Alliance
for Water
Efficiency

Peak Day Water Demand
Management Study
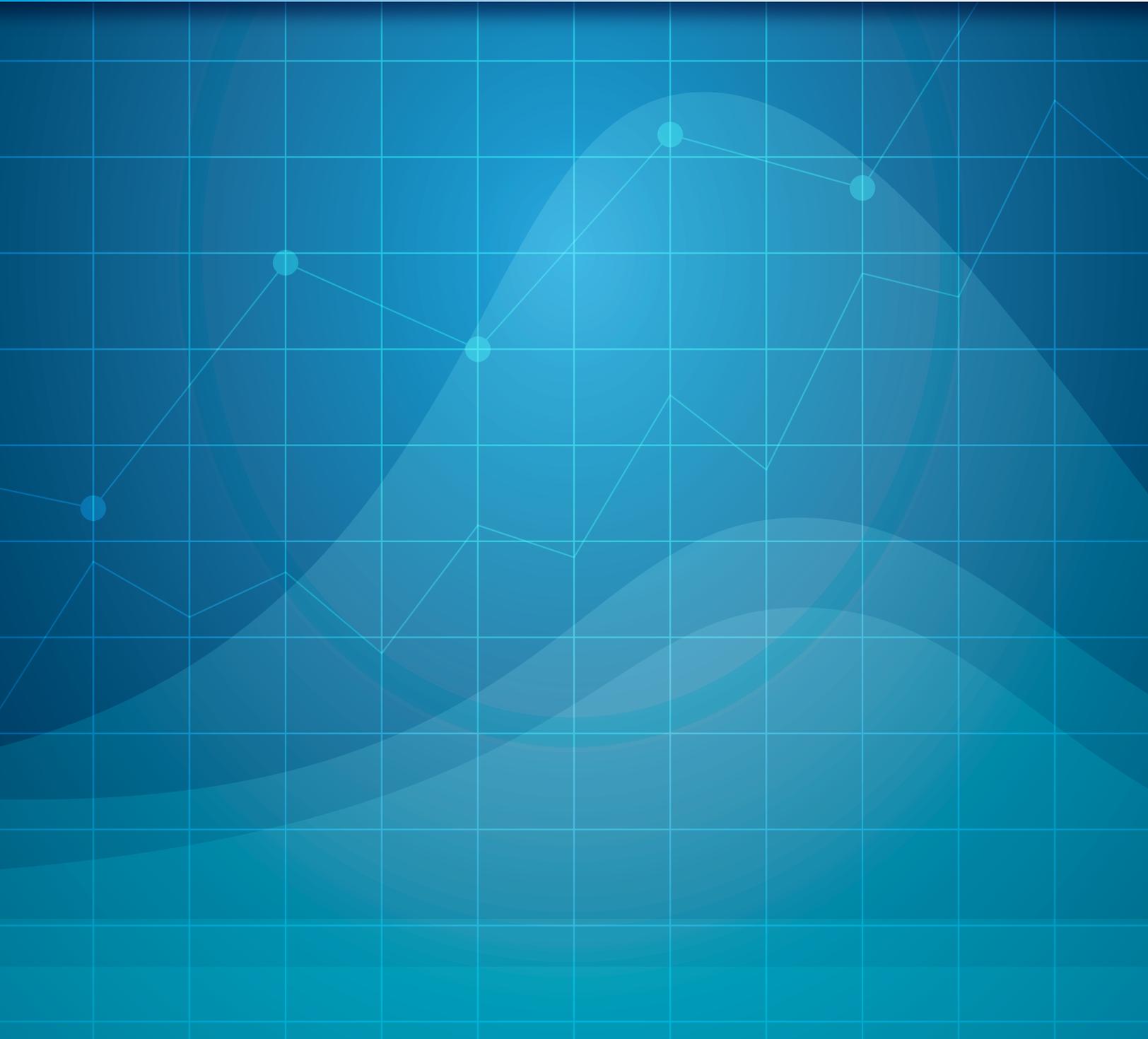
JULY 2017

PEAK DAY WATER DEMAND MANAGEMENT STUDY

JULY 2017

By

Peter Mayer, P.E.
Principal
WaterDM

and

Rebecca Smith
Ph.D. Candidate
Dept. of Civil, Environmental and Architectural Engineering
University of Colorado, Boulder

On behalf of

Alliance for Water Efficiency
33 N LaSalle Street, Suite 2275
Chicago, IL 60602
+1-773-360-5100 | www.a4we.org

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This research would not have been possible without the assistance, dedication, and support of the following individuals:

New Jersey American Water

- Margaret Hunter
- John Kij
- Kevin Keane
- Jonathan Fink

Middletown Sprinkler Company

- Robert Dobson

Rachio, Inc.

- Ric Miles
- Clay Kraus
- Emil Motycka

Alliance for Water Efficiency

- Mary Ann Dickinson
- Jeffrey Hughes
- Megan Chery

EXECUTIVE SUMMARY

In 2016, New Jersey American Water (NJAW) partnered with Peter Mayer, P.E. of WaterDM, Rachio smart irrigation control company, and Middletown Sprinkler Company to conduct a peak water demand shaving pilot project. The objectives of the study were to: determine the viability of using remotely-controlled irrigation systems to reduce peak water demands and thus delay or avoid costly infrastructure, to test implementation methods, and to discover potential barriers for water providers who want to use the technology.

In August, fifteen NJAW customers agreed to have their irrigation remotely interrupted on two separate dates. Irrigation programs were successfully interrupted and resumed normal operation the following day, demonstrating the ability to precisely target specific sites and dates to shave peak demands. Based on historic water use records of the participants, an estimated total of 84 kgal of peak demand reduction occurred on each day of interruption.

Further analysis of historic irrigation patterns was undertaken to extrapolate the potential peak reduction that could be seen if this method was implemented on a larger scale. The results of the analysis suggest that 1 MGD of irrigation reduction can be achieved with approximately 500 to 1,700 participants; reduction of 5 MGD can be achieved with approximately 2,500 to 8,600 participants; and a 10 MGD-reduction can be achieved with approximately 5,000 to 17,300 participants[1].

Considering the potential peak shaving impact that relatively modest customer participation could have, larger-scale application of this method is recommended. However, the limited success of this study in recruiting participants shows that future projects would be helped by increasing customers' understanding of the irrigation controllers and by developing better recruitment materials and methods.

---

[1]Variability in landscape size, character, and irrigation system output necessitate a broad range estimate, particularly when extrapolating from a small sample. Future research will further refine these estimates.

INTRODUCTION

Water utilities across the U.S. must size their water treatment infrastructure and system capacity to satisfy the maximum daily (and even hourly) water demands of their customers. Most water providers experience the peak day demand during the height of summer when many customers simultaneously operate their automatic irrigation systems on the same day. Providing continuous, reliable water service is a cornerstone objective of the water industry; thus, water treatment infrastructure must be up-sized to ensure production capacity is sufficient to meet the peak day.

Automatic irrigation systems are an increasingly popular amenity for homes and businesses offering convenience and higher landscape quality, but automatic irrigation may result in substantially higher water demands which drives the need for increased water system production capacity. Expanding system capacity is expensive and results in rate increases for all customers; thus, programs that can delay or eliminate the need for capacity expansion may offer tremendous cost savings.

Electric Utilities Reduce Peaks

Electric utilities have confronted the issue of peak day and peak hour demands for many years and have developed sophisticated demand-response peak shaving programs that have effectively cut demands and reduced the need for expanded generation capacity. The general approach taken by electric utilities is to enter into an agreement with customers that enables the utility to remotely cut back or shut down air-conditioning equipment during peak demand periods. Customers are provided financial incentives and occasionally free equipment in exchange for participating in the program. Publicly regulated energy utilities are provided revenue recovery for investment in these demand side management programs and investment can be capitalized.[2] These peak reduction efforts have been highly successful and are widely practiced across the US by electric utilities facing peak demand constraints.

Peak Day Water Demand Management

New technological developments in the irrigation industry offer an opportunity for water providers to mimic the demand-response peak reduction programs from the electric industry. Specifically, it is now possible to remotely control and program an irrigation system to reduce or eliminate irrigation on any given day using a web-enabled irrigation controller. It is possible to remotely halt irrigation across hundreds or even thousands of internet-based irrigation controllers within a water service territory.

For the first time, water providers have the potential to anticipate peak day demands and to effectively reduce or "shave" the peak by shifting the timing of irrigation at a sufficient number

---

[2]A comparable policy is not available in the publicly regulated water sector, but could be beneficial.

of sites to impact the peak. This could create a paradigm shift for the water industry. If a utility can reliably reduce peak day demands, while at the same time maintaining a high level of customer service and satisfaction, it is possible that expensive expansion to water treatment infrastructure can be delayed or even avoided completely, offering tremendous cost savings.

While electric peaks are often controlled in 15 minute increments and generated by multiple sources serving many communities, finished water is typically treated and stored locally and water systems are sized to meet or exceed the anticipated maximum peak day (24 hours) of water use of each specific community. In many communities with automatic irrigation systems, simultaneous operation drives the peak day demand each summer and thus also drives new infrastructure costs.   Managing occasional summertime peak demands through remote irrigation system management poses a potential low-cost, customer-oriented approach for water utilities.

2016 PEAK DEMAND MANAGEMENT PILOT RESEARCH

In 2016, a pilot research project was conducted to determine the viability of peak water demand reduction through remote control of irrigation systems for water utilities and to gain insight into implementation methods and barriers. The study was conducted by New Jersey American Water (NJAW) (www.amwater.com) in partnership with WaterDM under contract with Alliance for Water Efficiency, the Rachio smart irrigation controller company

Figure 1: *Rachio Irrigation Controller and Mobile App*

(www.rachio.com), and subcontractor Middletown Sprinkler Company.

