DISCLAIMER

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

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University of Arizona
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Final Report

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Project Title: Expanding the Landscape Drip Schedule App

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Summary
This project expanded on a previously developed landscape drip app (http://cals.arizona.edu/dripirrigation) that is available to schedule drip irrigation in most areas of California, Arizona, and Nevada. The app was expanded to include more user-friendly features such as calculations for inches per hour, sharing schedules between different users, and allowing the use of the app offline. An additional 44 zip codes have been added to allow the use of the app in the greater Las Vegas, NV area. Irrigation at several sites comparing actual quantities of water applied versus those recommended by the drip app found that there is great potential for water conservation by encouraging people to monitor their water use and examine their irrigation scheduling practices.

Goals and deliverables:

1. Enhance and improve flexibility of the current drip irrigation scheduling software program created using the previous funding from the 2013 Innovative Conservation Program (http://mwdh2o.com/ICP).

Deliverables completed:

- ✓ Include inches-per-hour calculations for all irrigation systems.
- ✓ Allow creation of 'groups' to make it possible to share schedules between select individuals.
- ✓ Make the program available when not connected to the internet, making the drip scheduler feel similar to an 'app'.

Deliverables modified:

- Flag plants that receive excessive or insufficient amount of water based on current emitters. This goal was not feasible to implement because it required substantially more data input than the current app requires the user to put in.
- Allow selection of 'indicator' plants (with highest crop coefficient) to drive the schedule.

These two deliverables were addressed in the 'About' section of the website. We changed the 'About' section and added information about irrigation system design to help users understand that a poorly designed irrigation system can never perform optimally. In the previous 'About' version we used the following wording regarding indicator plants that we now have omitted: "If this is the case, an 'indicator' plant(s) or the plant with the shortest rooting depth and highest crop coefficient, within the zone can be designated to drive the interval between irrigation events.” The reason for omitting the indicator plant in a landscape is that it would encourage poor scheduling to accommodate indicator plants that are high water users and may not be suitable for a particular zone.

We also eliminated the following section from the previous ‘About’ version: ”The program uses a Management Allowed Depletion (MAD) of 30% on the more shallow rooted plants. This reduces the volume of soil that needs to be re-filled during each watering event and will improve deeper water movement within the root zone. This MAD impacts the interval between irrigation events, but does not increase the overall water applied over time.” The reason for eliminating this information was that it is too technical and does not enhance the majority of the user’s understanding of the program. Instead, we added a new section on irrigation system design to encourage users to review their current zones.

Following is the new addition:

“IRRIGATION SYSTEM DESIGN
Well-designed systems with trees in a separate irrigation zone from the other plants will perform best. Water amounts are based on the existing emitters and not on the plant size. As plants grow and mature, additional emitters will be needed to supply sufficient quantities of water.

Schedules for systems with mixed plant types of widely differing water requirements present a challenge and will not be optimal for all plant types. Trees will be at a disadvantage in mixed landscapes with many other plants types as the schedule will apply water more frequently to accommodate plants with shallower root zones. This will result in trees being irrigated more frequently than they need and promoting shallow tree root systems.

If plants within a zone are extremely high water users they should be put on a separate irrigation zone in order to prevent chronic over-irrigation and water waste of the other plants.”

2. Develop a ‘static’ weather network data base for Las Vegas, Nevada, similar to those already developed for Arizona and California, to allow the use of the drip scheduling app in these locations.

Deliverables completed:

- ✓ Using long-term (10 or more years) weather records from golf courses and other sources of weather data to estimate evapotranspiration (ET) by zip code.
- ✓ Obtain weather data from previous research projects conducted by the Southern Nevada Water Authority to incorporate into this new data set.
- ✓ Use daily minimum and maximum temperatures (Hargreaves calculation) to estimate ET if no other weather data is available.

A total of 44 additional zip codes were added to the app. Daily evapotranspiration (ETo) was calculated with the Hargreaves formula using a ten year average minimum and maximum temperatures from 2007 to 2016 for Las Vegas proper, Boulder, North Las Vegas, Henderson, and Green Valley.

3. Quantify potential savings in water using the new drip schedule compared to standard scheduling practices on commercial landscape sites.

