TO: COMMITTEE MEMBERS

FROM: BRUCE BUEL

DATE: JULY 24, 2009

AGENDA ITEMS
2
JULY 27, 2009

COMPARE IRRIGATION TECHNOLOGIES

ITEMS

COMPARE IRRIGATION TECHNOLOGIES [DISCUSSION AND ANSWER QUESTIONS]

BACKGROUND

The Nipomo Community Services District is presently considering initiation of an irrigation controller program as a means of conserving water use in the landscape.

Presentations of irrigation controller technologies will be done.

RECOMMENDATION

Discussion and answer questions.

Santa Barbara County ET Controller Distribution and Installation Program
Final Report - June 30, 2003

Project Procedure:

General Overview:

In Santa Barbara County, the average amount of landscaping at residential properties is approximately 1 acre and it is estimated that approximately 50 percent of the water used at a residence goes to the landscape. To increase residential landscape water efficiency, the Santa Barbara County Water Agency, the City of Santa Barbara, the Goleta Water District, the City of Lompoc, the City of Santa Maria and Vandenberg Village Community Services District jointly developed the Santa Barbara County ET Controller Distribution and Installation Program (ET Controller Program).

The WeatherTRAK ET Controller technology was chosen for the ET Controller Program because a study conducted by Irvine Ranch Water District it provided conclusive evidence that the WeatherTRAK controller supplies accurate irrigation scheduling by automatically creating a weekly irrigation schedule based on "real time" evapotranspiration (ET) data from local weather stations.

Santa Barbara County's ET Controller Program was selected to receive funding from a Water Use Efficiency Grant through the CALFED Bay Delta Program in May of 2001. According to the original program plan, the program partners would distribute 300 ET controllers with rain sensors and soil probes at no cost to participating customers. The program partners would be responsible for selecting customers, marketing the program, conducting pre-screening surveys to ensure customers met program criteria. If the customer met the program criteria, the program partner would arrange a meeting with the customer to complete all paperwork associated with the program, review the customer's water use history, and conduct a cursory survey of the irrigation system to make sure it met program criteria (12 stations or less or stations that could be combined to equal 12). Customers would be responsible for paying the signal fee to Hydropoint Data Services to ensure customer buy-in to the program. The cost for the signal fee was $4 per month, which would be paid in a lump sum of $144 (to cover three years) at the beginning of their participation in the program. (Customers whose controllers were in an outdoor location were also required to purchase an outdoor box to protect the controller.) Local landscape contractors would be trained to evaluate the customer's irrigation system, prepare a written report on recommend improvements to irrigation system, distribute soil probes and demonstrate of its use, and wire and program the controller. Payment for the installation services, which were estimated to take 2 to 3 hours would be $100 per controller and would be paid with grant funding.

Many changes to the original program plan occurred during implementation of the program. Those changes and the reasons for them are outlined below.

Administrative Set-up:

The ET Controller Program began with the development of a local Work Team. The original Work Team consisted of representatives from the Santa Barbara County Water Agency, City of

Santa Barbara, Goleta Water District, ConserVision Consulting and Network Services, Inc. (which later became Hydropoint Data Systems).

The Santa Barbara County Water Agency acted as the fiscal agent for the ET Controller Program and entered into a contract with ConserVision Consulting for the purchase of the WeatherTRAK ET Controllers, customer service, and the training workshops for local landscape contractors.

Soon after the program began, the program partners realized that customer service should be provided by Hydropoint Data Systems rather than the consultant (who was based in Los Angeles), since the staff at Hydropoint Data Systems were available every day from 8:00 to 5:00 and had the expertise to walk customers through any problems. Hydropoint Data Systems also hired a customer service representative in the Santa Barbara area to do any site visits required.

Training Workshops and Demonstration Site Installations:
Two Installer Training Workshops and one training lab were held to create a list of trained installers for the ET Controller Program. Only licensed landscape contractors were invited to the Installers Training Workshop. The program partners worked with the local chapter of the California Licensed Contractors Association to develop a local address list for distribution of workshop invitations (See Attachment 1: Workshop Brochure).

The Workshop consisted of a classroom style presentation, hands-on programming and field installation of the WeatherTRAK ET Controller. The program partners developed a number of materials describing the specifics of Santa Barbara County's Program for distribution during the workshop including the Program Overview, the Site Visit Forms F1-F4, an example payment ticket, a WeatherTRAK Operator's Guide and CD, an Installer's Duties List, the installation Materials List, and the WeatherTRAK Adjustment Guide. (See enclosed Installation Training Notebook). After the initial training conducted by ConserVision, the staff at Hydropoint Data Systems took over the training duties for the ET Controller Program.

The Goleta Water District's Demonstration Garden at 4699 Hollister Avenue and the Santa Barbara Public Library at 40 East Anapamu Street were chosen as demonstration sites for the ET Controller Program. Potential customers are encouraged to visit these locations so they can see examples of landscapes maintained with the ET Controller technology. The controller at the Demonstration Garden was installed prior to the first training workshop to provide an example of a landscape that was using the technology. The controller at the Public Library was installed as part of the first training workshop to give installers a "hands-on" lesson for programming and wiring of the controller. During the second Installation Training Workshop in Lompoc, the hands-on installation took place at a residence.

During the training workshops, the landscape contractors provided feedback to the program partners indicating that the current list of installation duties would take much longer than the estimated 2 to 3 hours. Therefore, the program partners decided it would be appropriate for the partners to conduct the evaluation of the customer's irrigation system, prepare a written report on recommend improvements to irrigation system, and distribute soil probes and demonstrate their use to the customer during their planned site visit instead of leaving it to the installers. The installers' duties were reduced to focus on the actual installation of the controllers and programming them using the information collected by the program partners.

In order to ensure that all program partners were conducting these new site visit tasks in the same way, the program partners set up a training workshop for their staff to learn how to conduct the site visits and to complete the information sheets required for programming of the WeatherTRAK ET Controller.

Target Selection and Program Marketing:
Each agency developed a list of high-water using customers who served as the target audience for the ET Controller Program. Average water use for January and February and average use for July, August and September for the prior three years was determined for each customer. Then these averages were used to create a ratio of the difference between summer and winter use to determine highest irrigation use. ET Controller Program brochures (See Attachment 2: Program Brochure) and letters from the water purveyor were mailed to the top 100 high water users from these lists for Goleta Water District and City of Santa Barbara and the top 25 for the other three agencies.

The marketing campaign for the ET Controller Program was launched in April 2002. The partner purveyors used a direct marketing campaign and ET Controller demonstration sites to attract residential customers with the highest irrigation water demand to participate in the program. Additional marketing was conducted by telephone by several of the program partners. Marketing of the campaign will continue through mass mailings and follow-up phone calls until all of the controllers are installed.

Pre-Screening, Data Gathering and Installation of ET Controllers for Residential Customers:
Pre-Screening: The information in the ET Controller Program's marketing brochures directed customers to call their water purveyor if they were interested in participating in the ET Controller Program. When a program partner received a call from an interested customer, they provided an overview of the ET Controller Program and answered any questions the customer had about the WeatherTRAK technology. In addition, the customer was made aware of the fact that although they would receive a free controller and free installation ($300 to $400 value), they would be responsible for paying for the signal fee for a period of three years ($144 upfront cost). If the customer was still interested in participating, the water purveyor's program representative would ask the customer a series of questions from the Pre-Screening Survey (See Attachment 3: Pre-Screening Survey) to determine if the customer met the criteria of the ET Controller Program. Eligibility criteria included the following:

1. Customer must be property owner.
2. Customer must already have an automatic irrigation controller and irrigation system installed.
3. Customer must not have made any major landscape changes in the last three years, nor have any planned for the next three years.

Site Visit: Once a customer was approved for participation in the ET Controller Program, purveyor staff scheduled a site visit to collect the data required for the installation and programming of the WeatherTRAK controllers.

Program partners developed a Customer Packet (See enclosed Customer Packet) that included all of the necessary materials for successfully completing a site visit. Items in the customer packet included:

1. Hold Harmless Agreement
2. ET Controller Owner's Manual
3. Installer's payment ticket
4. Soil Probe and WeatherTRAK Adjustment Brochure
5. Site visit Forms F1-F4
6. Site visit checklist for agency staff
7. *How To Water Your Garden* by Sunset Publications
8. Customer "To Do" List
9. Customer Service Reminder Card (To direct customers to Hydropoint Data Systems for future customer service requests).

Site visits included the following activities: customer briefing and paperwork completion, an irrigation system check, precipitation rate determination (after July 2002 – see Monitoring section for more information), and wrap-up as described in detail below.

At the beginning of each site visit, purveyor staff would meet with the customer to answer any questions about the program, review the customer's water use history and the program description and begin the process of completing the necessary paperwork for program participation. A number of contractual documents were required to ensure the customer understood who was responsible for each portion of the ET Controller Program and what the limitations of the service were. Paperwork included the contract with Hydropoint Data Services for the ET signal, customer service, & support; the Hold Harmless Agreement between the water purveyor and the customer, and the payment and invoice for the signal fee. Once the paperwork was complete, the customer was asked to not use water during the site visit.

Purveyor staff then proceeded to conduct an irrigation check by collecting information for Weather TRAK Programming (Forms F1 and F2), evaluating the irrigation system and trouble shooting problems (Form F3), and measuring of lawn areas and running each station for determination of precipitation rates (Form F4). If the system included more than 12 active stations, staff would also determine which stations would be merged at this time.

Following the irrigation system check, purveyors staff would then conclude the site visit by giving the customer their controller, a soil probe (with a demonstration of its use), and a Customer To Do list, along with two copies of the site visit information forms. The Customer To Do list provided information on the required repairs and installer contact information. The customer was directed to complete the repairs prior to setting an appointment with installer. The customer was directed to call Hydropoint Data Systems customer service line for any customer service issues following the installation of the controller.

The completion of each of these tasks generally required two staff members and took approximately 2-4 hours to complete for a total site visit time of approximately 6 hours per controller, according to estimates provided by the program partners.

Monitoring:
A database tracking water savings by customer was developed in December 2002 and new customer information is added each quarter. Due to variations in the time of installation of the WeatherTRAK controller, the term used to determine the water savings percentage varies by customer. The term for the water savings data monitoring begins either the month following the installation of the WeatherTRAK Controller or the month following the programming of custom precipitation rates for those customers whose controllers were installed before custom precipitation rates were included in the site visits. The total water use over this time frame was then compared to the average water use for the same time frame of the two years prior to the installation year.

After monitoring the first few installations for a month or two, the partner purveyors and the customers were rather surprised at the increases in water bills of some of the customers. The program partners soon learned that in order to achieve the highest level of efficiency possible, it was necessary to determine the precipitation rates of the irrigation systems and program that information into the controller, rather than relying on the factory settings. Therefore, the program partners arranged for our local customer service representative to conduct a number of follow up evaluations to review the controller set up and input precipitation rates for spray heads in turf areas and precipitation rate determinations were included as part of the initial site visit for all installations after July 2002.

Project Results:
Six agencies participated in the program and collectively nine staff members have been trained to complete the tasks associated with the ET Controller Program. Twenty licensed landscape contractors completed the installation training for the Program. Although, some installers opted out of the Program after completing the training, several remained active and were very excited about being involved with this new technology.

Approximately 430 brochures and letters have been sent to high water using customers throughout Santa Barbara County.

As of June 30, 2003 sixty-two WeatherTRAK ET Controllers have been installed in Santa Barbara County and there are ten people on the waiting list for installations. The remaining 238 controllers will be installed during fiscal year 2003/2004. The discrepancy between the ending of the funding period and ending of the installation program is due to changes that occurred after the original proposal and contract were complete. In January 2003, staff from DWR contacted the Water Agency indicating that the contract deadline for the Santa Barbara County ET Controller Distribution and Installation Program had been changed to June 1, 2003. The original contract date, as listed in the signed CALFED WUE grant contract held by the Santa Barbara County Water Agency was June 14, 2004. For a number of reasons, the new date posed significant problems for program partners. Therefore, in April 2003, the program partners and DWR staff agreed that agencies participating in the Santa Barbara County ET Controller Distribution and Installation Program agreed to proceed with as many installations as possible to use the installation fees as stated in the contract budget, and would bill DWR for Water Agency staff time (up to $15,000) to make up for any installations that were planned for Fiscal Year

2003/2004. A final quarterly report, final invoice, and preliminary project report would be submitted to DWR no later than June 1, 2003. Program partners will continue to conduct installations until June 2004 so that all controllers purchased through this grant funding would be installed as stated in the original proposal.

Water Savings:
Our initial data indicates that customers are reducing their monthly water use by approximately 26%, with a high of 59% savings and a low of 8% savings. These estimates are still preliminary, as only a small number of customers have used the WeatherTRAK controller for one complete year. The partner purveyors will continue to monitor all program participants for a period of three years after the installation of their controller to ensure that the data is complete. If the current level of savings continues, this program will increase water supply reliability within the Bay-Delta by reducing local water purveyors' need to supplement local water supplies with State Water.