Rachio, Inc. is an irrigation controller company based in Denver, Colorado that developed a Smart Water Application Technology (SWAT)-tested, WaterSense-approved smart irrigation controller that is programmed remotely and offers utilities the ability to simultaneously remotely control any number of irrigation controllers installed in their service area. Other smart irrigation control technologies have some similar capabilities, but Rachio is unique in that all programming for the controller is accomplished via the Internet and there are no buttons, dials, or controls of any kind on the controller. The Rachio controller is suitable for residential and small commercial installations (offering control for 8 to 16 zones) and the company is developing a larger controller for parks and common areas. Zones are areas in a customer's yard that have different watering requirements and can be independently controlled.

In this study, conducted during the summer of 2016, Rachio internet-based irrigation controllers were installed at no cost to customers at fifteen residential customers in Rumson, New Jersey. On two selected days, these 15 controllers were simultaneously shut off for a 24-hour period, thus eliminating the contribution of these fifteen irrigation systems to the peak demand on those days. Monthly billed consumption data were analyzed to estimate the impact of the peak reduction experiment.

RESEARCH METHODS

The research team worked closely with staff from NJAW to select the appropriate site location for the study and to recruit participants.

Study Site Selection

To determine the most beneficial location for the Peak Reduction Pilot in the Coastal North service area, the NJAW team performed a high-level GIS analysis, using customer billing data for the year of 2015. Residential customers in this service area are billed monthly. Two fields were added to the dataset using preexisting data to compare customer consumption across the service area: "discretionary use" and "peaking factor." Both of these metrics are essential in understanding residential customer usage patterns.

$$(Apr + May + Jun + Jul + Aug + Sep) - (Jan + Feb + Mar + Oct + Nov + Dec)$$
$$= Discretionary\ Use$$
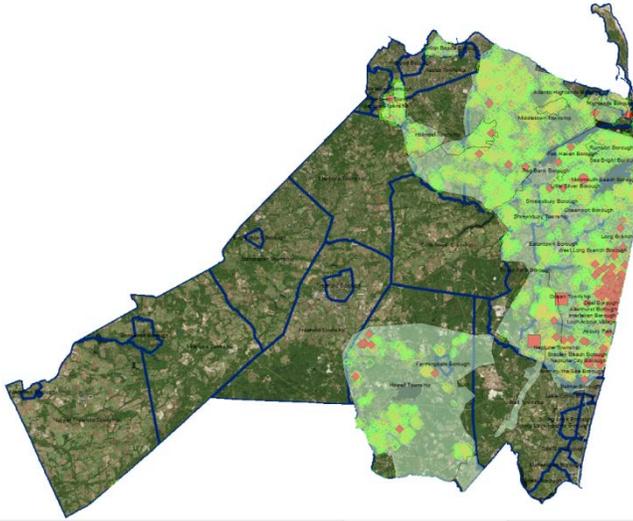
Figure 2: *New Jersey American Water Service Area*

$$\frac{Apr + May + Jun + Jul + Aug + Sep}{Jan + Feb + Mar + Oct + Nov + Dec} = Peaking\ Factor$$

Each residential customer was categorized by both discretionary use and peaking factor. Customers with both high discretionary use and high peaking factor are good candidates for peak-shaving efforts because reducing a single day of their irrigation levels can have a significant impact on system demand. Clusters of such customers were identified within smaller, easy to monitor gradients, or service blocks. Based on this assessment, several locations were identified as potential pilot locations.

Potential Study Site Locations

Three potential study site locations were identified: the Holmdel gradient; the Rumson gradient; and the Water Witch gradient. Characteristics of these three locations are shown in Table 1.

Table 1: *Potential Study Site Locations*

Gradient	Township / Borough	Customers in Gradient	2015 Use (mg)	Discretionary Use % of Selected Customers[3]
Holmdel	Holmdel	560	71.996	21%
Rumson	Rumson	155	34.73	64%
Water Witch	Middletown	830	72.332	24%

The customers in the southeast portion of the Holmdel gradient could have been targeted for the pilot based on their measured discretionary use and peaking factor combinations. The Water Witch gradient, located in Middletown, NJ contains 830 premises, but this gradient is geographically separated into two locations making it less than ideal from an implementation perspective. The Rumson gradient, ultimately the site selected for the study, is located in Borough of Rumson, NJ and is shown in Figure 3. Furthermore, it has a higher outdoor use than Holmdel, making it a more attractive study site because of the potential for greater peak reduction. The Rumson gradient contains 155 customer premises, and was targeted for participation based on measured discretionary use and peaking factors and ease of implementation due to the small size of the Borough from a communications perspective. Some participants were recruited from outside of the Rumson gradient, in the neighboring Borough of Fairhaven, to increase the overall sample size.

Figure 3: *The Rumson Gradient, Rumson, NJ. Dots Indicate Premises with High Discretionary Use and High Peaking Factors.*

---

[3]These customers were identified by American Water as potential participants. Metered consumption data were used to estimate discretionary (mostly outdoor) use.

Participant Recruitment

The NJAW team developed outreach materials and a participant application form to recruit participants from the Rumson gradient into the peak reduction study. Figure 4 is the recruitment brochure developed specifically for the study and Figure 5 is the participant application form. Additionally, other correspondence was sent to the Mayor of Rumson and other officials informing them of the intentions with the pilot study.

Invitations to participate were mailed to residents across the area and brochures were distributed through landscape maintenance companies.   The Rachio irrigation controller and installation was provided to customers as the key incentive to participate. Interested parties were asked to call NJAW. A script was prepared and used for telephone outreach and recruitment.

The recruitment process commenced in May 2016 and was concluded in mid-August 2016 to permit time for the experiments. Recruiting participants proved more challenging than expected. The Rumson gradient is a comparatively wealthy area of New Jersey and includes some larger properties and some famous residents. Originally NJAW hoped to install 30 or more Rachio units as part of the pilot, but after extensive efforts, mail and telephone recruitment, and even extending the breadth of outreach beyond the Rumson gradient, ultimately 15 residential participants volunteered for and were included in the project.

The NJAW team spent a substantial amount of time and effort to recruit these 15 participants including dozens of phone calls and follow up. For this type of project to be successful on a large scale, more efficient and effective methods of recruiting participants must be developed.

In addition, over the course of the pilot program, it was determined that more explicit communication is needed to assure customer satisfaction for this type of peak reduction program. The interface of the Rachio software was misleading in displaying volumetric savings amounts that were estimated and not based on actual metered data. The wording of recruitment brochures and education regarding the use of the controllers will need to be improved for future programs.

Site Review and Controller Installation

Once a participation application was received and approved, the task of inspecting each site for suitability and installing the Rachio irrigation controller was handled by Middletown Sprinkler, a local irrigation contractor under contract with Rachio. Middletown Sprinkler was critically important to the success of the project in recruiting participants and installing the Rachio controllers.

Middletown Sprinkler visited each potential site to establish suitability for the study, prior to installing the Rachio controller. In a few cases, potential participants could not be included

because of an incompatibility with their existing irrigation system and the Rachio controller. In a few cases, properties had enormous irrigation systems with zones exceeding the capacity of the largest Rachio controller. In these cases, potential participants were considered ineligible for the pilot program.

During the site visit, Middletown Sprinkler also completed a careful site report and inventory of each irrigation system in the study including:

- Make and model of the existing controller
- Number of zones
- Characterization of the landscape in each zone
- Historical irrigation programs
- Aerial site image
- Photo of the original controller

An example of one of the site reports prepared for this study is provided in Appendix A. Middletown Sprinkler's careful reporting on the systems enabled more accurate analysis of peak demand reductions.

Site visits and installations were completed on August 16, 2016, with a total of 15 sites equipped with Rachio controllers and set for the peak shaving pilot experiments.

Figure 4: *Study Recruitment Brochure Produced by New Jersey American Water*

Smart Irrigation Pilot Program
APPLICATION

NEW JERSEY AMERICAN WATER

1. Does your facility/property have an automatic irrigation system?
   - ❏ Yes (please proceed with survey)
   - ❏ No (Sorry to take your time. This pilot is focusing on properties that have irrigation systems installed.)

2. Approximately how many acres of land are you currently irrigating?
   - ❏ Approximately _____ acres
   - ❏ 0 to 5 acres
   - ❏ 5 to 10 acres
   - ❏ Greater than 10 acres

3. How many irrigation controllers/timers control your irrigation system? _____

4. How many irrigation zones do you have?? If you do not know exactly, please estimate. _____

5. Describe your current irrigation control system.
   - ❏ Individual timers/controllers
   - ❏ Controllers connected to a central computer
   - ❏ Smart Controllers
   - ❏ Other (please describe)_____
     _____

   Manufacture(s) of your irrigation controller(s) _____

   Model number(s) (if known) _____

   Does each controller have a rain sensor?
   - ❏ Yes, every controller has a rain sensor.
   - ❏ Some controllers have rain sensors.
   - ❏ No rain sensors.

   If your system has rain sensors:
   - ❏ The sensors have been tested and are functional.
   - ❏ The sensors have not been tested, but I believe they are functional.
   - ❏ I believe some of the sensors are not functional.
   - ❏ I do not know if the sensors are functional.

