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CALIFORNIA FARM WATER SUCCESS STORIES

Juliet Christian-Smith, Lucy Allen, Michael J. Cohen, Peter Schulte, Courtney Smith, and Peter H. Gleick

March 2010

California Farm Water Success Stories

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The full report is available online at
http://www.pacinst.org/reports/success_stories

ISBN: 1-893790-24-X
ISBN-13: 978-1-893790-24-7

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Cover photo of Yolo County Bypass:
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About the Pacific Institute

The Pacific Institute is one of the world's leading independent nonprofits conducting research and advocacy to create a healthier planet and sustainable communities. Based in Oakland, California, we conduct interdisciplinary research and partner with stakeholders to produce solutions that advance environmental protection, economic development, and social equity—in California, nationally, and internationally. We work to change policy and find real-world solutions to problems like water shortages, habitat destruction, global warming, and environmental injustice. Since our founding in 1987, the Pacific Institute has become a locus for independent, innovative thinking that cuts across traditional areas of study, helping us make connections and bring opposing groups together. The result is effective, actionable solutions addressing issues in the fields of freshwater resources, climate change, environmental justice, and globalization. More information about the Institute and our staff, directors, funders, and programs can be found at www.pacinst.org.

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Acknowledgements

We would like to sincerely thank all of the individuals who took time to share their inspiring work with us. Special thanks goes out to Craig McNamara, Tom Rogers, Karen Ross, Marcos Hedrick, Dale Huss, Barbara Meister, Eric Averett, Dave Feliz, John Currey, Robin Kulakow, John Williamson, Jacob Christfort, John Uhl, Kent Frame, Peter Nelson, Dan Parks, Michelle Malahoff, Heather Engel, Jack Porrelli, Dan Carlson, and Afreen Malik. We would also like to thank our funders for their generous support of the Pacific Institute's Water and Sustainability Program, including The William and Flora Hewlett Foundation, The David and Lucile Packard Foundation, the Horace W. Goldsmith Foundation, and the S.D. Bechtel, Jr. Foundation.

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Introduction

Background and Project Description

In 2009, the Pacific Institute published *Sustaining California Agriculture in an Uncertain Future*,[1] which presented a positive vision of where California agriculture could be in the year 2050 and a detailed analysis of how to get there using existing efficient water technologies and management practices. That analysis offered compelling support for the argument that alternative approaches to agricultural water management can be—and have been—very successful. Despite mounting evidence of the applicability and effectiveness of many of the report's suggestions, some water policymakers and managers remain uninformed or skeptical about the role of improving efficiency in tackling California's water problems. This is in part due to lack of information, incomplete data, and poor communication among the many different actors in the water community.

As stated in our 2009 report, long-term sustainable use of water does not require drastic advances in technology or heroic or extraordinary actions. Instead, it requires a commitment to an ethic of sustainability and efficiency and the will to continue expanding on positive trends that are already underway. As a follow-up to that first study, the Pacific Institute initiated the *California Farm Water Success Stories* project to identify, describe, and analyze successful examples of sustainable water policies and practices in the state. The goal of this new project is to show policymakers and the public how innovative growers and irrigation districts are already beginning to move California toward more equitable and efficient water management and use. The case studies documented here provide multiple benefits both on and off the farm.

We reviewed dozens of case studies and, ultimately, chose seven as examples of diverse strategies for innovative water planning, use of technology, institutional management, economic incentives, and environmental protection and restoration. As examples of successful practices already in use, these cases demonstrate viable alternatives to traditional approaches to meeting today's water management challenges. In each case we identify the key factors that led to success, with the objectives of highlighting smart practices for individual managers and actors and identifying policies that can promote such practices.

For this report, we selected activities that led to more efficient applied water use or enhanced water quality, increased crop yields or quality, and provided multiple benefits. We include practices that have been implemented by both large and small farms, as well as by irrigation districts. Successful examples of planning and management practices, technological improvements, information dissemination, use of recycled water, and incentive and assistance programs are all included.

[1] Cooley, H., J. Christian-Smith, and P. Gleick. 2009. *Sustaining California Agriculture in an Uncertain Future.* Pacific Institute: Oakland, California. Available online at www.pacinst.org.

The Case Studies: What Makes Success?

What makes a program a success? Achieving a specified goal? Learning something unexpected? Exceeding an expectation? In this report, we identify programs that did all of this while teaching lessons about ways to solve California's complex water problems. Many individuals, organizations, and institutions are involved in California water issues, and while this mix sometimes produces rancorous debates and disagreements, it also can produce unusual collaborations and innovations.

As we evaluated many different possible stories, we developed criteria for evaluating the "success" of a project. Ultimately, we followed a set of guidelines for selecting success stories, including ensuring that the case studies were:

- Replicable;
- Durable;
- Acceptable to multiple stakeholders;
- Adequately monitored and documented; and
- Geographically diverse.

These guidelines are standards by which projects and activities could be measured. Each case that we studied was different—with a unique set of actors, characteristics, and approaches. We recognize that these differences mean that the approaches and methods described in the case studies may require some modification and adaptation to local conditions, but each offers important lessons that can be adopted in other areas. In the end, we chose examples that hold the most promise for teaching us how to think about agricultural water management in the future. Below, we identify four themes that capture the common lessons learned from these case studies.

The Case Studies: Common Themes

Successful Water Management Provides Multiple Benefits

Throughout California, innovative members of the agricultural community are identifying common interests and managing water resources for multiple benefits. Successful water management provides benefits for a variety of stakeholders, and in so doing, garners widespread support. California's wine industry has become a leader in sustainable practices, emphasizing the "triple bottom line": economics, environment, and equity. The Sustainable Winegrowing Program created a self-assessment program that has provided the industry with data to communicate their progress to customers and regulators, and a mechanism through which their farmers can identify opportunities to increase efficiencies, manage risks, improve product quality, and cut costs. Today, the California Sustainable Winegrowing Alliance offers independent, third-party assessment of on-farm and winery management practices (see Chapter 1).

In another example of managing for multiple benefits, growers in the Yolo County Bypass are working with the Department of Fish and Game to manage some of California's last remaining seasonal wetlands—the Yolo Bypass Wildlife Area—a critical habitat for migrating birds. This unique partnership incorporates agricultural production into the management of the wildlife area, while continuing to allow seasonal inundation and flood conveyance around the city of Sacramento as well as environmental education and recreational opportunities. The project represents an important model for creating multiple benefits, for farmers, wildlife, and the public (see Chapter 2).

Accurate Monitoring and Measurement are Critical

In order to manage a system, one must first understand it. Collecting and disseminating accurate data and information permits individuals, organizations, and government agencies to make fast and well-informed changes in water management and use. Several of the case studies described in this report show the value of accurate monitoring and real-time measurement in improving water management.

Good information on water supply and demand at the field level is also critical to farmers interested in carefully managing water resources. In 1982, the California Department of Water Resources (DWR) and the University of California created the California Irrigation Management Information System (CIMIS) to encourage farmers and other water users to include weather information in irrigation decisions (see Chapter 3). If growers have, and use, actual data on evaporation and transpiration rates in a region, they can irrigate in a more accurate and timely manner, replacing only the water actually used by crops. More and more growers are also monitoring critical field conditions with in-field monitoring systems. These systems typically combine in-field measuring devices, including soil probes, plant moisture sensors, and weather stations, with software that allows the grower to easily access and interpret the measurements collected. Many provide near real-time data, which can be accessed from anywhere with an internet connection, and may have additional features such as email or cell phone alerts and remote control or automation of the irrigation system. These types of systems greatly increase the amount and precision of information available to growers, allowing more precise management of water resources.

Another example of the value of good information is the Coachella Valley Water District's (CVWD) agricultural water efficiency initiative, known as the Extraordinary Water Conservation Program (ECP). The ECP documented savings of more than 75,500 acre-feet of water over six years, at a cost to the district of about $40/acre-foot (see Chapter 5). The ECP incorporates precise irrigation scheduling—relying on CIMIS data and crop needs—and a sophisticated salinity management program to decrease water use while optimizing crop production. CVWD also implemented a district-wide communications and technology upgrade that provides its staff with water orders and system status in real time. This technology has greatly increased flexibility and autonomy to adjust deliveries to optimize water balancing and system efficiency, decreasing waste and better meeting irrigators' needs. About 80% of water districts in California do not provide water on-demand, representing an important area for future improvement.

Existing Technologies Have Enormous Untapped Potential

Many technologies that are already available can play a vitally important role in conserving water, protecting water quality, providing recycled water for different uses, monitoring and measuring water availability and use, or managing complex demand and supply situations. The continued adoption of these cost-effective, proven technologies will have a long-term beneficial effect on California water policy by reducing demand and increasing available supply through improvements in water quality and management.

In recent years, California farmers have made progress converting appropriate cropland to water-efficient drip irrigation systems, significantly reducing applied water requirements for many growers. Much of this conversion has happened on land planted with high-value vineyards, orchards, and vegetable crops. Nevertheless, 60% of California's irrigated acreage is still flood irrigated. In many areas of the state, growers and irrigation districts are looking for innovative funding mechanisms to offset the high initial investment costs associated with many sprinkler and drip systems (see Chapter 7).

The potential for cleaning and re-using wastewater has barely been tapped. Only recently has recycled wastewater been used extensively for agricultural irrigation. Sea Mist Farms in the North Salinas Valley and growers in Sonoma County are using recycled water on a variety of crops, reducing pressure on scarce groundwater supplies, and in the case of Sea Mist Farms, decreasing seawater intrusion into the local aquifer (see Chapter 6). However, demand for recycled water still far outstrips supply and only a small fraction of irrigated land has access to highly treated wastewater in California.

In addition, the case study of the Rosedale-Rio Bravo Water Storage District's conjunctive use program demonstrates the advantages associated with utilizing underground storage, particularly in terms of adapting to more extreme weather events, e.g., storing excess flows during floods and drawing on stored groundwater during droughts (see Chapter 4). Yet vast amounts of dewatered storage space remain, nearly 10 million acre-feet in the Central Valley alone. These examples show that existing technology has far greater potential than has yet been realized if the legal and institutional barriers can be overcome.

Setting Targets for Achievement and Providing Economic Incentives Accelerates Progress

Quantitative targets for achievement are extremely valuable in terms of accelerating the adoption of sustainable management practices statewide. These targets can be driven by the private sector or the public sector. For instance, the California Sustainable Winegrowing Program is an industry-driven initiative to expand the use of best practices from the vineyard to the winery. When the program released its first Sustainability Report, benchmarking practices across the industry, it also set a target of 20% improvement across all sustainability criteria over the next five years. This has provided an important bar for achievement for the program and its members.

On the other hand, the case study of the Coachella Valley Water District demonstrates how a federally mediated process to reduce the excess use of Colorado River water by

California prompted significant improvements in district water-use efficiency. In 2004, the Coachella Valley Water District began its multi-year agricultural water efficiency initiative, the aforementioned Extraordinary Water Conservation Program (ECP), to meet state and federal water conservation targets of 73,000 acre-feet over eight years. In addition, federal- and state-mandated reductions in drainage water from the Panoche Water and Drainage District resulted in a series of major district upgrades. The district drastically reduced the volume of drainage water through a series of measures including canal lining, drainage water recycling, and conversion of 70% of the district to efficient irrigation technologies (funded through state low-interest loans). Finally, initial investments in recycled water were driven, in large part, by the federal Clean Water Act, which not only set quantitative water quality targets but also funded the infrastructure for centralized wastewater treatment facilities which can be used to recycle water.

Economic incentives are clearly critical in terms of defraying the sometimes high initial investment required for water conservation and efficiency improvements. The case study of federal and state financing describes some of the on-farm impacts of cost-share programs authorized by the federal Farm Bill, as well as the district upgrades funded through low-interest loans and grant programs provided by statewide voter-approved bonds (see Chapter 7). These funding programs are critical in terms of investing in our agricultural water infrastructure, which is woefully outdated in many areas of California. The studies show how quantitative targets and economic incentives can both be effective tools, and often work synergistically, to accelerate water management improvements.

Conclusions

The success stories described here are just a few examples of the innovations already occurring throughout California agriculture. In communities around the state, smart and committed individuals and groups are finding better ways to manage our state's scarce freshwater resources. Official state water policies now often lag behind—rather than define—the state-of-the-art. It is important to incorporate the lessons drawn from these case studies in future water policy and planning in order to accelerate the adoption of sustainable water management principles and practices.

Two key sustainable water management principles are managing for multiple benefits and forging collaborative partnerships among different stakeholders. We urge that projects include these principles. Sustainable water management practices are also far more likely to succeed when they include accurate monitoring and measurement of water use, which is critical to make better use of our scarce water resources and to provide more flexibility to farmers. Moving to such consistent and transparent monitoring is, therefore, another key recommendation.

In addition, despite significant improvements already, existing technologies still have great potential to further increase agricultural water-use efficiency statewide. More effort should be made to encourage the appropriate use of these technologies. Finally, we find that setting quantitative targets and providing economic incentives to achieve them can work synergistically to accelerate change. Integrating these success stories into long-term policy and planning could lead to a very different California—one where efficient, equitable, and sustainable water use is the norm, rather than the dream.

Chapter 1

Industry-Driven Standards for Water Efficiency: The California Sustainable Winegrowing Program

Courtney Smith

> ***"When growers and vintners came together to create the Sustainable Winegrowing Program, they truly wanted it to be an example and to help inspire other sectors of agriculture because we really believe this is a terrific way to brand California."***
>
> **-Karen Ross, Past-President of the California Association of Winegrape Growers**

Introduction

In California, water is an increasingly precious resource. Pressures from population growth, management policy, and climate change all threaten the security of our water. The availability of water is of incredible importance to farmers—the future of farming depends on it. With a stake in the future of this resource, farmers also have an opportunity to help protect it. Improving the conservation and efficient use of agricultural water and other natural resources can reduce the risks that come from water scarcity, and many individual farmers have taken proactive approaches to improving how they manage resources. But a consolidated, industry-wide effort is still relatively uncommon, although it can be powerful in bringing resilience to farming's future—and extending the benefits agriculture brings society to include model stewardship of the state's natural resources.

Recognizing the numerous benefits that come from enlisting an entire industry, California's wine industry has taken a proactive approach to putting sustainable practices into action under the California Sustainable Winegrowing Program (SWP). By adopting industry-driven, voluntary efforts, the state's wine community has become a leader in sustainability. The self-assessment program they created has provided their industry many benefits, including market advantages, data with which to communicate their progress to regulators, and a mechanism through which their farmers can identify opportunities to increase efficiencies, manage risks, improve product quality, and cut costs. Using the wine industry's efforts as a model, other crop industries are beginning their own programs to gauge, and ultimately improve, the adoption of industry-specific sustainability best practices.

Background

Over a decade ago, California's wine industry began working to provide its growers and vintners with the tools and resources necessary to make California a world leader in the adoption of sustainable wine-growing practices. In 2001, the Wine Institute and the California Association of Winegrape Growers (CAWG) established the California Sustainable Winegrowing Program (SWP), a first-of-its kind, industry-driven, crop-specific sustainability program that helps educate growers and vintners on the benefits of sustainable practices, provides tools for participants to self-assess their practices and progress, and provides the industry with information on what it is doing well and what it can improve (CSWA 2004).

The Wine Institute and CAWG teamed up with SureHarvest—a consulting firm that served as the key architect for the program—to design and implement the sustainability program. After a multi-stakeholder process, the program created the Code of Sustainable Winegrowing Practices—a self-assessment workbook covering over 200 vineyard and winery criteria and associated best-practices for soil, ecosystems, air quality, pest control, water conservation, recycling, energy efficiency, and wine quality, among others. The Code allows participants to assess their practices to determine where they lie on a continuum of sustainability. First published in 2002, this self-assessment tool was built largely upon the innovative efforts already begun by regional leaders and organizations, including the Lodi-Woodbridge Winegrape Commission (LWWC) and the Central Coast Vineyard Team (CCVT). The CCVT developed the first vineyard self-assessment in 1996, a series of yes/no questions focused on sustainable vineyard practices. A few years later, the LWWC published the *Lodi Winegrower's Workbook* (LWWC 1999), based on a self-assessment model developed by Farm*A*Syst. Many of the vineyard chapters in the Code of Sustainable Practices were adopted directly from the *Lodi Winegrower's Workbook*, though additional chapters were added to address other vineyard issues and practices inside the winery itself (Ross 2002).

California Sustainable Winegrowing Program

> ***"As we talk to people in the trade about our practices, we're willing to document them…That's part of the Sustainable Winegrowing program––our commitment to transparency––and so everything that we're doing is available on our website."***
>
> **–Karen Ross, Past-President of CAWG**

What began as a three-ring binder workbook is now a web-based system created and managed by SureHarvest that allows growers and wineries to complete their self-assessment online, file action plans and performance reports, access educational content, and stay informed of industry events (SureHarvest). In addition to the creation of the self-assessment workbook, the SWP held hundreds of workshops to help vineyards and wineries complete the self assessment and to increase industry participation.

