatment plants - so serious that legislation has been proposed to restrict the use of some chemicals in urban landscape areas. This could pose an additional hardship to the golf course superintendent if part of their chemical arsenal was lost due to poor irrigation system performance and management.

A similar problem occurs with deep percolation. Excess water applied due to non-uniformity can carry with it the same fertilizers and chemicals to the underlying aquifer. In urban areas these aquifers are routinely tapped to provide water to the local populace. If golf course irrigation is shown to be contributing to the degradation of the underlying aquifer, severe restrictions could be imposed.

A third issue is customer satisfaction as it relates to aesthetics, playability and reduced player disruption. More uniformly green playing surfaces absent of wet and dry areas provide improved conditions for the game of golf. Eliminating or limiting the need to spot water areas with hand held hoses or portable hose end sprinklers reduces player disruption and inconvenience, increasing customer satisfaction.

The lack of uniform irrigation forces irrigation managers to choose one of the following options;

1) to irrigate the dry spots to an acceptable level of green by severely over irrigating the rest of the turf grass,

2) to irrigate to the initial development of any wet areas, and severely stressing the drier areas, or

3) to irrigate to the initial development of any wet areas then utilize hand directed watering at considerable expense to irrigate the dry areas to an acceptable level of green color.

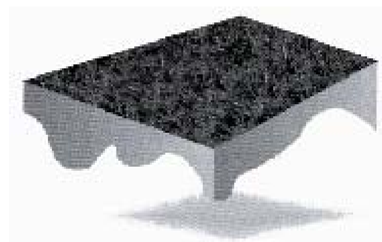
None of these three options is desirable. Improved irrigation uniformity may not provide large savings in applied water if the course is generally under-irrigated (large dry areas). However, it is likely to significantly reduce the need for hand-watering, which is inefficient, costly and disruptive to the golfer.

Methodology

One way to estimate or measure water application uniformity is to perform a sprinkler audit. This can be done by hiring someone who has been professionally trained as a Certified Golf Irrigation Auditor (CGIA). This is a comprehensive auditing program managed and certified by the Irrigation Association. Superintendents can also perform their own audits. Catch cans are systematically spread out over the coverage area. The sprinklers are operated for a period of time with the amount of water collected and location of each catch can is recorded. The catch can values are used to calculate uniformity.

The differences in uniformity are illustrated below with high uniformity in water application being relatively even across the irrigated area, while the low uniformity has mixed areas of overly wet and dry areas which are difficult to manage.

High Uniformity



Low Uniformity

Evaluating Sprinkler Uniformity

Distribution Uniformity

The most common calculation for uniformity is known as Distribution Uniformity or just DU. Basically DU is the ratio of the dry or under watered area to the average applied within the sprinkler coverage area. The calculation requires ranking the catch can values from highest to lowest, with the average of the lowest 25% divided by the overall average of the catch cans. The calculation is expressed as DU_{LQ} which indicates the calculation is based on the low quarter ($_{LQ}$) or lowest 25% of the catch can values. The result is then multiplied by 100 and expressed as a percentage. A DU of 100% would indicate perfectly uniform irrigation. Unfortunately, this is not achievable under field conditions.

According to the Irrigation Association's Certified Golf Irrigation Auditor manual, rotary sprinkler DU is listed in three categories; with 80% or so considered Excellent (achievable), 70% or so considered Good (expected), or 55% or less considered Poor. The CGIA manual also offers an estimated run time multiplier based on the measured DU. The lower the DU, the longer the system must operate to provide the turf grass with the required water. However, this can waste water and energy.

Scheduling Coefficient

A second way to calculate potential water savings is to use the Scheduling Coefficient (SC). The Scheduling Coefficient is a unique approach to measuring sprinkler uniformity. It identifies the driest, contiguous part of the coverage area and compares it to the average water applied. This ratio of the average driest area (determined as a percentage of the whole) is divided into the average. The driest area is usually user defined as 1, 2, or 5 percent of the coverage area.