Deliverables completed

- ✓ A total of 20 zones in various commercial landscape sites were used to compare potential water savings using the new drip schedule app. Locations had mature landscapes with representative landscape plants including trees, shrubs, groundcovers, and accent plants typically found in the desert southwest.

- ✓ An initial full audit of each selected drip irrigation zone documented current emitter types, flowrates, plant types and sizes. Current irrigation schedules for all zones at each site were obtained. Plant health at each site was evaluated and found satisfactory. Soil samples were collected and analyzed for physical (particle analysis and soil classification) and chemical properties (mineral analysis and fertility indicators).

- ✓ In lieu of crop coefficents, percentages of actual ETo (reference evapotranspiration) were determined using the current irrigation schedule. Schedules were calculated for each zone using the landscape drip app. Next, comparisons were calculated between the suggested schedule based on the drip app and the actual irrigation applied to calculate potential water savings.

- ✓ Differences in both irrigation runtime and the interval between individual irrigation events were quantified to compare total water use in previous years versus current water use based on the drip schedule app.

Site evaluations comparing actual scheduling practices show a high variability due to a number of factors. Change in personnel responsible for a site has caused disruption of seasonal schedule adjustments. Water line breaks, active construction blocking access to valve boxes, stuck valves, clogged emitters, and poor irrigation uniformity all contribute to variable water use. Comparisons of crop coefficients between actual irrigation and the app will work well in zones that are irrigated consistently according to the planned schedule and a well maintained and functioning irrigation system. In zones where these assumptions do not apply, only the total water use per site can be compared.

Site 1. Park

Following is the irrigation schedule (Table 1) for the month of June and the total annual irrigation for a park using the drip scheduling software. The schedule includes native and non-native plants, and three levels of water use plants, both for trees and shrubs. We show June, which has the highest water demand.

Runtimes for the current schedule per irrigation event of this site are very close to the drip schedule recommendations, however, the interval of irrigation application is more than twice the number recommended by the app. For the example given with the data from the park, the actual irrigation application in June and July applied as much water as the drip schedule app would recommend for more than one year.

Table 1. Example of recommended irrigation schedule for a park for the month of June including runtimes and number of cycles for native and non-native trees and shrubs. Weather data or reference evapotranspiration used for these calculations are a 15-year average for the local zip code (AZMET data).

Pocket Park schedule using 'Drip Scheduler'														
soil: Sandy-Loam														
			emitters/plant							June				
	Kc		#	GPH	in./h	runtime (min.)	# of plants	cycles / year	yearly water use (gal.)	cycles	gal	normal (in.)	rain	%-net ET
|------- Native -------|	low							11	1021	2	187	9.45	0.092	18%
	med	Trees	3	2	0.6	85	11	22	2041	4	374	11.55	0.247	30%
	high							36	3340	6	561	11.14	0.112	46%
	low							17	7858	4	1865	13.12	0.321	18%
	med	shrubs	3	1	0.46	74	126	33	15254	6	2797	11.11	0.162	31%
	high							57	26347	9	4196	10.88	0.244	48%
|---- Non-native ----|	low							19	1763	3	281	9.45	0.092	27%
	med	Trees	3	2	0.6	85	11	36	3340	6	561	10.79	0.102	48%
	high							96	5567	11	1029	10.88	0.244	88%
	low							29	13405	5	2331	10.79	0.102	27%
	med	shrubs	3	1	0.46	74	126	57	26347	9	4196	10.88	0.244	48%
	high							57	44375	15	6993	10.18	0.241	86%

Table 2. Calculated irrigation with the drip app in gallons for native plants at the park from the example in Table 1 and actual amounts applied for the entire years of 2016 and 2017.