From these assessments, confidential reports were provided to individual growers. Then, the results from these self-assessments were compiled to gauge industry-wide progress. The resulting Sustainability Report was the first time an entire sector measured the sustainability practices among its members and reported them publicly (CSWA 2004). This first report provided the industry with a picture of how it was doing and gave it the ability to identify strengths and weaknesses and target educational efforts, demonstrations, and workshops.

The process of industry-wide self-assessment has many benefits beyond working toward better stewardship of the environment. An industry-wide self-assessment effort can serve to unify the growing community by creating a common understanding and language of what it means to be sustainable. A more cohesive community of growers working to improve their practices sends a powerful message to the marketplace and to regulators that the industry is forward-thinking and proactive in working toward sustainable resource use. Self-assessment provides an industry with a way to communicate—with numbers—the positive steps it is taking.

In addition to industry benefits, the self-assessment process can provide many advantages to individual growers. Not only does it allow growers to evaluate their farm operations, it can help farmers identify opportunities to increase efficiencies, manage risks, improve product quality, and cut costs. As a part of a larger industry-specific program, self-assessment allows farmers to compare their practices to others in the region and the industry and to develop action plans to increase their operation's sustainability. Such an assessment can also help growers to find funding to help offset the costs of best management practices. In partnership with the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS), the SWP workbook criteria and practices have been matched to corresponding NRCS standards and practices for the Environmental Quality Incentives Program (EQIP). EQIP is a cost-share program, authorized by the federal Farm Bill (see Chapter 7).

Results To-Date

> ***"Because of increasing statewide demand for a constrained water supply, it is imperative that all users maximize their effective and efficient use of this crucial natural resource. Winegrowers should continue to lead the state's agriculture sector by implementing the high levels of beneficial practices for conserving and ensuring the quality of California's water."***
>
> ***–Sustainability Report 2009***

The SWP has documented its progress through two sustainability reports. The most recent report, released in January 2010, measured the California wine industry's performance against 227 criteria and associated best management practices from the second edition of the *Code of Sustainable Winegrowing Practices Self-Assessment Workbook* (CSWA 2010). To date, 1,566 vineyard and winery organizations representing 68% of California's 526,000 wine acres and 63% of the state's 240 million case production have evaluated their vineyards and wineries with CSWA's Code. The report found that during the past five years, there was demonstrated improvement in 60% of the Code criteria (CSWA 2010). The self-assessment report updated industry-wide strengths and weaknesses, and found that despite significant progress since 2004 in vineyard water management and winery water conservation and quality, the industry scored in the middle ground for these two chapters. This result signifies that while the industry is making progress, opportunity exists to further improve.

In terms of on-farm management, 92% of growers have defined comprehensive water management plans, though only 33% have implemented this plan for more than one year. Eighty-five percent of growers are on micro-irrigation or sprinkler systems. About half of growers are monitoring their irrigation system annually, which is important for detecting leaks and determining the distribution uniformity of the system, and about half are using evapotranspiration data to determine irrigation requirements. A little more than half of growers are metering their water use—34% are monitoring the irrigation flow through their system, however only 18% are recording the volume of each irrigation application. The most significant improvements in on-farm practices since 2004 are the increased use of flow meters and evapotranspiration data to schedule irrigation.

The program also evaluates winery water conservation and quality best practices, with about half of participating wineries conducting water audits in the last two years. Yet the Sustainability Report notes: "In the 21st century just thinking about water isn't enough. It is now time to take action and this requires measuring the amount of water used at the winery. Many wineries have installed water meters at key operational points…A small but growing percentage of wineries have installed water meters throughout their entire facilities to monitor water consumption." In the future, both vineyard and winery water management are classified as areas for potential improvement.

Moving Forward: Third-Party Verification

While the SWP has focused on education and self-assessment for the last several years, they are now expanding to include a statewide certification program that provides third-party verification of adherence to a "process of continuous improvement" in the adoption and implementation of sustainable winegrowing practices. This marks a step toward even more transparency and may provide additional legitimacy in the marketplace. Introduced in January 2010, the CSWA's new voluntary program, Certified California Sustainable Winegrowing, is open to all California wineries and vineyards and requires applicants to meet 58 prerequisite criteria, annually assess winery and/or vineyard operations, and create and implement an annual action plan and show improvement over time (CCSW 2010).

Adoption by Other Crop Industries

Recognizing the multiple benefits self-assessment can bring to the individual farmer, industry, and the environment, the SWP's self-assessment program is serving as a model for other sectors of California agriculture. For instance, as part of a larger industry-wide sustainability effort, the California Almond Board recently initiated the development of their own self-assessment program designed to inventory the in-orchard practices among its growers (CAB 2010). The initial focus of the self-assessment will be on irrigation and fertilizer management practices.

Nineteen growers recently participated in a pilot self-assessment. One of the participants, Brain Ramos, said, "What I like about this program is it tells a person about what we're doing…It's nothing but win-win" (quoted in Boyd 2010). The Almond Board likes it because it collects valuable information to focus research into areas where information may be lacking, to back grower claims, to improve practices, and to answer questions buyers have about the industry's sustainability practices. The latter is increasingly important as large food distributors and retailers, such as Walmart and Safeway, launch sustainability initiatives and are interested in metric-based programs that document grower practices.

Conclusions

The proactive approaches that these industries are taking demonstrate that it is possible to improve how we use our state's resources, particularly water. In addition, sustainable management provides multiple benefits, from higher quality products and marketing advantages to healthier ecosystems and less contentious relations with other resource users and regulators. Indeed, the practices outlined by the SWP and the transparency of the assessment program have engendered widespread support. Karen Ross sees many opportunities for other commodity groups to put in place similar programs. She stresses that "using sustainable practices is a great way to brand California as the special place it is for growing lots of different crops" (K. Ross, Past-President of the California Association of Winegrape Growers, personal communication, September 28, 2009).

References

Boyd, V. 2010. “Winning numbers: Almond industry begins to collect data to back sustainability claims.” The Grower. January 2010.

California Almond Board (CAB). 2010. Outlook Newsletter: January 2010. Retrieved on February 2, 2010 from http://www.almondboard.com/outlook/2010/january/article5.asp.

California Sustainable Wine Growing Alliance (CSWA). 2004. California Wine Community 2004 Sustainability Report: Executive Summary. Retrieved on February 2, 2010 from http://www.sustainablewinegrowing.org/docs/cswa_2004_report_executive_summary.pdf .

California Sustainable Wine Growing Alliance (CSWA). 2009. California Wine Community 2009 Sustainability Report. Retrieved on February 2, 2010 from http://www.sustainablewinegrowing.org/2009sustainabilityreport.php.

Certified California Sustainable Winegrowing (CCSW). 2010. Certified California Sustainable Winegrowing. Retrieved on February 2, 2010 from http://www.sustainablewinegrowing.org/swpcertification.php.

Ross, Karen. 2002. “Thinking outside the agriculture box.” Practical Winery and Vineyard. Nov/Dec. 2002. Retrieved on February 2, 2010 from http://www.practicalwinery.com/novdec02/novdec02p68.htm.

Ross, Karen. 2009. Past-President of the California Association of Winegrape Growers. September 28, 2009. Personal Communication.

SureHarvest. Sustainability Solutions for the California Winegrowing Sector. Retrieved on February 2, 2010 from http://www.sureharvest.com/amass/documents/document/36/Sustainability%20Solutions%20for%20the%20CA%20Winegrowring%20Sector.pdf .

Chapter 2

Managing for Multiple Benefits: Farming, Flood Protection, and Habitat Restoration in the Yolo Bypass Wildlife Area

Juliet Christian-Smith

> ***"Whether a farmer is driving the tractor or I am, we are both essentially land managers…Why not benefit from that capacity and expertise?"***
>
> **-Dave Feliz, Yolo Bypass Wildlife Area Manager**

Introduction

The Yolo Bypass is a 59,000-acre floodplain on the west side of the lower Sacramento River, straddling Yolo and Solano Counties. The Bypass is a primary component of the Sacramento River Flood Control Project, which carries floodwaters from several northern California rivers around several low-lying communities, including the state capitol, to the Sacramento–San Joaquin River Delta.

The area's once thriving wetlands supported an array of wildlife and birds. Shortly after the Gold Rush, settlers began reclaiming the land and in the process, much of the natural habitat was lost. Today, some of this habitat, critical to millions of migrating birds that travel along the Pacific Flyway, is being restored within the 16,000-acre Yolo Bypass Wildlife Area (Wildlife Area). On the Wildlife Area, wildlife, agriculture, and seasonal floods coexist, and it has been nationally recognized as an outstanding example of how public land can provide multiple public benefits, including flood conveyance for the Sacramento Valley, agricultural land for a variety of farming uses, and riparian and managed wetland habitats that are home to a wide range of species and serve as a resting spot along the Pacific Flyway. In the future, this type of multi-purpose, adaptive management will be increasingly important as we cope with the effects of climate change, particularly more frequent and intense flooding.

> ***"The [Yolo Bypass] Working Group envisions the Bypass as a mix of land uses, where agricultural economic viability, flood conveyance capacity, and fish and wildlife habitats can be balanced. The Bypass can be a place where landowners are fairly compensated for land use and flood conveyance changes. It can be a place where landowners need not be threatened by the presence of additional wildlife habitat and special-status species. It can be a place where realistic goals and objectives can be achieved, resulting in benefits for all parties involved." (Jones and Stokes 2001).***

Background

The Sacramento River is joined by the Feather and American Rivers just above the city of Sacramento. The water that these three rivers carries drains a large portion of the Northern Sierra Nevada mountain range, and the volume can be greater than 30 million acre-feet annually (Jones and Stokes 2001). Historical records have recorded flows up to 600,000 cubic feet per second from the mouth of the Sacramento River into the Suisun Bay. Thus, the region is prone to large seasonal floods in response to both winter rains and spring snowmelt.

The Yolo basin parallels the Sacramento River, encompassing over 100,000 acres including the areas around Woodland and Davis southward toward Rio Vista. In the 1800s, this basin filled with water from the three rivers for most of the winter months, forming a seasonal inland sea. The area supported a diverse tule marsh ecosystem and provided important winter bird habitat. Depending on the water year, the basin could be inundated for more than 100 days, limiting travel and access to the state capitol.

> ***"Soon after the Gold Rush which exploded in the late 1840s, thousands of the people who came to Central California followed a brief fling at the mines by moving down from the mountains to settle in the fertile Sacramento Valley. Here they shortly encountered a gravely threatening natural phenomenon. They discovered that during the annual winter cycle of torrential storms that for millennia have swept in from the Pacific, or in the season of the spring snow melt in the northern Sierra Nevada, the Sacramento River and its tributaries rose like a vast taking in of breath to flow out over their banks onto the wide Valley floor… For the better part of the next several generations, embattled farmers and townspeople struggled to get control of their great river system so that they might live in safety on the Valley floor and put its rich soils to the plow" (Robert Kelley,*** **Battling the Inland Sea,** ***1989).***

In 1911, Congress approved the Sacramento River Flood Control Project, which sought to divert these large flows through a series of weirs and bypass channels. The Yolo Bypass is one of two primary bypass systems constructed in the Sacramento Valley to attenuate flood flow. When flows on the Sacramento River exceed 60,000 cubic feet per second at the Fremont Weir, water begins to spill into the Bypass. This relieves pressure on the main levee system along the river channel.

The Bypass encompasses an area 3 miles wide and 40 miles long, extending from the confluence of the Feather and Sacramento Rivers to a point above the city of Rio Vista (Tokita and Cameron-Harley1999), where it empties into the Delta. The Bypass is designed to withstand flows up to 500,000 cubic feet per second. When the Bypass is fully inundated, the wetted area of the Sacramento-San Joaquin Delta system approximately doubles (Smalling et al. 2005).

Beginning in 1989, the Yolo Basin Foundation, a non-profit community-based organization, began spearheading an effort to establish the Wildlife Area. In 1992, the California Department of Fish and Game began acquiring property within the Bypass. Over the last two decades, the Wildlife Area has grown to over 16,000 acres, and is one of the largest public-private restoration projects in the nation. At the 1997 dedication of the Wildlife Area, then-President Clinton said, "We can do anything if we roll up our sleeves and get down to work and honestly listen to people who have different experiences, different perspectives, and different genuine interests. That's what you've done here" (quoted in Feliz 2004). More than a decade later, the Wildlife Area is still thriving and has become a model of managing for multiple benefits.

Figure 1. View of downtown Sacramento from the Yolo Basin Wildlife Area
(photo: Dave Feliz, California Department of Fish and Game)

The Wildlife Area

California has lost approximately 95% of its wetland habitats over the past 150 years, making efforts to preserve what remains so critical (CDFG 2007). Over 8,000 acres of land in the Wildlife Area have been restored to wetlands and other associated habitats to support a wide variety of aquatic and avian wildlife (Figure 1). A complex system of pumps, canals, and water-control structures are utilized to flood and drain wetlands according to established prescriptions. These actions mimic the natural flooding and drainage that once occurred in the Yolo Basin. Today, the Wildlife Area provides vital habitat for hundreds of wetland-dependent species.

In addition, the Wildlife Area provides a mosaic of land uses and habitats, creating opportunities for agricultural production, wildlife habitat, environmental education, and recreation (Figure 2). The Wildlife Area continues to be actively farmed and agriculture is considered critical to maintaining the landscape values that the Wildlife Area was established to protect, and to ensure the long-term management of the property. Department of Fish and Game staff works with growers in order to develop cultivation and harvesting techniques that are beneficial to the farmer and to wildlife. Finally, the area still functions as a flood conveyance system as it was originally intended, diverting large flows around low-lying cities and towns in the region.

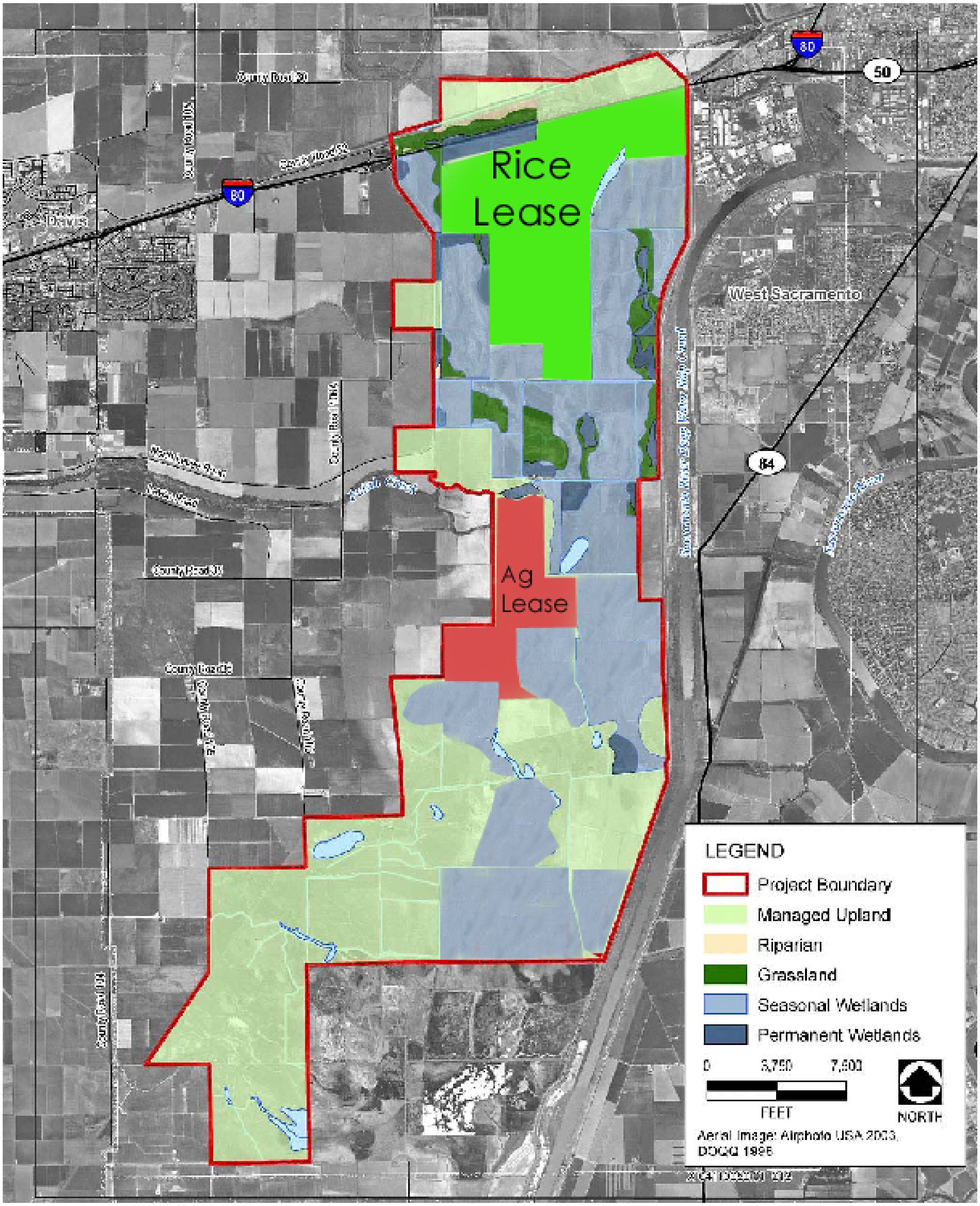


Figure 2. Yolo Bypass Wildlife Area managed permanent and seasonal wetlands, along with leased agricultural lands

Agricultural Benefits

Through a unique partnership, the Department of Fish and Game (DFG) owns the land but leases it out to agricultural producers through the Dixon Resource Conservation District (RCD). The Yolo Wildlife Area is home to a variety of agricultural enterprises, primarily producing field crops, truck crops, and grains (Figure 3). There are three agricultural leases within the boundaries of the Wildlife Area. These leases were obtained through an open bidding process, whereby potential lessees prepared production and management plans that explained not only the price they were willing to pay and the crops they expected to grow, but also methods for achieving wildlife habitat goals outlined by the DFG land managers. In 2008, the combined agricultural rental income (from 163 acres of corn, 589 acres of tomatoes, 881 acres of irrigated pasture and 5,381 acres of dryland grazing) was $379,000.