Other Environmental Benefits:
A study conducted by Irvine Ranch Water District indicated that the use of the WeatherTRAK ET Controller reduced runoff by 63 to 71%. Runoff from landscaped areas can carry pesticides and fertilizers into streams and eventually to the ocean. Although the Irvine Ranch study did not find a significant change in the water quality of the runoff at the storm drain outside of each study area, it is likely that the compounded results of reduced runoff from a larger portion of the watershed could reduce beach closures. As a result of this study, Santa Barbara County's Project Clean Water is mapping the sites with ET Controllers as a layer in their GIS system and will use the information as they monitor the water quality in our local streams and the ocean.

Project Costs:
The main costs associated with the ET Controller Program were the cost of the WeatherTRAK controllers ($200 per controller); installation fees ($100 to $150 per controller); soil probes ($12 probe); and consultant fees for marketing assistance, training workshops, and customer service. These costs were funded through the grant. Additional costs for the program included staff time for customer selection, site visits, and administrative duties; brochure production and printing; and postage. These costs were provided through in-kind contributions from each of the partner agencies.

Most of the costs associated with the project were known at the time the proposal was developed due to information provided by other similar programs. However, there were two areas where additional costs were incurred due to some of the unique features of the Santa Barbara County Program. These additional costs were centered on the fact that the original estimates for the site visit and installation times were extremely optimistic and based on a program where installations were conducted in an area where irrigation systems were relatively new and the size of the yard was fairly small. Based on these criteria, the program partners were given information that indicated that the installers could easily conduct the site visits and the whole process, including installation, would take about 2 to 3 hours.

However, the Santa Barbara County Program was open to any customer that was designated as a high water user and on average, the high water users had large yards (approximately 1 acre of landscaped area) with irrigations systems of up to 25 stations that were fairly old and in poor condition. Therefore, the site visit alone took two staff members approximately 2 to 4 hours to complete and installations took an average of 4 hours to complete.

In the grant proposal, agency staff estimated that two hours per controller would be required of agency staff for all administrative duties and customer selection and site visit duties were assigned to the installers. Soon after the program began, it became apparent that the agency staff would be required to conduct the site visits, thereby increasing the staff time in-kind contribution substantially.

Additionally, after receiving input from several of the installers, agency staff discovered that installation times had also been greatly underestimated and the payment offered was inadequate. This was especially apparent when installations required the hard-wiring of the WeatherTRAK controller. In an effort to address this discrepancy, the program partners increased the installation payment for hardwiring to $150 per installation. Part of the funding for this increased payment was provided through a grant from the U.S. Bureau of Reclamation.

Photos, Presentations, Comments:

Project partners presented preliminary findings from the Santa Barbara County ET Controller and Distribution Program at the California Urban Water Conservation Council's ET and Weather Based Controllers Workshop on March 20, 2003 in Claremont, CA. (See Attachment 4: CUWCC Presentation Slides). In addition, a number of articles updating the ET Controller Program's progress have appeared in the Santa Barbara County Water Agency's *Water Connection* Newsletter (See Attached). Santa Barbara's ET Controller Program is also highlighted on the Hydropoint website at www.hydropoint.com. Program partners also submitted a number of items for discussion at the Irrigation Association Roundtable for ET Controllers that took place in October of 2002.

Summary

The Santa Barbara County ET Controller Distribution and Installation Program has been an enlightening and rewarding experience for the program partners. The WeatherTRAK Controller is an exceptional water savings device and we hope to see extensive use of this technology in the future. The lessons learned by the program partners during the first year and a half of the program in order of importance were: **a custom precipitation rate for turf areas is a must; manufacturer customer service and installation training is essential; an increased number of stations would be valuable; and information gathering for programming of controller and post-installation adjustments cannot be left to customer.**

The program partners have found that using the factory settings for precipitation rates in the WeatherTRAK controllers does not result in reliable savings. In fact, on average the WeatherTRAK schedules were over watering turf areas and under watered areas with drip systems. Although the Santa Barbara County program distributed soil probes and brochures describing how customers could adjust the controller to correct these issues, only 2 customers actually made the adjustments. The staff at Hydropoint Data Systems is currently working to perfect the assumptions for precipitation rates and to incorporate more weather data to allow for variations within ET zones to address this problem.

The Santa Barbara County Program has been using the Hydropoint Data Systems Customer Service line since July of 2002 and also worked with Hydropoint staff to run the installation training workshops. Using Hydropoint's experienced staff and the existing customer service line provided essential support to our program and allowed immediate reconciliation of any problems that arose. Despite extensive training workshops for local installers, the program partners have found that even the experienced landscape contractors still have a difficult time with installations. In addition to providing support to the customers, Hydropoint's staff was also able to provide further assistance to the installers during difficult installations.

The Weather TRAK Residential ET Controller only allows for twelve irrigation stations. This does not allow for easy conversion from a standard controller. Most residential landscapes in Santa Barbara County need anywhere from 18 to 24 stations available. The problems that arise from the lack of stations on the controller include: inability to provide a new controller to customer because physical restraints on merging stations; difficulties in finding appropriate stations to merge to reduce the station number to 12; and confusion on the part of the homeowner/installer regarding the installation and programming of the controller.

The program partners worked closely with their customers, the gardeners and the local installers to ensure the proper installation and programming of the WeatherTRAK controller. At the beginning of the program, the partners had hoped that the customers and/or their gardeners would be able to provide information about their landscapes that was needed to program the controllers properly. However, when the programming sheets were left with the customers, they were not completed so agency staff included this task in their site visit. In addition, customers did not use their soil probes or the Adjustment Brochure to fine-tune the controller after installation. Rather, they would call their installer and/or Hydropoint Customer Service for assistance. The installers were instructed to have the customers call Hydropoint and Hydropoint would lead them through the adjustment process.

While the Santa Barbara County ET Controller Distribution and Installation program partners have experienced some challenges, there are significant benefits to the WeatherTRAK ET Controller technology that are major improvements in saving water over the conventional irrigation controllers currently on the retail market for residential use. With fine turning and hand holding, the program partners are achieving significant savings in many of the sites using the Weather TRAK irrigation controller.

Residential Studies, Hydropoint WeatherTRAK
ET-Based Signal-Broadcast Scheduling, Smart Irrigation Controllers

http://www.irwd.com/Conservation/ETsavings%5B1%5D.pdf

Bamezai, A. *ET Controller Savings Through the Second Post-Retrofit Year: A Brief Update*. April 2001

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http://www.irrigation.org/swat/images/irvine.pdf

Hunt, T, Lessick, D, Berg, J., Wiedmann, J., Ash, T. Pagano, D., Marian, M., Bamezai, A. *Residential Weather-Based Irrigation Scheduling: Evidence from the Irvine "ETController" Study*. June 2001.

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http://www.cuwcc.org/Landscape_Irr_Tech/LADWP_Irrigation_Controller_Pilot_Study_04-08-03.pdf

Bamezai, Anil, *LADWP Weather based Irrigation Controller Pilot Study,A Report Submitted to the Los Angeles Department of Water and Power*. April 2003

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http://www.irwd.com/Conservation/R3-ExecSum10-26-04%5B1%5D.pdf

The Residential Runoff Reduction Study, Municipal Water District of Orange County and Irvine Ranch Water District, July 2004

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http://www.irrigation.org/swat/images/santa_barbara.pdf

Santa Barbara County Water Agency, *County ET Control-ler Distribution and Installation Program, Final Report*, 2003.

OTHER STUDIES:

SWAT Protocol, 2005. Irrigation Association.

City of Bend, Oregon, 2004-2005

University of Nevada at Las Vegas and Southern Nevada Water Authority, 2004 – 2005

University of Nevada at Reno Study, 2001-2002

University of Arizona (ongoing)

Colorado State University, 2003

Soquel Creek Water District, 2005

Newhall County Water District, 2005

Victor Valley Water District 2004-2005

TO: COMMITTEE MEMBERS

FROM: BRUCE BUEL

DATE: JULY 24, 2009

AGENDA ITEMS
6
JULY 27, 2009

DISCUSSION OF SPONSORING AN OUTDOOR-WATER CONSERVATION PRESENTATION BY ELLEN HAYAK (PPIC) AND/OR RON MUND (SLO)

ITEMS

DISCUSSION OF SPONSORING AN OUTDOOR-WATER CONSERVATION PRESENTATION BY ELLEN HANAK (PPIC) AND/OR RON MUND (SLO) [FORWARD RECOMMENDATIONS TO THE BOARD]

BACKGROUND

Director Michael Winn has requested the consideration of sponsoring a presentation on outdoor water conservation.

Please refer to Memo from Celeste Whitlow, NCSD's Water Conservation Coordinator.

RECOMMENDATION

FORWARD RECOMMENDATIONS TO THE BOARD.

NIPOMO COMMUNITY SERVICES DISTRICT

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MEMORANDUM

TO: BRUCE BUEL, GENERAL MANAGER

FROM: CELESTE WHITLOW, WATER CONSERVATION COORDINATOR

DATE: JULY 27, 2009

RE: ITEM – 6: DISCUSSION OF SPONSORING AN OUTDOOR-WATER CONSERVATION PRESENTATION BY ELLEN HANAK OR RON MUNDS.

BACKGROUND

Recently a Board Member circulated a publication from the Public Policy Institute of California, Californi Economic Policy, Volume 2, Number 2, July 2006, by Ellen Hanak and Matthew Davis.

On review of the publication, I found that the information and assumptions upon which the authors based their conclusions were invalid; therefore, their conclusions are invalid.

In the publication there is evidence of a lack of knowledge of water conservation and the many issues surrounding it.

I have prepared an Analysis of the paper, which is attached.

Another option for presentation was one by SLO City's Ron Munds. While Mr. Munds has years in water conservation, the nature of the City's water conservation needs are different than Nipomo's. SLO City has mainly small residential lots, where Nipomo has a mixture of small lots and larger lots (1 acre or more). SLO City has had water conservation measures in place for about 20 years, where Nipomo has just recently started implementing measures. SLO City has a very strong conservation-based rate structure which would ensure water conservation even if he did not do anything.

Because the situations between Nipomo and SLO City are so different, Mr. Munds' experience with SLO City would not in some cases transfer to our experience in Nipomo.

RECOMMENDATIONS

1. I strongly recommend that Ellen Hanak not be asked to give a presentation here because of the findings on the publication she authored.
2. I recommend that Ron Munds not be asked to give a presentation here because of the difference between SLO City and Nipomo.
3. If a presentation is desired from an outside presenter, I would suggest that Allison Jordan, from the Santa Barbara Water Authority be asked. Her experience with the irrigation controller study in Santa Barbara of homes on lots 1 acre and larger would be appropriate for Nipomo.

Analysis of *Lawns and Water Demand*
California Economic Policy, Vol. 2, July 2006
(Public Policy Institute of California)

Background

As the need for water conservation increases, there have been "immediate experts" willing to claim the title of water conservation expert without basic knowledge of the industry. Sometimes these new experts do their work by reviewing studies others have done, and making assumptions they would not make if they were truly knowledgeable about water conservation. Sometimes they do not have the basic knowledge sufficient to determine if a study they are reviewing is credible. The result is the appearance of policy papers and "analysis" of hugely complex water-conservation related issues, which, because of a lack of basic knowledge of the many facets of water conservation, have fatal flaws, which make the conclusions invalid.

These new experts may bring in their own prejudices to a policy paper, and slant the "analysis" to fit their pre-formed conclusions. Whether this is conscious or unconscious, the result is the same: biased research produces biased conclusions.

What is clear is that this is truly a time for the reader to beware of the possibility that the water conservation policy paper they are reading may not have valid conclusions, and that the writer may have an agenda by which the policy paper is written.

Issues

- **The assumption that everyone who wants to live in California should be able to do so, without consideration of there being adequate resources to support an infinitely growing population.**
- **The assumption that it is residential land use ("ranchettes" and larger lots) in the inland areas, and not temperature or any other factor, driving water consumption.**
- **The assumption that SFR uses twice as much water for landscaping when compared to MFR.**

Starting on page one, authors state that over the next 25 years California's population is expected to grow by 11 million residents, and the majority of the growth will be in the hotter inland areas will use more water, which will be impacted somewhat but the real impact comes from residential land use.

This "growth-to-infinity" belief is not a given fact. Some communities have decided to live within their resources, and have virtually stopped new development. These communities have decided to put the best interests of those already living there ahead of degrading the quality of their community's lifestyle by allowing more residents than the community's resources can support.

The belief that it is primarily residential land responsible for water consumption in the inland areas (or any area) is also not a given fact. Throughout the report, the authors focus on gallons-per-capita-per-day as their litmus device for defining and measuring water use and conservation, without addressing the amount of water used by MFR versus SFR per acre of land. While a MFR may use less water per person, the population density on a given parcel of land vastly increases the amount of water needed to sustain that parcel's occupants.

The claim that SFR uses twice as much water for landscaping when compared to MFR, mainly because of ranchettes, is not substantiated. The authors give reference to a DWR report, but I could not locate the report. The fact that it is DWR data raises the concern about the chronic under-reporting of the true water consumption of MFR residences. In California, the annual DWR reports filed by water suppliers are the usual source. The DWR's MFR figure only indicates the amount of residential water used by MFRs. Most MFRs have meter(s) for residential (indoor) water use, and meter(s) for landscape (outdoor) water use. Only the MFR residential metered water is reported, resulting in inaccurate (low) MFR reported consumption of water.

