Liquid Asset Management:

Design, Chemical and Cultural Considerations to Stretch Irrigation Supplies

Mike Huck
Irrigation & Turfgrass Services
Dana Point, CA
Today’s Topic: Water Use Efficiency

“I believe that the organizers of this conference have chosen a very timely subject for our discussion - because the 21st century will confront us with an entirely new set of challenges.”

Lord Robertson – NATO Secretary General
The Value of Water

$351,980 AF
$809 CCF

$325,851 AF
$748 CCF

$724,114 AF
$1664 CCF

Sports Event, Airport, etc.

$3.00 /16 oz

$150 to $3,000 AF
$0.34 to $6.90 CCF

$7,820,424 AF
$17,977 CCF

$410,141 AF
$942 CCF
Efficiency & Uniformity: Man vs. Equipment

“You can't always get what you want,
But if you try sometimes well you might
find you get what you need”

The Rolling Stones
Irrigation Efficiency (IE) Vs Distribution Uniformity (DU)

- **IE** = The amount, percentage or ratio of water used by the plant compared to the amount of water applied that includes runoff and deep percolation.

- **DU** = A measure of how uniformly water is applied to the area being watered, expressed as a percentage.
Why uniformity & efficiency are important for water conservation.

Highest concentrations of salts will be at the leading edge of the wetting front.
Summary Report of Performance Evaluations on Lawn Sprinkler Systems

- Based upon combined data of 6800 audits
  - A few sprinkler systems performed exceptionally well with DU in the high 70’s to mid 80’s had these things in common:
    - Precise (uniform) spacing
    - Correct water (uniform) pressure for the type of head
    - Correct (& uniform sized) nozzles and arcs
    - Heads were set in the ground properly / level
  - Report by Brent Mecham – Northern Colorado Water Conservation District
Irrigation Design, Rocket Science and the SPACE Program

To Infinity & Beyond

Buzz Lightyear
Uniformity Myth, Half Truth

- We are led to believe “head to head coverage provides optimum uniformity”
  - Half truth as results depend also on the application profile shape and sprinkler layout.
- Question: Has anyone here evaluated sprinklers / nozzles with CIT SPACE data from Cal State Fresno?
  - SPACE data cannot assure success, but can guarantee avoiding failure!
Profiling Sprinkler Performance

Graph 1:
- Riser: 0.0in
- Radius: 63°
- Arc: 360°
- Flow: 22.40 gpm

Graph 2:
- Riser: 0.0in
- Radius: 65°
- Arc: 360°
- Flow: 27.70 gpm

Graph 3:
- Riser: 0.0in
- Radius: 61°
- Arc: 360°
- Flow: 34.00 gpm
The Theoretical Ideal
Triangular Spacing & Wedge Profile
Not all sprinklers are perform equally!
Field Results
Conducted by:
The Center for Irrigation Technology at California State University-Fresno

Sponsored by:
The State of California Department of Water Resources
Case Study Overview

- Five sites evaluated *(4-18 and 1-36 hole sites)*
- Locations represent wide range of climatic conditions, cool and warm season turf
  - North San Francisco Bay Area
  - Coastal and Inland Los Angeles County
  - Coastal & Inland San Diego County
- 606 total irrigated acres represented
- 108 golf holes *(6-18 hole equivalents)*
- Each site had recently replaced 100% of nozzles
Used CIT laboratory or field audit data for before & after nozzle replacement to compare:
- Distribution Uniformity (DU%)
- Run Time Multiplier (RTM)
- Scheduling Coefficient (SC)

Calculated estimated & actual water use based upon 12 months before and 12 months after nozzle replacement:
- Metered water use data
- CIMIS weather station ET
- Accounted for useful rainfall data
Indoor Profile Testing
Outdoor Audits

Outdoor Audits

Indoor Profile & Computer Overlap
Estimated Vs. Actual Water Savings

- The estimated potential water savings using Scheduling Coefficient was 20% (1.2 vs. 1.5)

- The estimated potential water savings using DU and a run-time-multiplier was 9% (110% applied water w/DU of 85% vs. 119% w/DU of 73%)

- Actual average savings achieved by golf courses participating in this was 6%
Individual Vs. Overall Results

- **Individual Courses**
  - Gross Water Savings Range:
    - (-11.3%) to 21.4%
  - Net Water Savings Range (adjusted for useful rainfall)
    - (-3.1%) to 14.7%

