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Via Email

Margaret Geiger, Board Administrator
N.C Irrigation Contractors' Licensing Board P.O. Box 41421
Raleigh, NC 27629-1421

March 16, 2023

Re: Petition for Amendment of 21 NCAC 23.0406 (2) – Components and Zone Design

Dear Ms. Geiger,

I write to petition for the amendment of 21 NCAC 23.0406 (2) which reads *Design sprinkler head spacing with an approximate "head-to-head" coverage*. The problem with this language is it restricts the use of new irrigation technologies that do not require head-to-head coverage, yet do accomplish the intent of head-to-head coverage, which is uniform distribution of water. Furthermore, as is the case with Irrigreen, these new technologies could offer uniform distribution *and* significant water usage efficiency.

To satisfy rule 21 NCAC 23.0406 Components and Zone Design (2) we propose the following (italicized) language be added: "Design sprinkler head spacing with an approximate "head-to-head" coverage *or according to manufacturer recommendations.*"

This proposed rule change would in effect allow for the installation of Irrigreen, and would have no affect on installation of currently approved products or methods.

To support this rule change we offer the following in more detail in Attachment A:

- 1) Unique design has been approved for similar rule adjustment in the states of Florida and Texas
- 2) University of Florida/Dr Dukes study regarding uniform distribution with the Irrigreen system
- 3) Florida Water Star Certification inclusive of Irrigreen's unique design and fulfillment of uniform distribution requirements

If you have any questions, please do not hesitate to contact me.

Kind Regards,

Shane Dyer

CEO Irrigreen, Inc.



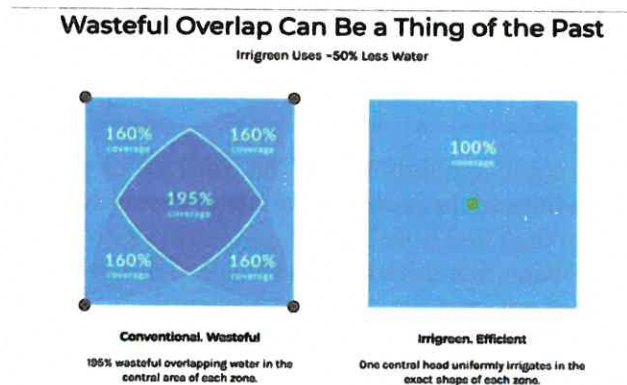
Re: Petition for Amendment of 21 NCAC 23.0406 (2) – Components and Zone Design

Attachment A (11 of pages total)

Irrigreen's Unique Design provides uniform distribution of water AND reduces water use:

The intent of the "head-to-head coverage" rule is to ensure uniform distribution of water and no dry spots. The Irrigreen system is designed for uniform distribution of water. In fact, instead of multiple sprinkler heads with overlapping spray (the resulting effect of "head-to-head coverage"), the Irrigreen system uses a center-zone placed digital sprinkler head that rotates 360 degrees to the exact shape of the irrigation zone, this eliminating overspray and water waste, while also providing uniform distribution of water.

Image: Center zone location of 360-degree rotating sprinkler head ensures uniform distribution



The NCICLB states a "commitment to environmentally responsible design" and to "promote water conservation practices on a continual basis". The Irrigreen system would give North Carolina residents a meaningful opportunity to use irrigation innovation that does indeed provide uniform distribution AND water usage efficiency. The states of Florida and Texas have permitted a rule change to allow Irrigreen installations by adding the language "or according to manufacturer recommendations" to their rules. We are optimistic the state of North Carolina will join them in this innovation leadership.