The assumption that 25% of plant water needs are covered by rainfall. This is what they say in the report:

"Cool-season turf is a typical high-water-using plant. (Warm-season turf grass, still not very common in California, has an ET requirement of 60 percent.) Various landscape alternatives, including shrubs and trees, fall into the medium category, and

many native species are low water users. A conventional residential mix might be half cool-season grass and half trees and shrubs, for an overall ET requirement of 65 percent.[19] Using California's irrigation efficiency standard of 62.5 percent, such a yard would require 105 percent of the ET0 shown in Tables 2 and 3. We estimate that the average for California yards in 2000 was in the range of 106 to 127 percent of the ET0.[20]"

This is what they give in the reference footnote:

*"[20] We obtained these figures by comparing outdoor water use estimates in the inland and coastal areas with our estimates of irrigated acreage and **assuming that 25 percent of plant water needs are covered by rainfall**. With DWR's estimate of outdoor residential water use (2.3 million acre-feet, or 42 percent of all residential use), we obtain an ET factor of 106. If outdoor use instead made up half of the residential total, the ET factor jumps to 127. Rates are higher in the inland regions in both scenarios."*

The rate and pattern of rainfall in each storm can vary greatly. The amount of rain actually percolating into the soil also varies due to amount of pervious surface and type of soil in a site. Buildings, large trees, and other large objects may cast rain shadows, which will vary depending on the direction the storm is moving. Therefore, it is illogical to assume that rainfall will take care of 25% of a landscape's need for water; it is an arbitrary assignment, not backed by irrigation industry standards.

That is why precipitation or rainfall is not part of the standard calculations used to find the amount of water that must be applied to a site.

There are three major calculations (and a few smaller calculations) involved in arriving at the amount of water a site needs. The amount of rainfall is not part of any of them.

(In addition to the three major calculations, there are additional adjustments that may be needed if, for example, irrigation is done with recycled water or saline water.)

Irrigation during and immediately after rain events is not desired, however, due to possibilities of run-off, washing away seeds, etc. There are two ways to prevent irrigation during a rain event:

1) Add on a rain sensor, which must be cleaned and verified for its working condition once a week during the rainy season and check to ensure the system is not irrigating during rain. The add-on rain sensors do not dependably wok, or work well. Dust, bird-poop and random water hitting the sensor interfere with correct sensing.
2) Buy a system that has, as part of its programming, a feature (such as WeatherTRAK's "rain pause") that stops irrigation during or after rain events.

The assumption that MFR outdoor water use is half the single-family average. This is what they say in the report:

"For *multifamily homes, we assume that outdoor water use is half the single-family average.*[14]"

This is the referenced materials:

"[14] This estimate is derived using the 2000 Census estimate of the share of multifamily units in the total (32.9%) and DWR's estimate that multifamily units accounted for 26.8 percent of residential water use in that year (see Department of Water Resources, 2004). For that same year, DWR (2005) estimates average indoor residential use at 3,233,000 acre-feet, or 0.28 acre-feet per household, and average outdoor use at 2,328,000 acre-feet. If average multifamily and single-family indoor use is the same, this implies an average single-family outdoor use of 0.24 acre-feet and average multifamily outdoor use of 0.11 acre-feet, 46 percent of the single-family value. We apply a rate of 50 percent, because it is also likely that multifamily homes have somewhat lower indoor use. Note that these ratios are similar to those found by Dzieglielewski et al. (1990) in a study conducted in Southern California (Department of Water Resources, 1994a)."

I simply do not know what they mean. I see nothing in the reference to support the claim that MFR outdoor water use is one-half that of SFR outdoor water use. It may be true, but I do not see that from the reference. I searched for the referenced documents, but could not find them. If it is felt important to dig through the DWR reports for 2005, I will be glad to do so.

Irrigation Controller Studies

Assumption of 50% irrigation efficiency in controller studies. Often when landscape water audits are performed, the irrigation efficiency (IE) is found to be poor; 50% is poor. Poor IE is because of lax oversight and standards for the use of irrigation controllers, and the necessity of keeping them well maintained and repaired. The poor "irrigation efficiency" is due to scheduling (run-times that are too long, or irrigation events scheduled too close together), or poor distribution uniformity (DU), or both. "DU" is the amount of irrigation water that falls on the landscape. Catch-cans are used to collect water from an irrigation event. Ideally, the amount of water in all catch-cans should be the same. That would be 100% irrigation efficiency. Often that is not the case, with some areas overwatered and some underwatered. Most companies will not install an irrigation controller if the DU is less than 70% because to avoid brown spots the controller will have to be turned up to a level where other parts of the landscape are being overwatered.

This should not be accepted as the norm. This is poor performance by whoever is controlling the controller and the landscape.

By 2010, Nipomo and/or San Luis Obispo County will have to adopt the state landscape ordinance (or design one more strict), which calls for an irrigation efficiency standard of 70%.

Irrigation controller studies reviewed for conclusions regarding best customer choices for irrigation controllers. The authors used two smart irrigation controller studies and one (apparently) interview with MWD personnel, upon which to make their recommendations. My review of these studies/interview shows the following:

<u>Irvine Residential Water District</u>. This study was an atypical irrigation-controller study because it utilized residences with small lots, and the customers had been subject to water-budget tiered rates for eight years prior to the study. Most of the wasted water had been saved, so the actual savings (18% to 22% of water) was actually lower than it would have been if a site was used that had not previously undergone aggressive water-conservation interventions. The goal of the study was to see if the automated smart controller with real-time ET (signal-broadcasted) irrigation scheduling would work. The irrigation controller used for this study was the prototype for the WeatherTRAK (Hydropoint) ET controller with broadcast-signal schedule adjustment, and it was direct-install program. The conclusion of the study was that it did work. There was 97% customer satisfaction and 18% to 22% savings. The plant health was judged by the customers to be better, and customer satisfaction was high because they did not have to do anything to save water.

<u>Santa Barbara Water Authority</u>. This study was of larger landscapes (1 acre and above). The controller used was the WeatherTRAK (Hydropoint) ET controller with broadcast-signal schedule adjustment. This was a direct-install program, which costs more but delivers higher and more reliable savings. This study has been ongoing for 10 years, and has a consistent average savings of 26%. Prior to this study, the SBWA had tried a program of just handing out irrigation controllers to customers, and it was a failure. (This is usually the case with programs where the controllers are handed out to customers.)

<u>Metropolitan Water District</u>. The reference given for this information is an interview. Therefore, there is no report to review. The MWD has done studies and offered rebates which always consisted of a variety of controllers, and not all ET controllers are created the same (nor do they give the same results). In addition, this reference is for ET controllers *in conjunction with another intervention, MP rotator nozzles, which, by themselves, can produce between 15% to 30% decrease in water, used, depending on the source.*

The authors' conclusions for irrigation controllers are for <u>all</u> smart irrigation controllers. The studies used for the conclusions are two that are strictly for one specific ET controller (WeatherTRAK with broadcast-signal automatic scheduling), and one that is for an assortment of controllers which were installed in conjunction with another water-conservation measure, MP rotator nozzles, which by themselves are said to produce 15% to 30% savings. The two WeatherTRAK studies were direct-install programs, which produce higher savings than programs where the customers are provided with the controllers and it is up to them to get them installed and programmed.

Conclusions for <u>all</u> smart controllers based on these three studies are invalid. One irrigation controller was overly represented (two of the three studies were solely for WeatherTRAK with signal-broadcast automatic scheduling, direct-install programs), and there is no indication of which controllers besides the WeatherTRAK were used in the

MWD studies. It is unclear if the MWD controllers were direct-installed, but previous MWD studies have not always included direct-install programs. In addition, the MWD study added another variable, the installation of irrigation controllers in conjunction with MP rotator nozzles, which are said to produce 15% to 30% savings on their own.

I believe using the references from which conclusions about all smart irrigation controllers is obtained indicates a lack of adequate water-conservation/irrigation-controller knowledge for authoring a paper of this type. All three of the studies are of different applications and technology, and/or as protocol. The IRWD and the SBWA studies were for the same controller, direct-install method, but IRWD was for very small lots, and the SBWA's study was for larger lots (1.0 acre or greater). It seems the authors do not know that all ET controllers are not alike, and that different controllers used under different programs and conditions, including how the scheduling is done, will deliver different savings.

Of the irrigation controller studies in the "references" section, all were for WeatherTRAK broadcast-signal scheduling. None of the controllers was for smart controllers with scheduling by on-site sensors.

Lack of clarification of terminology having more than one meaning. The authors refer to "sensors" in the report. Specifically, they mean solar or temperature sensors, which are add-on gadgets to old irrigation controller technology. They are inexpensive and inaccurate. Sensors require maintenance (dust, bird poop, and other foreign material renders them inaccurate or inoperable), including batteries, proper placement, and cleaning, have short life spans, and return questionable data, and sensor controllers do not calculate efficient irrigation schedules. They change only the minutes by a percentage of the irrigation up or down.

"Sensors" does not refer to soil-moisture sensors.

Lack of understanding the specifics of each study and the impact made on results of controller study. One of the studies cited in the review of controller studies was the Santa Barbara Water Authority study, which was a study of the impact of using a WeatherTRAK ET-based smart controller with signal-broadcast scheduling on *large residential lots, 1.0 acre and larger*.

Yet this is given in the report to describe the findings in Table 6, Smart Controller Costs and Savings:

"*Table 6 presents consumer and utility costs under some different scenarios. The calculations assume the use of a new, smart controller **in a typical small lot** in each of the four climatic zones, currently planted half turf and half shrubs and trees and being watered at 50 percent irrigation efficiency.*"

The savings given in the SBWA report on their study is in percentage: 26% average water savings consistent over ten years. There is a huge difference in 26% water savings of a "typical small lot" and 26% water savings in a lot of 1.0 acre or more.

Invalid conclusions due to invalid study and comparisons.

The authors state "Field studies have shown that smart controllers can reduce residential water use considerably." The authors conclude, "For consumers, the best bet is likely to be controllers with on-site sensors..." Out of the three field studies used to assess for water savings, two of them were for WeatherTRAK ET controllers with broadcast-signal automatic scheduling. Indeed, in the reference section, the only studies are for WeatherTRAK ET broadcast-signal scheduled controllers. There are no studies referenced for sensor-controlled irrigation controllers.

It is clear that the authors took information about ET broadcast-signal scheduled controllers, applied them to all controllers (including sensor controllers, for which no studies are referenced in the report), and then, based on cost ($4 a month) alone, concluded that sensor-based smart controllers were the "best bet" for controllers.

The conclusion that an ET controller with a signal fee of $4 a month is so expensive that the customer or agency cannot recover their costs of the system in 15 years.

The only studies referenced in this report are WeatherTRAK ET-based broadcast-signal scheduled irrigation controllers. They do not list any on-site sensor-based studies. There is no way the can make a conclusion about sensor-based controllers when they were not included in the report.

(As described previously, I believe the authors know so little about water conservation and irrigation controllers that they did not check to see what kind of controllers were used in each study, and what kind of scheduling (signal-broadcast or onsite-sensor) they employed. They then took the findings on broadcast-signal scheduled irrigation and concluded that, because broadcast-signal-scheduled irrigation scheduling requires a $4/month charge, that sensor-based irrigation controllers were better.)

The conclusion that ET controllers with broadcast scheduling were not the best for residents because of the $48/year fee for the broadcast is illogical, partly because of faulty analysis, and partly because of lack of knowledge.

The broadcast fee is not just for broadcasting a number from CIMIS. According to the *Weather and Soil Moisture Based Landscape Irrigation Scheduling Devices (Technical Review Report, 2nd Edition)*, from the U.S. Bureau of Reclamation, August 2007:

> *"The WeatherTRAK system uses data from over 14,000 weather stations across the U.S., including the National Oceanic and Atmospheric Administration's (NOAA) network, state and county networks and private weather stations. The WeatherTRAK system uses advanced climatologic modeling techniques developed at Penn State University. This proprietary system is called ET EverywhereTM, and has proven accuracy to a standard deviation of .01 inch of daily ET down to one square kilometer. The WeatherTRAK ET Everywhere service provides local ET (microzone) without the need for any additional Weather and Soil Moisture Based Landscape Scheduling Devices weather stations or single sensors on a site. The WeatherTRAK system calculates ET using the standardized Penman-Monteith equation. The HydroPoint Data Center validates the weather data and transmits calculated ET through three satellite servers to each controller every day. The three satellite servers provide over-lapping coverage of the U.S. to ensure signal reception to WeatherTRAK controllers located anywhere. The number that is broadcast is from an intricate network of microclimates, derived from CIMIS, NOAA, other government weather stations, and a federal government database of topography and weather patterns. It is like having a CIMIS station on every block".*

The broadcast fee includes customer service assistance. If a customer (or their agent) has a problem with the controller or needs assistance, they can call the 800 number on the controller; the customer service person (bilingual) can then access the information from the controller and really be of assistance. The customer can even send pictures over a cell-phone to the customer service rep so that a visual of the site can add to the assessment. There is no other irrigation controller vendor providing customer service on-demand for part of a $4/month fee.

Clearly, one service call on an irrigation controller would cost more than $48. The $4/month fee is not only for the broadcast scheduling signal, but also a kind of insurance for customer service.

I realize the policy paper is now three years old, but even in 2006, water prices for residential customers were at the point where certainly a $4/month signal fee is justified.