	Calculated with drip app	2016 applied (gal.)	Applied versus calculated amount (%) in 2016	2017 applied (gal.)	Applied versus calculated amount (%) in 2017
Native low water use plants	8,879	167,552	1,887	341,088	3,841

This example illustrates the potential savings in water use over the course of two years at this small park which has 11 trees and 126 shrubs or groundcovers. In 2016, irrigation application exceeded that in comparison to the drip app by 1,887% (Table 2). In 2017, over-application more than doubled compared to 2016. We were not able to determine why plants were overirrigated to this extent in 2016, and especially why this more than doubled in 2017. Plants were installed in 2016

Figure 1 illustrates actual and recommended irrigation at the park. Please note the difference in scale for the top and middle image, where the green line represents the amount of irrigation recommended by the app. Irrigation as recommended by the app follows the ETo at the site closely (middle image), but the actual irrigation does not adhere to seasonal changes in evapotranspiration demand (lower image). The app also shows minimal irrigation need during the times of year when rain fulfills some of the water needs.

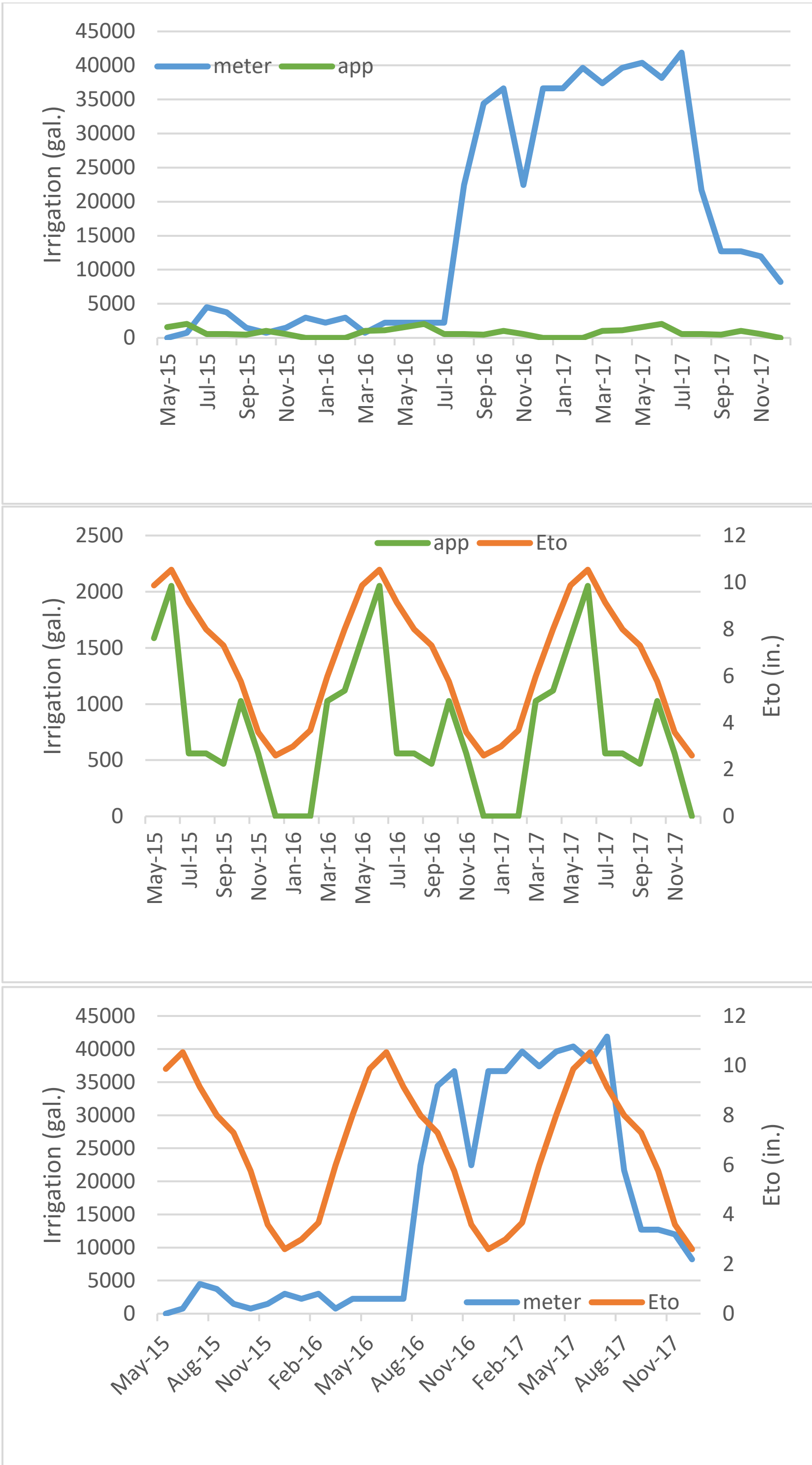


Fig. 1. Irrigation as recommended by the app (green line) and as applied at the park (blue line) (top figure), reference ETo and irrigation as recommended by the app (middle figure), and reference ETo and irrigation applied at the park.