The St. Johns River Water Management District in Palatka, Florida has also reviewed the Irrigreen system and acknowledged the need to consider Irrigreen's unique design when evaluating it for use. The St. John's River Water Management District has approved Irrigreen as a **Florida Water Star certified** product. (see page 2)

A study by The University of Florida (Dr. Dukes) concluded Irrigreen is effective without "head-to-head" coverage by proving uniform distribution of water and the ability to meet coverage and efficiency standards. (see pages 3-11)



St. Johns River Water Management District

Ann B. Shortelle, Ph.D., Executive Director

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November 17, 2020

Ms. Kim Levin
Irrigreen
5250 W. 73rd Street, Ste 1
Edina, Mn 55439

Re: Use of the Irrigreen irrigation system in Florida Water StarSM

Dear Ms. Levin;

Thank you for your staff's recent demonstration of the water efficiency of the Irrigreen sprinkler system. Thanks also for the links to the recent performance research. As I discussed with your staff, this system is different than traditional irrigation systems with multiple irrigation sprinklers in every zone. The Florida Water Star criteria address typical design performance standards so a landscape with Irrigreen does not meet the criteria as designed.

Based up the information shared at the meeting and the CIT research report, a landscape with the Irrigreen system does have the ability to meet the efficiency standard expected in Florida Water Star irrigation systems. Upon designing a system with a client seeking certification, feel free to reach out to me to go over specific details of that design so that I can confirm the design will meet the criteria that are applicable.

I am available at (386) 546-8437, should you have any questions regarding this letter.

Sincerely,

A handwritten signature in black ink, which appears to read 'Deirdre Irwin'. The signature is fluid and cursive, with a large initial 'D'.

Deirdre Irwin, Water Conservation Coordinator

Bureau of Water Supply Planning

C: Darrell Leyman, Triconic LLC.

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Evaluating Sprinkler Operational Efficiency using SMS

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Abstract. *Evaluating irrigation sprinkler operational efficiency with catch cups is a labor-intensive process that provides data regarding the output of the irrigation system using mechanical spray and rotary sprinklers. Catch cups are a proxy for the available moisture in the soil due to many factors such as: soil saturation, soil type, run-off, etc. While soil moisture sensing (SMS) can automate the measurement process, much needs to be learned about the limits and benefits of using soil moisture to measure irrigation sprinkler operational efficiency. This presentation will cover examples of using soil moisture to measure sprinkler operational efficiency; limits in making before and after soil moisture measurements; advantages in using soil moisture sensing and what we still need to learn.*

Keywords. SMS, sprinkler, irrigation, efficiency, soil, moisture, measure.

Introduction

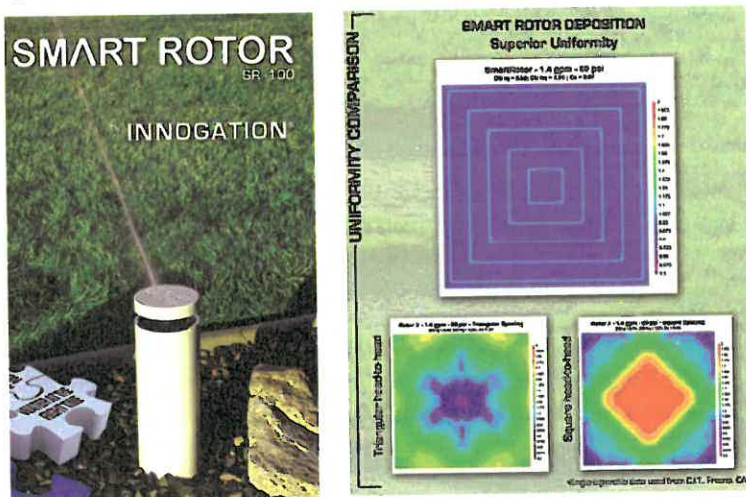
For many years, the irrigation industry has used catch-cups to sample water output from irrigation sprays and rotors to evaluate water application efficiency. The most common method is to compute distribution uniformity lower quartile (DULQ). DULQ is computed from a set of data by taking the average of the lower 25% of the data set compared to the average of the entire data set. More recently, the industry has defined the SWAT protocol which defines methods of placing catch-cups along with calculations for operational efficiency. SWAT operational efficiency is computed by subtracting percolation losses and overspray losses. The percolation loss is computed by taking sum of the differences of the upper 75% of the data points minus the 75% data point divided by the sum of the entire data set. For this paper, the term *efficiency* will simply mean how efficiently a sprinkler is applying water in the field. The term *digital* refers to controlling a sprinkler rotation and throw distance using digital electronics.