If a difference of $4/month is a deal-breaker for a type of irrigation controller, then it calls into question whether any irrigation controller is worth the cost.

Turf-replacement programs

This section has problems, too, but I have spent significant time on the report analysis, and will only continue the analysis into this section if requested to do so.

Summary

This report is riddled with errors, erroneous assumptions, and a lack of understanding of the many facets of water conservation. This has produced a report with invalid conclusions and recommendations.

The average reader would not recognize these flaws, and would assume that the conclusions were based on sound evidence and reasoning.

In California, we are faced with the need to conserve water, with decreased resources. Any resources spent for a program must be based on accurate information. The findings of this report, if used to design a program, would result in a program that not only would not produce the anticipated results based on this report, but might also sour a water agency for attempting an irrigation controller program in the future.

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Lawns and Water Demand in California

By Ellen Hanak and Matthew Davis

SUMMARY

Over the next 25 years, California's population is expected to grow by some 11 million residents, with over half of this growth occurring in the hotter inland counties. This shift raises the prospect of substantial increases in urban water demand, especially for outdoor uses, because landscaping typically accounts for at least half of all residential water use in inland areas. Because water demand growth poses both financial and environmental challenges, many water utilities are now launching conservation programs to curb water use outdoors. In this issue of CEP, we examine the role of residential land use in the demand for water outdoors, with a focus on the water needs of cool-season turf grass lawns. We also explore the savings potential of some key water conservation tools.

Drawing on detailed residential housing data, we find that outdoor water needs for typical residential lots are likely to be more than two to three times higher in inland areas than along the coast. Although climate plays a role in this difference, residential land use patterns are far more important. Single-family homes, which typically use about twice as much landscaping water as multifamily units, make up a much larger share of inland housing. Inland areas also generally have larger lots, including a higher proportion of "ranchettes" (i.e., lots between one and 20 acres). Recent housing trends suggest some attenuation of these differences, with the rise of denser single-family tract developments in the Central Valley and the Inland Empire. But in contrast to the coast, where there has been a surge in multifamily housing since 2000, the inland region has seen multifamily homes continue to fall as a share of total housing.

Recent conservation efforts have aimed to lower outdoor water use by improving the efficiency of landscape irrigation and replacing some lawns with less thirsty plants. Field studies suggest that both strategies offer considerable potential for saving water. At the state level, there has also been renewed attention to the role of water rates, which often fail to provide residents with correct signals about the scarcity of water resources. Conservation-oriented water rates can play an important role in both new and existing neighborhoods. Our analysis also suggests that improved irrigation technologies may be cost effective in many parts of the state, even when water rates are relatively low. By contrast, "cash for grass" programs, which give homeowners rebates for replacing turf with drought-tolerant plants, are likely to pay off only if the new landscapes also

California Economic Policy *is a quarterly series analyzing and discussing policy issues affecting the California economy.*

lead to substantial savings in garden supplies and labor. Promotional strategies to implement conservation include public education and outreach, customer rebates, and regulatory restrictions on landscaping options. Whether education and outreach will be sufficient to encourage new development to be "water smart," or whether regulatory solutions are required, is still an open question.

Introduction

Without efforts to reduce per capita water use, California faces significant increases in urban water demand over the coming decades—a prospect that poses both environmental and financial challenges. Lawns are one of the biggest culprits. Outdoor water use often accounts for half or more of all residential water demand, especially in the hotter inland areas where population growth is now fastest. California's inland counties are expected to accommodate over half of the 11.3 million new California residents anticipated over the next 25 years. In addition, an increasing share of growth is occurring in warmer inland areas of coastal counties.[1]

Recognizing the water demand that this population growth will bring, water utilities are paying more attention to urban water conservation than ever before. Whereas conservation efforts during the 1990s focused mainly on indoor uses, the focus is now shifting to the outdoors. The policy toolkit includes a host of incentives and technological fixes to encourage residents to water their yards more efficiently and to landscape with low-water plants. To help spearhead these efforts, the legislature recently called for the creation of a Landscape Task Force, composed of stakeholders from the water and landscaping sectors, to evaluate and recommend proposals for improving the efficiency of water use in new and existing urban irrigated landscapes in California.

Landscape choices are considered key because Californians—like their neighbors in other semiarid western states—have tended to use plants more suited to humid climates. The typical California lawn, a cool-season turf grass, can require several times more water than native plants. Inefficient watering systems, such as incorrectly timed automatic sprinklers, can significantly compound the problem, creating overwatered lawns and excess water spillage.[2] In addition to the resource costs associated with water waste, overwatering generates polluted run-off, which damages rivers, lakes, and coastal waters.

Land use patterns also matter. Denser development—with more multifamily homes and smaller single-family lots—is typically also more water smart. On a per household basis, multifamily homes use half as much water outdoors as do single-family homes. Among single-family homes, those with larger lots typically use more water for landscaping.

This edition of CEP looks at a range of issues related to residential outdoor water use. Drawing on detailed residential housing data, we first assess whether housing patterns are reinforcing or extenuating the pressures posed by California's demographic shift inland. To determine patterns in outdoor water use, we examine differences across regions and over time in the composition of the housing stock (in particular, the share of multifamily homes) and in the size of single-family lots. We use the reference evapotranspiration rate—a measure of the amount of water required to maintain turf grass in different climatic zones—to estimate the water needs of typical yards across regions. Finally, we assess the potential for key elements in the conservation policy toolkit—including water pricing and various programs to improve irrigation efficiency and encourage the use of low-water plants—to reduce outdoor water use in different parts of the state.

Water Use and Population Growth in California

According to the Department of Water Resources (DWR) 2005 update of the *California Water Plan*, California's cities and suburbs used approximately 8.9 million acre-feet (maf) of water in 2000, or about 232 gallons per capita per day (gpcd).[3] This total—often known as the "urban" water demand—includes all residential, commercial, governmental, and industrial uses, with residential uses constituting about two-thirds of the whole, or 5.8 maf. In the same year, California's farmers irrigated an estimated 9.6 million acres of cropland with 34.2 maf of water. Thus, urban uses accounted for 20 percent of total human water use in the state in 2000.

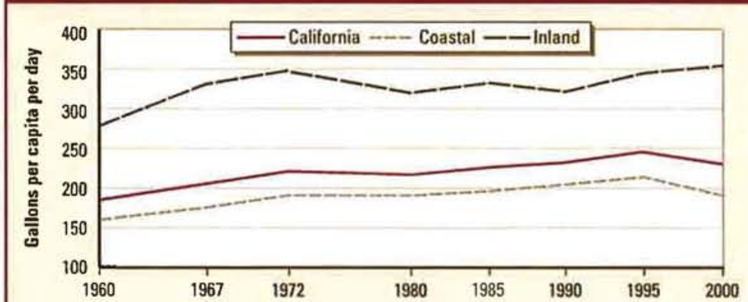
California's cities and suburbs used approximately 8.9 million acre-feet of water in 2000, or about 232 gallons per person per day.

The urban share has been growing over time; in 1980, it accounted for only 14 percent of the total (Department of Water Resources, 1983). This increase is not simply the result of population growth. Per capita use rose steadily throughout the latter half of the 20th century, with declines setting in only during the 1990s (Figure 1). Average urban per capita use was 185 gallons per day in 1960, 20 percent lower than in 2000.

The growth in per capita use probably reflects several factors. One is rising incomes, which tend to increase water demand, in part because of greater demand for water-using appliances (Baumann, Boland, and Hanemann, 1997). A second is residential lot sizes, which, as we shall see, increased over much of this period. A third is the faster rate of population growth in hotter inland areas, where water use is considerably higher. In 2000, inland water use averaged 355 gpcd compared to 195 gpcd along the coast.

Even with continued efforts in conservation, total urban water use could grow significantly over

Figure 1. Urban Water Use in California, 1960 to 2000 (gpcd)



Sources: Department of Water Resources (1966, 1970, 1974, 1983, 1987, 1994b, 1998, 2005).

Notes: "Coastal" includes the North Coast, San Francisco Bay, Central Coast, and South Coast hydrologic regions. "Inland" includes the Sacramento River, San Joaquin River, Tulare Basin, North Lahontan, South Lahontan, and Colorado River hydrologic regions. Although the individual regional classifications varied somewhat in earlier periods, the broad distinction between coastal and inland is fairly consistent over time.

the coming decades. The *California Water Plan*'s "current trends" scenario anticipates demand growth by 3.0 maf between 2000 and 2030, despite a projected modest decrease in per capita use, from 232 to 221 gpcd. Southern California's urban utilities will face additional needs because of requirements to reduce their use of Colorado River water by 0.8 maf.

Such levels of demand growth pose considerable challenges for California's urban water utilities. Most new sources of water are relatively costly, and many options pose risks to the environment because of their effects on wildlife habitat. In principle, a good deal of urban demand growth could be accommodated by transfers of agricultural water rights to urban users, because agricultural water use is expected to decline as a result of various market forces, including land development (Department of Water Resources, 2005). In practice, transfers are likely to account for only a portion of urban needs because of institutional and logistical constraints (Hanak, 2003). Among other alternatives, the *Plan* highlights urban conservation as one of the single largest sources of cost-effective "new" water to support growth.[4]

Although a majority of California's population still lives in the two main metropolitan coastal regions . . . forecasts suggest that some of the biggest growth pressures in the coming decades will be in hotter inland areas.

Growth Patterns and Outdoor Water Use

Because water meters do not generally track indoor and outdoor uses separately, the share of urban water used outdoors can only be estimated. The 2005 *California Water Plan* estimates that the residential sector used roughly 2.3 maf outdoors in 2000, or 42 percent of total residential demand. Parks, golf courses, and other "large landscapes" used another 0.7 maf.[5] (The *Plan* did not separately estimate outdoor uses for commercial and industrial customers.)

The *Plan*'s estimates for outdoor residential use may be on the low side. One study of a cross-section of 12 U.S. cities found an average outdoor rate of 58 percent (Mayer et al., 1999). California's Landscape Task Force concluded that outdoor use constitutes about half of residential demand in the state (California Urban Water Conservation Council, 2005). This share can be much lower in milder coastal zones and much higher in hot, dry, desert areas. The water provider for the Las Vegas Valley, located in the Mojave Desert, estimates that roughly 70 percent of residential demand goes to outdoor irrigation.[6] Officials in Riverside County estimate that 80 percent of residential water in the Coachella Valley—an area with a similar climate—is used outdoors (Bowles, 2005).

Although a majority of California's population still lives in the two main metropolitan coastal regions—the Los Angeles Basin and the San Francisco Bay Area—forecasts suggest that some of the biggest growth pressures in the coming decades will be in hotter inland areas (Table 1). California's population is projected to grow by 11.3 million people between 2005 and 2030, and over half of that growth will occur inland—the Sacramento Metro region, the San Joaquin Valley, and the Inland Empire.

Residential Lot and Yard Sizes

Outdoor water use tends to rise with single-family lot sizes, because larger properties have larger yards. County assessor records make it possible to measure lot sizes for single-family homes in most of the counties in our main metropolitan regions (for details, see the web-only appendix, http://www.ppic.org/content/other/706EHEP_web_only_appendix.pdf). We define "yards" as lot size minus the building footprint. Because it is likely that residents with very large lots water a smaller portion of their yards, we have broken these data into small lots (one acre or less) and large lots (between one and 20 acres). Figure 2 presents the cumulative average lot sizes by region for single-family residences

Table 1. Projected Population Growth in California Regions, 2005–2030 (millions)

Region	Counties	Population, 2005	Projected Growth, 2005–2030	Percent of Projected Growth
San Francisco Bay Area	Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, Sonoma	7.10	2.08	18.4
South Coast	Los Angeles, Orange, San Diego, Ventura	17.15	2.74	24.3
Sacramento Metro region	El Dorado, Placer, Sacramento, Yolo	2.04	1.37	12.1
San Joaquin Valley	Merced, San Joaquin, Stanislaus, Fresno, Kern, Kings, Madera, Tulare	3.73	2.19	19.4
Inland Empire	Riverside, San Bernardino	3.82	2.12	18.8
Rest of state	Alpine, Amador, Butte, Calaveras, Colusa, Del Norte, Glenn, Humboldt, Imperial, Inyo, Lake, Lassen, Mariposa, Mendocino, Modoc, Mono, Monterey, Nevada, Plumas, San Benito, San Luis Obispo, Santa Barbara, Santa Cruz, Shasta, Sierra, Siskiyou, Sutter, Tehama, Trinity, Tuolumne, Yuba	2.98	0.80	7.1
California		36.81	11.30	100

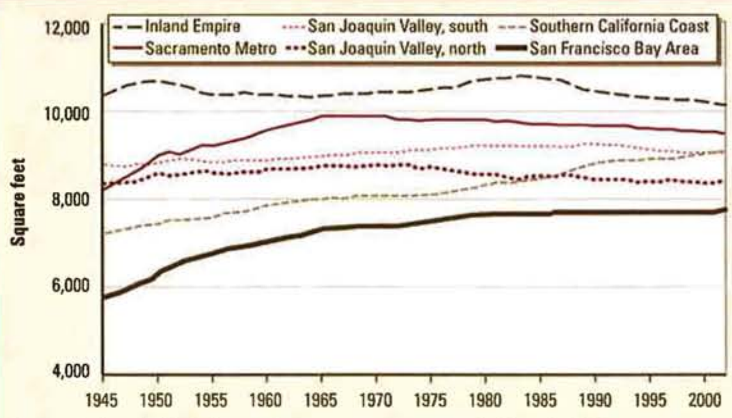
Sources: Department of Finance (2004, 2005).

on small lots.[7] The San Joaquin Valley is split into two regions to isolate the effects of growth pressures that link its northern end to the Bay Area and its southern end to the population centers in Southern California.