6. Does your facility have access to Internet? ❏ Yes. Internet provider: _____ ❏ No ❏ Not sure

7. How satisfied are you with the performance of your current irrigation system? ❏ Satisfied ❏ Neutral ❏ Dissatisfied

8. How would you rate the performance of your irrigation control system with regard to water consumption (Choose all that apply)?
   - ❏ I feel the irrigation control system adequately irrigate the landscape with an appropriate amount of water.
   - ❏ At times, I feel the irrigation control system applies more water than necessary to maintain a healthy landscape.
   - ❏ At times, I feel the control system does not apply sufficient water to maintain a healthy landscape.

9. Any additional information regarding your current irrigation system?

10. Contact information and best method of communication for follow up (Name and Email or Phone)?

Please complete and return by May 15 to:
Margaret Hunter, New Jersey American Water, 1025 Laurel Oak Road, Voorhees, NJ 08043 using the self-addressed envelope provided.

05-2015

Visit us online at www.newjerseyamwater.com

Figure 5: *Participation Application Form*

RESULTS

Peak Shaving Experiments

Two peak shaving experiments were conducted for this study during the summer of 2016. Experiment 1 was conducted on August 19 and Experiment 2 was conducted on August 26. The designated experiment days were selected by staff from NJAW in consultation with Rachio, WaterDM, and Middletown Sprinkler. The weekly weather forecast was scrutinized to anticipate a hot and dry experiment day when irrigation would normally occur.

The goal of the project was to conduct the peak shaving experiments during the peak New Jersey irrigation season in July and August. Since the recruitment and installation phase of the project stretched into August, it was imperative to conduct the experiments as soon as possible after installation was declared complete.

The goal of the project was to conduct two peak shaving experiments during the summer of 2016. At the conclusion of the two experiments on August 19th and 26th, the field research aspect of the project was concluded.

Experiment 1 – August 19, 2016

On August 16, the research team reviewed the weather forecasts and selected Friday, August 19, 2016 as the date for the first experiment.

NJAW sent an email message to the study group participants two days prior to the experiment. The email specifically instructed participants not to irrigate manually or to adjust their smart controller in any way on the designated day of the experiment. A copy of this email is provided in Appendix B.

On Thursday, August 18, Rachio sent electronic instructions to the 15 designated irrigation controllers in Rumson, NJ, to cease irrigation for a 24-hour period beginning at 12:01 a.m. on August 19 and ending at 11:59 p.m.

Rachio received confirmation of the 24-hour irrigation delay from each of the 15 Rachio controllers, but when data was downloaded from each individual irrigation controller it was found that on August 19, irrigation was remotely halted at only 14 of these 15 sites (93.3%).[4] Analysis of controller records show that the single participant that irrigated on August 19 manually intervened to override the shutoff sent from Rachio.

---

[4]The irrigation shutoff confirmation messages were saved by the project team, but are not included in this report as they include identifying information about the study participants who were guaranteed anonymity.

A summary of the irrigation system operation patterns in the days leading up to and immediately following Experiment 1 are shown in Table 2. Irrigation resumed at the 14 shutoff sites on August 20, the day following the experiment. Please note that the volumes irrigated are not listed as the participants' meters were read and billed monthly. This pilot would be best combined with Advanced Metering Infrastructure (AMI) or daily meter reads for customers to get more frequent feedback regarding the volume of their irrigation use and thus the impact to their bill.

Table 2 also shows the maximum and minimum temperature (°F) and the inches of precipitation for each day, measured at the Borough of Rumson weather station. August 19, the day of the experiment was hot and dry as anticipated, exactly the type of day when irrigation typically occurs.

Table 2: *Irrigation System Operation Patterns, Experiment 1*

Household	8/14/16	8/15/16	8/16/16	8/17/16	8/18/16	8/19/16	8/20/16
1	0	0	0	0	X	0	X
2	0	0	0	X	X	0	X
3	X	X	X	X	X	0	X
4	X	X	0	0	0	0	X
5	X	X	X	X	X	0	X
6	X	X	0	X	0	0	X
7	X	0	X	X	X	0	X
8	X	X	X	X	X	0	X
9	X	X	X	X	X	0	X
10	X	X	X	X	X	0	X
11	X	X	X	0	0	0	X
12	X	X	X	X	X	0	X
13	0	0	X	0	0	X	0
14	X	X	0	X	0	0	X
15	X	0	X	0	0	0	X
Max. Temp	99.7°F	89.6°F	94.5°F	91.6°F	87.1°F	93.4°F	90.7°F
Min. Temp	79.5°F	75.9°F	76.1°F	73.8°F	73.2°F	71.6°F	71.4°F
Precip. (in.)	0	0	0	0.09	0.02	0	0
X	= irrigation system operated			0	= irrigation system idle		

Experiment 2 – August 26, 2016

The research team selected Friday, August 26, 2016 as the date for the second experiment.

NJAW once again sent an email message to the study group participants two days prior to the experiment. The email specifically instructed customers not to irrigate manually or to adjust their smart controller in any way on the designated day of the experiment. A copy of this email is provided in Appendix B.

On Thursday, August 25, Rachio sent electronic instructions to the 15 designated irrigation controllers in Rumson, NJ, to cease irrigation for a 24-hour period beginning at 12:01 a.m. on August 26 and ending at 11:59 p.m.

Rachio received confirmation of the 24-hour irrigation delay from each of the 15 Rachio controllers, but when data was downloaded from each individual irrigation controller it was found that on August 26, irrigation was remotely halted at only 14 of these 15 sites (93.3%).[5] Analysis of controller records once again show that the single participant (a different one this time) that irrigated on August 26 manually intervened to override the shutoff sent from Rachio.

A summary of the irrigation system operation patterns in the days leading up to and immediately following Experiment 2 are shown in Table 3 Irrigation resumed at the 14 shutoff sites on August 27, the day following the experiment.

Table 3 also shows the maximum and minimum temperature (°F) and the inches of precipitation for each day, measured at the Borough of Rumson weather station. August 26, the day of the experiment was hot and dry as anticipated, exactly the type of day when irrigation typically occurs.

On August 22, Middletown Sprinkler manually shut off irrigation at most participating study sites in response to substantially cooler temperatures. This was for irrigation management purposes and was not considered part of the peak shaving experiment.

---

[5]The irrigation shutoff confirmation messages were saved by the project team, but are not included in this report as they include identifying information about the study participants who were guaranteed anonymity.

Table 3: *Irrigation System Operation Patterns, Experiment 2*

Household	8/21/16	8/22/16	8/23/16	8/24/16	8/25/16	8/26/16	8/27/16
1	0	0	X	X	X	0	X
2	0	0	X	X	0	0	X
3	0	0	X	X	X	0	X
4	X	0	X	0	X	X	X
5	0	0	X	X	X	0	X
6	0	0	X	X	0	0	X
7	0	X	0	X	X	0	X
8	X	0	X	X	X	0	X
9	0	0	X	X	X	0	X
10	0	0	X	X	X	0	X
11	0	0	X	X	X	0	X
12	X	0	X	X	X	0	X
13	X	0	X	X	X	0	X
14	0	0	X	X	X	0	X
15	0	0	0	X	0	0	0
Max. Temp	87.1°F	82.8°F	86.4°F	90.5°F	86.7°F	94.8°F	89.2°F
Min. Temp	73.0°F	67.1°F	58.8°F	61.2°F	65.3°F	72.1°F	69.6°F
Precip. (in.)	0	0	0	0	0	0	0
X	= irrigation system operated			0	= irrigation system idle		

Analysis of Customer Water Billing Records

At the conclusion of the peak shaving study period, up to ten years of monthly billed use data (January 2007 through August 2016) were provided for each participating household. The amount of consumption data available for each customer is subject to length of time the accounts have existed.

Non-Seasonal and Seasonal Use

Figure 6 characterizes each of the 15 households by their total annual use, separated by non-seasonal (indoor) and seasonal (outdoor) uses. Total annual use was calculated by taking the average annual use from the five most recent full years available (2011 through 2015), but fewer years were used where the accounts did not have a five-year record.

Average non-seasonal use was calculated by averaging the use from the five most recent December, January, and February monthly use totals, also subject to length of the accounts' billing histories. Once non-seasonal use was established, seasonal use was taken as the difference between total annual use (averaged from the preceding 5 years) and non-seasonal use. The customers in this study capture a wide range of total, indoor, and outdoor usages.