Smart Water Application Technologies (SWAT)

According to the Irrigation Association website: "*Smart Water Application Technologies is a partnership of water providers and irrigation companies, working to promote landscape water-use efficiency through innovative technology.*" The SWAT Spray Head Sprinkler Nozzles Performance Characteristics testing protocol defines test methods, test shapes and calculations such as: precipitation rate, distribution uniformity, overspray losses, percolation losses and operational efficiency.

New Technology Influence on Sprinkler Measurement

In 2013, IrriGreen began offering a digital irrigation sprinkler that used multiple streams of water to uniformly water the soil by setting stream volumes that match the area at each stream distance. This new technology created challenges using catch-cup measurements to measure water application efficiency because some streams miss the catch-cups while others are deflected by the catch-cups. Like previous digital irrigation sprinklers (Figure 1) which used digitally adjusted spray or streams, catch-cups did not tell us what is happening in soil when the sprinkler output is streaming and moving. Do we need an alternative measurement of digital sprinkler efficiency that uses soil moisture measurements?



“Based on the dryness distribution plot in Figure 3, an intelligent system can reduce water use by 40% to 50% in most cases.”

- Robert Walters

Figure 1 – Adjustable Spray Sprinkler by Innogation

Multi-Volume, Multi-Stream Nozzle Catch-Cup Measurements

In 2012 and 2013, IrriGreen did extensive catch-cup testing to refine the performance of a multi-volume, multi-stream nozzle. Figure 2 shows an example of how early testing was performed using 6-inch catch-cups. The catch-cups close to the nozzle lost water due to stream deflection while the catch-cups farther away missed water falling between the catch-cups. To improve the result, measurements were done with catch-cups adjacent to one another. While this works fine for research, it is not very practical in the field.

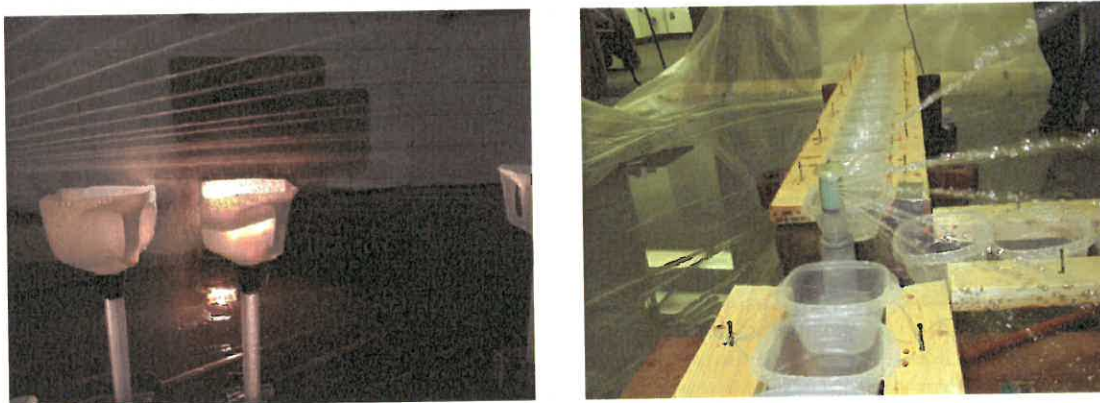


Figure 2 – Multi-Stream, Multi-Volume Nozzle

The resulting data from this early development was used to refine the IrriGreen nozzle to design the distance between the streams so the soil would be able to fill in the gaps like drip irrigation. Figure 3 shows how the water volume changes with distance for the multi-stream nozzle.

