RESEARCH ARTICLE

Volunteer programs are effective at reducing urban water use in Marin County, California

Households receiving tips from Master Gardeners use less water for their landscape irrigation.

by Steven V. Swain, Margaret S. Mathers and David J. Lewis

Online: https://doi.org/10.3733/001c.156065

Abstract

Reducing irrigation usage for residential landscapes is a key strategy for managing water demand, but many property owners struggle to implement effective water conservation. Garden Walks is an educational program that supports trained volunteers to visit local residential properties. They suggest improvements to irrigation systems, mulch usage, grouping plants based on similar water needs, and other water-efficient landscaping techniques. Working with a Marin County water district, we measured water use for 481 households participating in Garden Walks and 478 non-participating households for six years to assess potential water savings. On average, participating households used 7,780 gallons less water in an irrigation season (8% less) than non-participating households. Much of the water savings appears to have come from leak detection. Irrigation leaks were detected in 6% of participating households, and fixing those leaks accounted for nearly 40% of program water savings.

Water conservation through education is an important element in meeting urban water needs by reducing water demand (Borisova and Useche 2013a; McCue et al. 2007). This study aims to assess the impact of conservation education on water use at the homeowner scale. The Garden Walks program in Marin County, California, provides on-site consultations to local residents of single-family homes, demonstrating how to assess their irrigation systems for leaks and efficiency, as well as providing garden-specific water conservation measures such as mulching and hydrozoning (grouping plants on the basis of their water needs). This evaluation compares the water use of program participants with non-participating households and finds that use was reduced as a result of the on-site consultations.

Managing demand by optimizing water use is a key strategy for extending existing water supplies. Marin County relies primarily upon seasonal rainfall stored in

UC Marin Master Gardeners conduct a Garden Walks consultation to help a Marin County homeowner analyze how to best save water and hydrozone their plants. *Photo:* Pam Polite-Fisco.

reservoirs for the majority of its water supply. No new reservoirs have been built in Marin County since 1980, and the capacity of existing reservoirs has not been expanded since 1982 (Adriane Mertens, Marin Water, personal communication). Approximately one-quarter of the water supply is imported from outside of the county, with other predetermined allocations for this water restricting its availability. Despite this fixed water supply, Marin County's population has increased 15% since 1980 (U.S. Census Bureau 1980, 2022), putting additional pressure on existing water supplies.

The Marin Municipal Water District (now Marin Water) has used a variety of conservation measures to manage demand, including rebates for water-efficient appliances, and household water use evaluations conducted by water district personnel. Marin Water also uses a tiered water rate system and rate increases to give price signals to customers about water use. In this system, the rate for a given amount of water used is higher for higher tiers, or quantities, of water used. Tiered water rates are designed to provide some low-cost water to every household, and more water, if needed, at successively greater cost to the consumer. Rates were increased across all four Marin Water pricing tiers, totaling a cumulative 39% increase within each tier over five years from 2007 to 2011 (fig. 1).

Tiered pricing structures have been demonstrated to change urban water consumption (Arbués et al. 2003), although the variety of factors that influence water use make it difficult to determine exactly how much water is saved. Some inherent factors include feedback loops between rising water rates and water conservation (Olmstead et al. 2007); in this case, customers' fear of using too much water in tiered pricing systems can lead to decreased water use, which in turn forces water utilities to raise prices to remain financially solvent, which leads to further reductions in customer water use.

Whatever water savings are realized through demand management programs are offset by continuing increased demand from growing populations. More people demand more water, which in turn calls for new water sources and/or further reduction of per-capita water demand. This is the case in Marin.

Educational programs may influence water consumption, although the efficacy of these programs has been the subject of much debate (Arbués et al. 2003; Worthington and Hoffman 2008). A study in Florida suggested that the savings from on-site water use audits of single-family landscapes were as high as 13% (McCue et al. 2007), but there was no control group for comparison in that study.