Figure 3. Tomato harvesting in the Yolo Bypass Wildlife Area (photo: Dave Feliz, California Department of Fish and Game)

Many innovative, natural-resource-compatible agricultural practices occur in the Wildlife Area that provide valuable habitat for a diverse assemblage of wildlife species (Table 1). Rice is grown, harvested, and flooded to provide food for thousands of waterfowl while aiding in the decomposition of the rice stubble. Corn fields are harvested to provide forage for geese and cranes. Crops such as safflower are cultivated and a portion of the crop is mowed to provide seed for upland species such as ring-necked pheasant and mourning dove. Much of the grassland in the southern portion of the Wildlife Area is managed with cattle grazing, controlling invasive plants and resulting in blooms of wildflowers during the spring months (CDFG 2007).

Table 1. 2004-2008 Average yields and habitat benefits for crops in the Wildlife Area (prepared by the Yolo Basin Foundation)

Crop	Yield Ranges 2004-2008	Habitat Benefits (achieved and potential)
Corn	4.5 to 5.3 tons/acre	Cover and food for upland game species during growing season and waterfowl habitat if flooded post-harvest.
Safflower	.69 to 1 tons/acre	Food source for mourning doves and pheasants; unharvested portions provide hunting opportunities.
Sunflower	1.1 to 1.3 tons/acre	Food source for tri-colored blackbirds and upland game species.
Rice Wild Rice	2.28 to 3.79 tons/acre .47 to .73 tons/acre	Spring breeding habitat for stilts and avocets; food source for egrets and ibis during growing season; wintering habitat for waterfowl and shorebirds during post-harvest flooding. In fallow years serves as year-round habitat and food for numerous wildlife species and if flooded in summer provides shorebird habitat while achieving weed control for subsequent crops. The rice irrigation infrastructure has proven versatile in providing options for wildlife habitat benefits. The flooded fields may also be providing food sources for the bat colony under the Causeway.
Annual Hay	1.8 to 2.21 tons/acre	Irrigation and haying can provide food sources for egrets, herons, swainson's hawk, crows; depending on harvest timing can provide nesting habitat for waterfowl and upland game species.
Tomatoes	23.5 to 25.2 tons/acre	Field preparation exposes rodents and insects for raptors.
Irrigated Pasture	.8 to 7.9 aum/acre	Food source for geese when pasture is sprouting; depending on timing can provide nesting habitat for pheasants and mallards.
Dryland Grazing	.2 to 1.1 aum/acre	Control of weeds and non-native vegetation to encourage desirable plant and animal species in wetland, upland, and vernal pool habitats as well as in hunting areas with too much vegetation. Cattle have also been used as a non-mechanical means of clearing an area prior to habitat construction and as a tool in managing mosquito-inducing vegetation in wetlands.

Wildlife Area Manager Dave Feliz sees agriculture as a critical part of maintaining important habitats (many of which are associated with agricultural production) and providing revenue for continued restoration and general operation of the Wildlife Area (D. Feliz, California Department of Fish and Game, personal communication, February 2, 2010). In cooperation with local farmers, he has focused on finding practices that maximize benefits to both the farmer and the environment; identifying these co-benefits has been key to the project's success. In addition, both the agricultural production and associated revenue have helped to ensure that the area is actively managed even when the state is financially constrained. In an era of land acquisition and conservation easements, it may be difficult for public land trusts and conservancies to fund the long-term management and monitoring of lands held in trust. Agriculture is increasingly seen as an opportunity for on-going management that can maximize co-benefits.

Wildlife Benefits

Over 280 terrestrial vertebrate species are known to use the Wildlife Area at some point during their annual life cycles, some 95 of which are known to breed in the Wildlife Area (CDFG 2007). In addition, the Wildlife Area provides habitat for special-status wildlife species including fairy shrimp, giant garter snake, northwestern pond turtle, snowy plover, grasshopper sparrow, great blue heron, bald eagle, and many more species that are locally rare or have specialized habitat requirements.

> ***"The Central Valley of California is one of the premier wintering areas in the world for waterfowl. We annually host over five million ducks and geese in the Valley. This is about 60% of the total waterfowl in the Pacific Flyway."***
>
> **– Dave Feliz, Wildlife Area Manager**

During the winter and early spring of some years, flooding of the Yolo Bypass brings dramatic changes to the Wildlife Area. The floods provide large expanses of aquatic habitat, a phenomenon capitalized upon by several native fish species that prey on the vast numbers of invertebrates, and birds that prey on the fish, invertebrates, and agricultural residue. The Wildlife Area takes an ecosystem management approach that maximizes benefits for the full range of species as opposed to management at the single-species level. As such it has been nationally recognized by The National Audubon Society as a Globally Important Bird Area. It supports globally significant numbers of waterfowl; continentally significant numbers of northern pintail *(Anas acuta)* and least sandpiper *(Calidris minutilla);* and nationally significant numbers of American white pelican *(Pelecanus erythrorhynchos;* canvasback *(Aythya valisineria);* and dunlin *(Calidris alpina)* (CDFG 2007).

Flood Protection

The Wildlife Area is managed so as to enhance the high productivity of seasonal wetlands. These wetlands undergo a dry period during the summer when annual plants germinate and set seed, which is an important food source for migratory waterfowl. However, if not managed correctly, this vegetation can slow the movement of flood water through the Yolo Bypass. Since flood control was the original purpose of the Bypass and is critical to the safety of surrounding communities, it is imperative to not compromise this function. Agreements with the Sacramento Valley Flood Protection Board have set detailed limitations on the amount of both emergent vegetation and riparian habitat on the Wildlife Area. In addition, studies have been done to ensure that the area has a zero net impact on the flood conveyance capacity of the Bypass. Through careful, adaptive management, the Wildlife Area is striking a balance between providing flood protection, agriculture, and habitat benefits.

Conclusions

The Yolo Bypass Wildlife Area offers an example of how to manage land and water flexibly and for multiple benefits. The Wildlife Area increases the Central Valley's ability to handle floods, while permitting agricultural production and wildlife to coexist and even thrive. The project has been nationally recognized as an outstanding example of multi-purpose, adaptive management that will be increasingly important as we cope with the effects of climate change.

As we look toward the future, climate change is already altering the timing and availability of water in California. Climate change studies indicate increased extreme weather events—including more frequent and intense winter runoff, especially in the Sacramento River region, compounded by changes in snowpack and snowmelt. It will be increasingly important to learn how to farm with both floods and droughts, while continuing to provide for critical environmental needs, and the lessons learned at the Yolo Bypass Wildlife Area can offer a template for other vulnerable areas of the Central Valley.

References

California Department of Fish and Game (CDFG). 2007. Notice of Determination for the Yolo Bypass Wildlife Area Land Management Plan in Yolo County, California. Retrieved on February 5, 2010 from http://www.dfg.ca.gov/lands/mgmtplans/ybwa/index.html.

Feliz, D. February 2, 2010. Yolo Bypass Wildlife Area Manager, California Department of Fish and Game. Personal Communication.

Feliz, D. 2004. "Yolo Fly By." Outdoor California. September/October, Vol. 65, No. 5.

Kelley, Robert. 1989. Battling the Inland Sea: Floods, Public Policy, and the Sacramento Valley. Berkeley: University of California Press.

Smalling, K. L., J.L. Orlando, and K.M. Kuivila. 2005. Analysis of Pesticides in Surface Water and Sediment from Yolo Bypass, California. 2004–2005: U.S. Geological Survey Scientific Investigations Report 2005–5220, p. 20.

Jones & Stokes. 2001. A Framework for the Future: Yolo Bypass Management Strategy: (J&S 99079.) August. Sacramento, CA. Prepared for Yolo Basin Foundation, Davis, CA.

Tokita, J. and J. Cameron-Harley. 1999. "Beneath the Flood." Department of Water Resources News. Retrieved on February 11, 2010 from http://geography.sierra.cc.ca.us/booth/california/9_water/yolo_bypass.htm

Chapter 3

Smart Irrigation Scheduling: Tom Rogers' Almond Ranch

Lucy Allen

> ***"Our goal here is use to water as it is needed, and without knowing what's going on in the soil and in temperature, you really can't water accurately. We can water according to a calendar, or we can water according to trees' needs…our goal here is to water according to the trees' needs."***
>
> **-Tom Rogers, almond grower**

Introduction

Wise use of irrigation water is a top priority for California growers, and many different practices and technologies can help improve on-farm water-use efficiency. Efficient irrigation systems, such as drip and micro-sprinklers, are one component. However, even these technologies do not ensure increased water-use efficiency—watering too often or for too long can lead to unproductive water use (water lost to evaporation, runoff, deep percolation, or weed growth). On the other hand, irrigating too little can cause water stress and reduce yields or crop quality. Irrigation needs vary based on a complex set of variables such as crop type, plant age, micro-climate, stored water, and soil type. Irrigation scheduling—deciding how often and for how long to irrigate—is a critical component of how efficiently water is used. Therefore, increasing the amount and quality of information available to growers is an essential first step in efficient irrigation.

Smart irrigation scheduling refers to technologies that help growers determine more precisely when crops need to be watered and how much water they require. With smart irrigation scheduling, growers are able to use their water more efficiently, either by reducing or by keeping constant the amount of applied water, while maintaining or improving yields. Having more precise knowledge of soil moisture levels also has a number of peripheral benefits, such as pest control.

Background

Decisions on when and how much to irrigate are critical both to crop health and to water-use efficiency, and there are many different methods growers use to make these decisions. According the USDA's Farm and Ranch Irrigation Survey, the most commonly used methods to schedule irrigation in California are the condition of the crop, the feel of the soil, and a personal calendar schedule (Table 2) (USDA 2009). In some irrigation districts, growers are restricted by scheduled water deliveries and must irrigate when their water arrives.

Table 2. Methods used by California farmers to decide when to irrigate, 2008

Method	Percent of CA farmers
Condition of crop	66
Feel of soil	45
Personal calendar schedule	32
Soil moisture sensing device	14
Daily ET reports	12.3
Scheduled by water delivery organization	10
Commercial or government scheduling service	9.7
When neighbors irrigate	6.1
Other	5.5
Plant moisture sensing device	3.1
Computer simulation model	2.7
Note: many farmers use more than one method when deciding when to irrigate, thus the total of all methods exceeds 100 percent.	

Source: Table 36 in USDA 2009

While these scheduling methods may work adequately in maintaining crop health, a more scientific approach can help growers to water more precisely to meet crop water requirements. Smart irrigation technologies make use of local weather stations that measure air temperature, humidity, wind speed, and rainfall; soil probes that measure soil moisture depth, temperature, and salinity; and plant moisture sensing devices that measure the water pressure in plant cells. Increasingly, software paired with these technologies allows growers to easily access real-time data on field conditions, receive alerts through email and text messages, and automate or control their irrigation systems remotely.

California Irrigation Management Information System

The California Irrigation Management Information System (CIMIS), a network of more than 130 automated weather systems across the state, was developed in 1982 by the California Department of Water Resources and the University of California to encourage growers to use weather information in their irrigation decisions. CIMIS provides localized weather data online, such as temperature and wind speed, free of charge to registered users. This data can be combined with other parameters which allow farmers to replace only the water that is actually used by crops (transpiration) or lost to the atmosphere (evaporation), referred to as evapotranspiration or ETo. CIMIS provides this calculated ETo value for most of the weather stations in its network and also provides a modeled two-kilometer-grid resolution of a daily ETo map for the entire state.

Each of the CIMIS weather stations consists of sensors that measure local conditions and a data-logger to either store or calculate hourly and daily averages and totals. Sensors collect data on solar radiation, soil temperature, air temperature, humidity, wind speed and direction, and precipitation. A central CIMIS computer automatically downloads data four times per day, then calculates reference evapotranspiration rates and checks the quality of the data. This data is then stored in an online database, which can be freely accessed online (http://wwwcimis.water.ca.gov/).

CIMIS currently has over 20,000 registered users of various categories (see Figure 4 for break-down of user categories) (CIMIS website). A survey by the Department of Agriculture and Resource Economics at the University of California, Berkeley evaluated the water use and yield of all major crop types for 55 growers across California who used CIMIS to determine water application. The study found that on average, the use of CIMIS increased yields by 8% and reduced water use by 13% (DWR 1997).

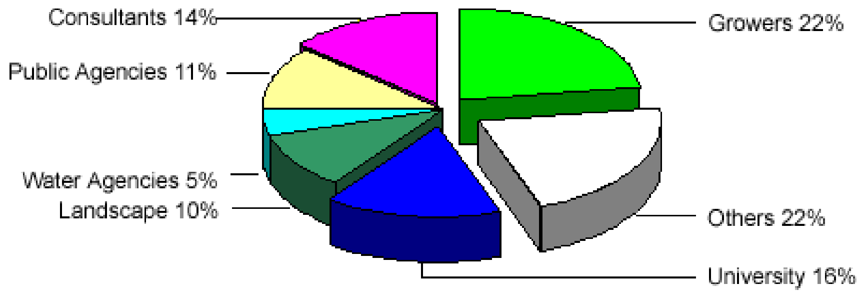


Figure 4: CIMIS Registered User Categories (Source: CIMIS website)

Crop Coefficients

Growers can use CIMIS information along with crop coefficients to estimate crop water requirements. Crop water requirements (ETc) are calculated by multiplying evapo-transpiration rates (ETo), which are provided by CIMIS, by crop coefficients (Kc) using the following equation: ETc = ETo x Kc. Crop coefficients are dimensionless numbers that reflect the average water-intensity or canopy cover of a particular crop (usually between 0.1 and 1.2).

For example, if you have an orange orchard and CIMIS reports that the daily evapotranspiration rate in your area is 0.25 inches per day, you would multiply the ETo (0.25 inches per day) by the crop coefficient for oranges that you have looked up (0.55). The resulting ETc is 0.14 inches per day, which means that your oranges need about an eighth of an inch of water to meet their full crop water needs that day. This process can be even further refined if you also understand the distributional uniformity, or efficiency, of your system and also include that in your calculations. For instance, if you know that your irrigation system is only 70% efficient, then you will divide the crop water requirement (0.14 inches per day) by 0.70, which equals 0.2 inches per day of applied water.

Water Budget Method

Many growers using CIMIS data also use a simple water budget to help guide decisions on the timing and amount of irrigation water to apply. This method keeps track of inputs and outputs to soil moisture and helps to ensure that soil moisture does not get so low that it damages yields. In order to use the water budget method, the grower must know some basic data about the soil and crop, including crop coefficients (discussed above); field capacity[2]; available water;[3] how dry the soil can get before crop health or yield are effected (known as "yield threshold depletion"); and starting soil moisture. Starting soil moisture can be estimated to be approximately equal to field capacity after winter rains, however, if a field is pre-irrigated, using soil moisture measuring devices provides a more

[2] Field capacity refers to the amount of water stored in soil after water drains through it.
[3] Available water refers to the portion of soil moisture that can potentially be taken up by the crop.

accurate starting point (K. Frame, CIMIS Program Chief, California Department of Water, personal communication, January 27, 2010).