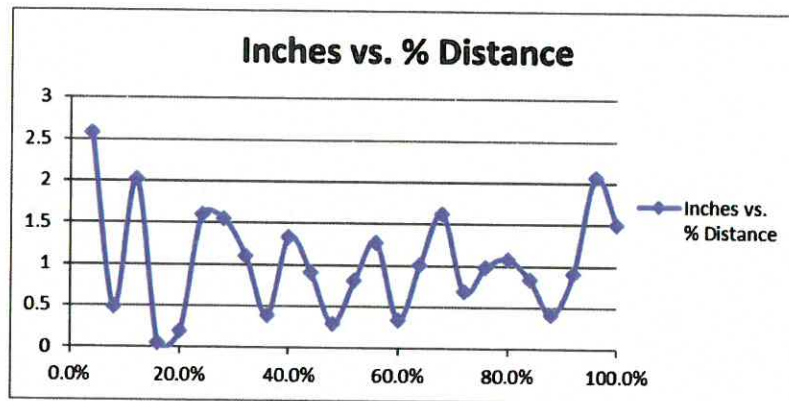


Figure 3 – Multi-Volume, Multi-Stream Digital Sprinkler

Uniformity Testing with Brian Horgan, PhD. University of Minnesota

In 2014, IrriGreen worked with Brian Horgan, PhD. from the University of Minnesota to perform catch-cup and soil moisture testing on turf. He used both catch-cups and a Spectrum TDR-300 soil moisture probe to make measurements. The goal was to sample test areas of turf grass where 3 mechanical rotors overlapped versus one IrriGreen digital sprinkler. He tested three 10 x 10 plots of turf grass. In his report, the coefficient of uniformity for catch-cups was 0.91 for a mechanical rotor and 0.68 for IrriGreen. When using TDR soil moisture measurements both mechanical and IrriGreen had 0.85 coefficient of uniformity. (Full report available at www.irrigreen.com)

Mark A. Crookston, P.E., D.WRE, Northern Water, Berthoud, CO 80513

Mark Crookston, Irrigation Management Department Manager at Northern Water heard about the IrriGreen system in 2016 and took the approach of using very large catch-cups (5-gallon pails) to overcome the difficulty of measuring streams. This yielded a DULQ of 0.58 and a SWAT sprinkler operational efficiency of 67%, not a very practical method to use in the field.



Figure 4 – Digital Sprinkler Test, Northern Water

Digital Sprinkler Testing at the Center for Irrigation Technology (CIT)

In 2016, IrriGreen worked with the Center for Irrigation Technology at Fresno State to test the IrriGreen digital sprinkler. We ran 3 tests: 30 x 60 rectangle, 30-foot square and 30-foot circle with the latter 2 tests defined by the SWAT protocol. CIT selected best-in-class mechanical irrigation sprinklers to be tested on the same plots as digital sprinklers. In each case there was one digital sprinkler in the center compared to 6-9 mechanical sprinklers around the edge. We tested on turf so we could perform catch-cup testing and soil moisture testing side by side.



Figure 5 – CIT Testing Digital Sprinkler

CIT Testing Considerations

The team at CIT used mechanical rotor sprinklers in the 30 x 60 rectangle to water the turf for 58 minutes using 2 GPM nozzles. Using mechanical rotors sprinklers as a reference, the IrriGreen team calculated the mechanical sprinklers low quarter and set the IrriGreen system to match at 5 revolutions, about .275 inches. At the time, we asked several experts including Dr. Michael Dukes about when to make SMS measurements and decided to make them immediately after making catch-cup measurements and at 3 hours. We wanted to make sure we did not over saturate the soil for either mechanical or digital sprinklers. For instance, the center areas of Figure 6 represent areas of high precipitation for mechanical sprinklers.