In Marin County, to increase the public's understanding of the importance of water conservation in the home and for landscape irrigation, publications and educational programs have been produced by the University of California Cooperative Extension (UCCE) and other organizations and agencies, such as ReScape and the Marin County Stormwater Pollution Prevention Program. In 2008, Marin Water, UC Cooperative Extension Marin, and the UC Marin Master Gardeners teamed up to expand household education through individual consultations on home garden and landscape water use. From 2008 to 2010, more than 500 households participated in the Marin Friendly Garden Walks program, receiving in-person assessment and recommendations from two trained volunteers.

Consultations in home gardens

The Garden Walks program offers a consultation approach to garden and landscape water demand management. While traditional educational workshops are typically held at a library or other gathering place (Borisova and Useche 2013b), Garden Walks provides hands-on education on the participant's property, allowing them to learn water conservation techniques in their own garden. In 2008, a joint team of academics and water district personnel established Garden Walks, enlisting University of California (UC) Marin Master Gardener volunteers to assess landscape irrigation efficiency at single-family residences within Marin Water's service area. The result is a hybrid model combining extension workshops, which present principles of water conservation for homeowners to use in reducing their water consumption, and on-site garden water use assessments. The on-site assessments offer direct water conservation principles, such as hydrozoning and watering in the early morning; indirect water conservation principles, such as the use of compost and mulches; assessment tools, such as leak detection,

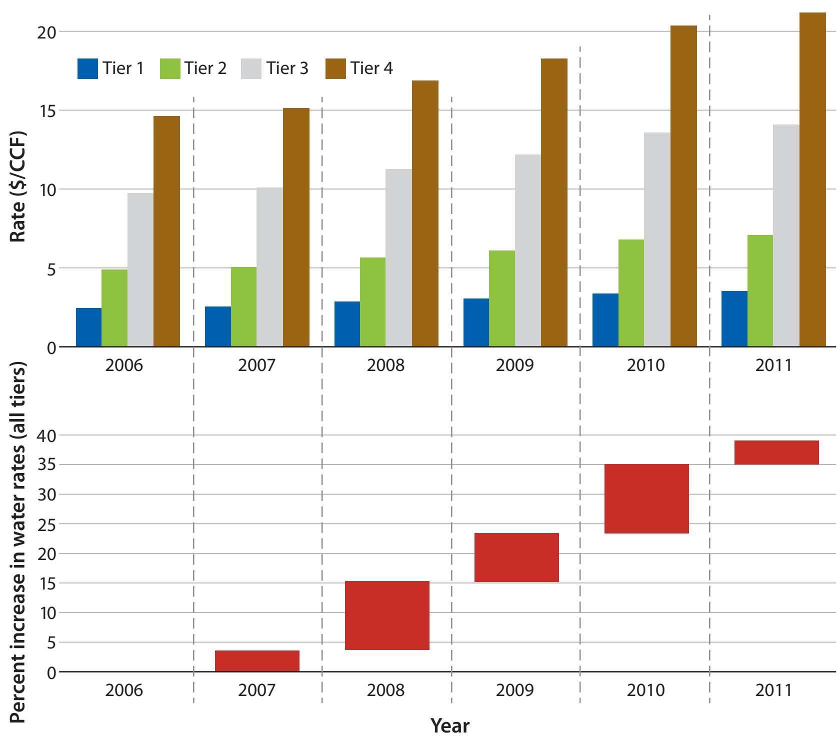

FIG. 1. Marin Water rate pricing structure (upper) and cumulative percent rate change (lower) from 2006 to 2011.

Garden Walks consultations include teaching residential gardeners how to read their water meter. *Photo*: Rebbeca Ryan.

measurement of flow rates, and systems maintenance; and technologically based approaches, such as smart controllers, rain sensors, and proper controller programming.

Training Master Gardeners

Before becoming UC Marin Master Gardeners, volunteers are trained in sustainable gardening practices by UC academics and experienced UC Marin Master Gardeners, including general irrigation system design and assessment by Marin Water personnel. This training provides a broad overview of gardening, including pruning, planting, soils, plant taxonomy, basic plant physiology, and other related topics, presented at weekly five-hour meetings over a five-month period. Once a volunteer is trained as a UC Marin Master Gardener, the volunteer can join the Garden Walks team by participating in a Marin Water one-day intensive irrigation course. Course content includes hands-on experience with irrigation system design, function, troubleshooting, and leak detection. This is then followed by a half-day practical demonstration conducted by the Garden Walks Coordinator in the Master Gardeners' own gardens, allowing new volunteers to practice giving Garden Walks consultations.