Annual Household Water Use
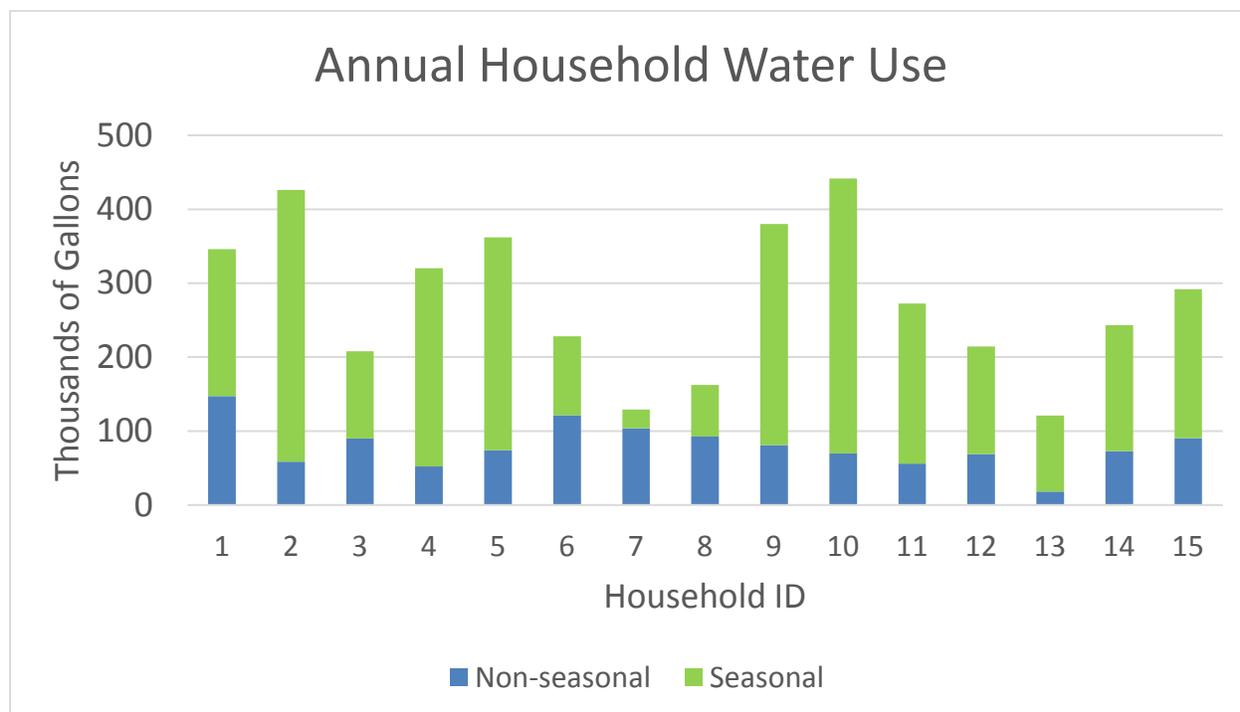
Figure 6: *Average Annual, Seasonal, and Non-Seasonal Household Water Use in 15 Participating Households, Averaged from 2011-2015*

Across the 15 households, average total annual water use was 276 thousand gallons (kgal). Household 13 had the lowest annual water use at 121 kgal, and Household 10 had the highest annual use at 442 kgal. Average annual non-seasonal use for the group was 80 kgal. The minimum non-seasonal use was again Household 13 with 18 kgal, and Household 1 had the highest non-seasonal use with 147 kgal per year.

Average annual seasonal use for these households was 197 kgal. Household 7 had the lowest annual seasonal use at 25 kgal, and Household 10 had the highest at 372 kgal. For this group, the average seasonal-to-total annual use was 67%. Household 7's seasonal use was 19% of its total use (lowest), and 86% of Household 2's total use was seasonal (highest).

Irrigation Demand

Monthly water use and historic irrigation patterns were used to determine how much water could be shifted at each household by eliminating an average irrigation day during peak irrigation season. Peak 2016 monthly use was determined by subtracting the historic average monthly indoor use (i.e. the volume represented in Figure 6) from both July and August 2016 billing data. The highest resulting value was taken as the household's peak 2016 monthly outdoor use, shown in Figure 7.

Peak 2016 Monthly Outdoor Use
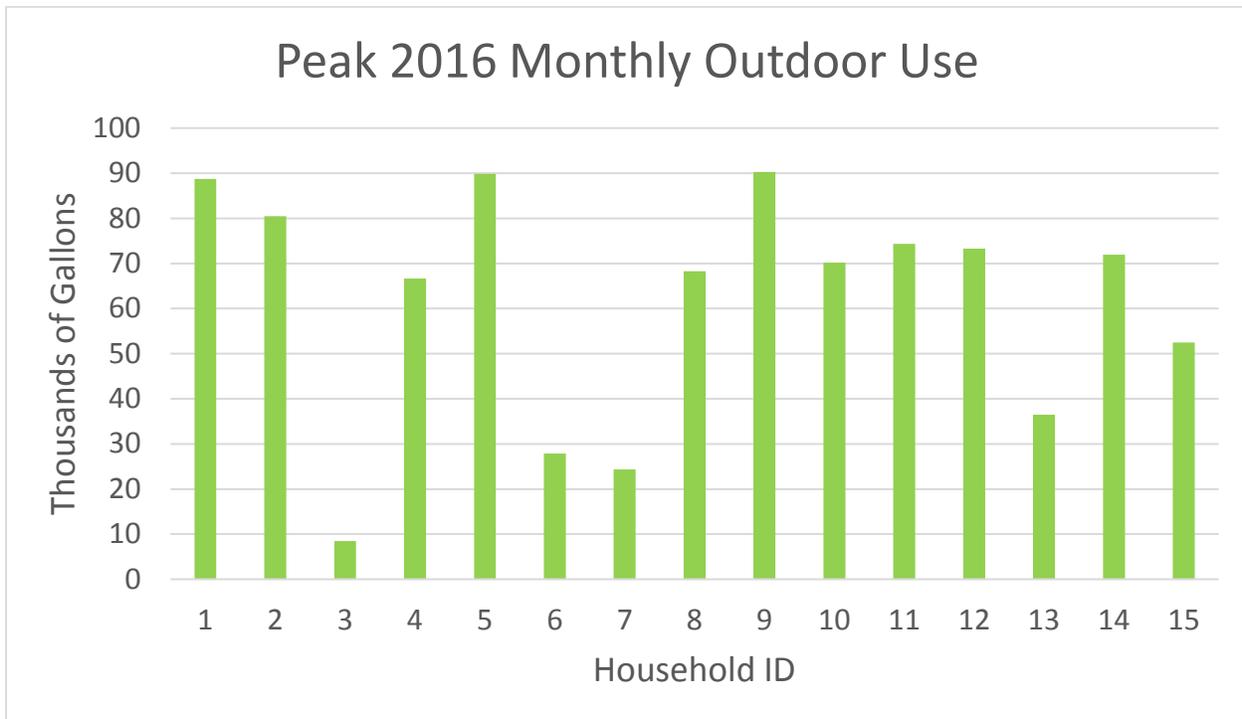
Figure 7: *Peak 2016 Outdoor Water Use Among Study Participants*

The average peak monthly use among these households for 2016 was 62 kgal. Household 3 had the lowest peak monthly use at 9 kgal, and Household 9 had the highest peak monthly use at 90 kgal.

Each household's automated irrigation program (or manual irrigation schedule) was recorded during the in-home interviews. This information was used to estimate the typical number of days per month that each household had been irrigating. Figure 8 shows the distribution of irrigation frequencies among these households.

Irrigation Frequency Before 2016 Pilot Study
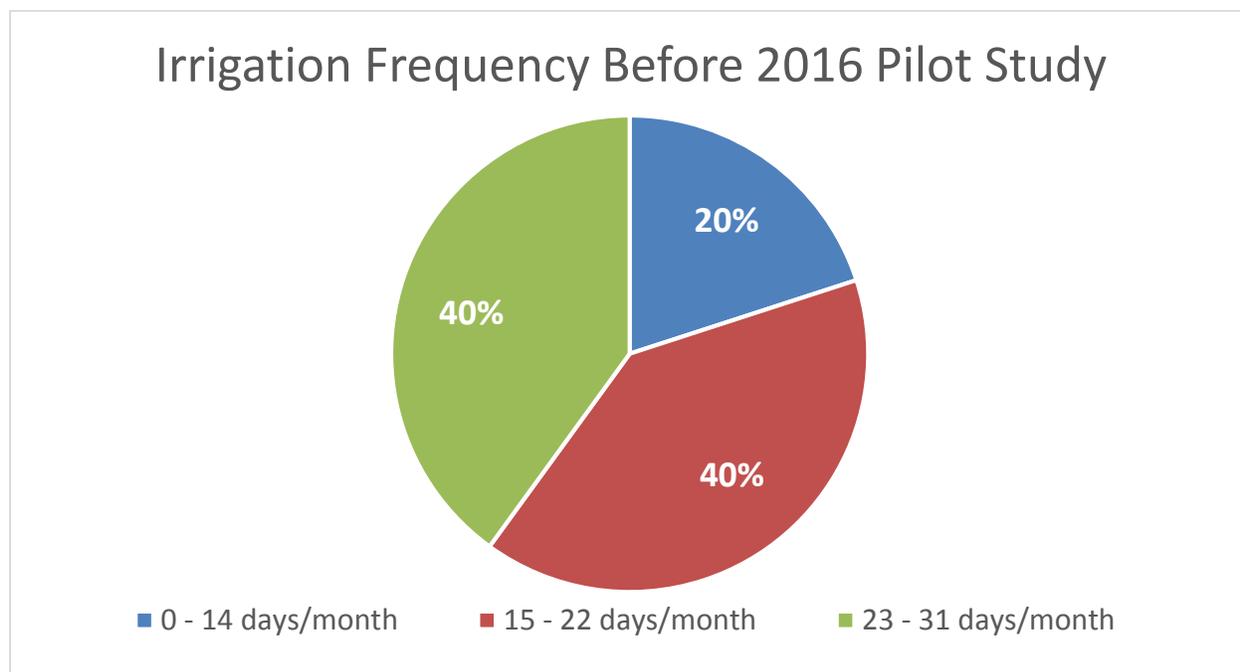
Figure 8: *Irrigation Frequency Among Study Participants*

In this group of households, 40% irrigate every day or almost every day during peak seasons (i.e. all or a subset of their irrigation zones are active every day or nearly so). Twenty percent of the households irrigate every other day or even less frequently. The remaining 40% irrigate approximately 4 to 5 days per week. Two households had incomplete historic irrigation information, and they were assumed to irrigate at the average frequency of this group: 22 days per month.

Note that in calculating the reduction achievable from these households, this study assumes that they would all be irrigating on any given day when irrigation would be remotely interrupted. Also, note that in some cases, the irrigation programs historically used by the households may be different than those set by the Rachio smart controller. Reduction potential from historic peak irrigation patterns was the ultimate basis for establishing the peak shaving potential of installing and remotely controlling these irrigation systems.