As expected, lot sizes are smallest in the region with the highest land prices, the San Francisco Bay Area (7,697 square feet), and they are generally largest in the inland regions, notably the Inland Empire (10,176 square feet) and the Sacramento Metro region (9,515 square feet). What is surprising, however, is the steady upward trend in coastal lot sizes, particularly in Los Angeles and San Diego Counties. Lots in the South Coast (9,076 square feet) are now larger, on average, than those in the northern San Joaquin Valley (8,416 square feet) and nearly as large as those in the southern San Joaquin Valley (9,056 square feet).

Because the proportion of homes with more than one story has been on the rise, there has been

Figure 2. Cumulative Average Small Single-Family Lot Sizes by Region



Source: Authors' calculations, using county assessor records through 2002.
Notes: Data include lots of one acre or less. One acre equals 43,560 square feet.

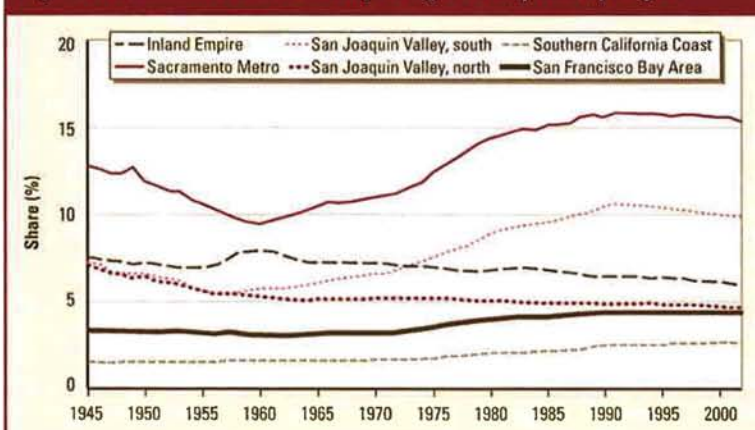
Despite the recent policy attention to denser land use—often known as "smart growth"—California actually built many more multifamily homes in the 1960s and 1970s than it does today.

relatively little increase in average building footprints (estimated as the building size divided by the number of stories), even though home sizes have been steadily increasing.[8] Thus, the general patterns for yard sizes are similar to those shown in Figure 2.

Meanwhile, lots between one and 20 acres, often called ranchettes, remain an important component of California's residential landscape (Figure 3). The shares of these lots are lowest in the two coastal regions and also relatively low in the northern San Joaquin Valley, which appears increasingly influenced by Bay Area housing patterns. Ranchettes average around three acres in size but somewhat higher in the Sacramento region (4.7 acres). They are particularly prominent in some counties—Napa and Sonoma in the Bay Area, El Dorado and Placer in the Sacramento Metro region, Kern in the southern San Joaquin Valley, and San Diego in the South Coast.[9]

The share of multifamily housing is another important factor in the outdoor water use equation. Because they share common outdoor space, multifamily homes use considerably less water outdoors than do single-family residences. Despite the recent policy attention to denser land use—often known as "smart growth"—California actually built many more multifamily homes in the 1960s and 1970s than it does today (Figure 4). Although the share of multifamily housing has increased since 2000, this is mainly a coastal phenomenon. In the hotter inland regions, the overall shares are much lower (Figure 5). As we shall see, these housing trends have a marked effect on outdoor water needs in different parts of the state.

Figure 3. Cumulative Share of Large Single-Family Lots by Region



Source: Authors' calculations, using county assessor records through 2002.
Note: Data include lots between one and 20 acres.

Climate Zones and Housing Trends

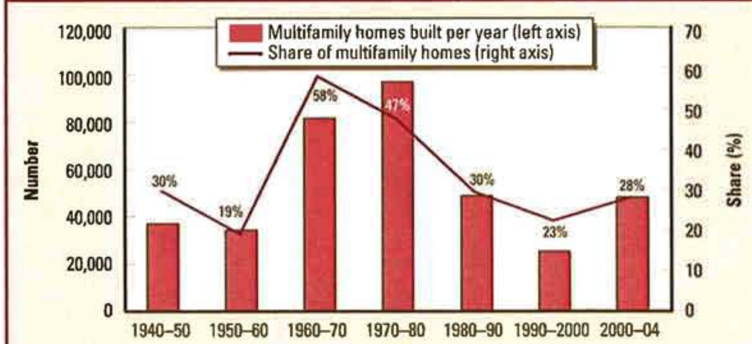
Because hotter climates increase water needs for any given lot size, we reclassified the housing data by climatic zone. These zones are based on evapotranspiration rates for the typical California lawn. Evapotranspiration (ET) is the rate at which plants lose water through evaporation from soil and plant surfaces and transpiration through plant canopies. "Reference evapotranspiration" (ET_0) rates provide a measure of the water needed by cool-season turf grass. Thus, ET_0 rates give a measure of the baseline water needs of a typical California lawn in different parts of the state. We assigned each Census tract to one of 18 ET_0 zones, using maps provided by DWR. For purposes of presentation, we consolidated the 18 zones into four "superzones": Coastal, Inner Coastal, Central, and Desert (Figure 6).[10]

The differences across zones are significant. In the Coastal zone, a square foot of cool-season turf grass will require 28 gallons of water or less per year. In the Desert zone, the same patch of grass will need 37 gallons of water or more. The differences are even more pronounced during the dry summer months, when irrigation needs are highest (Figure 6).

These evapotranspiration zones provide a much finer breakdown of climatic differences than do regional and county boundaries. Whereas climates in some regions appear relatively homogeneous (for instance, the Sacramento Metro region and the northern San Joaquin Valley fall entirely within the Central zone), other areas display a great deal of variation. Los Angeles County, for example, spans the entire spectrum from mild coastal to harsh desert climates (for details on individual counties, see the web-only appendix, http://www.ppic.org/content/other/706EHEP_web_only_appendix.pdf).

As of the 2000 Census, 33 percent of the state's population resided in the Coastal zone, 43 percent in the Inner Coastal zone, 19 percent in the Central zone, and 4 percent in the Desert zone. However, housing production in the Central and Desert zones is growing fast (Figure 7). Nearly 39 percent of the units built in the 1990s were in these two zones, up from 32 percent in the 1980s and just 26 percent in the 1970s. Housing production in the Central zone has now eclipsed production in the Coastal zone. Single-family lots are 60 percent larger in the Desert zone than in the Coastal zone, and large lots are still far more preponderant in the hot inland zones. In addition, the share of multifamily homes recorded by the 2000 Census reads, in inverse order of climate conditions: Coastal (40.1%), Inner Coastal (33.6%), Central (21.1%), and Desert (20.4%).

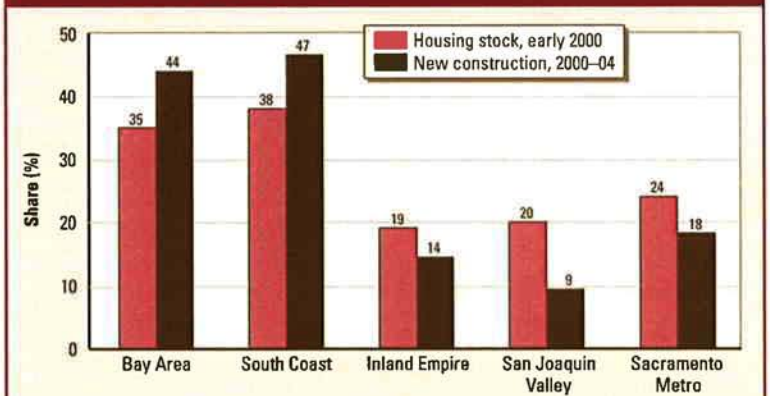
Figure 4. Statewide Trends in Multifamily Construction, 1940–2004



Sources: Authors' calculations, using data from the Census (1940–2000) (changes in housing stock) and the Construction Industry Research Board (2004) (housing permits).

Notes: The multifamily category includes structures with two or more residential units; it excludes both detached and undetached single-family homes. Data exclude "other" housing categories, such as mobile homes and boats.

Figure 5. Regional Shares of Multifamily Homes in Housing Stock and New Construction



Source: Authors' calculations, using the 2000 Census (stock) and Construction Industry Research Board (permits).

Implications for Outdoor Water Demand

Clearly, land use differences across climatic zones appear to be reinforcing the pressures of the demographic shift inland. Despite some signs of inland densification—declines both in lot sizes and in the share of ranchettes—inland areas have lower shares of multifamily homes, higher shares of ranchettes, and higher average lot sizes than does the coast. What do these land use trends mean for outdoor water use?

Theoretical Water Needs

To get a sense for outdoor water demand, we estimated the average water requirements for cool-season turf grass, our ET_0 crop. Table 2 provides these estimates for small single-family lots by region and by ET_0 superzone. We assume that households irrigate 35 percent of their yard, with the remainder covered either in hardscape or in non-irrigated landscape.[11] Across regions, this amounts to an average irrigated area in the range of 2,000 to 3,600 square feet. Average water requirements are obtained by multiplying this area by average ET_0 rates.[12]

Figure 6. Evapotranspiration "Superzones"

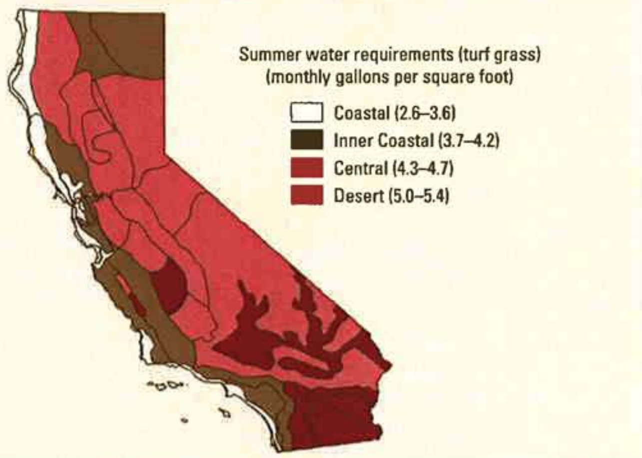
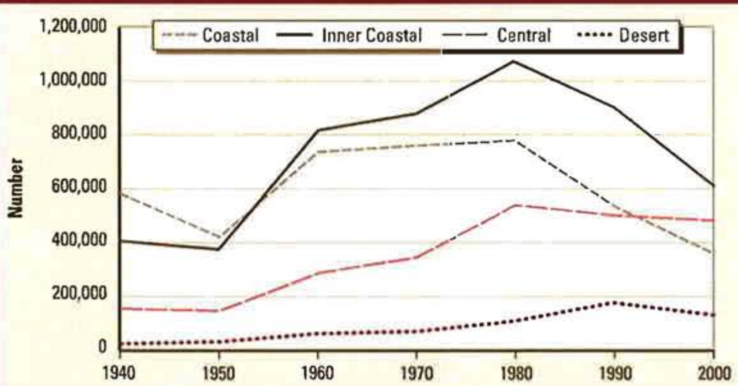


Figure 7. Units Built by Decade by ET_0 Superzone



Source: Authors' calculations based on the 2000 Census.
Note: Includes all California counties.

Because of larger lot sizes and drier climates, the amount of water lost through evapotranspiration from a typical grass lawn is much greater in California's inland areas. In the Coastal zone, a typical single-family lawn requires 0.17 acre-feet per year, whereas its Desert zone counterpart needs nearly three times as much.

With some additional assumptions, we can apply this same framework to the entire housing stock, incorporating ranchettes and multifamily lots (Table 3). For ranchettes, we assume only 10 percent irrigated landscaping, corresponding to an average area of roughly one-quarter of an acre.[13] For multifamily homes, we assume that outdoor water use is half the single-family average.[14] These estimates imply that California households irrigated a total of just under 633,000 acres in 2000.[15]

For the most part, incorporating these additional housing stock characteristics exacerbates the differences in regional water needs described in Table 2. Water needs decrease in the Bay Area and the South Coast and in the corresponding climatic zones (Coastal and Inner Coastal)—a benefit of the high share of multifamily homes. Elsewhere, the effect of large lots dominates. This effect is most striking for the Sacramento Metro region, where ranchettes are most common: The average household's outdoor water needs increase by 60 percent. For the Central and Desert zones as a whole, these needs increase by 20 to 30 percent. Water requirements in these zones are more than two to three times greater than on the coast.

Because climate and land use are working in the same direction, it is useful to see how much each factor contributes to these regional differences. Figure 8 compares estimated water needs in inland zones with the water needs these zones would face if they shared the more compact housing patterns of the coast. Actual land use patterns account for a substantially greater share of the additional water needs than climate does. In the Central and Desert zones, land use—not climate—is the clear driver, accounting for four-fifths of the total increase relative to the Coastal zone.