- **Overall Average Results**
  - Gross Savings of Applied Water
    - 6.5%
  - Net Savings of Applied Water
    - 5.7% (adjusted for useful rainfall)
Superintendents Comments

- Eliminated donuts
- Less numerous and smaller size wet / dry spots
- Able to run sprinklers longer without puddling
- Improved turf quality & playing conditions
- Able to reduce ET demand by 5%
- Reduced hand watering significantly, estimated $8000.00 labor savings
High Efficiency Nozzles

Profile Metal Nozzles
Underhill Corp.
20505 Crescent Bay Dr.
Lake Forest, CA 92630
866-863-3744 or
949-305-7050
http://www.underhill.us/
Low Heads?

- **LEVELIFT**
  - Improve distribution uniformity
  - Reduce labor (@10 to 15 min per head)
  - Reduce wiring damage
  - Reduce water use
  - Eliminate turf disruption surrounding sprinkler

- 877-465-3835
- [http://www.levelift.net/](http://www.levelift.net/)
Looked good on paper, but did it work?

“Perfection is not attainable, but if we chase perfection we can catch excellence.”

Vince Lombardi
A Design Created Management Challenge

- Opposing part circle sprinklers to maximize control.
  - Difficult to adjust arc exactly,
  - Cannot control “pause” time on direction change
  - Have a broad spray pattern
- Increased black layer reported on putting green perimeters during grow-in.
- The idea looks good on paper but,,,,,
Opposing Part Circle Heads At Pink Flags

Wet Spots at Blue Flags
Back to Back Part Circle - The Math!

- Assume 60’ spacing / radius or 120 foot diameter
- $3.14 \times 120’$ diameter = 376.8’ circumference
- 360 degrees / 377’ circumference = 1.05’ per degree of rotation
- One 180 degree rotation @ 1.5 minutes (90 seconds) = approximately 2 degrees per second or 2.1 feet per second.

- Measured 2 to 4 second pause while changing direction in field.
- Assume a 3 second pause while changing directions = 3X application over 2.1 foot wide area.
- If arc adjustments overlap slightly they result in an overlap 2x overlap plus the pause factor.
Daily Vs Infrequent ET Replacement

“I do not question the power of our weapons and the efficiency of our logistics; I cannot say these things delight me as they seem to delight some of our officials, but they are certainly impressive.”

J. William Fulbright, US Senator (Vietnam War Era)
Member Senate Foreign Relations Committee
Trivia Question:

- Where in the United States does it “rain” between 0.25” and 0.30” each day during the month of July?
- That would be on just about every Southwestern U.S. Desert Golf Course / Landscape replacing ET on a daily basis, it just happens to be manmade rain applied through sprinklers.
- Essentially through irrigation we have created a rainforest in the desert.
  - Officially need 100” precipitation to qualify as a rainforest (100” / 365 = 0.274” per day average)
## Southwest Peak July ET

<table>
<thead>
<tr>
<th>City</th>
<th>Annual Rainfall</th>
<th>Annual ET</th>
<th>Wettest Month</th>
<th>Highest ET</th>
<th>Daily Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles</td>
<td>16.90”</td>
<td>38.96”</td>
<td>Feb. 3.55”</td>
<td>July 6.13”</td>
<td>0.20”</td>
</tr>
<tr>
<td>San Francisco</td>
<td>19.76”</td>
<td>33.40”</td>
<td>Jan. 4.14”</td>
<td>July 4.99”</td>
<td>0.16”</td>
</tr>
<tr>
<td>Palm Springs</td>
<td>8.01”</td>
<td>48.28”</td>
<td>Feb. 1.49”</td>
<td>July 8.90”</td>
<td>0.29”</td>
</tr>
<tr>
<td>Reno</td>
<td>8.30”</td>
<td>28.67”</td>
<td>Jan. 1.20”</td>
<td>July 6.21”</td>
<td>0.20”</td>
</tr>
<tr>
<td>Las Vegas</td>
<td>5.10”</td>
<td>48.77”</td>
<td>Jan. 0.61”</td>
<td>July 9.24”</td>
<td>0.30</td>
</tr>
<tr>
<td>Salt Lake City</td>
<td>15.67”</td>
<td>31.18”</td>
<td>Apr. 1.81”</td>
<td>July 6.92”</td>
<td>0.22</td>
</tr>
<tr>
<td>Denver</td>
<td>14.81”</td>
<td>18.93”</td>
<td>May 2.53”</td>
<td>July 4.42”</td>
<td>0.14</td>
</tr>
<tr>
<td>Phoenix</td>
<td>9.02”</td>
<td>56.75”</td>
<td>Aug. 1.56”</td>
<td>July 10.11”</td>
<td>0.33</td>
</tr>
<tr>
<td>Tucson</td>
<td>13.42”</td>
<td>46.66”</td>
<td>Aug. 3.14”</td>
<td>July 8.11”</td>
<td>0.26</td>
</tr>
</tbody>
</table>