An example of how uniformity data can be used to compare performance of an existing irrigation system, and the expected change (improvement) of the same irrigation system after changing nozzles is provided below:

The original or existing irrigation system was operated at 55 psi at the base of the sprinkler. The sprinkler heads were spaced on a 65 ft equilateral triangle. The distribution uniformity (DU) of the sprinkler coverage was calculated at 73%, and scheduling coefficient (SC) was calculated at 1.5 using a 5% window. According to the CGIA manual, this is considered good or average. Using the Run Time Multiplier table found on page 80 of the CGIA manual, a DU_{LQ} of 73% requires operating the irrigation system 19% longer than the minimum to meet the water needs of the driest turf grass areas.

Graphic Representation

Another method to depict irrigation uniformity is the densogram. It is a non-quantitative way to show the wet and dry areas within the sprinkler coverage area. Wetter areas (higher precipitation) are indicated by darker blue patterns and drier areas (lower precipitation) are indicated by lighter blue areas. It gives the irrigator an overview of how water is distributed in a repeating pattern between the sprinklers. It also provides a good indication of where the dry and wet spots are likely to show up on the fairways.

The densogram in Figure 1 shows a graphic representation of the wet and dry areas within the sprinkler coverage area. Three green dots indicate the location of the sprinklers (top left and right corners, bottom middle) contributing to the overlap of coverage measured in this example. The Red box indicates the driest 5% of the pattern area. Using the original nozzles, the driest point receives only 57% of the average. The Green box indicates the wettest 5% of the pattern area, with the wettest point receiving 139% of the average.

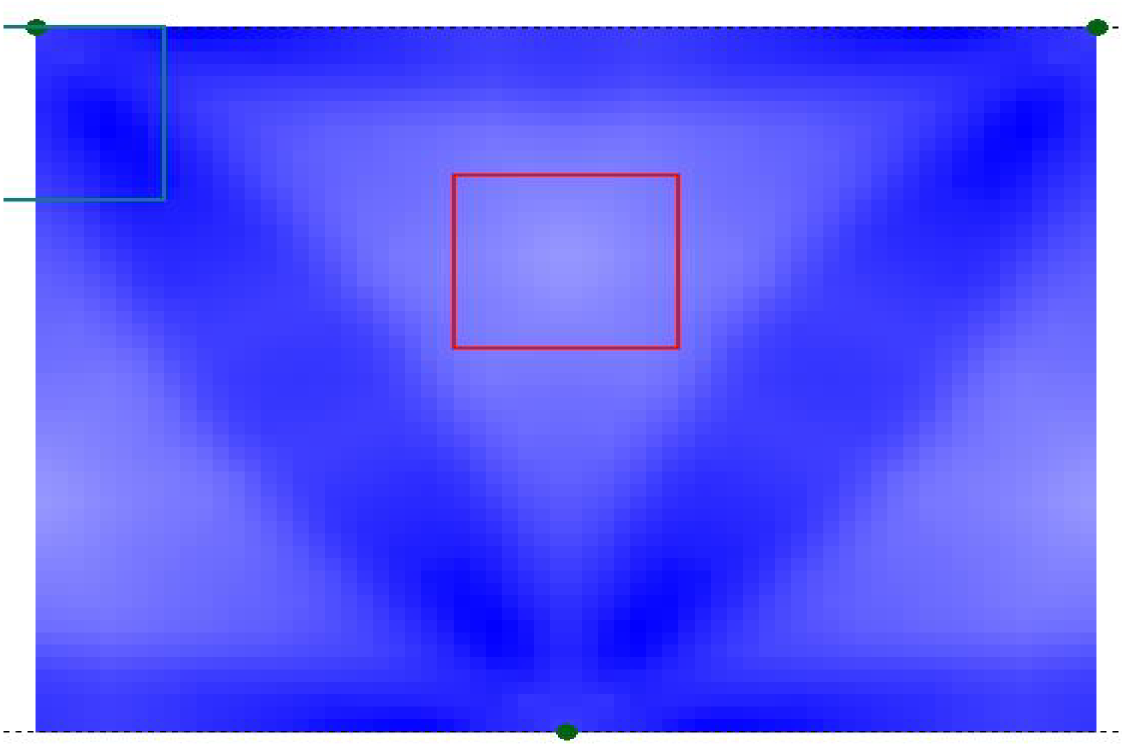


Figure 1. Densogram of the Sprinkler and Original Nozzle Application Uniformity

Now let's compare the same irrigation system only with replacement nozzles and again operated at 55 psi at the base of the sprinkler. The same spacing of 65 ft equilateral triangle is used. The DU of the sprinkler coverage is calculated at 85%, and the SC is calculated at 1.2 using a 5% window. Referencing the Run Time Multiplier table in the CGIA manual, a DU of 85% will require operating the irrigation system only 10% longer than the minimum to meet the water needs of the driest turf grass areas.