Once this starting point is determined, a grower can use CIMIS data to keep track of outputs (ETo) and inputs (precipitation and irrigation) to soil moisture. To prevent smaller yields, growers must irrigate before reaching the previously identified yield threshold depletion level. Typically, a grower will set a management allowable depletion level (MAD), which is used as a trigger to irrigate and prevents soil from reaching that yield threshold depletion level. This may be based on a percentage of available water (for example, it might be set to 50% of available water; see example below).

Available water (AW) in root zone = 5.0 inches
Management allowable depletion (MAD)= 50%AW = 2.5 inches
Yield threshold depletion (YTD) = 2.6 inches

Date	Effective Rainfall	Irrigation (inches)	Crop ET	Depletion	Before MAD
July 1	0.00	0.00	0.00	0.00	2.50
July 2	0.00	0.00	0.30	0.30	2.20
July 3	0.00	0.00	0.19	0.49	2.01
July 4	0.00	0.00	0.22	0.71	1.79
July 5	0.00	0.00	0.28	0.99	1.51
July 6	0.00	0.00	0.25	1.24	1.26
July 7	0.00	0.00	0.26	1.50	1.00
July 8	0.00	0.00	0.28	1.78	0.72
July 9	0.00	0.00	0.32	2.10	0.40
July 10	0.00	0.00	0.36	2.46	0.04
July 11	0.00	2.50	0.40	0.36	2.14
July 12	0.00	0.00	0.22	0.58	1.92
July 13	0.42	0.00	0.11	0.27	2.23
July 14	0.25	0.00	0.15	0.17	2.33
July 15	0.00	0.00	0.25	0.42	2.08

Figure 5: Water Budget Scheduling Example for Alfalfa (Source: Frame 2003).

In-field Monitoring and Irrigation Scheduling Systems

Increasingly, growers are using in-field monitoring systems to inform their irrigation decisions. These systems typically combine in-field measuring devices, including soil probes, plant moisture sensors, and weather stations, paired with software that allows the grower to easily access and interpret the measurements collected. Many provide near real-time data, which can be accessed from anywhere with an internet connection, and may have additional features such as email or cell phone alerts and remote control or automation of the irrigation system.

These types of systems greatly increase the amount and precision of information available to growers on key parameters such as soil moisture. For example, many systems allow the grower to monitor soil moisture at various depths, and in various field locations. User-friendly interfaces allow growers to access and interpret this data (see examples of soil moisture graphs from PureSense and Ranch Systems LLC below).

This information can be used to irrigate much more precisely as it can provide 24-hour tracking of the soil moisture profile, which tells the grower how much applied water is leaching through the ground without being taken up by the plants.

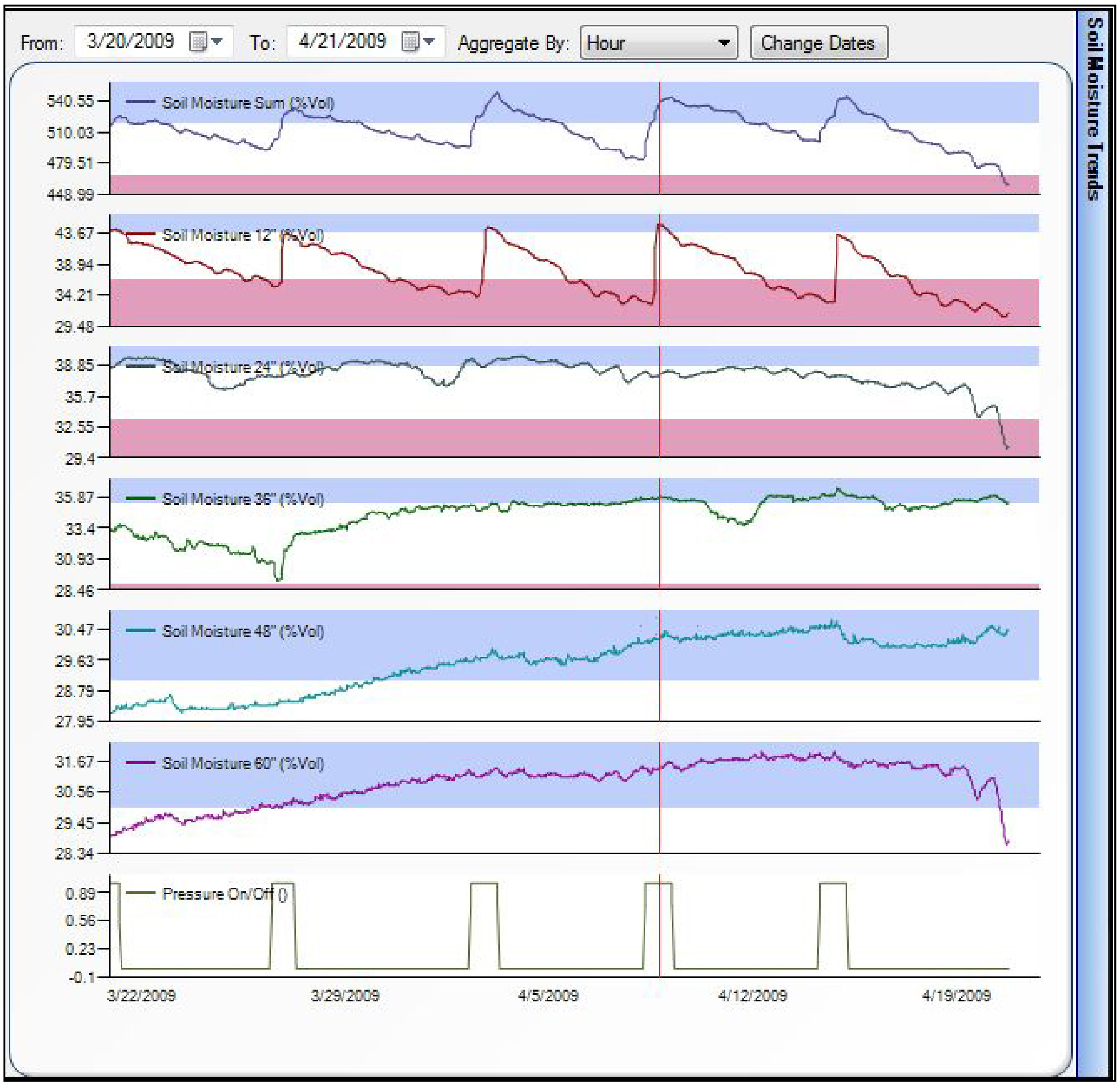


Figure 6: Graph created by PureSense software showing soil moisture over time by depth

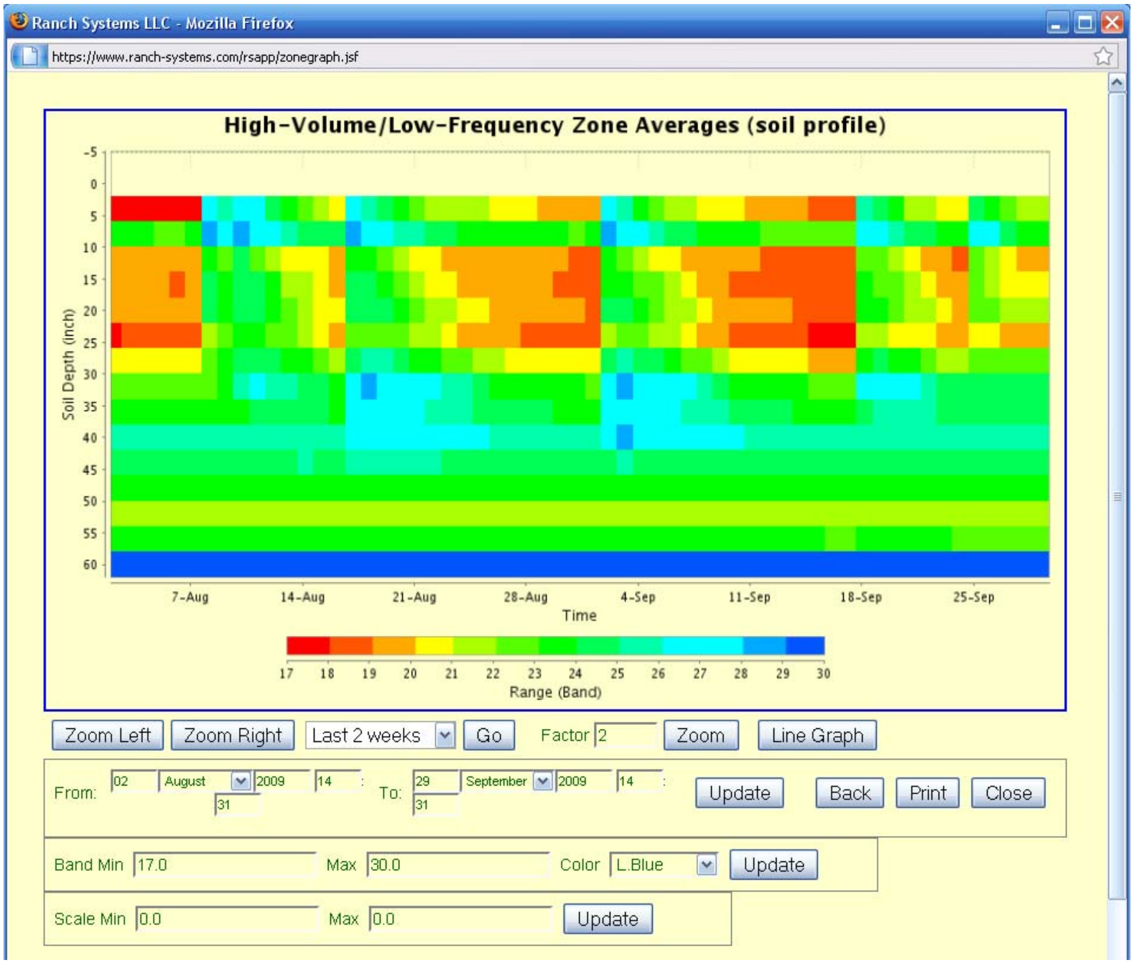


Figure 7: Graph created by Ranch Systems LLC software showing soil moisture by depth, over time (Different colors indicate different soil moisture levels; thresholds for different colors can be set by the user).

Some of these systems create an irrigation schedule for the grower, taking into account the specifics of the irrigation system, soil moisture and other measurements, and pre-determined plant water needs (see screenshot of PureSense irrigation scheduler, Figure 8 below). These programs can help the grower to plan for water needs throughout various growth stages. By combining the schedule provided by the software, graphs of their actual soil moisture at various depths, and knowledge of plant water requirements, growers can irrigate to match crop water needs.

Figure 8: Screenshot of PureSense irrigation scheduling software

Another important feature that can help improve water-use efficiency is automated irrigation control. Some irrigation scheduling systems allow growers to program irrigation valves to turn off or on according to parameters of their choice, such as a certain soil moisture level. This can help ensure that the irrigation schedule is implemented as planned. It also allows the grower to water when evapotranspiration is minimal, i.e., at night when field staff are not working, and to water in short intervals without increasing the amount of labor needed to turn the system on and off (J. Uhl, Director of Business Development, Ranch Systems, personal communication, January 27, 2010).

Benefits of Smart Irrigation Scheduling

> ***"How we manage water is critical to being able to sustain our vineyards... precise water management is the fastest and best way to improve wine quality. When we really understand that interaction of water, how much to use, and precisely the right time, we'll improve our fruit quality, which improves our wine quality."***
>
> **-Karen Ross, Past-President, California Association of Winegrape Growers**

Smart irrigation scheduling has a number of benefits to the grower derived from the ability to closely monitor stress to plants, including deficit irrigation, which itself has a number of benefits including increased quality in some crops and disease and pest management, as well as a number of peripheral benefits.

Increased water-use efficiency

Increasing water-use efficiency benefits growers by increasing yields and/or decreasing the costs associated with irrigation, including the cost of water and energy needed to pump water. Smart irrigation scheduling may result in a decrease or an increase in water applied, but has been shown to consistently increase water-use efficiency. Here, we define water use efficiency to mean the ratio of outputs to inputs, where outputs are yield and crop value, and inputs are irrigation water.

Using the right amount of water is essential to plant health and efficient photosynthesis—and therefore can lead to increases in yield; a number of studies have found that smart irrigation scheduling can increase yield relative to water inputs. For example, a study in Kansas found that smart irrigation scheduling reduced water use by 20% and resulted in a net gain of nearly $13 per acre (Buckleiter et al. 1996). Kranz et al. (1992) found that irrigation scheduling in Nebraska reduced the applied water on corn by 11% while improving yields by 3.5%.

Irrigation scheduling consultants also report increases in water-use efficiency. A consulting firm in Washington providing irrigation scheduling and soil moisture monitoring services found that some farmers were able to reduce their water use by as much as 50%. Others were found to be under-irrigating, and were able to increase yields by increasing applied water (Dokter 1996). A consulting firm in eastern Oregon found that clients reduced their water use by about 15% on average (Dokter 1996).

Crop quality

Irrigation scheduling can also be an important tool in improving crop quality. For example, studies suggest that regulated deficit irrigation, or intentionally imposing water stress during drought-tolerant growth stages, can improve crop quality (Williams and Matthews 1990, Girona et al. 2006). Irrigation scheduling can help growers safely implement regulated deficit irrigation, avoiding long-term damage to the plants.

Particularly for winegrapes and tree crops, in which the value of the crop is contingent on quality, increased crop quality as a result of technological irrigation scheduling can result in significant economic returns for the grower. A survey of users of irrigation scheduling in Washington indicated that the primary reason they were willing to invest in technological irrigation systems was to “insure quality of high-value crops” (Leib et al. 1998).

Pest and disease management

Too much or too little water can cause plant stress, which can lead to disease and vulnerability to pests. Studies show that more precise watering can be used to reduce pest infestations and weed growth. For example, the University of Minnesota Extension reports that scheduling irrigation appropriately can significantly reduce white mold in dry beans (UME 1999). Daane et al (1995) found lower leafhopper densities on vines which received less irrigation. Recent studies on almonds highlight the importance of proper timing and amount of irrigation for pest management, particularly in preventing hull rot (Curtis 2007).

Reduced input costs

In addition to potential reduced water and associated pumping costs, smart irrigation scheduling can result in reduced fertilizer and pesticide applications. In part, reduced pesticide needs are related to the pest management benefits outlined above. But in addition, reductions in water runoff and deep percolation can reduce the loss of fertilizer and pesticides, and therefore reduce the amount that needs to be applied. Automated soil moisture, weather, and other monitoring may also reduce labor costs.

Frost protection

Frost protection is another benefit of many in-field monitoring and irrigation scheduling systems. Some systems can be programmed to alert the grower, through email or cell phone, to conditions which may cause frost damage; other systems can automatically turn on fans or sprinklers when frost damage may occur.

Environmental benefits

Reducing the amount of applied water, and therefore runoff and deep percolation, can have environmental benefits by decreasing the amount of pesticides and fertilizers entering waterways and groundwater. In parts of California where the soil contains high levels of selenium, which can be toxic to wildlife, irrigation scheduling can help to reduce drainage and therefore decrease inputs of selenium to local waterways.

Tom Rogers' Almond Ranch: Smart Irrigation Scheduling in Action

> ***"In order to know what's going on, you have to monitor... it's just absolutely imperative that you know where your water is, and if you're actually using it or flushing it through the system."***
>
> **– Tom Rogers**

Tom Rogers and his brother farm 176 acres of almonds in Madera County, California. Following in their father's footsteps, they see accurate water monitoring as central to their on-farm water management. Today, they use a combination of careful soil moisture monitoring and weather information from on-site stations to help them decide when and how much to irrigate. Rogers estimates that irrigation scheduling has reduced their water use by up to 20% in some fields, while their yields are higher than many of their neighbors', which he attributes to the careful monitoring of crop water use (T. Rogers, almond grower and Vice-President of the Madera County Farm Bureau, personal communication, September 29, 2009).

Soil probes on the Rogers farm measure soil moisture in the first five feet, the tree root profile. Readings are taken every 15 minutes, giving a detailed picture of how water is moving through the soil, and whether it is actually being taken up by the trees or flushing through the soil. Weather stations in his fields provide information on temperature above and below the tree's canopy, humidity, wind speed, and rainfall. This allows him to keep track of how much water is being added to his fields through precipitation and lost through evaporation and transpiration. All of the information from the moisture probes and the weather stations is looked at together to decide when and how much to irrigate.