The volume of water used by each household on an average irrigation day during peak irrigation season was calculated by dividing the household's peak 2016 monthly outdoor use by its number of irrigation days per month. Each household's estimated volume of outdoor water use on an average irrigation day during the peak irrigation month is presented in Figure 9.
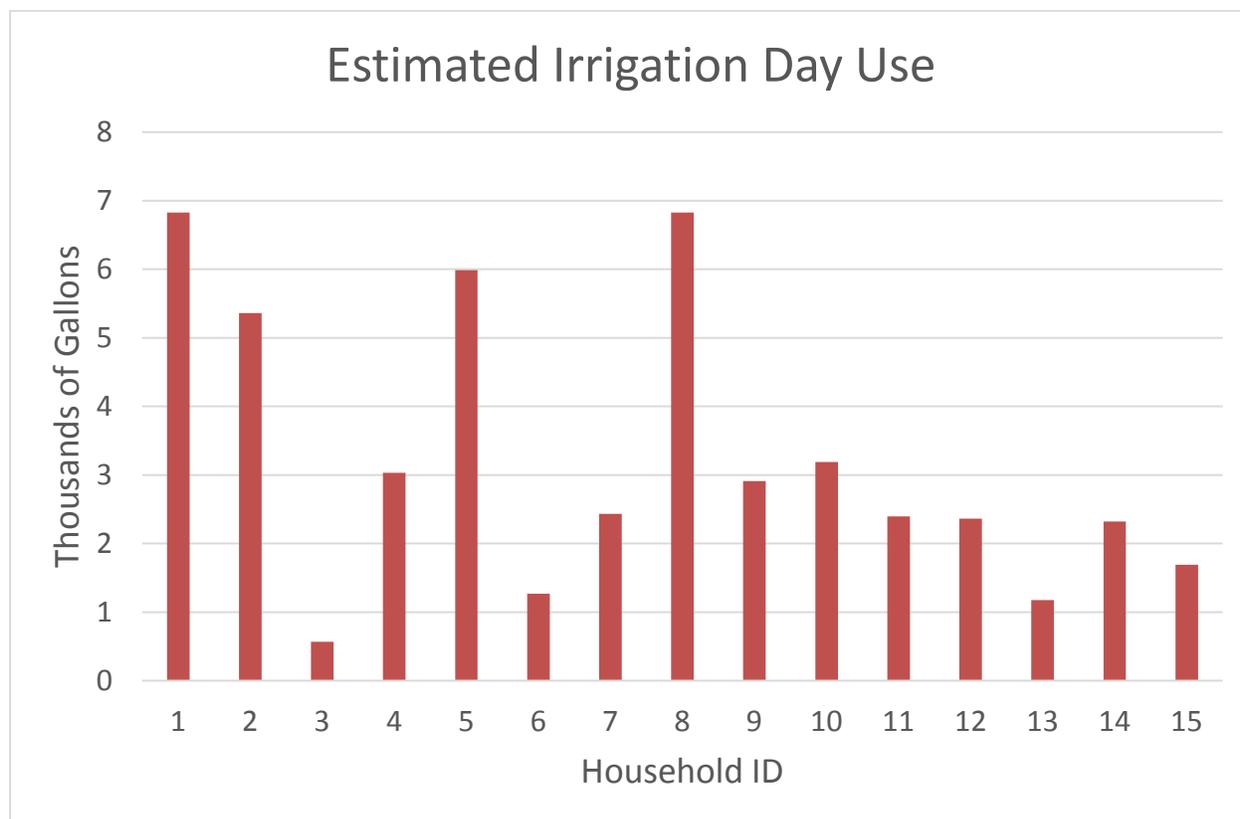
Figure 9: *Estimated Daily Volume of Outdoor Use During the Peak Irrigation Month*

The average irrigation day use per household during peak season is 3 kgal. Household 3 has the lowest irrigation day use at 0.6 kgal, and Household 1 has the highest irrigation day use at 6.8 kgal.

In this study, the total estimated volume of water shaved in a single day during the peak irrigation period across these 15 households (assuming they would all have been irrigating in the absence of remote interruption) was approximately 48 kgal. The average single-day volume offset per customer was approximately 3.2 kgal. Using this average offset-per-customer volume, 310 households would need to participate in a peak shaving program to achieve 1 million gallons per day (MGD) offset.

Several of the homes included in this study are on large lots with extensive landscaping. In fact, only four of the participants had fewer than 10 irrigation zones on their system and two participants had more than 20 zones. Figure 10 shows the total number of zones at each household in the study.
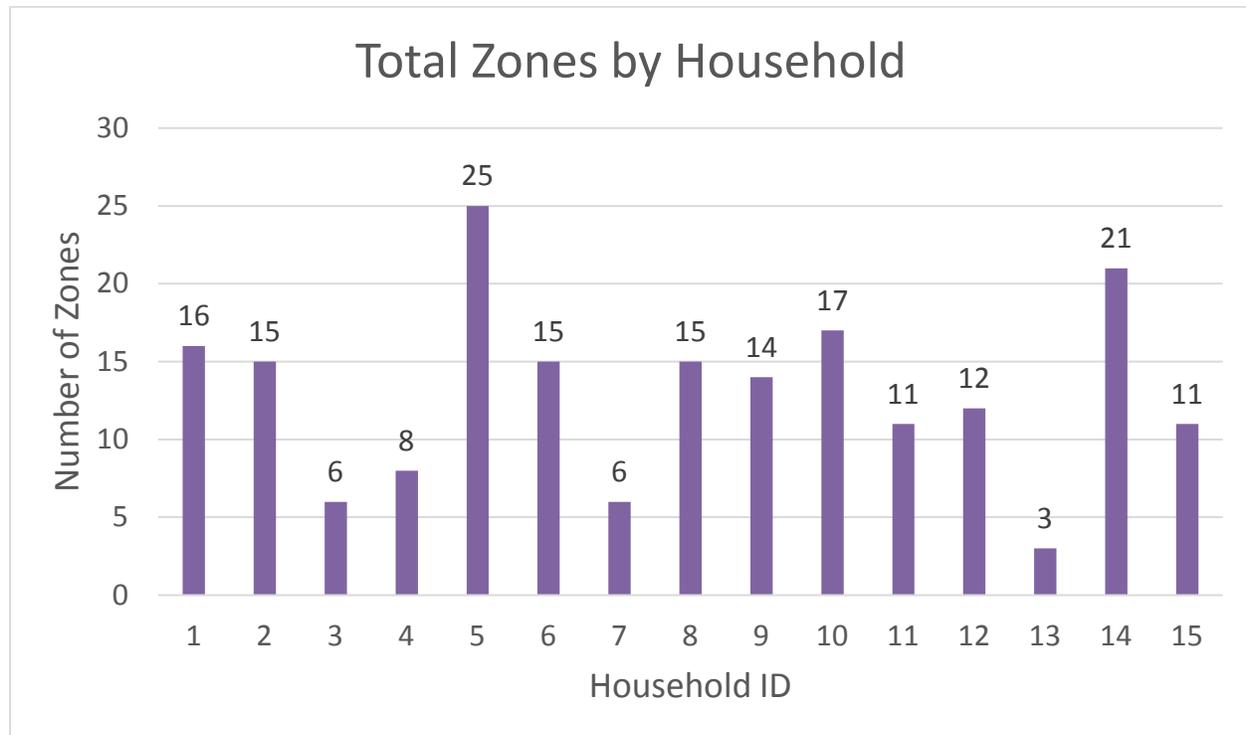
Figure 10: *Number of Automatic Irrigation Zones at Each Participating Household*

Household 13 has 3 zones, Household 5 has 25 zones, and the average number of zones for these 15 customers is 13. Six of these households have 15 or more zones, which means this sample of customers skews toward large lots with extensive irrigation. As such, irrigation volume per zone, instead of irrigation volume per household, is potentially more useful for making broad inferences.

Each household's water use per zone is calculated by dividing its volume of irrigation from an average day during peak season by the number of zones activated per irrigation day. In some cases, the number of activated zones is lower than the total number of zones because of how the historic irrigation habits are characterized (e.g. odd-numbered zones run on odd days, even-numbered zones run on even days). In such cases, the number of active zones on an irrigation day is used to calculate use per zone shown in Figure 11.