The densogram in Figure 2 shows a graphic pictorial of the wet and dry areas within the sprinkler coverage area. Three green dots again indicate the location of the sprinklers (top left and right corners, bottom middle) contributing to the overlap of coverage measured in this example. The Red box indicates the driest 5% of the pattern area. In the configuration with replacement nozzles, the driest point receives 70% of the average. The Green box indicates the wettest 5% of the pattern area, with the wettest point receiving 128% of the average.

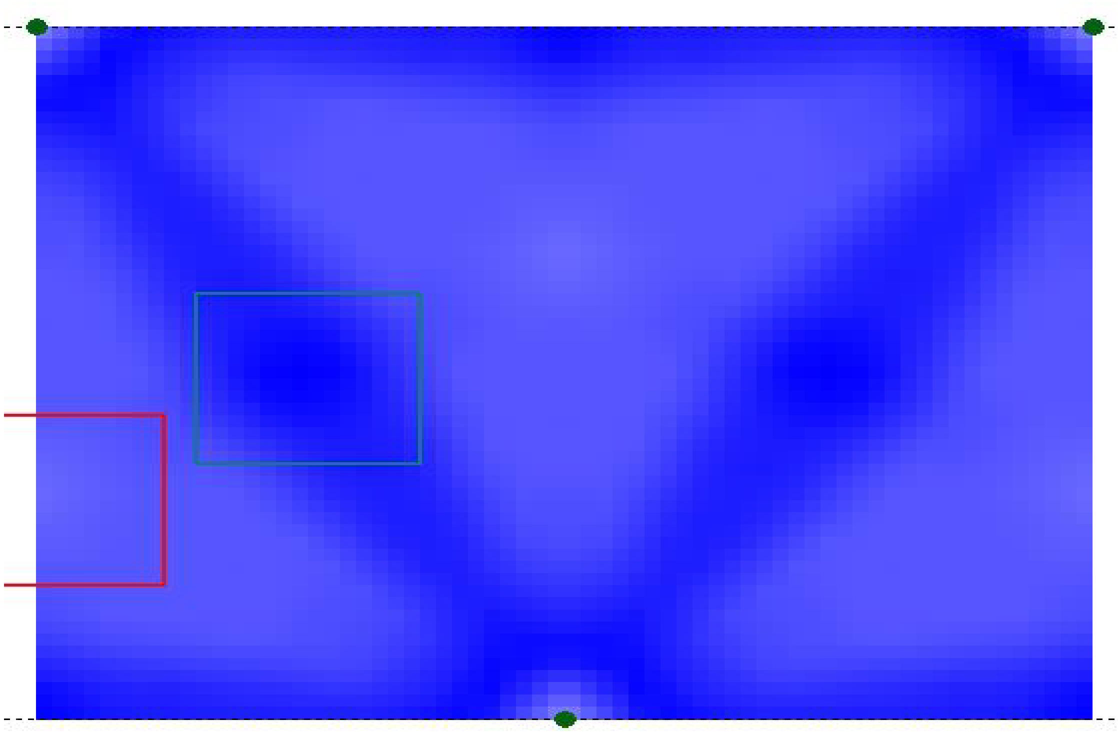


Figure 2. Denso-gram of the Sprinkler and Replacement Nozzle Application Uniformity

Findings

Range of Calculated Savings

The calculated savings or difference as determined by the Run Time Multiplier between the original sprinkler irrigation system and the sprinkler irrigation system with replacement nozzles is 9% based on the calculated DU_{LQ}. The difference in applied water is estimated at 30% using the SC method. Both these methods assume some minimum applied water to the driest parts of the sprinkler coverage area. In reality, there is several other phenomenon to consider. One is that water potentially moves across the ground laterally from the position initially applied by the sprinkler due to slope, splash, wind, or soil type. Turf quality, micro climates (ETo & rainfall), cultural practices, and traffic areas all play into the superintendents water management decisions. Thus the calculated potential water savings may not directly end up as actual water savings.