Site 2. Right of Way

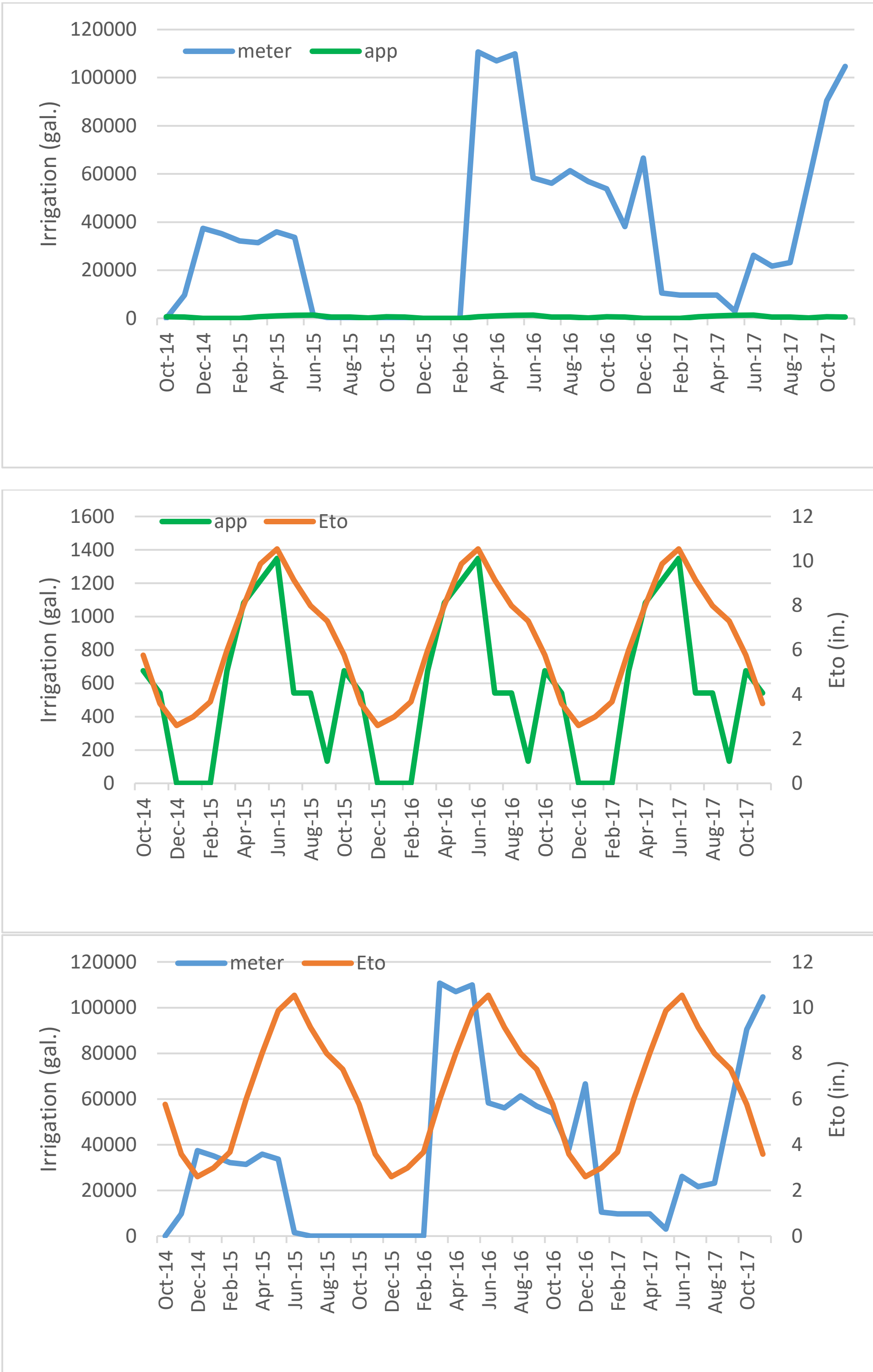


Fig. 2. Irrigation as recommended by the app (green line) and as applied at a right of way planting (blue line) (top figure), reference ETo and irrigation as recommended by the app (middle figure), and reference ETo and irrigation applied at the right of way planting.