*Source: Rainfall / Evaporation Data - The Toro Company*
<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Available Water (In Water / In Soil)</th>
<th>Basic Infiltration Rate (inches / hour)</th>
<th>Management Allowed Depletion% (MAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>0.15</td>
<td>0.12</td>
<td>30</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>0.16</td>
<td>0.18</td>
<td>40</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>0.20</td>
<td>0.25</td>
<td>40</td>
</tr>
<tr>
<td>Silty Clay Loam</td>
<td>0.20</td>
<td>0.25</td>
<td>50</td>
</tr>
<tr>
<td>Sandy Clay Loam</td>
<td>0.15</td>
<td>0.20</td>
<td>50</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>0.16</td>
<td>0.12</td>
<td>50</td>
</tr>
<tr>
<td>Silt</td>
<td>0.17</td>
<td>0.40</td>
<td>50</td>
</tr>
<tr>
<td>Silt Loam</td>
<td>0.20</td>
<td>0.43</td>
<td>50</td>
</tr>
<tr>
<td>Loam</td>
<td>0.17</td>
<td>0.54</td>
<td>50</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>0.12</td>
<td>0.75</td>
<td>50</td>
</tr>
<tr>
<td>Loamy Sand</td>
<td>0.07</td>
<td>0.88</td>
<td>50</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>0.06</td>
<td>1.25</td>
<td>60</td>
</tr>
</tbody>
</table>

Source: Irrigation Association Certified Golf Irrigation Auditor’s Handbook
Uniformity, efficiency and scheduling for salt management

Highest concentrations of salts will be at the leading edge of the wetting front
Deep and Infrequent Scheduling

Time to Irrigate

Soil Available Water

Allowable Depletion

Dry Soil

Total = 1.85 inches lost

0.25 inches
0.25 inches
0.25 inches
0.30 inches
0.35 inches
0.20 inches
0.25 inches
Trivia Question:

- Is daily ET replacement adjusted by a Kc an efficient strategy for water conservation? (True or False)
- **False!!** Research has shown deep and less frequent applications can save up to 33% to 35% over less frequent applications.
Water use and irrigation frequency.

Figure 11.1. Evapotranspiration rate of creeping bentgrass (cv. Penncross) irrigated once per week (1x), twice per week (2x), and three times per week (3x). The test was performed in turfgrass grown in loamy soil and mowed at 3/8 inch height in field plots at the Rutgers University Turfgrass Research Farm, North Brunswick, New Jersey.

Source: Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes
Water Use after Irrigating to Field Capacity

Scandinavian Turfgrass Environmental Research Foundation (STERF)
“Irrigation of Turf on Golf Courses a Greenkeepers guide to understanding theory and practice.”
Water Use, Irrigation Amount & Frequency

- Turf with free access to water has a much higher transpiration rate than if growing on dry soils.
- Water consumption on first day after irrigation to field capacity is 2 to 3 times higher than average consumption on the next 5 days.
- The crop coefficient, $k_c$, varies with water content of the soil.