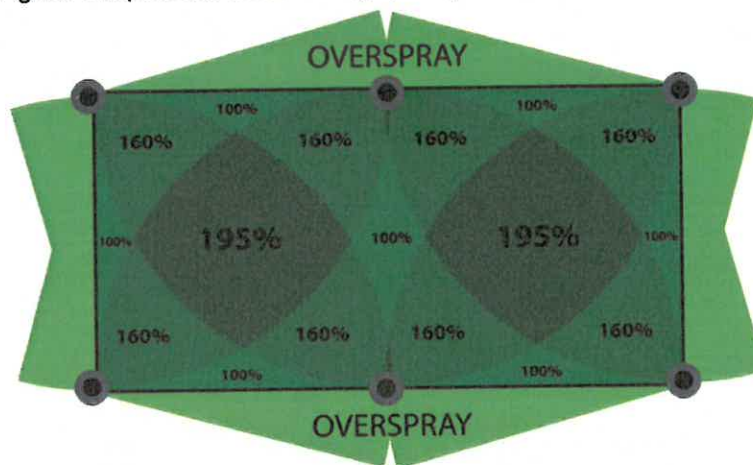


Figure 6 – Overlap and Overspray from Mechanical Sprinklers (0.65 DULQ)

Unlike a mechanical sprinkler that overlaps and is positioned head-to-head, a digital sprinkler is placed in the center of the landscape and waters uniformly from the inside out. For the digital sprinkler, areas of high and low soil moisture measurement occur between the streams as shown in Figure 3.



Figure 7 – Example Mechanical and Digital Sprinklers

CIT Test Results

As expected due to the challenge of using catch-cups with streams, the distribution uniformity and operational efficiency numbers for the digital sprinkler catch-cup measurements are lower than mechanical measurements in Table 1. The same uniformity and efficiency measurements for the digital sprinkler using SMS data are closer to mechanical measurements. Assuming SMS readings are valid measurements for operational efficiency, then the digital sprinkler performed nearly as well as the mechanical sprinkler. (Full CIT report is available at www.irrigreen.com)

CIT Test	SWAT Operational Efficiency	DULQ
Mechanical Sprinkler CC	80%	0.71
Digital Sprinkler CC	54%	0.43
Mechanical Sprinkler SMS	70%	0.37
Digital Sprinkler SMS	65%	0.55

Table 1 – CIT 30 x 60 Test Result Summary Mechanical and Digital Sprinklers

Differences in gallons collected

What is even more dramatic than the differences in SMS versus catch-cups measurements, is the difference in the volume of water collected given a similar change in soil moisture, about 40% less volume (gallons) for digital versus mechanical sprinklers. (With catch-cups it is unnecessary to collect volume because the cup is a volume measurement). Volume and SMS measurements may tell us more accurately what is happening in the soil. These results led IrriGreen to plan additional research into using SMS as a measurement for sprinkler efficiency.

Working with Dr. Dukes, University of Florida on SMS measurements

It became clear from the work done at CIT that in the future the irrigation industry may need an alternative way to measure sprinkler performance using soil moisture measurements. Given Dr. Michael Dukes past research in soil moisture measurements in the field, IrriGreen chose to work with Dr. Dukes and the University of Florida to perform further research into using soil moisture as a performance measurement and use the resulting protocol to test mechanical and digital sprinklers with more replication.

What SMS Measurements Are Needed

Since there are physical boundaries for using SMS as a measurement tool, we decided to define what those are. Like a catch-cup, soil can only hold so much water so we needed to define those measurement boundaries. Here is the process we chose for doing the research:

1. Installation and set-up of 1 IrriGreen Genius® Sprinkler (30 x 60 ft. turf plot).
2. Installation and set-up of a conventional 6 rotor system (same 30 x 60 ft. turf plot).
3. Estimate Volumetric Water Content (VWC) range based on starting an irrigation event at 8% VWC (maximum allowable depletion) and ending it at 12% VWC (field capacity).
4. Calculate and run 1 IrriGreen Sprinkler from 8% VWC (maximum allowable depletion) and ending it at 12% (field capacity).
5. Calculate and run 6 mechanical rotors from 8% VWC (maximum allowable depletion) and ending it at 12% (field capacity).
6. Compare results from 4 & 5 above, and re-calculate and re-run if necessary.
7. **INTERIM RESULT:** Have a good idea of which is the maximum allowable depletion point and which is the average field capacity of the area.
8. Run 1st set of comparative tests for delta VWC percentages based on the designed irrigation event determined in Step 7 above (includes tests for catch-cup results – immediately after irrigation, SMS probe – immediately, SMS – 3 hours after and SMS – 24 hours after).
9. Run 2nd set of comparative tests for delta VWC percentages based on insufficient water than designed irrigation event determined in Step 7 above (includes tests for catch-cup results – immediately after irrigation, SMS – immediately, SMS – 3 hours after and SMS – 24 hours after).
10. Run 3rd set of comparative tests for delta VWC percentages based on excess water than the designed irrigation event determined in Step 7 above (includes tests for catch-cup results – immediately after irrigation, SMS – immediately, SMS – 3 hours after and SMS – 24 hours after).
11. **FINAL RESULT:** Write a report that can be distributed by UF and IrriGreen showing study results.