Irrigation scheduling has resulted in a number of benefits on the Rogers farm, including good plant health and yields, reduction of water use, and frost protection. Combined with improvements in fertilization of his almonds, Tom estimates that technological irrigation scheduling has resulted in higher water-use efficiency and yield gains. With permanent crops like almond trees, attentiveness to long-term plant health is particularly important. Tree age and health, permeability of soils, and microclimates all affect tree's water needs and mean that different parts of orchards may have different water needs. Tom's soil moisture probes allow him to be attentive to the differing water needs of his trees of different ages and trees of different production levels. Tom also sees off-farm benefits, including his ability to show water officials or the public that water used on his farm is being used carefully and put to beneficial use.

Conclusions

Growers already using smart irrigation scheduling have shown it to be useful in improving water-use efficiency and to have a number of additional benefits. Moreover, scheduling irrigation based on ET and in-field monitoring will become increasingly important in the future, as climate change adds uncertainty about future climatic conditions and basing future irrigation decisions on past conditions becomes increasingly unviable. However, available data suggest that these methods are still used by relatively few California growers (USDA 2009). Increasing the amount and precision of information available to growers to make their irrigation decisions, therefore, is an essential part of better management of agricultural water in California.

There are a number of hurdles that may prevent growers from implementing technological irrigation scheduling. First, some growers receive scheduled irrigation deliveries, and therefore must irrigate when they receive water. Improving irrigation delivery at the irrigation district level, including increased automation of head-gates, is needed so that technology-based irrigation scheduling is a possibility for all growers. Secondly, upfront costs of installing in-field systems can be significant. Providing low-interest loans for on-farm improvements (for example, through irrigation districts) is one potential solution (see Chapter 7). Finally, continuing to expand and improve the CIMIS program can ensure that basic ETo information for scheduling irrigation is freely available to all growers.

References

Buchleiter, G.W., D.F. Heermann, R.J. Wenstrom. 1996. Economic Analysis of On-Farm Irrigation Scheduling. In: Evapotranspiration and Irrigation Scheduling: Proceedings of the International Conference, November 3-6, 1996. San Antonio, Texas.

California Irrigation Management Information System (CIMIS) website. www.cimis.water.ca.gov.

Curtis, Bob. 2007. Late-season irrigation affects almond yield, pests. Farm Press. September 1, 2007. Retrieved February 8, 2010 from http://westernfarmpress.com/mag/farming_lateseason_irrigation_affects/.

Department of Water Resources (DWR). 1997. Fifteen Years of Growth and a Promising Future: The California Irrigation Management Information System.

Dokter, D.T. 1996. AgriMet – The Pacific Northwest Cooperative Agricultural Weather Station Network. Evapotranspiration and Irrigation Scheduling: Proceedings of the International Conference. November 3-6, 1996. San Antonio, Texas.

Girona J., M. Mata, J. del Campo, A. Arbonés, E. Bartra, and J. Marsal. 2006. The use of midday leaf water potential for scheduling deficit irrigation in vineyards. Irrigation Science 24:115–127.

Leib B.G., Hattendorf M., Elliott T., Matthews G. 2002. Adoption and adaptation of scientific irrigation scheduling: Trends from Washington, USA as of 1998. Agricultural Water Management, 55 (2): 105-120.

Ortega-Farías, S., C. Acevedo, A. Acevedo and B. Leyton. 2004. Talca Irrigation Management System (TIMAS) for Grapevine. Research and Extension Center for Irrigation and Agroclimatology (CITRA). Universidad de Talca, Casilla, Chile.

PureSense website. http://www.puresense.com/.

Ranch Systems LLC website. http://www.ranchsystems.com/ssite/index.shtml.

Rijks, D. and Gbeckor-Kove, N. 1990. Agrometeorological Information for Effective Irrigation Scheduling. Acta Hort. (ISHS) 278:833-840. Frame, Kent. 2003. Quantitative Irrigation Scheduling is Simple and Does Work. CIMIS website. Retrieved January 7, 2009 from http://wwwcimis.water.ca.gov/cimis/resourceArticleWcnQuantIrrig.jsp; jsessionid=F4BA348D4E6E1EFF83F1C3B2EAB728C0.

Rogers, T. September 29, 2009. Almond grower and Vice-President of the Madera County Farm Bureau. Personal communication.

United States Department of Agriculture (USDA). (2009). Farm and Ranch Irrigation Survey. Retrieved March 1, 2010 from http://www.agcensus.usda.gov/Publications/2007/ Online_Highlights/Farm_and_Ranch_Irrigation_Survey/index.asp.

University of Minnesota Extension (UME). 1999. IPM Control of White Mold in Irrigated Dry Beans. Retrieved February 8, 2010 from http://www.extension.umn.edu/distribution/cropsystems/DC7397.html/.

Williams, L.E. and M.A. Matthews. 1990. Grapevines. In Stewart BA and Nielsen DR (Eds.). Irrigation of agricultural crops, Agronomy 30: 1019–1055.

Chapter 4

Improving Water Management through Groundwater Banking: Kern County and the Rosedale-Rio Bravo Water Storage District

Juliet Christian-Smith

Introduction

"Conjunctive use" refers to coordinating the use of surface water and groundwater to improve the overall reliability of water supply. In general, when surface water supplies are plentiful, they are either used by water customers in lieu of groundwater or diverted to recharge groundwater reserves. Groundwater is then used during dry periods when surface water is less available. Surface water can recharge groundwater basins through both natural and artificial means. Natural or incidental recharge results from percolation into the basin from natural waterways, fed by rainfall or snowmelt, and from excess water applied for crop irrigation. Artificial recharge replicates and promotes natural processes by capturing and retaining water in surface impoundments (dams, dikes, and infiltration areas) to allow water to percolate into the underlying basin. Another form of artificial recharge is direct injection of water into groundwater basins through injection wells. An additional form of recharge is "in-lieu," which refers to the groundwater that remains in basin when groundwater users switch to surface water instead of pumping from aquifers. Whether physical or in-lieu recharge methods are used, groundwater is stored in the basin for later use.

In the past decade, "groundwater banking" has come to refer to the practice of recharging specific amounts of water in a groundwater basin that can later be withdrawn and used by the entity that deposited the water. It differs from the more general description of conjunctive use because the water deposited in the bank is attributed to a specific entity and may be imported from non-local sources. Likewise, withdrawals must be in amounts specific to the amount deposited and available and can be used outside of the basin in which the deposits were made. In effect, groundwater banking uses aquifers for storage purposes and offers other water users, including those who do not overlie a groundwater basin, the opportunity to store water there. It also allows flexibility to respond to seasonal and inter-annual variability, as water can be stored in wet periods for use in dry ones. This will be increasingly important as climate change is projected to increase the frequency and intensity of extreme weather events, including floods and droughts.

As a storage alternative, water banking has several advantages over surface reservoirs. Groundwater storage is generally considered less environmentally damaging than dam or reservoir construction, and significantly reduces evaporative losses. Rising temperatures associated with climate change will increase this unproductive evaporation. Water stored underground does not evaporate, though losses can still occur as the water is being transferred to underground storage. In general, water banking has lower capital costs than dam and reservoir construction, though banking projects can require extensive distribution networks, infiltration areas, and injection wells. Infiltration areas require specific soil types and sometimes changes in land use. Annual operation and maintenance costs may also be higher than conventional surface storage, particularly when considering the recovery costs, e.g., pumping water for withdrawal during dry years. This case study reviews water banking programs in the Central Valley that have led to better coordination and use of limited water supplies.

Background

Water banking requires certain physical characteristics in terms of the groundwater basin, surface water availability, and access to transport, as well as the institutional factors related to the management and use of the basin. Ideal natural characteristics for conjunctive use and water banking include:

- Aquifers with accessible storage— unconfined, with adequate de-watered storage space at relatively shallow depth (decreased pumping costs);
- Aquifers that are easy to fill—overlying area has soils with high permeability;
- Aquifers that are easy to pump—high yielding wells with minimal pumping drawdown; and
- Areas that minimize negative impacts—no risk of land subsidence, liquefaction, or water-quality degradation as water levels change, lack of direct hydraulic connectivity with perennial streams that would induce recharge from other sources (Brown 1993).

Additionally, sources of surface water and transportation and distribution facilities to both receive and distribute banked water are needed. Banking requires that participants have access to surface water when it is available and the ability to transport it to the banking facility. Banking projects must also provide for a method of transporting recovered water to banking participants. Projects utilizing in-lieu recharge must have sufficient distribution systems to support conjunctive use. Beyond the physical infrastructure, these exchanges require institutional infrastructure including agreements, monitoring, and accounting methods to guarantee a secure right to the banked water.

There are several concerns related to groundwater banking. Overlying landowners, for instance, have concerns about local impacts on groundwater in terms of both quality and quantity. While recharge may have positive benefits, e.g., temporarily raising the water table, withdrawals have the opposite effect, drawing down the water table and possibly resulting in subsidence and water-quality degradation. In addition, residents within the boundaries of the groundwater basin may object to using stored water outside of the basin; in some cases there are county ordinances prohibiting out-of-basin use. Participants in groundwater banks may also be concerned about the security of their deposits since in some cases stored groundwater may not be 100% recoverable, or may not be recoverable at particular times.

Groundwater in the Central Valley

The groundwater basin that underlies the Central Valley contains one-fifth of all groundwater pumped in the nation—and thus is, in effect, California's largest reservoir. In 2009, the United States Geological Service released the first comprehensive, long-term analysis of groundwater levels in California's Central Valley. Among the major findings of the study was that groundwater levels have been rapidly declining in the southern, Tulare Basin portion of the San Joaquin Valley as more water is pumped out than recharges naturally (Figure 9). But the southern valley also shows the most promise for large-scale groundwater recharge, particularly along the eastern side with its coarse-grained soils from river and alluvial-fan sediments.

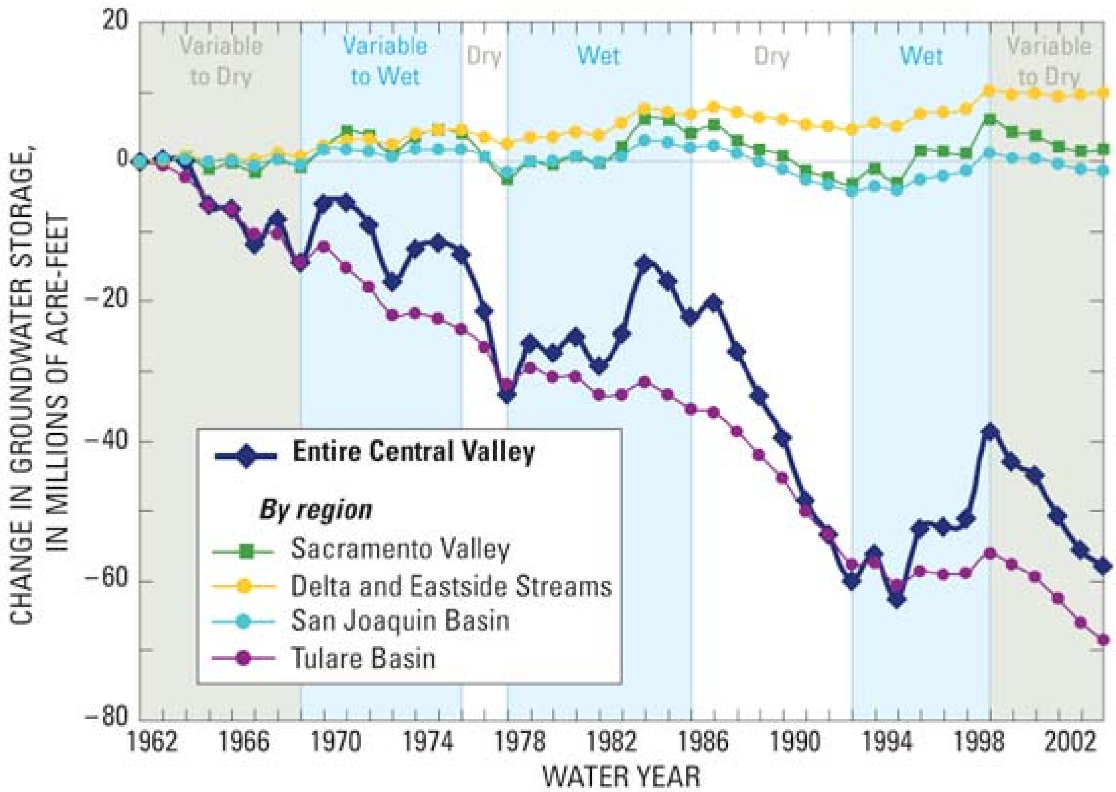


Figure 9. Changes in groundwater storage in the entire Central Valley and by region in millions of acre-feet, 1962-2003 (originally published in Faunt, C.C., ed., 2009)

The report found severe aquifer overdraft between 1962 and 2003, when an average 9.1 million acre-feet of water went into storage annually, yet an average of 10.5 million acre-feet were removed annually (Faunt et al. 2009). Thus, in typical years the net loss in groundwater storage is about 1.4 million acre-feet. Over the last four decades the entire Central Valley has lost about 60 million acre-feet of groundwater, driven by the declines in the Tulare Basin, which lost almost 70 million acre-feet over the time period. This drawdown has had numerous negative effects, including localized subsidence and increased well-drilling and groundwater pumping costs. However, it also provides an opportunity as there is a vast amount of groundwater storage potential in the dewatered portions of the aquifer.

Water Banking in the Central Valley

Water banking in the Central Valley is primarily done through surface water impoundments in the southern part of the valley. Located at the southern end of the San Joaquin Valley, Kern County is the one of the most productive agricultural counties in the nation. With over 800,000 acres of irrigated farmland, the county relies on surface and groundwater sources to meet its water demand. Kern County offers an example of an area that has implemented water banking programs as an important water supply management tool to increase water supply reliability for both local and non-local actors (Figure 10).

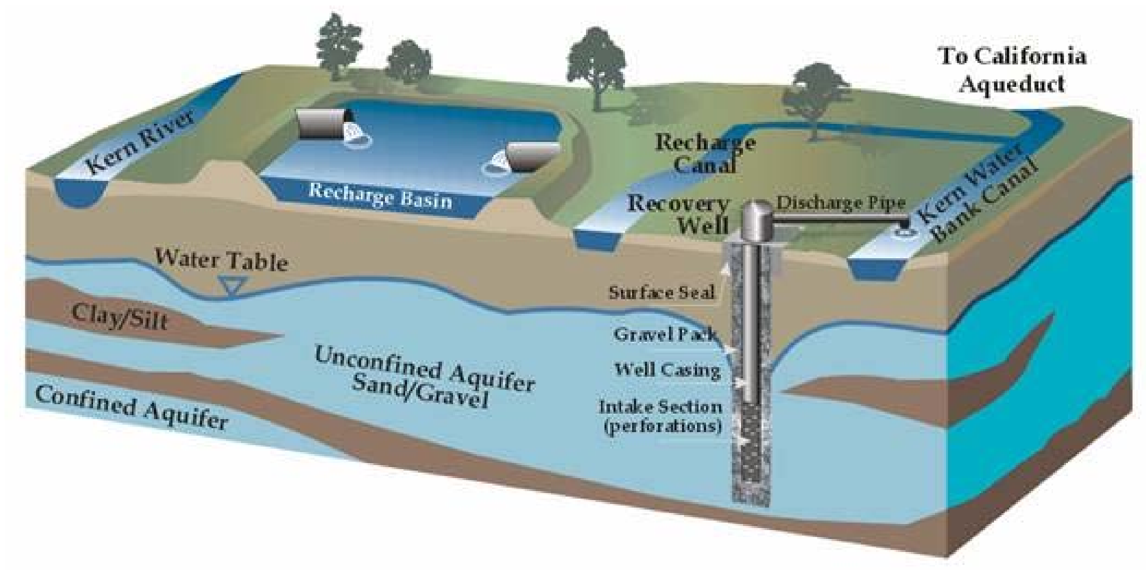


Figure 10. Cross-section of the Kern Water Bank in Kern County (Kern Water Bank 2010).

A number of factors make Kern County a prime area for water banking. The area is conveniently situated, in terms of geology and proximity, to water-supply and delivery systems. Kern County banks water from local rivers, the State Water Project (SWP), and the Central Valley Project (CVP). Most of the water banks are located on alluvial fans, consisting of sandy sediments on the valley floor, which are highly permeable and, therefore, well-suited for recharging underlying aquifers (Faunt et al. 2009). The heavy reliance on groundwater pumping over the last several decades has resulted in substantial dewatered storage. The county also has several options for moving water around via the Kern River, the Friant-Kern Canal (CVP), the California Aqueduct (SWP), and the Cross Valley Canal. In addition, a distribution network of canals and pipelines serves much of the irrigated acreage.