Coordinating with water district

The Garden Walks program is managed by a part-time paid staff position via a contract with Marin Water, supervised and housed by UCCE Marin. The Garden Walks staff is responsible for coordinating program outreach efforts, overseeing walk scheduling, and managing a database of completed walks. Pairs of trained volunteers are assigned to visit local residences and evaluate multiple aspects of landscape irrigation efficiency, including leak detection, hydrozoning, and other sustainable landscaping practices.

Property and environmental data

Participant households self-selected by submitting a request for a Garden Walks consultation. Just over 500 walks were performed from 2008 to 2010. Given that our participant pool was self-selecting, there is always the possibility that this will introduce some bias into our results. We hoped to avoid some of this bias by having large sample sizes drawn from the same residential population for the non-participant households.

In order to generate our control (non-participant) household group, we used Google Earth to randomly select one of ten similar households that did not request a Garden Walk within approximately 437 yards (400 meters) of each participant household. Similar non-participant households were defined by having similar property and house size (within 20% of the participant house and property size), and either did or did not have a swimming pool, as relevant.

Water use data was provided by Marin Water in anonymized batches, for participant and non-participant households for the irrigation season from May through October for the years 2006 to 2011. Our dataset comprises these six annual irrigation season water use amounts for 481 participant homes and 478 non-participant homes. The difference between our treatment or participant and control or non-participant numbers is due to incomplete datasets for three of the control households. Because the data was anonymized and delivered in batches, when we found any control household datasets that were incomplete, it was impossible to retrace the participant households for which we needed a new control dataset. We therefore chose to move ahead with the analysis without the three control households. Two other participant household datasets were similarly thrown out prior to control selection due to incomplete datasets.

Additional environmental data was gathered from multiple sources. Annual precipitation and annual and season evapotranspiration for the six years was obtained from two local California Irrigation Management Information System stations, run by the California Department of Water Resources. Values for the Standard Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al. 2010) were used to account for precipitation and potential evapotranspiration in determining drought for both the 12-month and 6-month time step through October of each year. These were sourced from the Climatology and Climate Services Laboratory (LCSC 2025).

Analyzing water use

We used two different statistical approaches to analyze the data. We used a linear mixed effects regression model to tease apart the reduction in water use compared to the many different factors influencing water demand. However, Nataraj and Hanemann (2011) have shown that the use of linear regression statistical models to analyze water use reduction in water billing systems with tiered pricing structures (such as those employed by Marin Water) can create the internal feedback loops discussed above; this may lead to estimation errors. We therefore also analyzed the same water use data using a difference of differences approach to analyze for water savings resulting strictly from the Garden Walks program.

Each household's water use was measured three times (bimonthly) per irrigation season (May through October) and summed for the resulting measurement of water used. Based on this sum, each household irrigation year was treated as one irrigation season measurement. Measurements were taken starting in 2006 for all households. Garden Walks were conducted for three consecutive years (2008 to 2010). Each household experienced its Garden Walk in only one of these years. For each of the years, we used different years for their pre- and post-Garden Walks data. For example, for the 2009 Garden Walks, we used 2006–2008 for their pre-Garden Walks water use data, and 2010–2011 for their post-Garden Walks data. For 2010 Garden Walks, we had only a single year, 2011, of post-Garden Walks data. Time frames for each control household water use were paired with the same time frames for each participant household.

We employed the data-driven linear mixed effects modeling, using STATA/IC 15.1, to confirm relationships of water use changes per household relative to participating in the educational Garden Walks program, and to consider other explanatory variables (Pinheiro and Bates 2000). Irrigation season water use for each household was set as the outcome variable, with each participant or non-participant home set as a group effect to adjust the *P*-values for repeated measures of water use at the same home. A forward stepping approach was used to develop the multivariate regression model, with *P*-value ≤ 0.05 set as the criterion for inclusion of the variable in the final model. This included testing the relationship of water use to annual cumulative rate change, annual precipitation, annual total evapotranspiration, SPEI 12-month and 6-month time step, program participation, and year of consultation delivery. We also tested for interactions and, specifically, the interaction between participation in the Garden Walks program and the year of the Garden Walks consultation for a participant household.