Clearly, however, higher application uniformity is desirable and should in most cases translate into savings of applied water (and energy) for the golf course. This can be further explained by variance of dry, average and wet areas in the two examples provided above. The sprinkler and original nozzle delivered only 57% of the average in the driest area, where the replacement nozzles delivered 70% of the average in the driest area. In the wettest areas, the original nozzles delivered 139% of the average, where the replacement nozzles delivered only 128% of the average applied water. Managing the water application extremes with the original nozzles is a much more difficult task than with the replacement nozzles.

The applied irrigation water totals were provided by the golf course superintendent from each of the golf courses reviewed in this study. The gross annual water savings (not adjusted) reported on an 18-hole course ranged from 55.5 acre feet to minus <22.8> acre feet. The average gross water savings per course was 16.6 acre feet. Gross water savings was simply determined as the annual water applied to the turf grass before the nozzle change less the annual water applied to the turf grass after the nozzle the change. The difference between the before and after is defined as the gross water savings (if positive).

A second calculation was conducted to include local, beneficial rainfall and ETo. Data was obtained from the nearest California Irrigation Management Information System (CIMIS) station to obtain rainfall and ETo information during the observation years. Effective or useful rainfall values were determined using the National Engineering Handbook, Part 623, Chapter 2, Table 2-43 (NRCS-USDA). This technique modifies total rainfall amounts indicate what percentage is efficiently used by the turf grass. Useful rainfall attempts to account for plant water demand from sources other than water applied through irrigation events.

After normalizing the rainfall data, the useful rainfall amounts were applied to each irrigation season. The water savings associated with the change in uniformity (re-nozzling) is calculated as the estimated crop ETo, minus the effective rainfall, and divided by the applied irrigation water per unit area. The data transformation is applied to the annual gross water data before and after changing the sprinkler nozzles.

The estimated total gross water savings for all the participants was 99.8 acre feet of water (32,519,304 gallons) or 6.5% of the applied water. Individual golf course gross water savings ranged from positive 21.4% to a negative <11.3%>. Adjusting for useful rainfall and ETo, the estimated savings drops to 82.9 acre feet (27,012,799 gallons) or 5.7% of the applied water. Individual golf course-adjusted water savings ranged from a positive 14.7% to negative <3.1%>. Assuming the actual amount is somewhere in between, the total savings experienced may be nearer 91.4 acre feet (29,782,507 gallons) and an average savings of 6.1% per golf course of the applied water (and energy). These figures align closely to observations made by one of the superintendents who acknowledged consciously reducing ETo by 5% after installing the new nozzles.

Return on Investment

In order to estimate the payback period, we need to know the value of the acre feet saved and the initial investment. A simple payback equation would look something like:

Number of years = Investment / Annual Return

For example, let's assume the one-time investment cost of nozzle replacement at $12,000. The cost of water and energy is $361 an acre foot. The total volume of water saved each year is 16.6 acre feet.

Two years=$12,000/ ($361*16.6)

Thus, if a golf course superintendent was operating under the average conditions outlined above, the payback period for investing $12,000 to re-nozzle the sprinkler system would be two years based on the volume and cost of water and energy saved. Water and energy costs higher than this would provide a shorter payback period, while lower water and energy costs would require a longer payback period to recoup the investment. Also higher or lower initial re-nozzling costs would affect this estimate.

Additionally, the golf course superintendent would likely put a dollar value on any perceived improvement in turf quality, lessening of weed and/or disease activity, reduction in hand-watering, and/or playability of the course. This would favorably impact or shorten the payback period. Finally, each golf course that participated in this study had water savings either higher or lower than the average example used. The ultimate determination is based on local economics, and must be based on all relevant conditions.

Energy Costs

All water used for the purpose of irrigation in a golf course is pumped. Therefore, every gallon of water delivered to the field has some energy (kWh) cost associated with it. The more water and pressure we use, the more energy we consume. Conversely, reducing the amount of water applied and/or reducing the operating pressure will minimize the total cost of energy.