Recent changes in land use may be shifting outdoor water needs. To track this trend, we compared the water needs of homes built between 1991 and 2000 with the needs of the 1990 housing stock. Figure 9 shows these comparisons, with new housing needs expressed as a percentage of the needs of homes already built by 1990. To isolate the effects of lot size and composition, we applied the ET_0 rates for older homes to the new housing.

For single-family homes of one acre or less, denser tract development in the four inland regions

Table 2. Average Water Requirements of Turf Grass for Small Single-Family Lots

Region	Yard Size (square feet)	Weighted Average ET_0 (inches/year)	Annual Water Requirements (acre-feet)	% Increase over Region with Lowest Need
San Francisco Bay Area	6,308	45.9	0.19	—
South Coast	7,623	49.8	0.25	31
San Joaquin Valley, north	7,060	54.4	0.26	33
San Joaquin Valley, south	7,711	56.2	0.29	50
Sacramento Metro region	8,129	56.8	0.31	59
Inland Empire	8,858	56.2	0.33	72
ET_0 zone				
Coastal	6,019	42.6	0.17	—
Inner Coastal	7,930	51.9	0.28	60
Central	7,687	56.0	0.29	68
Desert	10,349	66.7	0.46	169

Table 3. Average Water Requirements of Turf Grass for Residential Lots

	Small Single-Family Lots		Large Single-Family Lots		Multifamily Lots	Average Annual Water Requirements	
Region	% of All Lots	Average Yard Size (square feet)	% of All Lots	Average Yard Size (square feet)	% of All Lots	Acre-Feet per Household	% Increase over Region with Lowest Need
San Francisco Bay Area	61.2	6,308	2.8	139,855	36.0	0.19	—
South Coast	59.1	7,623	1.6	119,824	39.3	0.22	16
San Joaquin Valley, north	76.1	7,060	3.7	134,766	20.2	0.27	46
San Joaquin Valley, south	67.8	7,711	7.4	152,849	24.8	0.36	89
Sacramento Metro region	63.8	8,129	11.5	203,920	24.7	0.50	165
Inland Empire	74.6	8,858	4.7	127,035	20.7	0.35	85
ET_0 zone							
Coastal	58.7	6,019	1.1	127,382	40.1	0.15	—
Inner Coastal	64.4	7,930	2.0	111,147	33.6	0.25	67
Central	71.4	7,687	7.5	175,058	21.1	0.38	158
Desert	70.0	10,349	9.6	144,556	20.4	0.55	276

Figure 8. Effects of Climate and Land Use on Outdoor Water Needs of Turf Grass

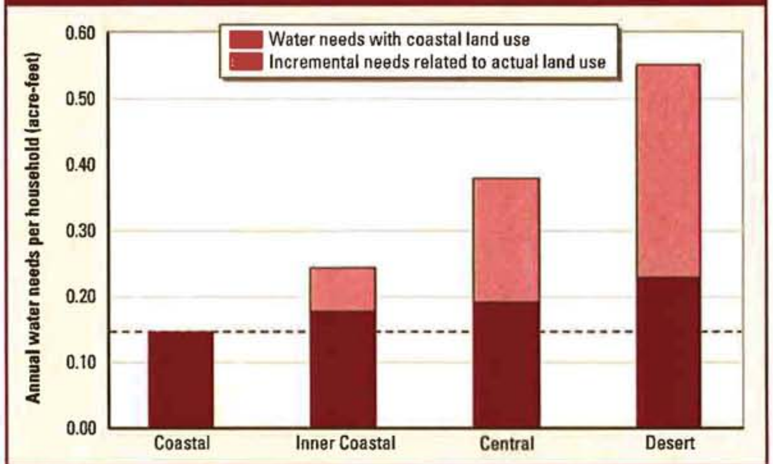
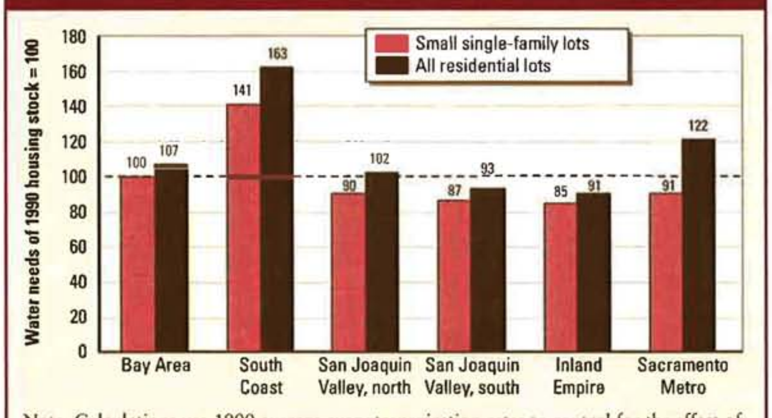


Figure 9. Comparison of Outdoor Water Needs for Homes Built During the 1990s and Older Homes



Note: Calculations use 1990 average evapotranspiration rates to control for the effect of changes in the location of new housing.

has reduced landscape water needs for new homes by 9 to 15 percent compared to the older housing stock. The opposite is true in the South Coast, where single-family lots have been getting larger.

The picture changes somewhat when we take into account all types of new housing combined. Some of the inland savings disappear, and water needs increase substantially in the South Coast and in the Sacramento Metro region. One factor is the declining share in new construction of multifamily housing in the 1990s, which occurred in every region. But an even bigger factor is the growing role of large lots. They rose slightly as a share of all housing in three regions (Sacramento Metro, South Coast, and the Bay Area), and they increased in average size everywhere. For the South Coast, the overall result is a profile of new housing with potential landscape water needs over 60 percent above the level in 1990. In the Bay Area and the South Coast, these needs have also increased somewhat because newer housing has located in warmer areas.[16] These trends have reduced some of the differences in water needs between coastal and inland regions.

Actual Water Needs

Of course, these figures provide only a "guesstimate" of households' actual outdoor water use. In practice, there is considerable variation in the proportion of yards that are watered, and not everyone plants only cool-season turf grass, our baseline crop.[17] Moreover, irrigation practices can differ widely. The ET_0 rates for turf grass allow for a lush, thick lawn, several inches high. In practice, experts assume that residential lawns can get by with about 80 percent of the ET_0 requirements.[18] However, the ET_0 rates also assume that no water is wasted, either in making the ground soggy or in spilling onto sidewalks and streets. Such wastage results in a level of irrigation efficiency—the share of water actually used by the plant—below 100 percent. Many residences and businesses still fall well below the existing statewide standard for landscape irrigation efficiency of 62.5 percent.

The amount of water a plant actually needs (sometimes known as the "ET adjustment factor") can be summarized in this fashion:

$$\text{ET adjustment factor} = \frac{\text{plant's ET requirement}}{\text{irrigation efficiency rate}}$$

Thus, a residential lawn with an 80 percent ET requirement, irrigated at 80 percent efficiency, needs 100 percent of its baseline water needs (the ET_0). If irrigation efficiency is lower, the actual water

Table 4. Landscape Water Needs with Different Plant Types and Irrigation Efficiencies

	Average Plant ET Requirement				
Irrigation Efficiency	High Water (80%)	Medium Water (50%)	Low Water (20%)	50% High 50% Medium (65%)	1/3:1/3:1/3[a] (50%)
50%	160	100	40	130	100
62%	129	81	32	105	80
70%	114	71	29	93	71
80%	100	63	25	81	62

Note: Numbers are expressed as a percentage of reference evapotranspiration.
[a]1/3:1/3:1/3 denotes a mix of one-third each high-, medium-, and low-water-using plants.

needed is greater than 100 percent. If it is higher, or if the plant mix is less thirsty, the actual water needed falls below 100 percent. Table 4 summarizes this relationship for some benchmark plant types and irrigation efficiency rates.

Cool-season turf is a typical high-water-using plant. (Warm-season turf grass, still not very common in California, has an ET requirement of 60 percent.) Various landscape alternatives, including shrubs and trees, fall into the medium category, and many native species are low water users. A conventional residential mix might be half cool-season grass and half trees and shrubs, for an overall ET requirement of 65 percent.[19] Using California's irrigation efficiency standard of 62.5 percent, such a yard would require 105 percent of the ET_0 shown in Tables 2 and 3. We estimate that the average for California yards in 2000 was in the range of 106 to 127 percent of the ET_0.[20]

In a normal year, rainfall during the cooler winter months can generally cover about a quarter of these needs, and the balance must be made up with irrigation. In dry years, which are no stranger to California, landscape water needs are typically higher. Because supplies are also scarcer in such times, droughts often lead utilities to impose outdoor watering restrictions.

Looking ahead, there is a strong possibility that climate warming will increase plant water needs in California—particularly in the hotter inland areas, where average temperatures are predicted to rise considerably (Hayhoe et al., 2004). Climate change is also expected to put greater pressures on water supplies by reducing the amount of water stored in the Sierra Nevada snowpack.[21] These shifts will raise the importance of efforts to curb outdoor water use.

Smart growth land use mixes that achieve higher density can truly be water smart. However, most approaches to outdoor conservation focus on ways to reduce water use with existing land use patterns.

Conservation Strategies

As the preceding analysis makes clear, land use patterns can have a tremendous effect on the potential outdoor water needs of the residential sector. Smart growth land use mixes that achieve higher density can truly be water smart. However, most approaches to outdoor conservation focus on ways to reduce water use with existing land use patterns. The following four strategies provide different paths toward water-smart yard maintenance and greater outdoor water conservation.

Water Pricing

One overarching tool that is gaining renewed attention is water pricing. There are four general kinds of rate structures: flat, declining block, uniform, and increasing block. Flat water rates—which do not vary by the amount of water used—are still common in the Central Valley, much of which remains unmetered. Declining block rates, which essentially offer a bulk discount to heavy water users, are now rare. Most residential lots in California are subject to uniform rates—which charge the same amount for every gallon—or increasing block rates—which charge more per gallon for higher levels of use (Hanak, 2005). (Seasonal pricing, under which rates are increased during the summer months of peak demand, is rarely used in California.) Since 1991, the California Urban Water Conservation Council has encouraged the adoption of "conservation pricing"—with rates set as close as possible to the utility's own long-run marginal cost of water, using either uniform or increasing block rates.[22]

Although water is a relatively "inelastic" commodity, recent evidence suggests that consumers are more sensitive to water prices than previously thought.[23] It appears that price sensitivity is higher when customers face increasing block rates rather than uniform rates.[24] Customers also appear to be more sensitive to prices for outdoor than indoor uses (Mansur and Olmstead, 2006). These findings suggest that increasing block rate structures may be better than uniform rates at encouraging conservation—and that pricing can be an especially important outdoor conservation tool. (Flat rates, in contrast, offer no incentive to conserve.) Increasing block rate structures also have a built-in equity component, given that larger lots and higher water use within an area are generally associated with higher-income households.

Although water is a relatively "inelastic" commodity, recent evidence suggests that consumers are more sensitive to water prices than previously thought.

To see how water rate structures interact with residential land use patterns, we matched our single-family lot data with water rate data for the four-fifths of our sample residing within the service areas of large utilities (Table 5).[25] As the table makes clear, water rates are least conducive to conservation in some of the state's hottest areas. However, flat and declining rate structures do not appear to be encouraging larger average lot sizes; lots are actually largest in the Central and Desert zone communities with increasing block rates.[26]

Increasing block rate structures are most prevalent in the Coastal and Inner Coastal zones, where water authorities have been more active in statewide conservation programs. Many utilities adopted these rate structures following the early 1990s drought. However, there has been little progress in shifting to increasing block rate structures or away from flat rate structures since the mid-1990s (Hanak, 2005).

Recent efforts to put conservation pricing back on the front burner come from two quarters. One is the Landscape Task Force, which developed new conservation pricing guidelines to encourage utilities to send more accurate price signals to customers.[27] The other is the California legislature, which has been pushing utilities with flat rates to convert to metering. After more than a decade of political wrangling, the legislature passed AB 2572 in 2004, which requires that all utilities with 3,000 or more customers install meters over the next two decades and begin using installed meters for billing by 2010. (Since 1992, builders have been required to install meters in new homes, but utilities have not been required to read them.) Some communities are starting to see the potential conservation benefits of this change: For instance, the fast-growing town of Lodi aims to finish installing meters long before the 2024 deadline, to realize conservation savings sooner (Hood, 2005).

Smart Sprinklers

Automatic sprinkling systems are popular because they are more convenient than manually operated hoses or sprinklers. The problem is that they often operate for too long or at times when watering is not needed. (As a rule of thumb, these systems operate with an irrigation efficiency rate of 50 percent or less.[28]) Rather than encourage people to go back to manual systems, many utilities are looking to address this problem by promoting "ET" or

Table 5. Average Small Single-Family Lot Sizes by Water Rate Type

ET_0 Superzone	Flat		Declining Block		Uniform		Increasing Block	
	Average (square feet)	% of Lots	Average (square feet)	% of Lots	Average (square feet)	% of Lots	Average (square feet)	% of Lots
Coastal	7,617	0	16,711	0	7,202	43	7,327	57
Inner Coastal	n/a	0	10,913	0	8,905	44	9,351	56
Central	8,306	49	8,266	6	8,051	29	10,083	16
Desert	9,429	2	n/a	0	10,929	62	11,709	37
Total	8,308	7	8,324	1	8,396	42	8,727	50

Source: Authors' calculations, using county assessor records through 2002.
Notes: Percentages show the share of homes in each climatic zone with each type of rate structure. Data include lots of one acre or less.