## Use Per Zone for Average Irrigation Day During Peak Season
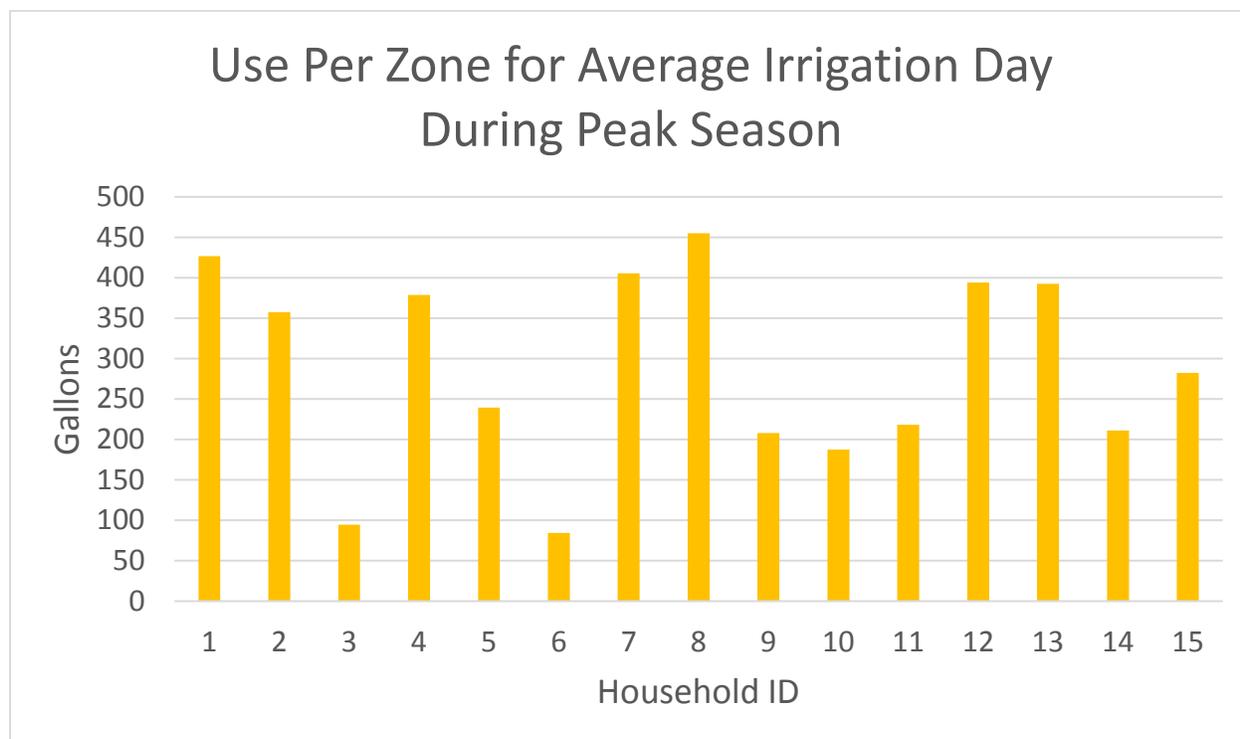
Figure 11: *Average Use Per Zone Per Day During Peak Irrigation Period*

The average use per zone for these households is 289 gallons (gal), but the households display a wide range of use-per-zone: Household 6 uses 84 gal per zone, and Household 8 uses 455 gal per zone. Households 6 and 8 have the same number of zones (see Figure 10), while Household 6 has a medium-low level of 2016 peak monthly outdoor use and Household 8 has a medium-high level (see Figure 7). The fact that peak monthly outdoor use and number of zones do not necessarily predict use per zone suggests that this metric is somewhat independent of property size or wealth. This makes it a more neutral metric on which to extrapolate peak shaving potential on a larger scale.

Hypothetical Peak Shaving Potential

The preceding results discussion began by estimating the total volume of irrigation reduction on each of the two days that the customers' irrigation programs were remotely interrupted in this study- approximately 48 kgal per day. The customers' willingness to participate in this pilot, the resulting demand reductions, and the ability to correctly time the interruption, form the basis for exploring the potential for this peak shaving method to have substantial impact on utilities' infrastructure plans and operations.

If utilities were to realize the substantial benefits suggested by these results, they would want to be able to achieve peak shaving on the order of perhaps 1, 5, or 10 million gallons per day (MGD). Thus, it is necessary to scale the results of this pilot up to the level of implementation that would provide these volumes of peak shaving.

Meaningful scale-up estimates require reducing the influence of the characteristics specific to the 15 pilot households. To achieve this, irrigation *per household* per day during peak season (Figure 9) was translated into irrigation *per zone* per peak season irrigation day (Figure 11). This value was generally robust to variations in total annual use, average irrigation day use, and number of irrigation zones per household. Below, irrigation per zone volumes are used to demonstrate the potential for remote interruption to provide large scale peak-shaving benefits.

Note that all estimates assume that all participating sites are irrigating on any given day that the interruption would occur.

The *minimum* use per zone per average irrigation day from the pilot households during peak irrigation season was 84 gallons. The *average* use per zone was 289 gallons. Using these values, conservative and average estimates were developed to determine the number of 6-, 8-, and 12-zone participants that would have to participate in a peak-shaving program in order to achieve 1, 5, and 10 MGD reductions. Figure 12, Figure 13, and Figure 14 compare these estimates. Scale-up results are summarized in Table 4 and discussed below it.
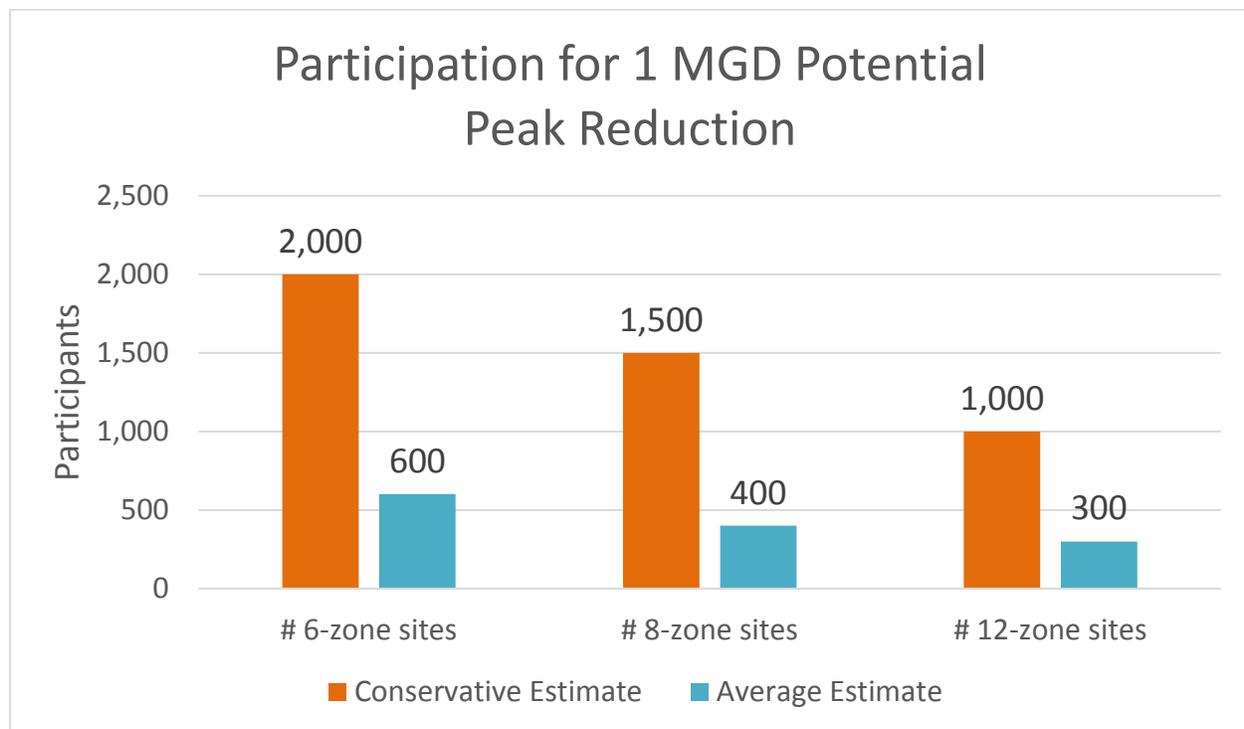

Figure 12: *Estimated Participants Needed for 1 MGD Peak Reduction*
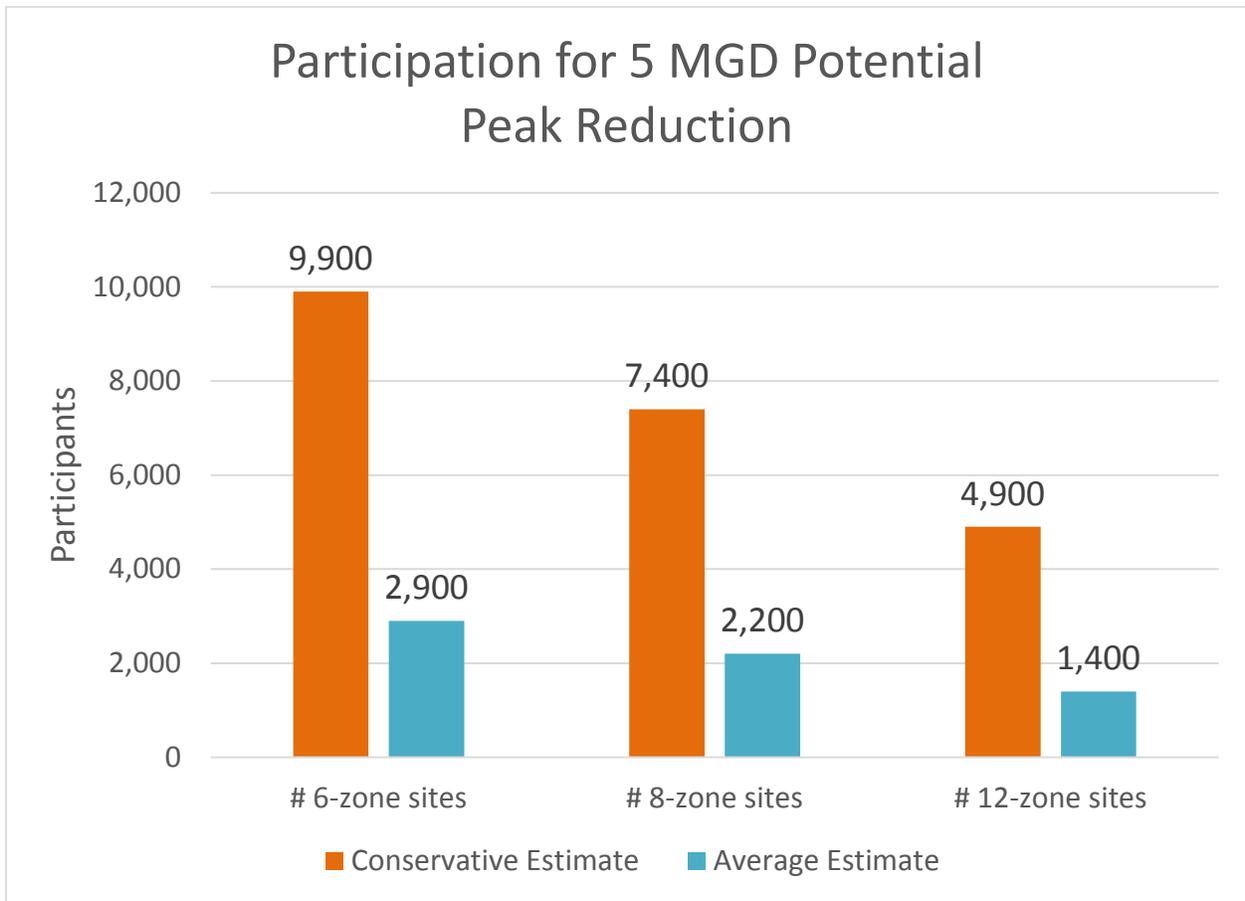
Figure 13: *Estimated Participants Needed for 5 MGD Peak Reduction*