Horsepower requirements of a pumping plant are a function of the flow of water (gpm) and pressure (psi) required to operate the irrigation system. Selecting sprinklers that provide excellent uniformity at lower operating pressures are one-way to reduce horsepower and energy demands. As demonstrated in Figure 2, excellent uniformity in water distribution can be achieved while operating at the relatively low operating pressure of 55 psi at the base of the sprinkler. Other systems reviewed in this study operated at pressures upward of 85 psi. By selecting the sprinkler, nozzle, and spacing combination that produces excellent uniformity at lower operating pressures, significant energy savings could be achieved. Using the data reviewed in this study, it is suggested that excellent uniformity can be achieved at pressures 30 psi lower than used by some other golf courses. There may or may not be any water savings, however, if both higher and lower pressure irrigation systems deliver water with excellent uniformity.

We can begin to look at the relationship between energy and water by reviewing operating costs changes associated with gross application and pressure requirements. Table 1 below illustrates the sensitivity of operating costs to changes in gross water application, pumping plant efficiency, and the cost of energy if calculated at $0.15 kWh. The estimate is based on a pumping system designed for operation at 2,500 gpm. For the purpose of this illustration, both high pumping plant efficiency (70%) and relatively low pumping plant efficiency (50%) are used to show the effect on energy costs. This example considers both irrigation systems (high and lower operating pressures) to be delivering the same excellent uniformity.

Table 1. Annual Energy Cost Savings with a 30 psi Reduction in Operating Pressure based on 100 Irrigated Acres at $0.15 per kWh

Annual Gross Water Applied (in. /yr)	Pump Efficiency (50%)	Pump Efficiency (70%)
12	$2,127	$1,521
24	$ 4,251	$3,045
36	$6,378	$4,566
48	$8,505	$6,087

If a golf course were able to reduce the operating pressure by 30 psi, while maintaining distribution uniformity, significant cost (energy) savings could occur. The values shown in Table 1. show the estimated potential savings associated with the 30 psi pressure reduction associated with various amounts of applied water. While each golf course irrigation system is custom designed for the specific location, the overarching message is to match the required operational pressure of the sprinkler to achieve excellent distribution uniformity. All of these calculations do require knowledgeable engineering, and any changes should be made in consultation with a professional engineer or irrigation consultant. However, the message is clear, lower operating pressures can save money. Also, higher energy costs per kWh ($0.15) will save additional money beyond what is portrayed in the example.

Conclusions

While the numbers present a quantitative view of the benefits of improving irrigation uniformity through selected nozzle changes, the superintendents provided insight into the perceived benefits of a more uniform irrigation system. Selected quotes include:

> "Dry spots and wet spots are much less numerous"
> "We are able to run sprinkler heads longer without puddling"
> "Turf areas had many donuts throughout the course. The new nozzles evenly distributed the water reducing and eliminating this issue on my golf course"
> "After installing the new nozzles I was able to reduce the ET demand 5% lower than the previous year"
> "Significantly improved coverage"
> "Less water around the head, less disruption of "head position" with mud and mess"
> "Better performance in higher elevation pressure sensitive areas"
> "Well worth the investment"
> "It has reduced our hand watering requirements, perhaps saving around $8,000 per year"
> "Absolutely would recommend the (nozzle) change given a similar situation"

Not all the superintendents were able to document a net savings in water and energy from the installation of new nozzles, but all five superintendents did see improvements in the quality of their turf grass from better water distribution. They indicated no hesitation in recommending re-nozzling of sprinklers to other superintendents who are facing the same lower uniformity issues seen in this study.

Based on the data and testimonials collected in this case study, it is apparent that even golf course irrigation systems with existing sprinkler uniformity characterized as “good” can achieve significant water and energy savings and/or turf quality improvements through upgrading their uniformity to “excellent”. The basic lessons learned were:

1) It is very important to know the distribution uniformity of your existing irrigation system. This information can be obtained by the superintendent performing an audit or contracting with a professional to conduct the audit,

2) If improvement is warranted (based on the outcome of the audit), then evaluate the numerous options available to improve existing uniformity. These options include, but are not limited to, pressure changes, sprinkler changes, spacing changes, and/or nozzle changes,

3) Replacing existing sprinkler nozzles with either manufacturer’s or third party vendor nozzles has been shown to be a viable option for some golf course superintendents to improve turf grass quality while reducing water and energy consumption (costs). It is highly recommended that the superintendent seek out professional consultation in selecting the “right” replacement nozzles, as simply replacing nozzles may not achieve the desired results.