"smart" irrigation controllers, which automatically adjust watering times based on plant cover and weather conditions. Smart controllers can operate either with on-site weather sensors or with communication links to a centralized weather-monitoring system.[29] Previously limited to large commercial or public landscapes, smart controllers are now available to residential customers through rebate programs in several water districts.

Field studies have shown that smart controllers can reduce residential water use considerably. In 2000, the Irvine Ranch Water District (IRWD) retrofitted 33 high-water-using homes with ET controllers.[30] After two years, these homes had reduced their total water consumption by 41 gallons per household per day—approximately 18 percent of outdoor water use. In 2002, several water districts targeted high residential water users in Santa Barbara County. By 2003, 62 customers had switched to ET controllers, and preliminary results indicate that their average total water use has gone down by 26 percent.[31] The Metropolitan Water District of Southern California (MWDSC), the large wholesale utility serving much of Southern California, estimates that smart controllers, in conjunction with highly efficient spray nozzles, could reduce outdoor residential water use by 28 percent within its service area.[32]

If ET controllers can save this much water, are they a good investment? To find out, we calculated the cost of saving water in different regions, using the savings rates obtained in field trials. Table 6 presents consumer and utility costs under some different scenarios. The calculations assume the use of a new, smart controller in a typical small lot in each of the four climatic zones, currently planted half turf and half shrubs and trees and being watered at 50 percent irrigation efficiency.[33]

The top panel of the table shows scenarios for water savings and customer costs. For the cost of the ET controller itself, the "low" alternative is for purchase and professional installation of an on-site sensor system and the "high" alternative is for a satellite system, which has a higher up-front cost and a monthly subscription fee.[34] These costs are shown spread out over 15 years (the estimated life of the controller), both with and without utility rebates of $180 to $220 per system.[35] The table's bottom panel shows the water costs to utilities and the potential water bill savings for customers. Utility costs are expressed as the investment costs of procuring this "new" water through the rebate program, again on the assumption that the savings are available for only 15 years. We include an allowance for administrative costs.[36]

For consumers, the best bet is likely to be controllers with on-site sensors. With the utility subsidy, these systems generate enough savings on the water bill to more than cover the $9 in annualized costs, even with lower efficiency gains and in places with

Table 6. Smart Controller Costs and Savings

	Inputs					
	Water Savings (gallons per day per household)			Annual Cost to Customer (per controller)		
ET Superzone	Low (15%)	High (25%)			Low (on-site)	High (satellite)
Coastal	22	37		Full cost	$26	$95
Inner Coastal	36	60		After rebate	$9	$79
Central	38	63				
Desert	60	101				

	Outputs					
	Costs to Utility ($/acre-foot)		Annual Savings to Customer (per controller)			
			Low Water Price ($242/acre-foot)		High Water Price ($678/acre-foot)	
ET Superzone	Low Water Savings	High Water Savings	Low Water Savings	High Water Savings	Low Water Savings	High Water Savings
Coastal	584	350	6	17	10	28
Inner Coastal	397	238	10	27	16	46
Central	379	228	10	29	17	48
Desert	256	154	16	46	27	76

Notes: Assumes that 25 percent of water needs is met by rainfall. Both utility and customer investments are amortized at a rate of 4 percent.

low water prices (the sole exception is low prices and low savings in the Coastal zone).[37] Meanwhile, it is hard to break even with the satellite-linked systems, which cost $79 after rebate, mainly because it is harder to cover the on-going subscription costs (now $48 per year) through water bill savings.

For utilities, the calculus involves comparing the costs of water procured through the rebate program with the costs of alternative sources. By this yardstick, these rebate programs have the potential to be cost effective. As a point of comparison, desalinated water has estimated annual costs in the range of $800 to $1,500 per acre foot, and average costs for recycled wastewater are estimated at $600 (Department of Water Resources, 2003a, 2003b).[38]

For both customers and utilities, savings would improve under rebate programs targeting high water users—those with particularly low irrigation efficiency, larger yards, and a higher share of turf in their overall yard mix. For customers, the savings would also improve if ET controllers reduce other costs (e.g., less wastage of fertilizers and pesticides from overwatering).[39] To the extent that ET controllers also help curb urban run-off, these programs can bring additional local benefits in pollution control.[40] However, smart controllers do not address other sprinkler system problems, such as incorrectly set valves or sprinkler heads or other inefficiencies in the layout of the system. For this reason, consumer education needs to accompany these programs.

Water-Wise Landscapes

Water consumption can also be greatly reduced through the use of drought-tolerant plants. Throughout the American West, utilities have promoted "water-wise" landscaping since the mid-1990s. Outreach efforts have focused not only on educating people about the water savings potential but also on the attractiveness of these landscapes, which include many beautiful, flowering plants, not just prickly cacti and rocks. Because plant availability can be a problem, utilities have begun locating their demonstration gardens at home and garden stores. The hope is that this will encourage major retailers like Home Depot to stock native plants, which they have begun doing only recently. Consumer education can be a major undertaking. Since 2002, MWDSC has spent more than $6 million on advertisements to promote "California friendly" landscaping, designed to reduce overwatering and encourage the use of native plants.[41]

To add teeth to these efforts, some water districts have launched turf buy-back programs, or so-called "cash-for-grass" initiatives. Through these programs, utilities pay customers to replace turf with less water-intensive plants and to install drip irrigation. Rebates range from $0.40 per square foot in Victorville, California, to $1 per square foot in Las Vegas, Nevada. These rebates cover only a portion of the cost to the consumer to replace turf. The Southern Nevada Water Authority (SNWA), which runs the Las Vegas program, estimates that customers pay from $2 to $5 per square foot to convert their landscapes.[42]

The potential water savings come from the combined effect of lower plant needs and higher irrigation efficiency, and they are truly spectacular. Well-installed drip irrigation can attain efficiency levels approaching 90 to 95 percent, and low-water plants need only 20 percent of the ET_0 rate (compared to 80 percent for lawns). A conversion of a cool-season turf lawn using a "dumb" automatic sprinkler system to a "smart" drip-irrigated garden with drought-tolerant plants could move overall plant needs from 160 percent to as low as 21 percent (Table 4).

Although the savings in practice are more modest, they are nevertheless considerable. Drawing on detailed field surveys, SNWA estimates that conversion from turf to low-water landscaping brought water use down from 73.0 gallons of water per square foot to just 17.2 gallons per square foot, a 76 percent savings.[43] The agency has encouraged residential customers to go for varied landscapes, keeping turf grass in places where they actually use it. Between 2001 and 2005, SNWA bought back over 1,500 acres of turf, or over 11,300 acre-feet of water. Purchases went up dramatically in 2003, when the rebate was raised from $0.40 to $1.00 per square foot.

In Las Vegas, conversion from turf to low-water landscaping brought water use down from 73.0 gallons of water per square foot to just 17.2 gallons per square foot, a 76 percent savings.

How might such a program fare in California? Table 7 compares the costs to utilities and customers of turf buy-back programs across California's climate zones, assuming water savings similar to that in Las Vegas (76%). To calculate these savings, we assume lower irrigation efficiency than in the smart controller example above (37.5% versus 50%).[44] Water savings and costs are shown per square foot, so that the only variation across zones is due to climate. Utility costs assume 15 years of savings, as above. For customers, costs are shown in terms of the number of years needed to recoup the net investment, assuming a total conversion cost ranging between $2 and $2.60 per square foot. The three payback scenarios reflect different assumptions about the savings from conversions: (1) savings on the water bill only, (2) additional savings from lower expenditures on garden supplies, and (3) additional savings from lower labor expenditures on garden maintenance. These "non-water" savings are drawn from a survey in the Las Vegas area, which found that homes with a greater proportion of lawns had higher labor and supply costs for mowing and other aspects of lawn maintenance.[45] It must be stressed that these results may not be representative.

For consumers, the water savings alone are unlikely to be a significant draw, even with a generous utility rebate. The picture changes dramatically, however, if homeowners reap additional savings in terms of lower garden supply and labor costs. These savings even make conversion a potentially attractive proposition in coastal areas and with higher net costs. These very different results underscore the importance of improving our understanding of

Table 7. Turf Conversion Costs and Savings

			Customer Years to Recoup Investment		
			Low Net Conversion Costs ($1.00/square foot)		
ET_0 Superzone	Water Savings (gallons/square foot)		I	II	III
Coastal	32		23	6	3
Inner Coastal	39		17	6	2
Central	42		15	5	2
Desert	51		12	5	2
	Costs to Utility ($/acre-foot)		High Net Conversion Costs ($1.60/square foot)		
	Low Rebate ($0.40/square foot)	High Rebate ($1.00/square foot)	I	II	III
Coastal	363	907	76	10	4
Inner Coastal	298	745	38	10	4
Central	276	690	32	9	4
Desert	232	580	23	8	4

Notes: Assumes a retail water price of $678 per acre-foot. Scenario I includes only water savings, scenario II also includes garden supply savings, and scenario III includes labor cost savings. Both utility and customer investments are amortized at a rate of 4 percent. Baseline irrigation efficiency is 37.5 percent, with 25 percent of plant water needs met by rainfall (or alternatively, 50% irrigation efficiency with no rainfall contribution).

the total costs of landscape alternatives to households, not just the water savings.

For utilities, purchasing water through a cash-for-grass program appears to be a considerably more expensive proposition than the rebate program for smart controllers, particularly at the price of $1 per square foot and in the milder climate zones. Actual costs may be higher, as we have not included the costs of program administration and we have assumed very high rates of water savings. If, on the other hand, the program creates a permanent shift in landscaping habits, rather than the 15 years assumed here, this would lower costs by about a third. As with smart controllers, there are additional benefits in control of polluted run-off.

Regulating Landscapes

In addition to public education and rebate programs, which aim to change tastes and behavior through voluntary means, some localities are emphasizing regulations. Such policies typically take the form of local ordinances, and they target landscaping practices in public, commercial, and residential areas. In California, the initial push for landscape regulations came from the state legislature, during the early 1990s drought. In 1990, the Water Conservation in Landscaping Act (AB 325) required that DWR draft a model water-efficient landscape ordinance. The model ordinance contained a number of stipulations involving irrigation design and efficiency and the use of native plants.[46] It applied to large commercial and public landscapes and to residential landscapes installed by developers. Local agencies were required to adopt the model ordinance, adopt their own ordinance, or issue legal findings that they did not need an ordinance. Although most cities and counties complied with the statute, actual implementation of the local ordinances has been inconsistent, and program monitoring has been minimal (Bamezai, Perry, and Pryor, 2001).

Some of the most enthusiastic local adopters are in fast-growing inland areas of Southern California. Many towns now require that developers use "California friendly" plants in all road medians and other public spaces. The City of Lancaster, for example, located in a hot area of eastern Los Angeles County, requires that all public landscaping be drought-tolerant. Several desert cities and utilities have adopted more widely applicable landscape ordinances. The Coachella Valley Water District (2003) recently adopted an ordinance requiring that new and refurbished landscaping feature vegetation that uses 25 percent less water than that required by the model ordinance. Other localities are taking the lead from cities in neighboring southwestern states, where landscaping restrictions have become increasingly common.

In weighing the pros and cons of landscape regulation, it is important to consider the value of lawns to households and communities. To the extent that lawns provide recreational space, low-water plants, no matter how beautiful, are not a good substitute. Even though common area lawns may be a more efficient way to provide this space, many households may prefer to have their own lawns for privacy and safety reasons. These considerations suggest that cost savings alone will not be enough to motivate all residents to make the switch. Encouraging people to cut back on turf in places where they do not use it—such as front yards and median strips—may be a more effective strategy than encouraging wholesale lawn removal.[47]

What Role for State Policy?

Many outdoor conservation policies stem from local and regional initiatives, but the state has not been absent from the scene. Various rebate programs are supported by state grants, state legislation provided the impetus for landscape ordinances, and legislation now requires that utilities start using meters to bill for water use. The recommendations of the Landscape Task Force, presented to the governor and the legislature in December 2005, call for the state to play a greater role in the future. The report contains 43 recommendations covering a wide range of actions (California Urban Water Conservation Council, 2005). In addition to stressing the importance of rate structure reform and more education and training, the recommendations focus on regulatory approaches: requiring smart irrigation controllers and dedicated landscape meters, adopting and enforcing statewide prohibitions on overspray and runoff, and strengthening and enforcing compliance with landscape ordinances. They also call for improvements in the knowledge base on irrigation requirements and plant water needs in different parts of the state. This includes extending the California Irrigation Management Information System (CIMIS)—a network of weather stations designed to gauge irrigation needs—to more urban areas.

Outdoor water conservation will need to be an important policy focus in many parts of the state, both to limit increases in water demand and to free up water supplies to accommodate new residents.

The emphasis on regulation parallels the established approach to indoor conservation; state and federal regulations on plumbing fixtures and appliances are widely viewed as central to the successes achieved to date. For the outdoor environment, where there is considerably more variability in the potential for water savings, it will be especially important to weigh the costs and benefits to households and to society before imposing regulatory solutions. As with indoor appliances, regulations focusing on new construction may have the greatest potential to achieve a beneficial outcome.