For complementary statistical confirmation, we also conducted a difference of differences estimate (Angrist and Pischke 2009; Card and Krueger 1994). In this analysis, we differentiated between participating (treatment) and non-participating households (control), and water use before and after the Garden Walks consultation.

Program helped reduce water use

Water use generally decreased from 2006 to 2011 for both participants and non-participants; table 1 and fig. 2 show mean seasonal water use for both groups. The environmental factors that affected the area generally,

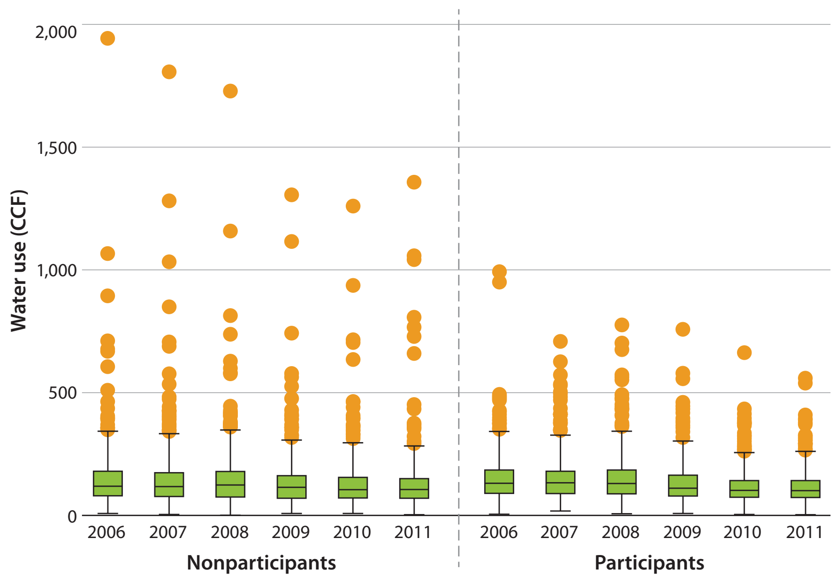

FIG. 2. Individual homeowner seasonal water use from 2006 to 2011 for water education program participants and non-participants. Box and whisker plot with mean water use by year maximum or top whisker, first quartile or top of box, median or line in box middle, third quartile or bottom of box, and minimum or lower whisker. Dots illustrate outliers.

TABLE 1. Values for mean seasonal water use for Garden Walks education program participants and nonparticipants, annual total precipitation, irrigation season evapotranspiration, and 12-month time scale Standardized Precipitation Evapotranspiration Index (SPEI) from 2006 to 2011

Year	Mean water use, CCF/irrig. season (m^3)		Precipitation* inches (cm)	Evapotranspiration† inches (cm)	SPEI‡
	Homeowners receiving consultation (n = 481 per year)	Homeowners not receiving consultation (n = 478 per year)			
2006	150.8 (53.29)	147.6 (52.16)	73.0 (185)	−25.6 (−65.0)	1.4
2007	149.0 (52.65)	149.1 (52.69)	36.3 (92.2)	−28.2 (−71.6)	−0.8
2008	152.9 (54.03)	150.2 (53.07)	41.2 (105)	−28.7 (−72.9)	−0.3
2009	130.6 (46.15)	134.3 (47.46)	42.9 (109)	−29.4 (−74.7)	0.1
2010	118.7 (41.94)	127.9 (45.19)	58.2 (148)	−28.9 (−73.4)	0.4
2011	116.9 (41.31)	127.9 (45.19)	70.2 (178)	−28.1 (−71.4)	0.9

* Precipitation is for calendar year (Jan. 1–Dec. 31 of each calendar year), matching Garden Walks program calendar.
† Evapotranspiration is for irrigation season (April 1 to Oct. 1 of each calendar year).
‡ Sourced for Marin County from Laboratory for Climatology and Climate Services (https://spei.csic.es/database.html).