The earliest groundwater programs began in this area in the late 1970s and early 1980s. The city of Bakersfield developed a series of recharge ponds within its 2800 Acre Recharge Facility, and Kern County Water Agency developed 240 acres of recharge ponds on lands along the Kern River for the Berrenda Mesa Water District, as well as recharge operations in a portion of the Kern River channel. The early 1990s saw the development of still more water banks, including the Kern Water Bank, Kern County Water Agency's "Pioneer Property," and programs in the Arvin- Edison and Semitropic Water Districts. These programs were motivated by the ability to provide greater water supply reliability through conjunctive use, particularly in drought years when the CVP and SWP are not able to meet contracted water deliveries.

Today, the three major water banks (Arvin–Edison, Kern, and Semitropic) have a combined storage capacity of about 3 million acre-feet. That is more than five times the amount of water in Millerton Lake, one of the larger reservoirs feeding the Central Valley surface-water system. In addition, several smaller banking programs have been launched by the Buena Vista Water Storage District, Rosedale-Rio Bravo Water Storage District, and Kern Delta Water District. Altogether, groundwater banks in Kern County can currently store over 800,000 acre-feet a year and return 700,000 acre-feet annually (Table 3). And several new water banks are being proposed.

Table 3. Updated information about various groundwater banking projects in Kern County, California (originally published in KCWA n.d.)

Water Bank	Acres	Maximum Annual Recharge (acre-feet/year)	Maximum Annual Recovery (acre-feet/year)
Berrenda Mesa	369	58,000	46,000
Bakersfield 2,800 Acres	2,760	168,000	46,000
Kern Water Bank	19,900	450,000	314,000
Pioneer Property	2,273	146,000	98,000
West Kern/Buena Vista	2,000	77,000	45,000
Arvin-Edison	130,000	150,000	150,000
Semitropic	221,000	430,000	423,000
Rosedale-Rio Bravo	40,000	234,000	45,000
Kern Delta	125,000	50,000	50,000
Buena Vista	50,000	110,00	32,000
Total	*566,000*	*864,000*	*700,000*

Rosedale-Rio Bravo Water Storage District's Conjunctive Use Program

Rosedale-Rio Bravo Water Storage District encompasses 44,150 acres in Kern County, with 28,500 acres developed as irrigated agriculture and about 6,000 acres developed for urban uses. The District was established in 1959 to develop a groundwater recharge program to offset overdraft conditions in the regional Kern County aquifer. To meet the long-term needs of its landowners, Rosedale developed the Groundwater Storage, Banking, Exchange, Extraction & Conjunctive Use Program (Conjunctive Use Program) in the late 1990s.

From the beginning, Rosedale took a unique approach to groundwater banking. Typically, the first step of a groundwater banking project is to secure partners that will provide capital for the development of infrastructure, and then to divide the banking capacity between those partners. Most of the banks in Kern County are actually banking water for wealthier out-of-basin interests, most notably the Metropolitan Water District, a large urban supplier. Rosedale decided to finance the construction of banking infrastructure themselves through a variety of local financing mechanisms, including revenue bonds. Then, they set a 2:1 banking requirement, which means that for every 2 AF of water banked, only 1 AF is available for return.

Essentially, the contribution from the banking partner comes to Rosedale in the form of water rather than initial capital. Rosedale General Manager Eric Averett explains, “We thought that there was a greater value in the water than the capital…This year is a great example, you could have $5 million in the bank but if there is no water available that money does no good. Early on the board recognized that water is the more valuable of the two commodities and have invested considerably to ensure we have an adequate supply of water to meet the district’s needs.”

The Conjunctive Use Program currently manages over 200,000 acre feet (AF) of stored groundwater in the underlying aquifer, which has an estimated total storage capacity in excess of 1.7 Million AF (ESA 2008). Water supplies for the Conjunctive Use Program are supplied by the participating water agencies and include high-flow Kern River water and water from the Central Valley Project (CVP) and State Water Project (SWP). Currently, the infrastructure for the Conjunctive Use Program includes over 1,000 acres of recharge basins and ten recovery wells**.** There are several participants in its Conjunctive Use Program: Arvin-Edison Water Storage District, Delano-Earlimart Irrigation District, Kern-Tulare Water District, Castaic Lake Water Agency, Irvine Ranch Water District, and Buena Vista Water Storage District (Averett, personal communication). The Program provides for maximum annual recharge of approximately 250,000 acre-feet/year and a maximum annual recovery of 45,000 acre-feet/year (E. Averett, General Manager of the Rosedale-Rio Bravo Water Storage District, personal communication, February 16, 2010).

Conclusions

In the last decade, the number of water banks has grown as districts seek to take advantage of groundwater storage options and improve the management and reliability of often-scarce surface water supplies. Groundwater banking offers a valuable supply-side tool, particularly as a response to climate change impacts on water resources in California. As surface runoff is concentrated in the winter and early spring due to earlier snowmelt, supply will be increasingly out of phase with demand. In addition, rising temperatures will also lead to rising evaporation rates. Given that the annual yield of all proposed surface storage projects in the state is less than 4 million acre-feet and that many of these projects have been declared unfeasible by the Bureau of Reclamation, the approximately 10 million acre-feet of storage available in just Central Valley aquifers represents a large additional storage capacity.

Yet, there are still some concerns around groundwater banking programs. A program's ability to transport water out of a basin raises issues related to water transfers and water rights. Two-to-one banking is one way to decrease local impacts and to ensure that water remains within the basin. In addition, appropriate monitoring of groundwater levels and accurate accounting of traded water are critical to maintain good relations with overlying and surrounding landowners, as well as the credibility of groundwater banking strategies. Finally, the lack of regulation of groundwater use in most areas of the state means that overlying landowners may pump from a groundwater bank without permission or monitoring. This could become a problem for banking efforts in the future.

Groundwater banking, like any conjunctive use strategy, cuts to the heart of links between surface and groundwater and basin impacts such as water quality, recharge, and groundwater levels. Thus, banking programs are best implemented as part of a larger, integrated planning effort. The state's recent focus on Integrated Regional Watershed Management Planning should include groundwater management, particularly in areas considering groundwater banking. Specifically, plans should require consistent monitoring of groundwater levels and quality and coordinate banking programs with other surface and groundwater uses. Groundwater banking programs can provide a valuable management tool to help better coordinate groundwater and surface water management to improve basin conditions.

References

Averett, Eric. February 16, 2010. General Manager of the Rosedale-Rio Bravo Water Storage District. Personal Communication.

Brown, L. 1993. Conjunctive Use: Problems and Advantages. Proceeding of the 19th Biennial Ground Water Conference, J.J. DeVries, J. Woled, editors. Water Resources Center Report No. 84. University of California, Davis.

ESA Association (ESA). 2008. Strand Ranch Integrated Banking Project: Draft Environmental Impact Report. Prepared for the Rosedale-Rio Bravo Water Storage District.

Faunt, C.C.. (ed.). 2009. Groundwater Availability of the Central Valley Aquifer, California: U.S. Geological Survey Professional Paper 1766.

Kern County Water Agency (KCWA). No date.. Kern County: Groundwater Banking Projects. Flyer. Bakersfield, CA. Date issued: February 5, 2010.

Kern Water Bank. 2010. "General Info." Kern Water Bank website. Retrieved February 11, 2010 from http://www.kwb.org/general_info.htm.

Chapter 5

Communication, Monitoring, and Measurement: Water Efficiency in the Coachella Valley

Michael J. Cohen

Introduction

In the desert of southeastern California, two recent programs have increased agricultural water use efficiency while maintaining or improving crop yields and boosting agency productivity. These two programs demonstrate that sophisticated information-gathering methods can be an effective tool to improve water use efficiency and agricultural productivity, even in a district that already demonstrates high efficiency. Elements of these programs could be adapted by other water districts that are interested in cost-effective strategies to improve agricultural water use efficiency.

In 2004, the Coachella Valley Water District (CVWD) began a multi-year agricultural water efficiency initiative known as the *Extraordinary Water Conservation Program* (ECP), to meet state and federal water conservation targets. The ECP documented savings of more than 75,500 acre-feet of water over five years, at a cost to the district of about $40/acre-foot. In 2006, CVWD completed a district-wide communications and technology upgrade that provides its staff with water orders and system status in real time. This technology has greatly increased flexibility and autonomy to adjust deliveries to optimize water balancing and system efficiency, decreasing waste and better meeting irrigators' needs.

Background

CVWD, formed in 1918, delivers domestic and irrigation water in the lower Coachella Valley, primarily in Riverside County, California (Figure 11). Reference evapotranspiration rates in the valley are very high, regularly exceeding 74 inches per year, markedly higher than the 57-58 inches per year in the Central Valley and the 33 inches per year along the coast. Precipitation in the district averages about three inches annually. This means that crop water demand is high; with limited water supplies it is especially critical to maximize water-use efficiency. Temperatures exceed 100°F more than one hundred days a year, with a frost-free growing season greater than 300 days. This makes the valley ideal for growing fruits and vegetables, such as table grapes, peppers, and citrus, for the winter market.

Figure 11. California districts receiving Colorado River water (Source: http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/colorado/California_Svc_Areas.gif)

Water Source and Distribution Network

Irrigators in the district originally relied on groundwater, but over-extraction and subsidence problems prompted a shift to Colorado River water,[4] first brought to the valley in 1948 by the Coachella branch of the All American Canal. Early on, CVWD took the unusual step of delivering water via a pipeline distribution system and metered deliveries to each account, to minimize evaporative losses and maximize water use efficiency. Farms in the district have about 2,300 miles of subsurface drains and almost no surface drains, almost wholly eliminating tailwater (surface) runoff.[5] Irrigators in the district also benefit from the absence of downstream diversions. Instead, the Salton Sea, an irrigation drainage depository designated in 1928 that receives agricultural drainage and stormwater runoff, enables irrigators to avoid water-quality standards that would exist if their drainage were applied to downstream fields. In recent years, Colorado River salinity at Imperial Dam, the diversion point for CVWD, has averaged about 700 mg/L TDS (total dissolved solids) though this rises to about 780 mg/L TDS by the time the water flows some 160 miles through the desert to the district. To push accumulating salts away from the root zone, farmers apply additional irrigation water to leach the soil. This leaching fraction varies based on soil type, irrigation demand, and crop type.

[4] For information on CVWD's rights to Colorado River water, see http://www.cvwd.org/about/waterandcv.php.

[5] Subsurface drains, also known as tile drains, collect and remove water below the land surface (often known as "tile water"). Surface drains, which may be little more than ditches at the end of the field or may be carefully constructed catchment basins, collect water (often known as "tail water") running off the surface of the field.

Customers and Costs

CVWD distributes irrigation water to more than 1,100 active accounts, representing more than 78,000 irrigable acres. In 2006, CVWD delivered 242,000 acre-feet of Colorado River water to its customers, who irrigated about 10,300 acres of table grapes; 8,500 acres of citrus; 7,400 acres of dates; 4,500 acres of peppers; and 3,600 acres of lettuce, among other crops, generating an estimated $575 million in revenue. Many of these are niche crops, benefitting from the valley's temperate winters to bring crops to market when other regions are unable to harvest.

In 2009, typical irrigators paid $24.05 per acre-foot, plus a $5 per acre-foot quagga mussel surcharge (to cover costs associated with preventing the spread of this invasive species) and a gate charge of $11.50 per day. Additionally, irrigators pay an "availability charge" of $91.39 per acre for general farming uses, which may be satisfied by water use charges. That is, payment of water charges goes toward satisfying the availability charge, and therefore the availability charge only applies to properties using less than $91.39 of water per acre. For an irrigator applying four acre-feet per acre, total water charges would come to $116.20 per acre, or an average unit cost of about $29.05 per acre-foot, not including gate charges. In 2006, 26% of reported acreage was flood irrigated, 20% was irrigated by sprinkler, and 54% was drip irrigated.

Genesis of CVWD's Conservation Efforts

In October, 2003, the Secretary of the Interior signed the Colorado River Water Delivery Agreement with California's Colorado River contractors, including CVWD. The agreement requires CVWD and other California water districts to reduce their use of Colorado River water in certain years, as shown in the table below, to pay back the use of Colorado River water in excess of entitlement accrued in 2001 and 2002. Under the terms of the agreement, each district may accelerate payback, at its own discretion. At the beginning of 2004, the U.S. Bureau of Reclamation's *Inadvertent Overrun and Payback Policy* (IOPP) went into effect. The IOPP requires Colorado River water contractors generally to undertake "extraordinary conservation" efforts to reduce their use of Colorado River water in order to pay back previous use in excess of the contractor's entitlement (Table 4). "Extraordinary conservation" here means measures that reduce Colorado River water consumptive use "above and beyond reductions that would otherwise normally occur."

Table 4. Payback Schedule of Overruns for Calendar Years 2001 and 2002, in Acre-feet (Exhibit C of the Colorado River Water Delivery Agreement of 2003).

Year	***IID***	***CVWD***	***MWD***	***Total***
2004	18,900	9,100	11,000	39,000
2005	18,900	9,100	11,000	39,000
2006	18,900	9,100	11,100	39,100
2007	18,900	9,100	11,100	39,100
2008	18,900	9,200	11,100	39,200
2009	18,900	9,200	11,100	39,200
2010	19,000	9,200	11,100	39,300
2011	19,000	9,200	11,100	39,300
Total	***151,400***	***73,200***	***88,600***	***313,200***

In addition to the 73,200 acre-feet of overruns accrued in 2001-2002, CVWD accrued an additional 2,347 acre-foot payback obligation in 2007. To satisfy its payback obligations, CVWD implemented an extraordinary agricultural water conservation program in 2004, known as the ECP. The ECP enabled CVWD to pay back its overrun obligations by June 2009.

CVWD Extraordinary Water Conservation Program

CVWD hired a consultant to develop and implement the ECP, providing a series of conservation services including “Scientific Irrigation Scheduling,” “Scientific Salinity Management,” and “Conversion to Micro-irrigation.” CVWD paid for the program; farmers could participate at no additional charge (D. Parks, Assistant General Manager, Coachella Valley Water District, personal communication, December 16, 2009). Under the program, the consultant enrolled willing growers in the district, reviewed their irrigation practices, identified individual fields for detailed assessment and monitoring, collected and analyzed data from the fields, and created reports and recommendations. A key element of the program was the assessment of monthly and annual water deliveries to “entities.” The consultant defined “entities” as the smallest unit of irrigated land served by an individual water meter, enabling direct measurement of water use per acre. The consultant then researched the entities’ water use in 1999. The use of entities permitted comparison of water usage and calculation of water savings, adjusted for differences in evapotranspiration, between the baseline year of 1999 and current year usage.

To satisfy state and federal payback obligations, repayment could only be claimed for lands irrigated with Colorado River water that could additionally demonstrate extraordinary conservation relative to a historic baseline. The ECP only recorded water conserved by irrigators meeting these two requirements. However, the ECP enrolled some irrigators who did not meet either or both of these requirements, even though these irrigators’ conservation efforts were not counted toward payback obligations. For example, the ECP enrolled farmers irrigating with groundwater, rather than Colorado

River water delivered via canal, even though conservation of groundwater did not satisfy payback obligations. As a result, the ECP actually conserved more water than documented. For example, as shown in the Table 5, in 2004, water conserved on 17% of the total acreage participating in the ECP did not count toward payback obligations and was not included in the 19,957 acre-feet claimed as extraordinary conservation that year. Assuming that the other fields conserved at roughly the same rate suggests that the ECP may have generated a total of 23,900 acre-feet of conserved water in 2004, and 91,000 acre-feet through 2009.

Table 5. ECP Acreage, 2004

	Number	Entities	Acres	% of total
Total enrolled fields	1,051		26,377	100%
with canal delivery	929	258	23,593	89%
with 1999 data	855	230	22,016	83%

Irrigation Scheduling

Although the ECP converted 444 acres to micro-irrigation in 2004, the core elements of the program were scientific irrigation scheduling and scientific salinity management. Scientific irrigation scheduling seeks to determine the optimal timing and volumes of water to apply to each crop. To do this, the consultants:

- identified various factors affecting irrigation scheduling, including crop, soil type, irrigation method, and management characteristics;
- measured water use and soil moisture, using multiple soil probes;
- measured irrigation rates and uniformity across fields;
- measured crop cover, development, stage, and root depth;
- monitored fertilizer application and harvesting;
- recorded actual irrigation schedules and volumes from program participants; and
- summarized crop productivity and water use.

Using evapotranspiration (ET) requirements for specific crops, calculated from CIMIS data, the consultants used the data acquired from the actions listed above to optimize irrigation schedules. Historically, irrigators may have over-applied water, to avoid the risk of crop stress and reduced yield. One of the major benefits of the program's monitoring and measurement was an improved understanding of actual crop water requirements (P. Nelson, Vice President, CVWD Board of Directors, personal communication, December 16, 2009). In 2004, growers with 18,333 acres of land, or 70% of total acreage enrolled in the program, participated in scientific irrigation scheduling (most participants enrolled in both irrigation scheduling and salinity management). For more information on irrigation scheduling, see chapter 3.