Participation for 10 MGD Potential Peak Reduction
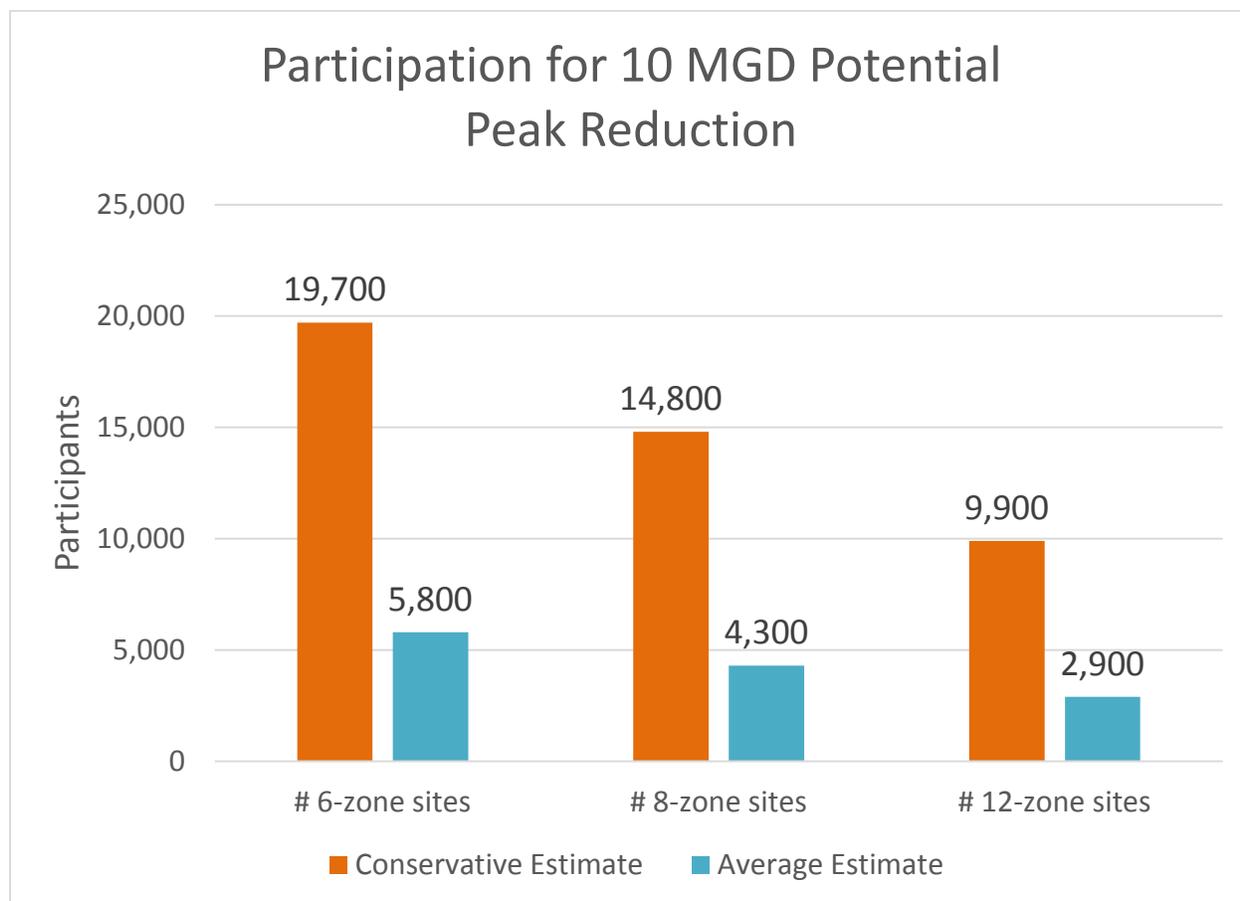
Figure 14: *Estimated Participants Needed for 10 MGD Peak Reduction*

Table 4: *Summary of Estimates for Various Levels of Peak Reduction Given Various Sizes of Participating Sites*

Peak Reduction Level	No. of 6-zone Sites	No. of 8-zone Sites	No. of 12-zone Sites
Conservative Estimate			
1 MGD	2,000	1,500	1,000
5 MGD	9,900	7,400	4,900
10 MGD	19,700	14,800	9,900
Average Estimate			
1 MGD	600	400	300
5 MGD	2,900	2,200	1,400
10 MGD	5,800	4,300	2,900

Table 4 shows the raw calculations for the numbers of participants needed to achieve three different levels of peak reduction, under two different assumptions about water use per zone, and with three different sizes of participating sites. Using this table and the figures above, the

comparisons between conservative and average estimates are relatively straightforward. To provide a more distilled comparison between conservative and average estimates of water use per zone, the values in the table below assume that recruitment to the peak shaving program consists of 60% 6-zone sites, 30% 8-zone sites, and 10% 12-zone sites. This mixture of irrigation systems, typical of the mix of systems found in mid to large cities, show the peak shaving potential of a system with a small mix of landscape sizes.

Table 5: *A Comparison of Total Participation Requirements if the Composition of Participants is 60% 6-Zone Sites, 30% 8-Zone Sites, and 10% 12-Zone Sites*

Peak Reduction Level	Total Participants
Conservative Estimate	
1 MGD	1,700
5 MGD	8,600
10 MGD	17,300
Average Estimate	
1 MGD	500
5 MGD	2,500
10 MGD	5,000

Based on the values in Table 5, recruiting 1,700 participants could yield anywhere from 1 MGD peak reduction (based on conservative water use per zone on an average irrigation day during peak irrigation season) to a peak reduction of over 3 MGD (based on average water use per zone on an average irrigation day during peak irrigation season).

Customer Responses

When conducting research with utility customers and new technology, it is important to consider customer feedback to improve on future implementation efforts. During the course of the study, American Water staff addressed various issues noted by study participants. Here are some examples of the customer feedback received.

This lack of precipitation increased several of the water bills of the pilot customers due to the controller trying to compensate for the lack of precipitation. One customer even became quite distressed over what they considered "false advertising." Another customer remarked that with the controller, the "lawn looks better" but couldn't sustain the higher water bills. These excerpts were taken from customer emails during and after the program in response to voluntary feedback.

Issues with brown spots during part of the summer distressed a few participants, but over time the Rachio controller was effective in maintaining the turf so that any impacted lawns

recovered before the end of the season. Field personnel noted that neighboring non-participant lawns has similar brown spots during that portion of the summer.

Smart controller technology is intended to keep the turf healthy, but may increase irrigation in hot & dry periods, which were the particular conditions of August 2016, angering some customers. August 2016 was the 2nd driest August on record in the area, with only 0.31 inches, compared to typically 4 or more inches of precipitation.

These and other customer responses noted in this report should be considered in the communication of a larger implementation of this pilot concept.

CONCLUSIONS AND RECOMMENDATIONS

Technological advancements have resulted in the ability for property owners to remotely control their automated irrigation programs. Rachio and other irrigation controller companies have expanded on this capability by allowing centralized remote control of multiple irrigation sites. These new developments can be very valuable for water utilities seeking to manage their peak day use, which dictates many costly infrastructure decisions. This study piloted the concept of using centralized remote irrigation control to reduce irrigation demands during peak irrigation season.

On two separate days that were designated by researchers and the participating water provider, NJAW, irrigation programs were overridden at 15 New Jersey residences. Confirmation of the overrides, as well as resumption of normal irrigation schedules on the following days, prove that utilities can indeed precisely and reliably reduce irrigation at participating properties to manage peak day use without adverse impacts to landscaping. Improved weather monitoring and daily consumption dashboards could improve resiliency and enable customers to get more information about their irrigation and its impacts on their bills.