TABLE 2. Linear mixed effects regression model for associations of participation in Garden Walks education program, using dummy variables for homeowners receiving and not receiving a consultation and years before and after consultations delivered

Factor	Coefficient	95% CI*	*P*-value*
Constant or intercept term for the model	151.9	(142.6, 161.3)	<0.0001
Standardized Precipitation Evapotranspiration Index (SPEI)†	−2.2	(−3.8, −0.5)	0.010
Cumulative rate change	−0.6	(−0.7, −0.4)	<0.0001
Interaction of participation and consultation delivery	−10.3	(−15.1, −5.6)	<0.0001
Participation in education program‡	0.7	(−12.4, 13.8)	0.918
Consultation delivery§	−1.7	(−6.9, 3.4)	0.506

* Adjusted for potential lack of independence due to repeated sampling of specific household water use across six years.

† Sourced from Laboratory of Climatology and Climate Services, August 2025 (https://spei.csic.es/database.html).

‡ Referent condition is non-participation in education program.

§ Referent condition is pre-consultation delivery.

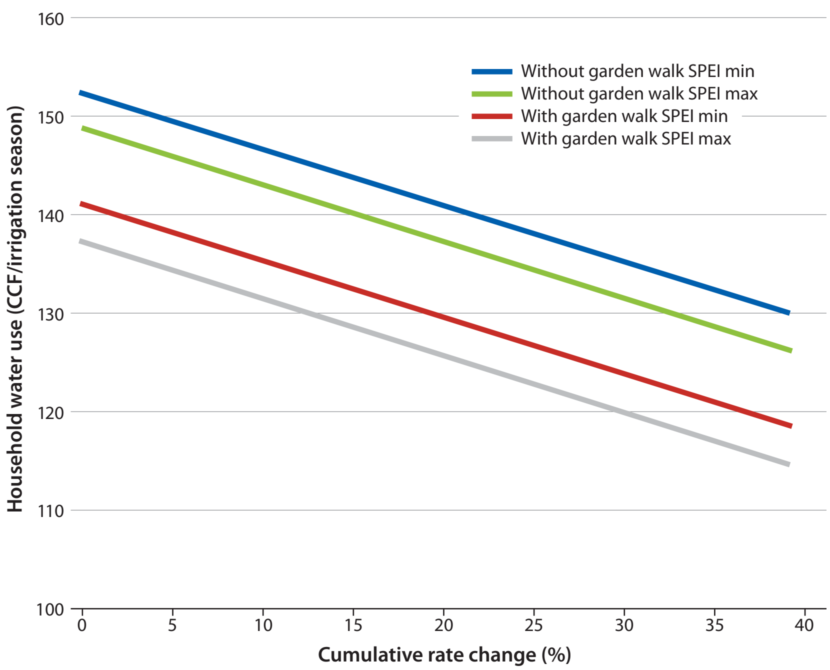

FIG. 3. Results from data-driven model illustrating the relationship of reduction of water use on the y-axis to cumulative increase in water rate on the x-axis. The difference in water use associated with participation in the Garden Walks education program is represented by comparing the blue and green lines (without Garden Walks) to the red and grey lines (with Garden Walks). The blue and red lines are associated with minimum SPEI (–0.8) or driest year, with the green and grey lines associated with maximum SPEI (1.4) or the wettest year.

such as annual precipitation and seasonal reference evapotranspiration, reflected the year-to-year variation that is common in a drought-prone region (table 1). For example, 2006 and 2011 experienced 73 and 70.2 inches of precipitation, compared with 36.3 inches in 2007. As indicated by SPEI, 2006 was the wettest of the six years, and 2007 was the driest.

Linear mixed effects model results for associations of household water use with explanatory variables are presented in table 2. Modeling was conducted using six years of water use measured for the 481 participant households and 478 non-participant households, resulting in 5,754 individual irrigation season measurements of household water use. The model constant is 151.9 hundred cubic feet of water (430.1 cubic meters [m^3]) (hereafter CCF, the billing unit used by Marin Water; 1 CCF equals 748 gallons). This is the starting point or baseline of seasonal home water use for participant and non-participant households during the irrigation season.