University of Florida Field Measurements Steps 1 – 6



Figure 8 Test Areas of Turf Grass at the University of Florida

The first half of the research process has been performed by the University of Florida yielding the results shown in Figures 9 and Table 2. Figure 9 shows the average VWC at 0, 3 and 24 hours. Figure 9 shows that making immediate measurements will yield better results because the water is rapidly draining and redistributing in the soil. Table 2 shows mechanical and digital sprinkler measurements at 0.5-inch application yielding 8%-10% change in VWC and 1-inch application yielding 15%-16% rise in VWC.

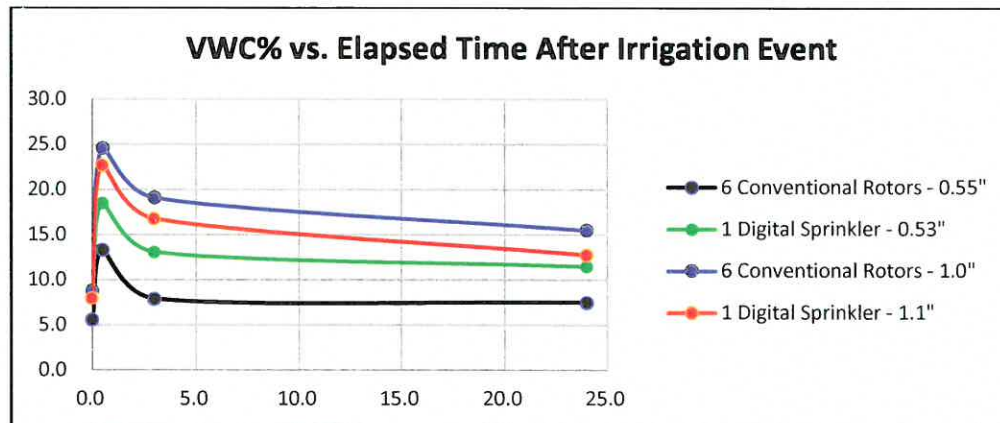


Figure 9 – Soil Volumetric Water Content Over Time

UF SMS Test	Delta VWC	SWAT Operational Efficiency	DULQ
Mechanical Sprinkler 0.5 in.	8%	53%	0.45
Digital Sprinkler 0.5 in.	10%	67%	0.38
Mechanical Sprinkler 1 in.	16%	83%	0.74
Digital Sprinkler 1.1 in.	15%	77%	0.66

Table 2 – UF 30 x 60 Test Result Summary Mechanical and Digital Sprinklers

Figure 10 graphs the data for the results in Table 2. While the curves are similar between digital and mechanical sprinklers, the digital sprinkler has more low and high data points, possibly due to using streams instead of sprays. Both mechanical and digital sprinkler curves become flatter at high soil saturation.