Figure 2 shows the total applied water for trees and shrubs for the landscape which extends approximatley half a mile on both sides of the street and consists of 24 trees and 36 shrubs total. The app recommended an annual irrigation of 6,752 gallons, assuming all trees and all shrubs were native and low water use plants which we confirmed on our site visit. The actual irrigation application did not follow the reference evapotranspiration at the site and far exceeded the amount of water necessary for the desert adapted trees and shrubs. Surprisingly, no irrigation was applied at the site from June 2015 to February 2016, probably due to a system malfunction or operator error. The following three months, over 100,000 gallons were applied per months according to the meter reading. It is questionable whether all this water was used for the plants. This is another example of how many landscapes are not closely monitored regarding irrigation application as long as the plant quality is acceptable. There is a great potential for water savings.

Site 3. Streetscape

This streetscape consists of 37 trees and 142 shrubs that are planted along a road on both sides including several medians planted with trees. The area spans about one quarter mile. All trees and shrubs material is well established and in good health and can be categorized as low water use native plants. Table 3 shows the recommended irrigation amounts calculated by the app and the actual applied irrigation for a period of six years during May, June, and July, the months with peak water demand.

Table 3. Irrigation of a streetscape during May, June, and July 2012 to 2017. App refers to irrigation as recommended by the drip app, actual applied are the results of the meter reading, and the third column shows the difference between the applied amount and the app. A negative number indicates the amount in gallons under applied, a positive number the amount overapplied 19 to 82 times the amount recommended by the app for particular months.

Date	App (gal.)	Actual applied (gal.)	Applied – App (gal.)
Jul-17	312	0	-312
Jun-17	974	0	-974
May-17	799	0	-799
Jul-16	312	0	-312
Jun-16	974	0	-974
May-16	799	0	-799
Jul-15	312	74800	74488
Jun-15	974	80784	79810
May-15	799	14960	14161
Jul-14	312	20196	19884
Jun-14	974	20196	19222
May-14	799	32912	32113
Jul-13	312	44880	44568
Jun-13	974	17952	16978
May-13	799	20196	19397
Jul-12	312	23936	23624
Jun-12	974	18700	17726
May-12	799	0	-799

From 2012 to 2015 the irrigation application exceeded the recommended amount. However, in May 2012 and during the peak demand months in 2016 and 2017 no irrigation was applied according to the meter readings. During those summer months, the app recommends application of 2,086 gallons for these native or desert-adapted low water use trees and shrubs. Despite lack of irrigation, plants appeared healthy during our site visits in summer and fall of 2017. This site illustrates the importance of regular monitoring of the meter readings and reviewing the schedule during different times of the year.

Conclusions

Comparing actual irrigation amounts of large commercial landscapes to the amounts recommended by the landscape drip app demonstrates tremendous opportunity for saving water in landscape irrigation applied via drip systems. It appears that personnel in charge of managing irrigation clocks are not aware of proper scheduling based on the plant material and the irrigation system they are working with at different sites. We noticed interruptions to irrigation that lasted from one to several months, even in summer. Over-irrigation appears to be the predominant management technique, although it is unlikely that the extent of over-irrigation is apparent to the irrigation manager.

The landscape drip app is a first step to raise awareness of how much water should be applied to a landscape. Even if the recommended rates are doubled, for all the landscapes we investigated it would be substantially less than water used on the different sites. The reluctance of many landscape managers to share their water meter data with us for this study suggests that they may suspect that their application rates exceed the amounts of water applied similar to the ones we examined. Common problems are a weather station not connected to a Smart irrigation controller (Fig. 3). Property owners could be encouraged to record their water use meter, especially if the meter is dedicated to landscape irrigation only. Plant materials that include high and low water use plants on the same valve (Fig. 5) are common on many properties. Motivating landscapers to lower water bills for a property might be an incentive to examine current irrigation scheduling more closely.