The climate measurement with the clearest relationship to water use was the SPEI for the 12-month period through October of each year. Water use and SPEI have a negative or inverse relationship, with approximately 2.2 CCF more water used for a one-unit decrease in SPEI. This reflects an increase in water use in drier years (fig. 3), with not only less rainfall but greater potential evapotranspiration.

Seasonal reference evapotranspiration (ETo) was not statistically significant. Neither was annual precipitation, perhaps because annual precipitation in California is concentrated in wet winter months, while landscape irrigation is concentrated in the dry summer months.

The relationship between water use and cumulative change in water rates was significant and inverse. For every percent increase in cumulative rate change, there is an associated 0.6 CCF decrease in water use (fig. 3). Similarly, the interaction between participation in the program and the year of the on-site consultation indicates a significant decrease in water use among program participants of 10.4 CCF (29.5 m^3) after receiving the educational consultation, as indicated by the model coefficient. The year in which each Garden Walk took place is important because water rates were increasing over time. While both participants and non-participants decreased water use in response to rate increases, participants had a greater reduction in their use than did non-participants (fig. 3).

Analyzing the influence of the education program on water use with the difference of differences approach yields a 10.8 CCF (30.6 m^3) reduction in seasonal water use for program participants over non-participants

Irrigation frequency and run times are reviewed for each planting zone at the sprinkler irrigation controller. *Photo*: Rebbeca Ryan.

Garden Walks provides hands-on education on the participant's property, allowing them to learn water conservation techniques in their own garden.

TABLE 3. Mean water use (CCF/summer season) for studied homes in Marin County for both the program participants and non-participants before and after home consultations were provided, with sample size and standard error provided

Variable	Homeowners not receiving consultation	Homeowners receiving consultation	Difference Receive – Not Receive
Before home consultation	144.5 (1,831, 3.1)	145.3 (1,858, 2.2)	0.8 (3.8)
After home consultation	130.5 (1,037, 3.6)	120.5 (1,028, 2.4)	−10 (4.4)
Change in water use	−14.0 (3.2)	−24.8 (3.5)	−10.8

Sample size *n* and standard error (SE) are presented in parentheses (e.g., 1,831, 3.1).

(table 3). Prior to the Garden Walks consultation, participating and non-participating households differed in their water use by less than one CCF (2.8 m^3) per irrigation season, on average. After the consultation, participating households used 10 CCF (28.3 m^3) less than non-participants.

Water savings as a result of participation in the Garden Walks program averaged 8% or 7,780 gallons per participating household during the irrigation season. Household water savings were calculated by evaluating water use for two years after the Garden Walk (except for walks done in 2010, which had only one year of post-measurement), so we know savings lasted at least that long. When we multiply the number of participating households (481) by the number of gallons saved per year, using 10.4 CCF from the linear mixed effects analysis, and the number of years the effect is known to last (at least two), we obtain a minimum net savings of 7.48 million gallons (28,400 m^3) of water over the study period (10.4 CCF/household-year × 481 participating households × 2 year minimum), or about 23.0 acre-feet over the study period. The cost to run the program for those four years was about $75,000, saving about 100 gallons (0.38 m^3) of water per dollar. The average price of water, across all tiers and years, delivered to residential customers by Marin Water in the analysis period was $7.50 per CCF (2.83 m^3), or about 100 gallons (0.38 m^3) per dollar.

Water rates and education affect water use

Perhaps unsurprisingly, the price of water was the largest driver of water conservation (Olmstead and Hanemann 2007). Residential water users county-wide reduced their water use by about 23.4 CCF (66.3 m^3) in response to rate tiers and increases, in comparison to 10.4 CCF (29.4 m^3) for participation in the Garden Walks program (fig. 3). However, participation in the Garden Walks program was not only measurable and statistically significant, but it made more of a difference during an irrigation season than did drought conditions (2.2 CCF, or 6.22 m^3) (fig. 3).