Conclusion

The magnitude and geographical distribution of population growth in California are poised to exert significant pressure on the state's water delivery systems over the coming decades. Outdoor water conservation will need to be an important policy focus in many parts of the state, both to limit increases in water demand and to free up water supplies to accommodate new residents. Key elements of the policy toolkit include water rate reform; the use of new, "smart" watering methods; and landscaping changes that reduce water use.

Many utilities are focusing on education and outreach to provide households with information on alternatives and to make low-water plants more readily available at nurseries. Some are proposing rebates. Regulatory restrictions on landscaping of new homes—restricting lawns to a fraction of the yard—are still rare in California but increasingly common in neighboring states. Our analysis suggests that rebates to homeowners may be a cost-effective way to improve irrigation systems, particularly in the hotter, dryer regions and when water prices are higher. The savings from replacing turf with low-water plants are less obvious. For new homes, it may be easier (and more cost-effective) to build "water smart" from the ground up. Whether education and outreach (particularly with builders) is sufficient to encourage this goal, or whether regulatory solutions are required, is still an open question. Conservation-oriented water rates, which signal water scarcity to households, should be a part of any conservation package. ❖

Notes

[1] An analysis of 2000 Census housing data by tract reveals that the average "reference evapotranspiration rate"—a measure of plant water needs resulting from climate—increased significantly in both the San Francisco Bay Area and the South Coast region for housing built since 1980. See the discussion on evapotranspiration zones. For trends in individual counties, see the web-only data box, http://www.ppic.org/content/other/706EHEP_web_only_appendix.pdf.

[2] For a sample of 1,129 households with sprinklers, Maddaus and Mayer (2001) found that the addition of an automatic sprinkler increased outdoor use by 55 to 60 percent. In the hotter zones, 57 percent of surveyed homes used these systems compared to 20 percent in the cooler, wetter climates.

[3] An acre-foot of water is equivalent to 325,851 gallons, the amount of water it takes to cover an acre of land one foot deep. One acre-foot is the amount of water used annually by five to eight people.

[4] The *Plan* cites several studies suggesting the potential for significant, cost-effective savings. A Pacific Institute study (Gleick et al., 2003) estimated that urban water use could be reduced by roughly 12 percent at a cost of $100 per acre-foot or less and by as much as a third at less than $600 per acre-foot (the benchmark price used by the study authors for alternative sources). The California Urban Water Agencies (2001, 2004) estimate that implementation of quantifiable "best management practices" (a narrower set of goals) would generate just over one million acre-feet cost-effectively by 2030. A study for the California Bay Delta Authority (2005) estimates a savings potential of up to 3.1 million acre-feet, although the last million might not be cost-effective.

[5] Measurement of water use in the "large landscape" category is more precise, thanks to separate meters.

[6] See http://www.snwa.com/html/cons_waterfacts.html.

[7] Although the graph only shows trends back to 1945, the cumulative average extends back to the earliest records, as early as 1803 in the South Coast.

[8] Single-family home sizes in California grew from an average of 1,277 square feet in the mid 1940s to nearly 2,600 square feet by the early 2000s. Building footprints increased from roughly 1,200 square feet to 1,900 square feet over this interval. It is possible that the total amount of hardscape—including garage area and pavement, in addition to the home's footprint—has increased by a greater amount, but we have no way to measure this.

[9] Because the data on lot sizes are less precise for some of these counties, it is possible that our analysis overstates the importance of these lots in the overall picture. Also, some of these ranchettes may be hobby farms or vineyards, for which water use would fall within agricultural demand.

[10] The Coastal superzone includes ET_0 zones 1 through 5, the Inner Coastal superzone includes ET_0 zones 6 through 10, the Central superzone includes ET_0 zones 11 through 15, and the Desert superzone includes ET_0 zones 16 through 18.

[11] This percentage is in line with recent field studies by the East Bay Municipal Utility District (EBMUD). In a 1995 survey, an average of 2,513 square feet, or 26 percent of the total lot, was irrigated—corresponding to roughly 31 percent of our definition of yard (Opitz and Hauer, 1995). In a 2001 survey, average irrigated area was estimated as roughly the same (2,510 square feet), but no total lot size was given (Water Resources Engineering, Inc., 2002). Our estimates from county assessor records suggest that this corresponds to roughly 36 percent of total lot size.

[12] The weighted average ET_0 for each region and superzone is calculated based on the number of lots in each of the 18 detailed ET zones. The numbers shown here reflect regional and zonal ET_0 using the distribution of single-family homes in the county assessor records. The results are nearly identical when we use the rates calculated from the distribution of homes in the 2000 Census.

[13] We also evaluated higher percentages, but these implied far too much aggregate outdoor residential water demand relative to DWR's estimates of total residential use.

[14] This estimate is derived using the 2000 Census estimate of the share of multifamily units in the total (32.9%) and DWR's estimate that multifamily units accounted for 26.8 percent of residential water use in that year (see Department of Water Resources, 2004). For that same year, DWR (2005) estimates average indoor residential use at 3,233,000 acre-feet, or 0.28 acre-feet per household, and average outdoor use at 2,328,000 acre-feet. If average multifamily and single-family indoor use is the same, this implies an average single-family outdoor use of 0.24 acre-feet and average multifamily outdoor use of 0.11 acre-feet, 46 percent of the single-family value. We apply a rate of 50 percent, because it is also likely that multifamily homes have somewhat lower indoor use. Note that these ratios are similar to those found by Dzieglielewski et al. (1990) in a study conducted in Southern California (Department of Water Resources, 1994a).

[15] The estimates are obtained by multiplying the average lot sizes in each ET_0 superzone by the volume of single and multifamily housing reported in the 2000 Census.

[16] The additional effect of shifts in the average ET_0 rate was a 7 percent increase in the Bay Area and a 3 percent increase in the South Coast. In the inland regions, the increases are under 1 percent.

[17] A recent survey of single-family homes in the EBMUD service area found, for instance, that roughly a quarter of all households had no irrigated landscape in the front or back yard (Water Resources Engineering, Inc., 2002).

[18] This is the standard for cool-season turf grass embodied in California's Model Landscape Ordinance, for instance.

[19] In the EBMUD studies, lawns accounted for about 40 percent of the irrigated landscape (Opitz and Hauer, 1995; Water Resources Engineering, Inc., 2002). The Metropolitan Water District of Southern California's outdoor water conservation programs assume that a conventional landscape consists of 60 percent lawn and 40 percent shrubs and trees.

[20] We obtained these figures by comparing outdoor water use estimates in the inland and coastal areas with our estimates of irrigated acreage and assuming that 25 percent of plant water needs are covered by rainfall. With DWR's estimate of outdoor residential water use (2.3 million acre-feet, or 42 percent of all residential use), we obtain an ET factor of 106. If outdoor use instead made up half of the residential total, the ET factor jumps to 127. Rates are higher in the inland regions in both scenarios.

[21] Hayhoe et al. (2004); Lund et al. (2003); Department of Water Resources (2005).

[22] The long-run marginal cost is the incremental per unit cost of expanding water supply, taking into account both investment and operational costs.

[23] In part, this new view stems from improved estimation techniques, which better capture the effect of fixed fees and jumps in prices associated with increasing block rates. See Hanemann and Hewitt (1995).

[24] In a study based on a climatically and geographically diverse dataset, Olmstead, Hanemann, and Stavins (2005) find that households subject to increasing block rate water prices exhibit nearly double the price elasticity of houses subject to uniform pricing structures. The study found a price elasticity of –0.64 for increasing block rate households versus –0.33 for uniform pricing households. In a meta-analysis incorporating over 300 estimates of water price elasticity, Dalhuisen et al. (2003) also found greater price sensitivity under increasing block rate systems.

[25] The data on rate structures are from Black and Veatch (2001, 2003) and phone surveys. The sample included 348 utilities meeting the size threshold for the Urban Water Management Plans Act (at least 3,000 customers or 3,000 acre-feet of annual water sales).

[26] In particular, this group includes water districts in the Sacramento Metro region, the Inland Empire, and Los Angeles County. Most switched from uniform to increasing block rates in the early to mid-1990s.

[27] In practice, this is proposed through benchmark shares of volumetric pricing in total revenues. To qualify as conservation pricing, 60 percent of total revenue through a tiered rate structure must come from volumetric revenue (as opposed to revenue from fixed charges). For uniform rate structures, volumetric revenue must constitute at least 75 of total revenue. See California Urban Water Conservation Council (2005).

[28] This is the rate the Metropolitan Water District of Southern California is assuming in its estimates of potential water savings from improved irrigation efficiency, for

instance. Maddaus and Mayer (2001) estimate that these rates could be even lower, within the range of 30 to 50 percent.

[29] On-site systems rely on either a solar sensor or a temperature sensor, in both cases combined with a rain sensor.

[30] Bamezai (2001); Hunt, et al. (2001); Municipal Water District of Orange County and Irvine Ranch Water District (2004). IRWD did not adjust the controllers after installation to simulate the minimal consumer adjustment that they expected would happen under normal circumstances.

[31] Santa Barbara County Water Agency (2003).

[32] Interview with Lynn Lipinski, John Wiedman, and Tim Blair, MWDSC, October 28, 2005; Kissinger and Solomon (2005). With these technologies, irrigation efficiency would jump from 50 to 69 percent.

[33] For a typical home in the Coastal zone, our estimates generate slightly lower per household savings from ET controllers than the 41 gallons per day found in the Irvine Ranch Water District (Bamezai, 2001). That pilot study targeted water users in the top 20 percent of households, who likely had either larger lawns, lower irrigation efficiency, or a combination of these factors.

[34] See http://www.mwdoc.com/SmarTimer/ETControllers.htm for a list of products eligible for rebates under a joint program by the Municipal Water District of Orange County and the Irvine Ranch Water District. One system listed has a starting price of $1,400, but it is mainly directed at commercial clients. The price of on-site sensor-based controllers ranges from $140 to $260 for an eight-valve system, and the price of satellite-linked systems starts in the range $560 to $650. After year two, a monthly subscription fee of $4 is charged. Installation costs range from $75 to $130 (the higher price includes rooftop installation of solar sensors).

[35] Utility rebates are assumed to be $20 per valve. For the Coastal zone, we assume an average of nine valves (the current practice in Orange County); for the Inner Coastal and Central zones, an average of ten valves; and for the Desert zone, an average of 11 valves, to take into account larger lot sizes.

[36] We assume a cost per controller of $40, in line with current programs in Orange County.

[37] These rates are calculated for a sample of 251 utilities with uniform rates using data in Black and Veatch (2003). The "low" price ($242/acre-foot) is the average rate charged in 2003 in the San Joaquin Valley, and the "high" price ($678/acre-foot) is the comparable rate for the South Coast region. Average rates were higher in the Bay Area ($827) and the Central Coast ($711) and lower in the Inland Empire ($453) and the Sacramento Valley ($265). Marginal rates may be higher in some increasing block rate systems, which are not included in these calculations.

[38] Some urban utilities have access to lower-cost sources, notably through purchases of farm water and underground storage, which can cost as little as $100 to $200 per acre-foot in some locations (Hanak, 2005).

[39] For instance, Gleick et al. (2003) have argued that the non-water cost savings from more efficient irrigation practices could be substantial.

[40] The Irvine studies mentioned above found that run-off was reduced by 50 percent for homes retrofitted with ET controllers (Municipal Water District of Orange County and Irvine Ranch Water District, 2004).

[41] Interview with Lynn Lipinski, John Wiedmann, and Tim Blair (MWDSC), October 28, 2005.

[42] Information provided by Tracy Bower, SNWA, February 2005 and Kent Sovocool, SNWA, January 2006. These estimates cover turf removal and installation of the new landscape, including a drip irrigation system. During the SNWA's field study in the late 1990s (Sovocool, 2005), the average costs were on the order of $2 per square foot. These costs have been rising in recent years, in part because more people are using contractors to do the conversion and in part because of a loss of scale economies as people convert smaller plots.

[43] Using irrigation submeters, SNWA monitored over 300 single-family homes that had converted at least 500 square feet of turf grass to "xeric" (low-water) landscapes (Sovocool, 2005).

[44] This assumes, as above, that 25 percent of water needs are met by rainfall. Alternatively, the same ET adjustment factor (160%) could be attained with 50 percent irrigation efficiency and no allocation of rainfall to cover plant needs.

[45] The maintenance survey was conducted by mail in the summer of 2000, drawing from a sample of participants in SNWA's turf conversion program. Respondents were asked to record their time and capital costs (lawnmowers, fertilizers, etc.) for their residential landscapes. Usable records on costs were available for 216 cases, of which 50 had at least 60 percent turf in their gardens and 166 had at least 60 percent xeriscape landscape, with an average landscaped area of 1,750 square feet. The annual capital costs were $214 lower for the yards with more xeriscape (yielding a savings of $0.12/square foot), and these residences used 2.3 fewer hours of labor per month (yielding a savings of $0.23/square foot if valued at $14.50 per hour, a price assumed for unskilled landscaping work). See Hessling (2001) and Sovocool (2005).

[46] Notably, it set a standard for irrigation efficiency of at least 62.5 percent, and it advocated a 1/3:1/3:1/3 crop mix (see Table 4). For details, see California Urban Water Conservation Council (2005).

[47] For an overview of flexible, water-smart landscaping approaches, see Department of Water Resources (2002).

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California Economic Policy

Lawns and Water Demand in California

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