![Diagram showing irrigation strategies](image)

*Figure 5. Illustration of three principally different irrigation strategies.*
<table>
<thead>
<tr>
<th>Irrigation Strategy</th>
<th>Visual turf quality (1-9)</th>
<th>Dry Spots % of plot area</th>
<th>Daily height increment (mm)</th>
<th>Ballroll, measured with a short stimpmeter (cm)</th>
<th>Hardness measured with a Clegg-hammer (gravities)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Field capacity, 6x per week</td>
<td>6.3 a</td>
<td>6 b</td>
<td>0.9 a</td>
<td>100 a</td>
<td>71 c</td>
</tr>
<tr>
<td>2. Field capacity, 2x per week</td>
<td>6.1 a</td>
<td>6 b</td>
<td>0.9 a</td>
<td>102 a</td>
<td>74 bc</td>
</tr>
<tr>
<td>3. Field capacity, 1x per week</td>
<td>5.4 ab</td>
<td>13 ab</td>
<td>0.8 a</td>
<td>100 a</td>
<td>79 b</td>
</tr>
<tr>
<td>4. Deficit, 6x per week</td>
<td>6.4 a</td>
<td>8 b</td>
<td>0.9 a</td>
<td>101 a</td>
<td>76 bc</td>
</tr>
<tr>
<td>5. Deficit, 2x per week</td>
<td>5.8 ab</td>
<td>11 b</td>
<td>0.9 a</td>
<td>100 a</td>
<td>75 bc</td>
</tr>
<tr>
<td>6. Deficit, 1x per week</td>
<td>4.9 b</td>
<td>27 a</td>
<td>0.8 a</td>
<td>103 a</td>
<td>85 a</td>
</tr>
</tbody>
</table>

Table 4. Impacts of different turf irrigation scheduling strategies based on irrigation experiments conducted in 2011 on a green with creeping bentgrass ‘Independence’. It was irrigated to field capacity or to approximately 70% of field capacity at different intervals. Within each column, figures followed by the same letter are not significantly different (significance level: P < 0.10).

<table>
<thead>
<tr>
<th>Irrigation Strategy</th>
<th>Water consumption during experimental period (63 days)</th>
<th>Water consumption relative to daily irrigation to field capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Field capacity, 6x per week</td>
<td>358</td>
<td>100</td>
</tr>
<tr>
<td>2. Field capacity, 2x per week</td>
<td>233</td>
<td>65</td>
</tr>
<tr>
<td>3. Field capacity, 1x per week</td>
<td>173</td>
<td>48</td>
</tr>
<tr>
<td>4. Deficit, 6x per week</td>
<td>123</td>
<td>34</td>
</tr>
<tr>
<td>5. Deficit, 2x per week</td>
<td>127</td>
<td>36</td>
</tr>
<tr>
<td>6. Deficit, 1x per week</td>
<td>106</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 5. Water consumption of creeping bentgrass ‘Independence’ at different irrigation strategies on a golf green at Bioforsk Landvik in 2011. The accumulated reference ET during the 63 day period was 174 mm.
Do DU Figures Lie?

*Figures Don’t Lie, But Liars Do Figure*

Mark Twain
Distribution Uniformity, *Known known, known unknown or unknown unknown?*

<table>
<thead>
<tr>
<th>Golf Sprinkler Performance (Rotary Sprinklers)</th>
<th>Excellent (Achievable)</th>
<th>Very Good</th>
<th>Good (Expected)</th>
<th>Fair</th>
<th>Poor (Needs Improvement)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cal Poly ITRC</em>&lt;sup&gt;1&lt;/sup&gt;</td>
<td>≥85%</td>
<td>80%</td>
<td>75%</td>
<td>65%</td>
<td>≤60%</td>
</tr>
<tr>
<td><em>Irrigation Association</em>&lt;sup&gt;2&lt;/sup&gt;</td>
<td>≥80%</td>
<td>70%</td>
<td></td>
<td></td>
<td>≤55%</td>
</tr>
</tbody>
</table>

1. Landscape Irrigation Auditors Manual Developed by Cal Poly Irrigation Training & Research Center for California Department of Water Resources.
2. Irrigation Association Certified Golf Irrigation Auditors Manual
78% DULQ
68 – 81% Range
DULQ 82%
76 – 85% Range
77% DULQ

67-77% Range
High DULQ but

- Visible turf quality issues
- Repeated wet patterns near sprinkler across property
- Hard data shows similar wet areas near sprinkler
“Case” Study

CIT DATA
- SC 1.1
- DU 90%
- CU 93%

Riser: 0.0in
Radius: 63'
Arc: 360°
Flow: 22.40 gpm
And then the **Light** Came On!  
*(Coors Light that is: I told you it was a Case Study.)*

- DULQ = Avg. LQ / Average
  - (It compares **driest** 25% to the average application.)
- But this problem is the wettest 10%, driest 25% is very uniform and comparable to the remaining 90% of the pattern,,,,
- LQDU “dilutes” the high values into the total average delivering a false positive
Are Better Evaluation Methods or Formulas Needed?