Garden Walks volunteer team members explore plant selection and hydrozones with a residential gardener. *Photo*: Rebbeca Ryan.

Our use of a controlled study builds on the findings of an uncontrolled study in Florida (McCue et al. 2007), which estimated about 13% water savings from a similar program. This is almost exactly what our uncontrolled back-of-the-envelope estimates looked like in 2009. The difficulty in using linear regression models to estimate water savings in tiered pricing systems discussed by Nataraj and Hanemann (2011) does not appear to be borne out in our results. The linear mixed effects model identified a water savings of 10.4 CCF (29.4 m^3) as compared to the difference of differences test, which identified nearly the same value for water savings of 10.8 CCF (30.6 m^3). The agreement of these values provides confirmation that the association between Garden Walks program participation and water savings is detectable in this dataset. Admittedly, our data set spans only one rate increase period and therefore avoids the feedback loop between rate hikes and water use over multiple rate increase periods.

Finding leaks saved water

Most of the water conserved through Garden Walks appears to have been due to locating leaking irrigation systems, which were found on 6% of the visits, but accounted for nearly 40% of total water saved. The average water consumption of leaking irrigation systems was seven times higher than systems in good repair, with an average reduction in water use (after repair) of 141 CCF (399 m^3), compared to the average reduction of 21.0 CCF (59.5 m^3) for systems in good order. The 8% reduction in overall water use achieved by program participants is similar to the installation of smart irrigation controllers (Cominola et al. 2021), which are more costly to install, but, like educational programs, may also lead to long-term water savings (at least, as long as they're maintained). This in turn suggests that routine monitoring of individual households' water use, whether by a volunteer program such as the one described in this study, or some other means, such as computer-detected large deviations in seasonal water use that would indicate leaks, are important tools in water conservation. Rupiper et al. (2022) recently reported a similar finding.

The amount of water saved by an educational program will be affected by the number of water-saving landscaping practices put in place by the program participants, and the amount of time the practices remain in use. Since Americans are moving less than they used to (Frost 2022), staying five years on average in a given location, we expect that the water-conserving landscaping practices implemented by the participants will continue to operate for at least that long, provided the systems are maintained. Because we did not explore how long participants remembered and applied the educational content, we will stick with the conservative finding of two years for projecting water savings.

Many California water districts face the prospect of trying to meet increasing residential water demand with static or decreasing water supplies. In Marin County, the cost of developing new water supplies, such as piping water over the Richmond-San Rafael bridge (presumably bought from water districts that may be facing their own shortages), building new reservoirs, or building desalination plants, far outstrips the cost of conservation measures such as the Garden Walks program.

We acknowledge that there is potential for bias in this study. One potential source for bias is volunteer selection (program participants were not randomly selected for this study). The results and conclusions may therefore be influenced by a strong environmental ethic on the part of participants. Even if this is the case, Garden Walks enables those with strong environmental ethics to make tangible changes in their water management and use. Regrettably, a large proportion of Marin Water's customer base does not sign up for Garden Walks, despite an outreach campaign aimed at informing them of the opportunity. While the Garden Walks program has proven to be a cost-effective way for Marin Water to conserve water, we can't help but wonder how much more water could be saved if all those other households participated. CA

S.V. Swain was Environmental Horticulture Advisor, UC Cooperative Extension Marin and Sonoma counties; M.S. Mathers is Community Education Specialist, UC Cooperative Extension

A Garden Walks volunteer confers with a home gardener on plant selection and sprinkler system management. *Photo*: Marie Narlock.

Marin County; D.J. Lewis is Watershed Advisor, UC Cooperative Extension Marin County.

In memory of Steven Swain, 1966–2025. Steven's curiosity and passion for science and his empathy and compassion for people were catalysts for many projects, like Garden Walks. He respected and adored the UC Marin Master Gardeners as colleagues and friends. May this publication be one way to carry forward his contributions and impact and for us to share our gratitude for his presence in our lives.