Salinity Management

By the time it reaches CVWD, the Colorado River water used for irrigation carries about a ton of salt per acre-foot. In the absence of surface drainage and under the valley's high evapotranspiration rates, these salts can quickly accumulate in crops' root zones, impairing growth and productivity. Irrigators flush, or leach, salts from the root zone every few years, by applying water via flood irrigation or sprinklers. Through precise monitoring of soil salinity and consistent with crop salinity tolerances, irrigators can refine their application of water for leaching, potentially conserving water without affecting crop yield. Through the ECP, the consultant reviewed irrigation and leaching practices to determine which growers might benefit from scientific salinity management.

In 2004, the consultants enrolled growers with 784 fields, representing 20,558 acres of land and 78% of the acreage enrolled in the ECP as a whole, in the scientific salinity management program. As part of the program, the consultant: identified fields to be leached that year; evaluated historic leaching practices; determined factors affecting leaching requirements (e.g., crop type, soil texture, salinity of applied water); determined the leaching requirement based on soil salinity and the calculated water requirement; monitored leaching use; and analyzed leaching activities, with additional soil sampling and analysis and a comparison of empirical and predicted values.

The ECP enabled growers to refine their application of water for leaching, targeting areas of fields identified as high in salinity. In some cases, this could conserve water, by avoiding untargeted leaching or optimizing leaching volumes, though the ECP did not specifically identify savings resulting from better salinity management rather than better irrigation management. Instead, the program simply determined water conservation by entities in the program generally. To optimize crop production, the consultant would recommend the application of more water for leaching than had been applied historically, if it determined that soil salinity warranted such action.

Figure 12. The Coachella Valley Resource Conservation District "Salt Sniffer," used to measure soil salinity (photo: Scott Lesch, U.S. Department of Agriculture)

The Salt Sniffer collects geo-referenced horizontal and vertical electromagnetic conductivity data at multiple locations across farmers' fields, enabling the creation of detailed maps of field salinity and identification of problem areas (Figure 12). The Salt Sniffer can also extract soil cores, to depths of 48 inches, for further analysis (Lesh and LeMert 2000).

Determining Conservation Volumes

To project total annual extraordinary water conservation, the program assumed a target irrigation efficiency rate of 92% would be achieved through program components. The consultant measured actual annual water conservation by calculating a water balance for each participating entity. The water balance used CVWD delivery records to determine the entity's water use in the baseline year of 1999, and then adjusted this 1999 water use for differences in monthly reference crop ET between 1999 and the program year. The difference between the adjusted 1999 water use and the measured use in the program year represented the volume of water conserved. The U.S. Bureau of Reclamation's Inadvertent Overrun and Payback Technical Committee reviewed the ECP each year and verified ECP performance with a series of spot checks on 5% of program acreage. These spot checks included meter readings, field visits, and interviews with irrigators.

Results

> ***"With the use of the irrigation scheduling we realized water savings from 10 to 15 percent, and better crop yields, especially with vegetables. The soil moisture monitoring was very accurate, very timely and soil sample results were analyzed quickly and efficiently."***
>
> **- Chuck Schmidt, with Richard Bagdasarian, Inc., headquartered in Mecca and among the Coachella Valley's largest producers of table grapes, citrus, and vegetables**

CVWD and its consultant initially projected that the ECP would satisfy the 73,200 acre-foot payback obligation by 2007. However, limited funding in 2007 diminished the scope of the program and the number of irrigators that could enroll, delaying full payback until 2009, as shown in Table 6.

Table 6. Annual Extraordinary Conservation Program water savings, in acre-feet

Year	**CRWDA** schedule	Calculated	**2007** payback	Anticipated
2004	9,100	19,957		19,100
2005	9,100	18,491		19,100
2006	9,100	16,608		17,360
2007	9,100	7,404		17,640
2008	9,200	6,753	2,347	
2009	9,200	*3,987**		
2010	9,200			
2011	9,200			
Totals	73,200	73,200	2,347	73,200

CRWDA & 2007 Total *75,547*

**provisional*

The consultant's first objective was to optimize crop yields. In many instances, the consultant determined that irrigators were applying insufficient irrigation water, or needed to increase the volume of water applied for leaching, over and above the irrigator's historic practice. In 2004, for example, 95 of the 230 entities actually increased their water use per acre. However, the majority of entities conserved water through the ECP. Average water savings in 2004 for the 230 entities was 0.8 acre-feet per acre (Figure 13), representing a 17% reduction in use relative to the adjusted 1999 baseline. Because many growers participated in both the Scientific Irrigation Scheduling and Scientific Salinity Management elements of the ECP, conservation data specific to program or crop type are not available.

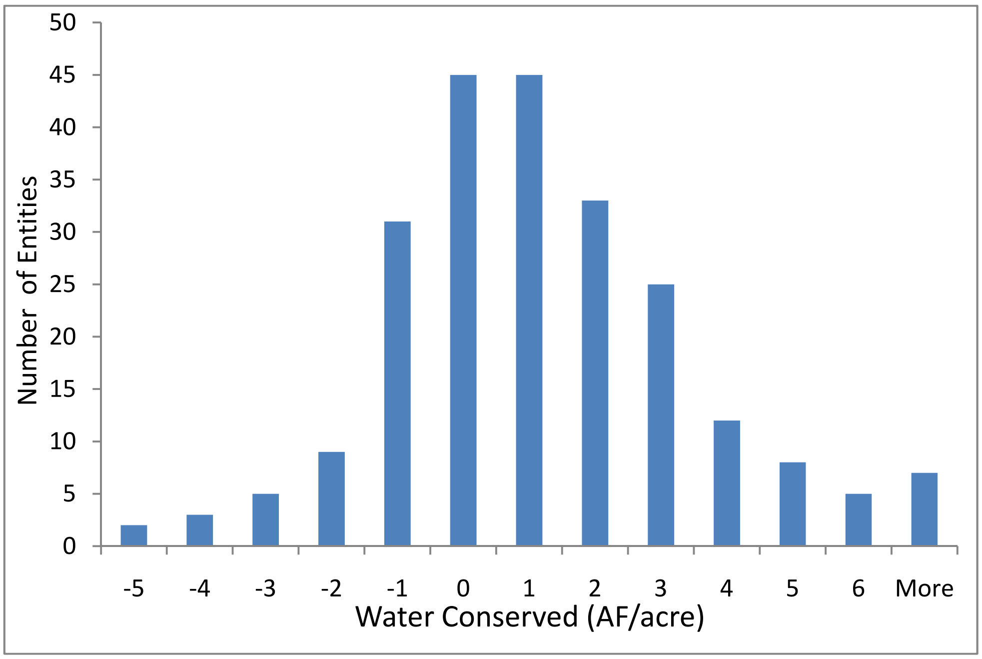


Figure 13. Water Conserved by entity, 2004

Communications Upgrade

Communication is a critical component of irrigation water delivery. Unlike the pressurized systems found in homes, where the user can simply open a valve to deliver the desired amount of water, most deliveries for farm irrigation are gravity-fed and require carefully controlled releases from canals, laterals, and reservoirs to deliver the desired volume of water to the user, without spilling water from the end of the system. Such agricultural deliveries require careful planning, to balance system contents, deliver the water at the desired time, and avoid operational spills. In CVWD, the *zanjero* (Spanish for "ditch-rider") is responsible for matching water orders with water deliveries, by riding along the canals and laterals and opening and closing gates to release the appropriate amount of water to fields and irrigators' water delivery systems.

Irrigators order water at a variety of time scales. Each October, CVWD estimates its water needs for the coming year and submits this to the U.S. Bureau of Reclamation, which controls releases from Hoover Dam to meet downstream demands. CVWD also submits weekly water orders, six days in advance, to account for the time it takes releases from Hoover to flow 293 miles to the diversion at Imperial Dam, and then another 160 miles through the All-American and Coachella canals to the district. In 1969, CVWD constructed Lake Cahuilla, a 1,500 acre-foot reservoir that provides some operational flexibility, but in general, CVWD and its zanjeros must balance water orders with water currently available in the canals and laterals.

CVWD has repeatedly upgraded its water delivery communication and control systems to optimize deliveries to irrigators while minimizing waste. More than forty years ago, CVWD centralized operations, enabling staff at headquarters to monitor and control, via telemetry, canal check gates and lateral gates throughout the district's 1000-square-mile service area. In 1997, CVWD increased operational flexibility and efficiency by moving away from fixed water order and delivery schedules to allowing water orders to be placed and delivered 24 hours a day. This flexibility benefits farmers by enabling them to schedule water deliveries according to their own, rather than the district's, timetable.

Wireless Upgrade

> ***"The improved communications system has had more benefits than I can list. It used to be that when you were in the field, you wished you were back at your desk where you could look up information. Now, we can be in the field and behind the computer at the same time. It makes it easier for us to do a good job and has improved customer service. It has truly been a blessing."***
>
> **– Eric Urban, Zanjero Supervisor at CVWD**

In 2005, CVWD replaced its 25-year-old low-band radio system with an integrated voice and data trunked radio system, the first system of its kind in California and the first in the area to employ data subscribers. Implemented largely to improve emergency preparedness, CVWD quickly realized the potential benefits the upgrade presented to many of its core services, including water delivery, and took the opportunity to bundle multiple projects with the upgrade. Although CVWD would not have upgraded its water delivery communications system independent of the general system upgrade, its success suggests that other districts should evaluate the potential benefits available when upgrading their communications and data systems.

The upgrade provides secure wireless connectivity between those in the field and the CVWD control center, allowing real-time communication. Previously, zanjeros had used hand-held devices to record meter readings. Prior to the shift, information for the day's water orders were loaded onto the devices; at the end of the shift, meter readings were unloaded and processed. This meant that water orders, and changes in water orders, required verbal communication with the zanjero after the shift began. Since zanjeros were often in the field and away from their vehicle's radios, such information often was not conveyed. The old system presented other drawbacks, including: errors associated with transferring data from the handheld devices at the end of the shift; billing inaccuracies and disputes due to handwritten changes to orders and other information on field changes that could not be sufficiently documented; a single on/off transaction per day, per account; and paper-based infrastructure repair orders written by zanjeros on their routes that were not effectively communicated to repair crews. Zanjeros had to be in frequent contact with the control room, to check water levels in canals and laterals and request changes to gates to facilitate water deliveries and system balancing. Lack of careful balancing can lead to insufficient water to deliver to fields, or conversely to excess water at the end of the line, leading to operational spills. In recent years, CVWD has reported an average of about 1,670 acre-feet per year of such spills, though these are spread over almost 50 separate locations.

With the upgrade, CVWD outfitted each zanjero's vehicle with a computer and communication device capable of transmitting water orders and system status in real time. This new system provides many benefits:

- the control room can transmit emergency and last-minute orders directly to the zanjero's on-board computer, documenting changes that the zanjero can retrieve when back in the vehicle;
- zanjeros enter meter reads directly into the system, providing immediate updates to the control room and improving water delivery management;
- the system provides real-time data on water elevations in canals and laterals, providing rapid feedback to the zanjero on water flows and balancing;
- maintenance orders are entered directly into the system, expediting maintenance efforts and decreasing system losses due to neglected repairs;
- change orders are entered directly into the system, providing clear documentation that improves billing and minimizes disputes, increasing revenue for the district;
- autonomy of field staff is increased, enabling them to react quickly to changes as needed; and
- water balancing throughout the system is improved, while decreasing waste and spills at the end of the system.

These upgrades have improved communications with field staff and optimized management of water deliveries and canal management. The zanjeros have expressed great satisfaction with the new system, since it provides them with better and faster information on the effects of their water deliveries on water balancing in the system generally, enabling them to make route sequencing decisions independently. The new system also affords the zanjeros greater autonomy by releasing them from the need to repeatedly radio back and forth with the control center. The communications upgrade is still too recent to have firm data on its affect on the volume of operational spills or on growers' productivity. But anecdotal data are promising, and show the value of flexibility and communication.

Conclusions

CVWD, constrained by a limited water supply and extreme climatic conditions, has long been at the forefront of water conservation efficiency. Two recent initiatives—the Extraordinary Water Conservation Program and a communications upgrade—have continued this trend, with documented water savings in the former and improved management more generally in the latter. Through the ECP, CVWD conserved more than 75,000 acre-feet of water, at a cost to the district of about $40 per acre-foot (and at no additional cost to participating irrigators). Although water savings from the communications upgrade have not yet been quantified, the upgrade has improved communications between field staff and the district, and benefitted growers by increasing the flexibility of water deliveries.

These two initiatives demonstrate that improving technology can bring benefits, especially a more rapid exchange of information and targeted information for growers, enabling them to make better decisions. While some elements of these initiatives may not be transferable to other districts, in general the programs could be adapted by growers in other areas, enabling them to improve irrigation scheduling and salinity management, as well as improving flexibility and operational controls in the field.

References

Bourre, M. 2006. “Making Ever Drop Count,” RadioResource Mission Critical Communications. October. Available at www.mccmag.com.

Coachella Valley Water District (CVWD). 2009. *2008*-09 Annual Review & Water Quality Report. 27 pp. Available at www.cvwd.org/news/publicinfo/2009_annual_review_water_quality_report.pdf.

_______. 2002. Coachella Valley Final Water Management Plan. 278 pp. Available at www.cvwd.org/news/publicinfo/Coachella_Valley_Final_WMP.pdf

_______. 2005. *Farm Water Watch* Vol. 9. November. Available at www.cvwd.org/news/fww/11012005_FWW.pdf

International Boundary and Water Commission (IBWC). (2009). A Report on Colorado River Salinity Operations, Under International Boundary and Water Commission Minute No. 242: January 1 to December 31, 2007. Available at www.ibwc.state.gov/Files/Annual_CO_Salinity_Report-2007.pdf.

JM Lord, Inc. 2005-2006. Extraordinary Water Conservation Program: Annual Report. Prepared for Coachella Valley Water District. On file with author.

_______. 2004-2009. Proposal for Engineering and Agronomic Services: Coachella Valley Water District - Extraordinary Water Conservation Program. On file with author.

Lesch, S and R LeMert. 2000. Development of the CVRCD Mobilized Salinity Assessment Platform. GEBJSL Technology Transfer Announcement. Available at www.ussl.ars.usda.gov/lcrsan/cvrcd_sniffer.PDF.

Nelson, Peter. December 16, 2009. Vice President, CVWD Board of Directors. 2009. Personal communication.

Parks, Dan. December 16, 2009. Assistant General Manager, Coachella Valley Water District. Personal communication.

U.S. Bureau of Reclamation. Annual. *Crop and Water Data*. Form 7-2045. Lower Colorado River Region.

Chapter 6

Using Recycled Water on Agriculture: Sea Mist Farms and Sonoma County

Peter Schulte

Introduction

Growers in California are increasingly looking to recycled water as a way to consistently meet their irrigation demands in the face of growing water scarcity and pollution concerns. Water recycling (also known as water reuse or water reclamation) is the application of water that has already been used for human purposes and discharged as wastewater, and it typically involves the treatment of wastewater in order to make it safe for reuse. At first, water recycling was used largely to reduce the pollution associated with wastewater discharge. However, in the last decade it has been used primarily as a supplement to dwindling water supplies. Recycled water in California is most commonly used for agricultural irrigation, but it also goes to groundwater recharge, environmental uses, industrial uses, landscape irrigation, and, increasingly, as a way to mitigate the intrusion of seawater into coastal aquifers.