Based on the success of the remote interruptions, analysis of customer-use records shows the potential for this peak shaving method to have meaningful impact on utility planning. Using recent water use records from the 15 pilot sites, researchers estimated that 48 kgal of irrigation were shaved on each of the interruption days. The peak demand reduction potential, and other estimates in this study, were based on historic peak irrigation patterns. Inherent in the successful peak demand reduction is the importance of proper timing of the remote interruption of the irrigation demand to have minimal impact on the customer's landscape and water bill. If the interruption is not timed properly or if hot dry conditions persist for an extended period, this concept may not be effective on its own. In order to rely on this technology for demand management, the utility should consider improving monitoring analytics similar to the electric utility in the various gradients of their distribution system to have better visibility in the peak day and peak hour periods for improved, and fine-tuned

demand management. Property size, percent of landscape cover, and number of irrigation zones can vary greatly from site to site. As such, researchers found that irrigation volume per zone, rather than volume per household, was a more useful basis for inferring the peak-shaving potential on a larger scale. After developing use-per-irrigation zone estimates based on these sites, researchers extrapolated from this pilot study the necessary recruitment to achieve 1-, 5- and 10-MGD. The results of these calculations suggest that 1 MGD of irrigation reduction can be achieved with approximately 500 to 1,700 participants; reduction of 5 MGD can be achieved with approximately 2,500 to 8,600 participants; and a 10 MGD-reduction can be achieved with approximately 5,000 to 17,300 participants.

The study found that recruitment was more difficult than anticipated. This may be partly because of the targeted customers, many of whom are wealthy and place great value on their extensive landscaping. Additionally, enthusiasm for a program like this may vary significantly by the level of awareness among customers of the impacts of their water use, and also by how much communication with their provider they are used to. Before drawing conclusions about the human impediments to broad application of this method, researchers recommend comparing these recruitment findings with similar attempts in a diverse set of locations.

Centralized remote interruption was successful. Considering the potential impact of modest participation rates, a larger-scale application of the concept is recommended. To expand on the progress made in this study, future applications should employ more efficient and effective recruitment methods. To this end, more education and clear communication regarding use of controllers and better wording of brochures are particularly needed.

This small pilot shows the potential of this approach to water demand management, but substantial **additional research and evaluation is necessary** if it is ever to be relied upon at a community scale. Through this evaluation process, improvements to this new water demand management approach can be made.

It is not enough to simply shut systems off one day and shift the load to the next, thus creating a different, but similarly large peak day. With thousands of enabled irrigation controllers in a system, much more sophisticated load shifting approaches become possible. In a fully developed water demand management system, urban irrigation could be orchestrated to match water production profiles during key parts of the summer. The system could also be used to remotely shutdown irrigation systems across a community or in specific neighborhoods during an emergency such as a water main break, a major fire, or an earthquake.

This pilot study is a small step in the direction of a more advanced approach to water demand management of urban water systems.

APPENDIX A – SAMPLE SITE REPORT

Name:		Survey by: Bob Dobson			Date:	Thursday, June 16, 2016		
Address:		Time In: 12:55 PM			Time Out: 2:05 AM			
Service Contractor: Dew Drop Lawn Sprinkler		Exist Controller Irritrol Total Control 16 Station			Location: Garage			
		Active Zones: 16		Start Time:	1:00 AM			
Predominate Soil Type	Sandy Loam	Scheduled Days: Mon / Wens / Fri						
Estimated Average Turf Root Zone Depth	6"	Wi-Fi Signal Strength: 3 Bars						
		Speedtest: Down - 9.11 Upload - 1.45						

| Zone No.	Area Covered	Sprinkler Type	Sprinkler Arc	Plant Type	Exposure	Slope	Existing Runtime
1	Front foundation shrubs & small lawn	spray	matched	shrubs/turf	full sun	flat	10
2	Left side of driveway planting	spray	matched	shrubs	full sun	flat	15
3	Sunny Ridge Drive	rotary	part circle	turf	full sun	moderate	30
4	Center front lawn	rotary	full circle / 1 pc	turf	full sun	moderate	40
5	Front and right side lawn	rotary	FC / PC	turf	full sun	moderate	30
6	Front walk lawn area	rotary	part circle	turf	full sun	slight	25
7	Rumson Road lawn	rotary	part circle	turf	partial shade	flat	30
8	Rear lower property line lawn	rotary	part circle	turf	full sun	moderate	30
9	Lower rear center lawn	rotary	full circle	turf	partial shade	moderate	30
10	Upper rear center lawn	rotary	FC / PC	turf	full sun	slight	30
11	Upper rear of house lawn	rotary	part circle / 1 FC	turf	full sun	slight	30
12	Lower center lawn close to house	rotary	full circle	turf	full sun	moderate	30
13	Rear & side lawn	rotary	part circle	turf	full sun	moderate	30
14	Left side of driveway lawn	rotary	part circle	turf	partial shade	flat	30
15	Left side of driveway lawn	rotary	part circle	turf	full sun	moderate	30
16	Left side of driveway center lawn	rotary	full circle	turf	full sun	moderate	25
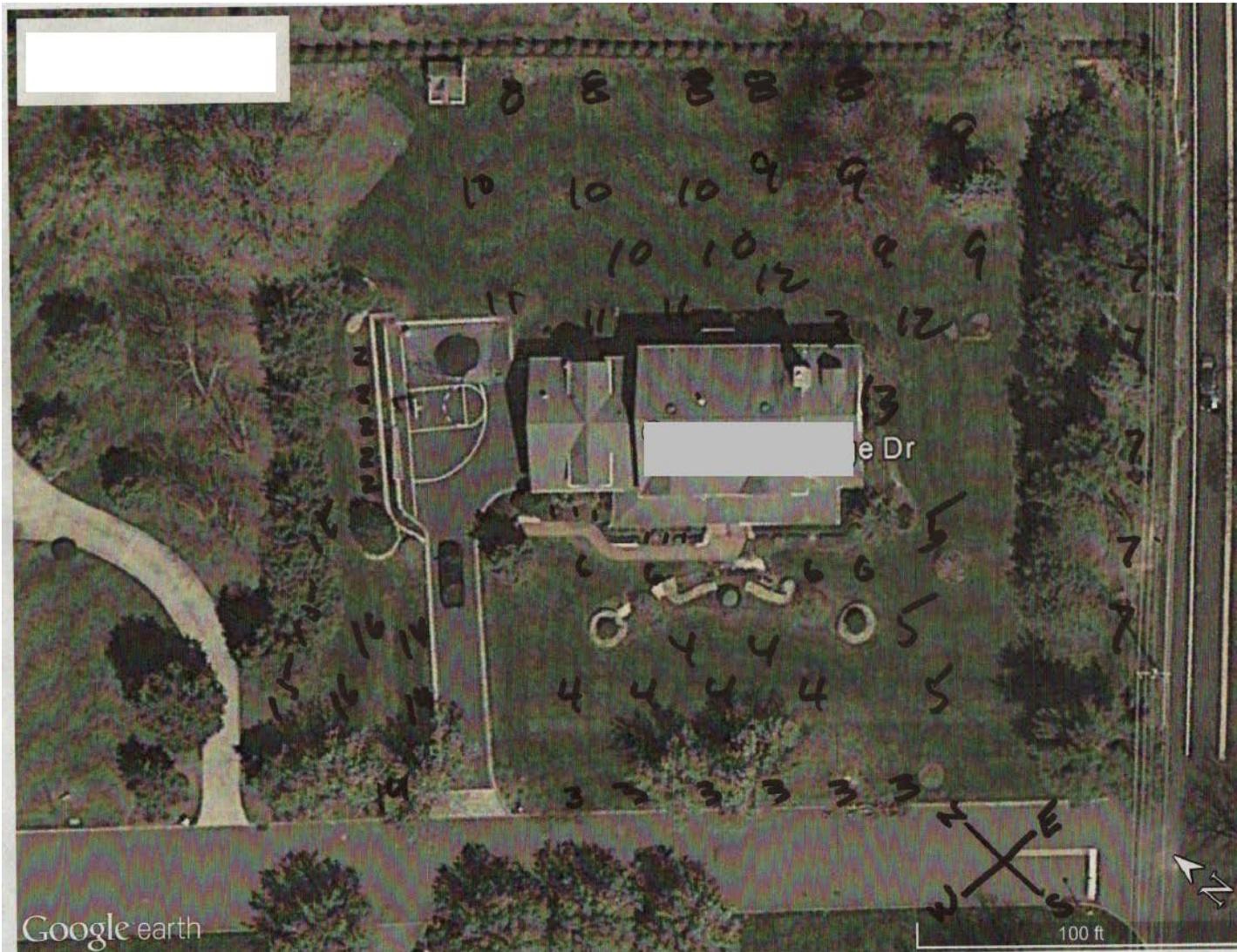
Figure 15: Sample Aerial Site Image

Figure 16: Existing Irrigation Controller Replaced for the Study.

APPENDIX B – NOTIFICATION EMAIL

The following email message was used to alert customers two days prior to each experiment.

Dear _____,

Thank you so much for participating in New Jersey American Water's Smart Irrigation Controller Pilot Study. We appreciate your commitment to helping New Jersey be more sustainable and hope you are enjoying your new Rachio Smart Controller.

As part of this pilot study, **American Water will be turning off your irrigation system on Friday, August 26th** to analyze the smart controller's effectiveness in managing peak water demands in the Rumson/Fair Haven area.

During this shut-down period your irrigation system will not run its scheduled program. The smart controller will make the necessary adjustments for the missed watering time after the 24-hour shutdown period. **We ask that you do not irrigate manually or make any adjustments to your smart controller on Friday.** Please note, this applies only to your irrigation system, and water throughout the rest of your household will remain unchanged.

This will be the last time that American Water will be turning off your irrigation system this summer. We will assess the water savings and the need to conduct similar programs in future summers, and will be reaching out to you in the near future to gather your feedback regarding this pilot.

If you have any further questions about this pilot, feel free to contact us at waterefficiency@amwater.com or via phone at 856-727-6255.