Naturally results will vary at each site based on soil and drainage characteristics, initial condition and performance of the irrigation system prior to upgrading nozzles as well as other various site-specific factors.

List of Golf Courses and Superintendents Participating in the Study

Location Number 1 – The Los Angeles Country Club
Los Angeles, CA 90024

1) Brief history of the irrigation system
   a) System installed in 1990-01
   b) Nozzle change out in spring of 1998
   c) Designed at 65 feet triangular and regulated at 50 psi at the sprinkler head
   d) Water source (well and potable city water supplies)
   e) CIMIS station- Santa Monica #99

2) Primary turf type
   a) Fairways, Common Bermuda grass
   b) Roughs, Common Bermudagrass, Perennial Ryegrass & Kentucky Bluegrass Mixture
   c) Greens, Creeping Bentgrass

3) Total irrigated acres
   a) 210 acres

Location Number 2 – Del Mar Country Club
Rancho Santa Fe, CA

1) Brief history of the irrigation system
   a) System installed in 1990
   b) Nozzles changed in November of 2001
   c) Designed at 65 feet triangular and regulated at 65 psi at the sprinkler head
   d) Water source (potable water supply)
   e) CIMIS station- Torrey Pines #173

2) Primary turf type
   a) Fairways, Tifway II Hybrid Bermudagrass
   b) Roughs, Kentucky Bluegrass, Perennial Ryegrass Mixture
   c) Greens, Creeping Bentgrass

3) Total irrigated acres
   a) 100 acres

Location Number 3 – San Gabriel Country Club
San Gabriel, CA 91776

1) Brief history of the irrigation system
   a) System installed in 1985
   b) Nozzles changed in summer 1998
   c) Designed at 65 ft triangular spacing with operating pressure of 80 to 85 psi (non-regulating) at the sprinkler head
   d) Water source (wells)
   e) CIMIS station – Pomona #78

2) Primary turf type
   a) Fairways, Kikuyu grass
   b) Roughs, Rye grass
   c) Greens, Poa annua / Creeping Bentgrass Mixture

3) Total irrigated acres
   a) 96 acres

Location Number 4 – The Meadow Club
Fairfax, CA 94930

1) Brief history of the irrigation system
   a) System installed in 1984
   b) Nozzle change out in spring of 2002
   c) Designed at 65 ft spacing and regulated at 65 psi at the sprinkler head
   d) Water source (potable and well water supply)
   e) CIMIS station – Petaluma East #144

2) Primary turf type
   a) Fairways, Perennial Ryegrass, Poa annua, Creeping Bentgrass, and Kentucky Blue grass mixture.
   b) Roughs, Perennial Ryegrass, Poa annua and Kentucky Bluegrass mixture
   c) Greens, Poa annua and Creeping Bentgrass Mixture

3) Total irrigated acres
   a) 100 acres

Location Number 5 – La Jolla Country Club
La Jolla, CA 92038

1) Brief history of the irrigation system
   a) System installed in 1987 with low pressure model
   b) Nozzle change out in spring of 2001-02
   c) Designed at 65 feet spacing and regulated at 50 psi at the sprinkler head
   d) Water source (potable water supply)
   e) CIMIS station – Torrey Pines #173

2) Primary turf type
   a) Fairways, Kikuyu grass
   b) Roughs, Kikuyugrass
   c) Greens, Creeping Bentgrass

3) Total irrigated acres
   a) 100 acres

Estimated Average Monthly Effective Precipitation (Inches) as Related to Mean Monthly Precipitation and Average Monthly Crop Evapotranspiration