The authors would like to thank Dr. Tina Saitone for direction on the difference of differences statistical analysis; Dan Carney of the (then) Marin Municipal Water District for some of the initial project ideas; Wendy Menara of Marin Water for coaching our volunteer coordinators; Keith Bancroft and Sergio Paganelli of Marin Water for their unflagging program support and hours of volunteer training; many of the Garden Walks coordinators who helped make the study possible, including Glen Smith, Karen Detweiler, Jeanne Ballestero, Pam Polite-Fisco, Ron Filson and Jean Burns; and finally to our scores of volunteers who, over the past 19 years, have provided more than 2,500 Garden Walks.

References

Angrist JD, Pischke JS. 2009. *Mostly Harmless Econometrics: An Empiricist's Companion.* New Jersey: Princeton University Press. 392 p.

Arbués F, Garcia-Valiñas MÁ, Martinez-Espiñeira R. 2003. Estimation of residential water demand: A state-of-the-art review. J Socio-Econ 32(1):81–102. https://doi.org/10.1016/S1053-5357(03)00005-2

Borisova T, Useche P. 2013a. Evaluating the performance of non-price residential water conservation programs using quasi-experiments. 2013b. Agricultural and Applied Economics Assn. Annual Meeting. https://econpapers.repec.org/paper/agsaaea13/151223.htm

Borisova T, Useche P. 2013b. Exploring the effects of extension workshops on household water-use behavior. Am Soc Hort Tech 23(5):668–76. https:/doi.org/10.21273/HORTTECH.23.5.668

Card D, Krueger AB. 1994. Minimum wages and employment: A case study of the fast-food industry in New Jersey and Pennsylvania. Am Econ Rev 84(4):772–93. www.jstor.org/stable/2118030

Cominola A, Giuliani M, Castelletti A. 2021. Long-term water conservation is fostered by smart meter-based feedback and digital user engagement. npj Clean Water 4(29). https://doi.org/10.1038/s41545-021-00119-0

Frost R. 2022. Domestic migration drove state and local population change in 2021. Joint Center for Housing Studies, Harvard University. www.jchs.harvard.edu/blog/domestic-migration-drove-state-and-local-population-change-2021 (accessed 25 October 2022).

[LCSC] Climatology and Climate Services Laboratory. 2025. Global Drought Crops Monitoring. https://lcsc.csic.es/lcsc-2/

McCue T, Murin J, Meinert D. 2007. Quantification of potable water savings derived from a residential irrigation audit program in Seminole County, Florida. Florida Water Resources Journal. August 2007:52–4. http://fwrj.com/techarticle07/0807%20fwrj%20tech.pdf (accessed 24 October 2024).

Nataraj S, Hanemann WM. 2011. Does marginal price matter? A regression discontinuity approach to estimating water demand. J Environ Econ Manag 61(2):198–212. https://doi.org/10.1016/j.jeem.2010.06.003

Olmstead SM, Hanemann WM, Stavins RN. 2007. Water demand under alternative price structures. J Environ Econ Manag 54(2):181–98. https://doi.org/10.1016/j.jeem.2007.03.002

Pinheiro JC, Bates DM. 2000. *Mixed Effects Models in S and S-PLUS.* New York: Springer-Verlag. 528 p.

Rupiper A, Weill J, Bruno E, et al. 2022. Could fixing leaky pipes help solve California's water problems? ARE Update 25(4):1–2. https://giannini.ucop.edu/filer/file/1650925435/20369/

U.S. Census Bureau. 2022. Quick Facts: Marin County. www.census.gov/quickfacts/geo/chart/marincountycalifornia/PST045221 (accessed 24 September 2022).

U.S. Census Bureau. 1980. 1980 Census of Population. www2.census.gov/prod2/decennial/documents/1980/1980censusofpopu8011uns_bw.pdf (accessed 24 September 2022).

Vicente-Serrano SM, Beguería S, López-Moreno JI. 2010. A multiscalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index J Climate 23(7):1696–1718. https://doi.org/10.1175%2F2009JCLI2909.1

Worthington AC, Hoffman M. 2008. An empirical survey of residential water demand modelling. J Econ Surveys 22(5):842–71. https://doi.org/10.1111/j.1467-6419.2008.00551.x