Fig. 3. This property has a Smartcontroller with a weather station, however, the weather station is not hooked up to the controller, thus not providing the required data.

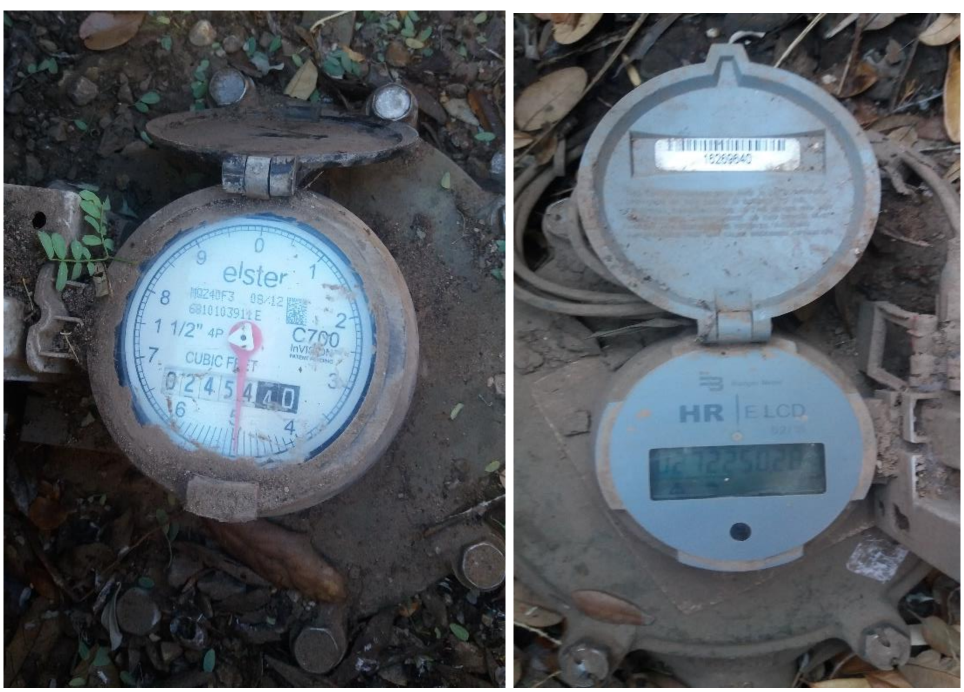
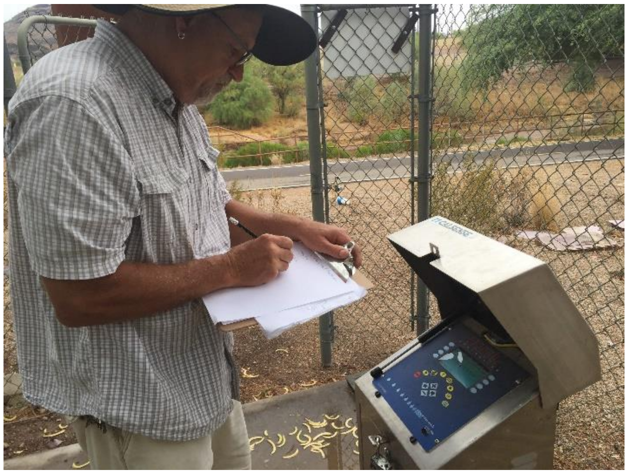


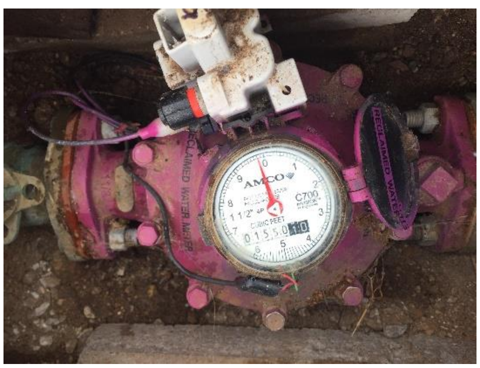
Fig. 4. Analog irrigation meter (left) is read by a person. The new digital irrigation meter (right) is read remotely by the City and we were able to obtain historic irrigation application data from both meters.