Monthly Mean Precipitation (Inches)	Average Monthly Crop Evapotranspiration, ET_c										
	0.00	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.5	0.28	0.30	0.32	0.34	0.36	0.38	0.40	0.42	0.45	0.47	0.50
1.0	0.59	0.63	0.66	0.70	0.74	0.78	0.83	0.88	0.93	0.98	1.00
1.5	0.87	0.93	0.98	1.03	1.09	1.16	1.22	1.29	1.37	1.45	1.50
2.0	1.14	1.21	1.27	1.35	1.43	1.51	1.59	1.69	1.78	1.88	1.99
2.5	1.39	1.47	1.56	1.65	1.74	1.84	1.95	2.06	2.18	2.30	2.44
3.0		1.73	1.83	1.94	2.05	2.17	2.29	2.42	2.56	2.71	2.86
3.5		1.98	2.10	2.22	2.35	2.48	2.62	2.77	2.93	3.10	3.28
4.0		2.23	2.36	2.49	2.63	2.79	2.95	3.12	3.29	3.46	3.68
4.5			2.61	2.76	2.92	3.09	3.26	3.45	3.65	3.85	4.08
5.0			2.86	3.02	3.20	3.28	3.57	3.78	4.00	4.23	4.47
5.5			3.10	3.28	3.47	3.67	3.88	4.10	4.34	4.59	4.85
6.0				3.53	3.74	3.95	4.18	4.42	4.67	4.94	5.23
6.5				3.79	4.00	4.23	4.48	4.73	5.00	5.29	5.60
7.0				4.03	4.26	4.51	4.77	5.04	5.33	5.64	5.96
7.5					4.52	4.78	5.06	5.35	5.65	5.98	6.32
8.0					4.78	5.05	5.34	5.65	5.97	6.32	6.68

Note: Based on 3 in. soil water storage. For other values of soil water storage, multiply by the following factors:

Storage (inches)	0.75	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	7.0
Factor	0.72	0.77	0.86	0.93	0.97	1.00	1.02	1.04	1.06	1.07

Source: *National Engineering Handbook*, Part 623, Chapter 2, Table 2-43 (NRCS-USDA)

Fairway Example, cont.

IV. Scheduling Run Time

P. Run Time Multiplier (RTM)

The Run Time Multiplier is a function of the distribution uniformity of the sprinkler zone and is used to adjust the calculated base run time. The RTM can be calculated or use the table to identify what it is. The RTM for a DU_{LQ} of 70 is **1.22**. Refer to the table below.

DU_{LQ}	RTM	DU_{LQ}	RTM	DU_{LQ}	RTM
100	1.00	70	1.22	40	1.56
98	1.01	68	1.24	39	1.58
96	1.02	66	1.26	36	1.62
94	1.04	64	1.28	33	1.67
92	1.05	62	1.30	30	1.72
90	1.06	60	1.32	27	1.78
88	1.08	58	1.34	24	1.84
86	1.09	56	1.36	21	1.90
84	1.11	54	1.38	18	1.97
82	1.12	52	1.40	15	2.04
80	1.14	50	1.43	12	2.12
78	1.15	48	1.45	9	2.20
76	1.17	46	1.48	6	2.29
74	1.18	44	1.51	3	2.39
72	1.20	42	1.53	0	2.50

Sprinkler System Uniformity

An irrigation system has good uniformity when a nearly equal amount of water is deposited on each square foot of irrigated surface area. This is important for plant materials such as turf, where every square inch of area is covered with a relatively dense root system. Trees and shrubs can get water from a wider and deeper root zone. In this case, uniformity can be lower at the square foot level but each plant can receive an adequate amount of water.

Sprinkler selection during the system design influences uniformity. Examples of selection options include: spray vs. single nozzle vs. multiple nozzle, sprinkler pressure and pressure variation, sprinkler spacing, and sprinkler location with respect to golf course features. Other factors affecting performance include wind, plant interference, and equipment damage. Installation and maintenance specifications must maintain the intent of the design to insure proper performance.

Table 3-3: Estimated DU for golf systems by sprinkler type and system quality

SPRINKLER TYPE	EXCELLENT (Achievable)	GOOD (Expected)	POOR (If lower than this, consider not scheduling)
Rotary Sprinklers	80%	70%	55%
Spray Sprinklers	75%	65%	50%

Sprinkler Distribution Profiles/Spacing

A design consideration affecting the performance of an irrigation system is the sprinkler water distribution profile. A single sprinkler head typically is not designed to distribute water evenly across a given area. As the distance from the sprinkler head increases, the water being delivered is spread over an increasingly larger area. Many sprinklers distribute about the same amount of water into each radius range. This results in less water being applied to the area farthest away from the sprinkler head. Sprinkler systems must be designed so that individual patterns overlap in order to provide a reasonable level of uniformity (Figure 3-4). If the spacing is not consistent, the uniformity will be adversely affected.

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