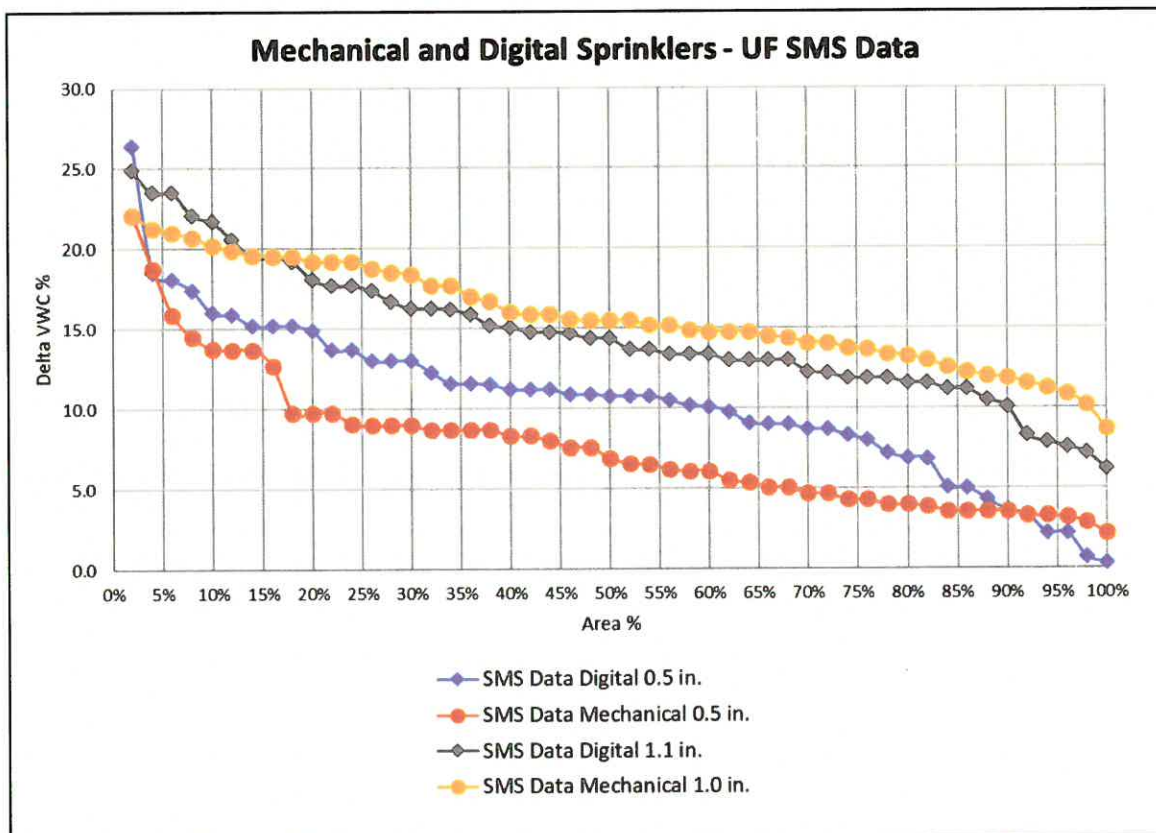


Figure 10 – UF 30 x 60 Test Results Mechanical and Digital Sprinklers

University of Florida Field Measurements Steps 7 - 11

Based on the interim results in steps 1-6, the final testing will be run at 0.25-inch, 0.5-inch and 1-inch of water application to give us a range in which to determine the optimal test result. Catch-cup tests will be taken alongside of soil moisture tests for reference. These results will be reported when available.

Conclusion Using SMS Data to Measure Sprinkler Efficiency

Volume and soil moisture measurements show promise as an alternative way to measure sprinkler efficiency. There is more to be learned about how the application rate and volume affect SMS measurement results. After we complete our research and based on our findings, IrriGreen and the University of Florida will run additional turf grass tests with both digital and mechanical rotors adding more replication to better understand the use of SMS data to measure sprinkler efficiency. We will publish these results in 2018.

Acknowledgements

www.innogation.com

Dr. Brian Horgan, PhD., Turf Grass Consultant, University of Minnesota

Mark A. Crookston, P.E., D.WRE, Irrigation Management Department Manager, Northern Water

David Zoldoske Ed.D, Tim Jacobsen, Edward Norum, CID, Fresno State, Center for Irrigation Technology

Dr. Michael D. Dukes, PhD., P.E., University of Florida, Agricultural and Biological Engineering Dept.

Jeffrey Woodson, Director of Operations, IrriGreen, Inc, Edina, MN.