Fig. 5. Typical vegetation in a large residential complex of townhouses. Trees on this property include palms, conifers, oaks, palo verde and mesquite. Shrubs include evergreen high water use and xeriscape adapted plants.

Appendix: Images of site audits and the app



Jeffrey Gilbert audits the CALSENSE irrigation controller for a right of way landscape (left) and is locating number of emitters per tree (right).



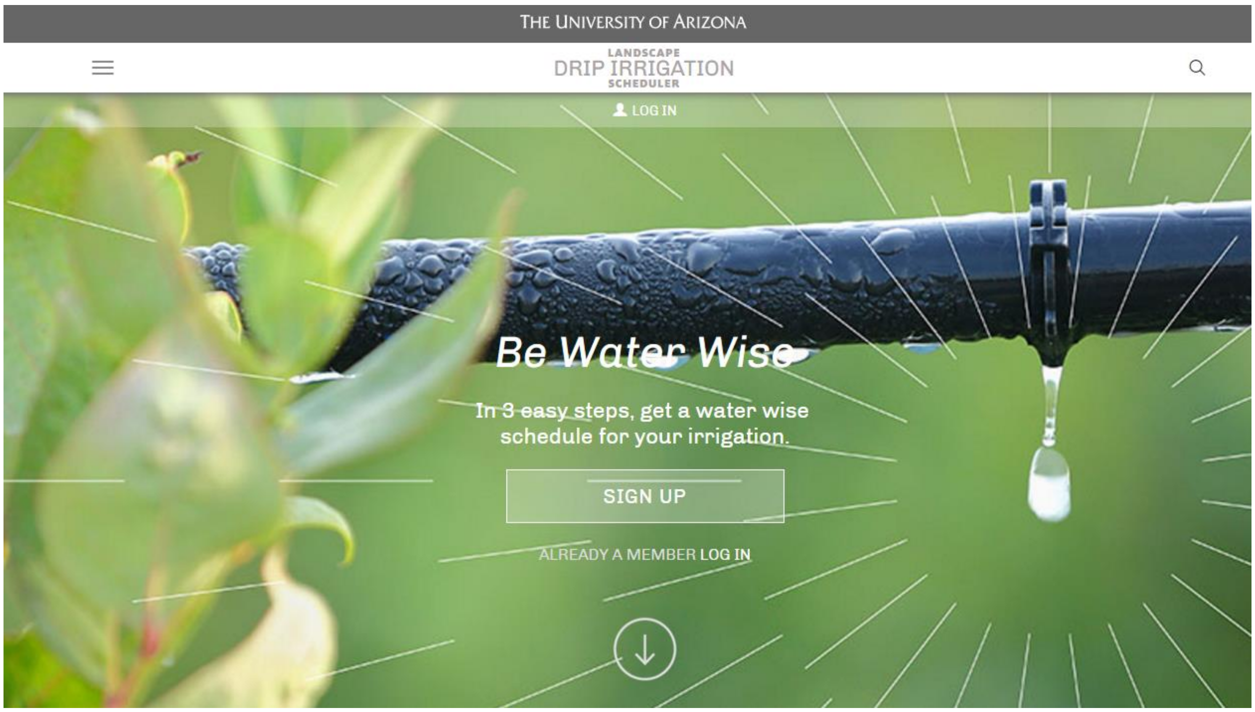
Obtaining flow rates for a tree and a shrub zone (valves on the right) from the dedicated water meter (left).

Small park with a plant palette representing arid adapted trees, shrubs, ground covers, and accent plants. The site also has a water harvesting basin fed by a curb cut (left). All plants are drip irrigated and two zones separately supply trees and the smaller plants.

Interactive website to schedule landscape drip irrigation

The purpose of the interactive website scheduler is to calculate a watering schedule appropriate to the plant material and the existing drip emitters. The website is functional for computers, tablets, and cell phones.

http://cals.arizona.edu/dripirrigation/



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- We thank our cooperators for providing testing sites and historical water use data.