- Can we develop better measuring tools to evaluate sprinkler performance than CU, DU, or SC?

Examples of 3D graphics results where dryer application areas are dispersed (left) versus concentrated (right). Both graphics represent: 75.3% CU and 74.3% DU_{LQ}. 
Preparing for the worst with a Drought Plan

Failing to plan is planning to fail!
Alan Lakein – Author
Develop a Written Drought Plan

- Prepare for rationing and prioritize areas
  - Greens,
  - Fairway and/or landing areas,
  - Tees
  - Rough,
  - Identify specimen trees in areas where water is cut off to the turf and plan to deep irrigate with a tree root feeder.
Formal Drought Plan

Currently Executing

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
<th>Water Reduction Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>Optimized water use through irrigation systems</td>
<td>22%</td>
</tr>
<tr>
<td>Phase 2</td>
<td>Improved water conservation practices</td>
<td>23%</td>
</tr>
<tr>
<td>Phase 3</td>
<td>Replacement of irrigation systems with efficient ones</td>
<td>24%</td>
</tr>
<tr>
<td>Phase 4</td>
<td>实行更高效的灌溉系统</td>
<td>25%</td>
</tr>
</tbody>
</table>

The Club will continue to make this important information available to members.
Permanent Irrigated Acreage Reduction
Maintenance Practices Affect Water Use

- Plant growth regulators. (11% to 44% Savings Reported)
- Mowing Height & Frequency
  - Perennial Rye when HOC raised from 1” to 2”, 37% increase
  - Common Bermuda HOC raised from 1” to 6”, 60% increase
  - Creeping Bent HOC raised from ¼” to 1”, 56% increase
  - Creeping Bent mowed 1x/14 days 41% more H2O than 6X/wk,
- Excessive N fertility increased H2O use (13%-KGB)
- Sufficient K enhances drought recovery
- Aeration enhanced infiltration & stress tolerance but increased water use temporarily.
- Wetting agents 28%-71% savings, effects gone 4 WAT
Combining Products - Preliminary

- 2016 California Study combined effects of Nitrogen + Primo + Revolution at 40% & 70% ETo Replacement
  - Bermudagrass significantly affected by lack of N fertilization
  - Turf recovered quickly after the first N app.
  - No difference between ETo replacements until early July.
  - At 40% ETo revolution treatments had acceptable quality for 2 months, after July 8 quality became unacceptable.
  - Revolution alone or in combination with Primo Maxx showed consistently better quality than plots without Revolution
  - Preliminary results suggest sufficient bermudagrass fertilization (5 lb N/M/YR) & regular Primo Maxx & Revolution use may be tools to manage bermudagrass with less water
Figure 1. Quality of plots irrigated at 70%ET₀ treated with either Primo Maxx, Revolution, a combination of the two or untreated. 2016. Riverside, CA.

Figure 2. Quality of plots irrigated at 40%ET₀ treated with either Primo Maxx, Revolution, a combination of the two or untreated. 2016. Riverside, CA.
Educate Yourself and Your Membership About Water Issues
Reference Book

- Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes.
  - $35 Hardcopy
  - $25 PDF
- Published by:
  - The Council for Agricultural Science and Technology
  - 4420 West Lincoln Way
  - Ames, Iowa 50014
  - www.cast-science.org
Reference Book

- University or California Agriculture and Natural Resources Publications
- Turfgrass Water Conservation 2nd Ed.
- Publication Number: 3523 ($24.00) 2011
- 1-800-994-8849
- http://anrcatalog.ucdavis.edu/
Online Resources

- **USGA Green Section**
  - Green Section Record [http://turf.lib.msu.edu/gsr/](http://turf.lib.msu.edu/gsr/)

- **University of California**
  - UCR Turf (CA Turfgrass Culture) [http://turfgrass.ucr.edu/](http://turfgrass.ucr.edu/)
    - [https://agops.ucr.edu/turf/](https://agops.ucr.edu/turf/)

- **University of Arizona (Tucson)**
  - [http://turf.arizona.edu/](http://turf.arizona.edu/)

- **New Mexico State University**
  - Turfgrass Research, Extension & Education: [http://aces.nmsu.edu/programs/turf/](http://aces.nmsu.edu/programs/turf/)
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