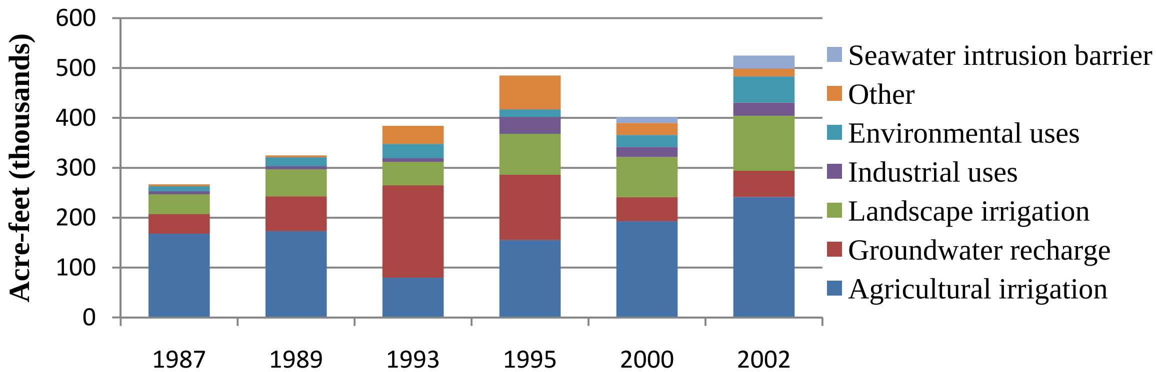
In the United States, recycled water is typically used only for non-potable or indirect-potable uses. It is rarely used directly as drinking water. Non-potable uses (e.g. irrigation and cooling) are those in which recycled water is not intended to come in contact with drinking water. Indirect-potable reuse refers to situations where recycled water is blended with potable water supplies, such as in groundwater basins, storage reservoirs, or streams. While recycled water helps mitigate water pollution and supplement water supplies, it also carries with it a stigma and some important human and environmental health concerns. In response, standards have been developed (Title 22 of the California Code of Regulations) that proscribe particular treatment technologies for different uses of recycled water, and require frequent testing and monitoring of recycled water quality at the treatment plant and at the point of application. Today, recycled water is increasingly recognized as a useful technology that will help growers, and other water users, in California meet their water demands well into the future.

Background

In the last twenty years, the number of water recycling projects and the volume of recycled water produced have grown dramatically. A comparison of recent surveys shows that the total volume of recycled water consumed in California has more than doubled since 1987 (Table 7). In the 1990s, agricultural irrigation and groundwater recharge were the largest volume uses for recycled water; however in the last decade, recycled water use has shifted from groundwater recharge to landscape irrigation, while agricultural irrigation remains by far the most common use. Recycled water use has grown in nearly all of the categories of use (with the notable exception of groundwater recharge). By 2000, there were already 234 wastewater treatment plants that provided recycled water in California (Sonoma County Water Agency 2007).

Table 7. Uses of recycled water in California, 1987, 1989, 1993, 1995, 2000, and 2005.

Sources: 1987 and 1989 data: State Water Conservation Coalition Reclamation/Reuse Task Force (1991). 1993 data: WateReuse (1993). 1995 data: DWR (1998). 2000 data: DWR *(*2003). 2002 data: DWR (2004).



Note: These surveys use different methodologies and received different response rates.

Many agricultural water recycling projects grew out of the necessity to find alternatives for wastewater disposal due to the restrictions set by the Clean Water Act (CWA). The CWA, passed by the U.S. Congress in 1972 to limit pollution of the nation's waters, requires the Environmental Protection Agency (EPA) to set minimum standards for treatment plant discharges. It also authorized major federal grant assistance for municipal sewage treatment plant construction and improvement. Thus, the CWA not only provided for new regulations related to water quality, but also funded the infrastructure for centralized wastewater treatment facilities which can be used to recycle water.

Reclaimed water can be treated to three different levels of increasing cleanliness/safety:

- *Primary:* A physical process removes some of the suspended solids and organic matter from the wastewater. The remaining effluent from primary treatment will ordinarily contain considerable organic material and will have a relatively high biochemical oxygen demand.
- *Secondary:* Biological processes involving microorganisms remove organic matter and suspended material. The effluent from secondary treatment usually has little biochemical oxygen demand and few suspended solids.
- *Tertiary:* This process further removes suspended and dissolved materials remaining after secondary treatment and often involves chemical disinfection and often involves chemical disinfection and filtration of the wastewater.

Figure 14. Descriptions of primary, secondary, and tertiary wastewater treatment (Source: Tchobanoglous, G. and E. Schroeder 1987)

The biggest concern regarding the use of recycled water on farms is the impact on human and environmental health. In response, California has put in place clear policies to regulate the type of treatment required for particular uses. Title 22 of the California Code of Regulations established by the California Department of Public Health governs the allowed uses for recycled water, the conditions of the use, and the physical and operational requirements to protect the health of workers and the public. Each application of recycled water is given a required degree of treatment (see Table 8), depending on its potential for harm to humans or the environment. For instance, if recycled water contacts the edible portion of the crop, e.g., all root crops, tertiary treatment and disinfection are required. Title 22 also requires frequent monitoring of recycled water quality at the treatment plant and the point of application. In addition, the California State Water Resources Control Board is responsible for regulating the production, conveyance, and use of recycled water through its nine Regional Water Quality Control Boards.

Table 8: Title 22 Wastewater reclamation regulations (originally published on the EBMUD website: www.ebmud.com/sites/default/files/pdfs/Recycled_Water_Uses_Allowed_in_California-2009.pdf)

USE	TREATMENT REQUIRED			
	Disinfected Tertiary Recycled Water	*Disinfected Secondary-2.2 Recycled Water*	*Disinfected Secondary-23 Recycled Water*	*Undisinfected Secondary Recycled Water*
Irrigation for:	Allowed	Not Allowed		
Food crops where recycled water contacts the edible portion of the crop, including all root crops	X			
Parks and playgrounds	X			
Schoolyards	X			
Residential landscaping	X			
Unrestricted access golf courses	X			
Any other irrigation uses not prohibited by other provisions of the California Code of Regulations	X			
Food crops where edible portion is produced above ground and not contacted by recycled water	X	X		
Cemeteries	X	X	X	
Freeway landscaping	X	X	X	
Restricted access golf courses	X	X	X	
Ornamental nursery stock and sod farms	X			
Pasture for milk animals	X	X	X	
Non-edible vegetation with access control to prevent use as a park, playground, or schoolyard	X	X	X	
Orchards with no contact between edible portion and recycled water	X	X	X	X
Vineyards with no contact between edible portion and recycled water	X	X	X	X
Non-food-bearing trees, including Christmas trees not irrigated less than 14 days before harvest	X	X	X	X
Fodder crops (e.g. alfalfa) and fiber crops (e.g. cotton)	X	X	X	X
Seed crops not eaten by humans	X	X	X	X
Food crops that undergo commercial pathogen-destroying processing before consumption by humans (e.g. sugar beets)	X	X	X	X
Ornamental nursery stock, sod farms not irrigated less than 14 days before harvest	X	X	X	X

In addition to these regulations that identify safe uses of recycled water for agriculture, there is growing scientific data that supports the safety of recycled water for these purposes. Perhaps most notably, the Monterey Wastewater Reclamation Study for Agriculture, an 11-year analysis of the safety of recycled water for the irrigation of crops, studied artichokes, broccoli, cauliflower, lettuce, and celery grown on two five-hectare plots in Castroville under two different types of recycled water (MRWPCA 1987). Among its key findings were:

- There were no viruses on samples of crops grown with the two types of recycled water used in the study;
- Levels of naturally occurring bacteria on samples of crops irrigated with recycled water were equivalent to those found on the control samples;
- There was no tendency for metals to accumulate in soils or plant tissues after irrigation with recycled water;
- Medical examinations and the serum banking program routinely conducted for the project personnel revealed no project-related health issues;
- The marketability, quality, and yield of crops were comparable with the control samples.

Benefits and Applications of Recycled Water

The use of recycled water on agriculture has grown significantly in California over the last decade due to its many benefits. These benefits are divided into four broad categories:

Reducing water pollution

Recycled water was originally and for over a century used primarily as a way to reduce the pollution associated with wastewater discharge. By treating wastewater and applying it for other uses, it no longer needed to be discharged to rivers, lakes, and streams and therefore significantly reduced pollution and the subsequent ecosystem damage and human health concerns. Redistributing this wastewater to agricultural land incentivizes better treatment (as it will be used for economically valuable purposes) and prevents accumulation of pollution in any one water body. Water pollution reduction continues to be one of the primary benefits of water recycled programs.

Augmenting water supply

As freshwater becomes scarcer, recycled water has increasingly been used as an alternative source of water for agriculture and industrial uses. Municipalities often treat their wastewater and send it to growers as irrigation waters. Industrial facilities also often treat their own water and reuse it immediately. In this way, recycling relieves pressure on surface waters and slows the depletion of groundwater. Recycled water not only provides more water, but is also often more reliable than surface supplies. Because municipal sources must use water by necessity (and therefore create wastewater), wastewater production—and thus the potential for water recycled supply— is relatively stable. Recycled water supplies are often used to mitigate water shortages caused by drought for this very reason.

Supporting healthy ecosystems

Water use and wastewater discharge often cause great damage to ecosystems by drastically reducing environmental flows or causing excessive pollution. Increased use of recycled water offers environmental benefits in the form of reduced effluent discharge, decreased pressure on existing water sources, increased in-stream flows, and avoiding the need for new water supply/infrastructure that may destroy local habitat (such as dams). Recycled water is also an option for supporting restoration projects, such as wetlands construction.

Reducing energy requirements and costs

Recycled water is also often preferable as a source of water due to its relatively low energy requirements compared to other water supply technologies. This is particularly true in Southern California where imported water must be transported long distances and pumped over mountains (requiring large amounts of energy) in order to reach growers. A recent study by the Inland Empire Utilities Agency shows that recycled water requires 400 kilowatt hours per acre-foot (kWh/AF) compared to 550 kWh/AF for groundwater pumping; 2,000 kWh/AF for the Colorado River Aqueduct Water; and 4,400 kWh/AF for desalination (Figure 16). Lower energy use not only reduces the environmental impacts associated with energy production, but also reduces energy costs to water districts, and so, the cost of providing the water itself.

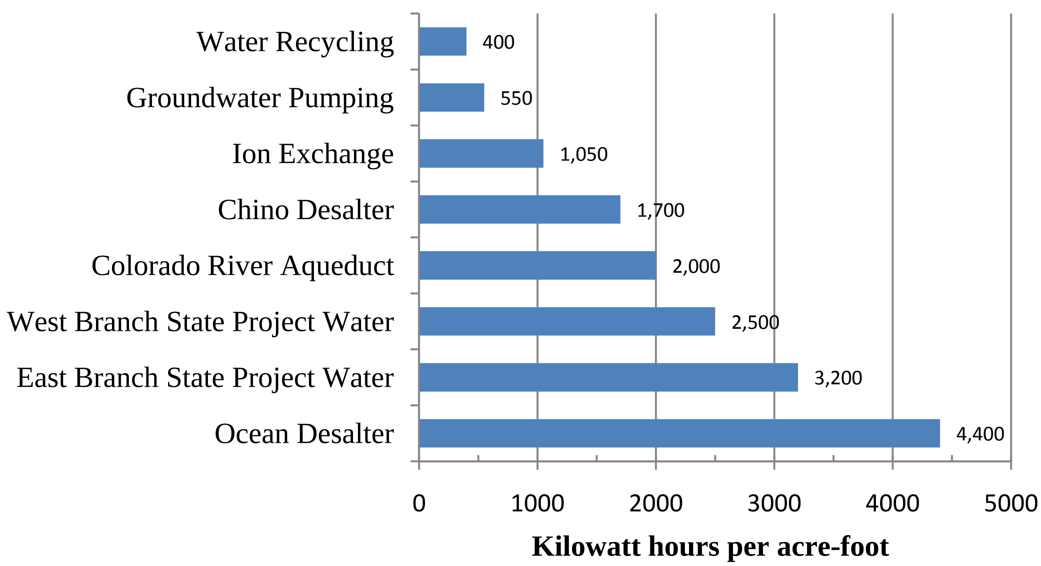


Figure 15. Energy requirements for Inland Empire Utilities Agency water supply (source: http://www.aceee.org/conf/05ee/05eer_ewhitman.pdf)

Sea Mist Farms

Sea Mist Farms, located in the Salinas Valley along the Central Coast of California, has successfully used recycled water since 1998. Sea Mist grows artichokes, spinach, lettuce, and variety of other crops on its nearly 11,000 acres of land. Recycled water comprises roughly two-thirds of the farm's total water use and is applied to roughly 80% of its acreage. Sea Mist uses well water only when its water demand exceeds the supply of recycled water.

Sea Mist receives its recycled water from the Monterey County Water Recycling Projects which consists of the Salinas Valley Reclamation Plant and the Castroville Seawater Intrusion Project (CSIP). CSIP is the 45 mile recycled water pipeline delivery system that was constructed in 1998 by the Monterey Regional Water Pollution Control Agency in order to minimize seawater intrusion in the aquifers on which the farms in the area rely by providing access to recycled water. Seawater intrusion occurs when coastal aquifers are drawn down and/or sea levels rise, so as to allow seawater to filter into freshwater aquifers. Seawater contamination is both a water-quality concern (excessive salinity is damaging to crops) and a water-scarcity issue (as it effectively makes these supplies unusable). Sea-level rise caused by climate change threatens to increase the number of aquifers subject to this intrusion. Recycled water is sometimes injected in these aquifers in order to stop this intrusion. However, as in the case in Castroville, recycled water is more often used as a source of irrigation water that reduces the need for groundwater pumping and therefore reduces intrusion. In 2008, CSIP delivered over 15,000 acre-feet of tertiary-treated recycled water to farmlands in the Salinas Valley. Sea Mist uses roughly two-thirds of all water produced by CSIP every year, making it by far the single biggest user of CSIP recycled water.

Dale Huss, General Manger of Sea Mist Farms for over two decades, is an advocate of recycled water for agriculture, saying that Sea Mist Farms is "proud of the fact that we are the biggest user of recycled water in the world." While acknowledging that this has been a concern among consumer and buyers, when asked about any food safety concerns due to the use of recycled water Huss explains, "Our water, from a food safety standpoint …is one of the safest water sources in the world…It is actually better, from an agronomic standpoint, than what the well water was." Finally, Huss notes that "in over eleven years of using recycled water to irrigate vegetable crops we have never had a food safety or human safety issue" (D. Huss, General Manager of Sea Mist Farms, personal communication, October 27, 2009).

Sea Mist has established a thorough monitoring system to ensure the quality of its soil and its products. These tests are more stringent than required by law and are checked by the County of Monterey's Department of Environmental Heath. Sea Mist has monitored its soil quality concerns twice a year since 2000 and compares those samples to soils from a nearby control site that uses well water instead of recycled water. These comparisons have shown the soils receiving recycled water to be consistently parallel to the control soils in respect to salinity and the soil absorption rate (SAR), and in many cases better. Moreover, the recycled water is disinfected and therefore has lower concentrations of microbial contaminants. There is an economic cost for this treatment, and Sea Mist Farms pays $180 per acre-foot of delivered water, compared to the $130-$150 per acre-foot they would pay to pump groundwater. However, Huss is comfortable with paying slightly more, citing the improved quality and reliability of recycled water.

Sonoma County

Sonoma County has used recycled water for decades and has seen a surge in demand from a variety of different users over the past ten years. The Laguna Wastewater Treatment Plant (WTP) treats wastewater collected from the cities of Santa Rosa, Rohnert Park, Cotati, and Sebastopol, from the South Park County Sanitation District, and from septic systems from most of Sonoma County. The Laguna plant opened in 1968, producing 2 million gallons of treated wastewater per day. Today, it produces over 21 million gallons of tertiary-treated wastewater every day (City of Santa Rosa 2009a).

While originally planned primarily as a wastewater disposal strategy, this recycled water is now largely used as a supplement to water supplies. Initially this water was primarily used for landscape irrigation, but Laguna WTP's conversion from secondary to tertiary-treated water in 1989 greatly increased the range of uses for its recycled water. The treatment plant now provides water to roughly 6,000 acres of farmland (City of Santa Rosa 2009b). Most of this acreage is used for pasture and fodder for dairy (about 4000 acres) and vineyards (about 1500 acres), although it is also used for turf, vegetables, and other crops. The treatment plant provides an average of 3.6 billion gallons per year for irrigation. A portion of the recycled water is also used for various created wetlands projects and the irrigation of parks, schoolyards, and other landscape areas. The treatment plant is only allowed to discharge to local water bodies (usually the Russian River) during the rainy season, October through May. Even then, recycled water can comprise only five percent of the river flow. The amount of water discharged to the river has decreased since 2003, when The Geysers—the largest geothermal power plant system in the world, located along the Sonoma and Lake County border—began operations using recycled water to produce steam. The Geysers now uses approximately 11 million gallons of recycled water every day.

Growers in Sonoma County currently receive recycled water for no charge; however, as soon as their contracts expire (around 2014), they will begin to be charged an as-yet undefined fee per acre-foot. Urban irrigators are provided recycled water at a rate set at 95% the potable rate, up from 75% ten years ago. These rate increases are largely due to growing demand for water in general and increased comfort with recycled water among growers and urban users. Similarly, though growers in Sonoma County were initially allowed to take as much recycled water as they could use, they are now being given allocations due to high demand.

The Sonoma County Water Agency (SCWA) recently proposed the *North Sonoma County Agricultural Reuse Project* to provide recycled water for an additional 21,100 acres of existing agricultural lands—nearly three times the current for Laguna WTP (SCWA 2007). This project would include the design and construction of storage reservoirs, pipelines, and pump stations. SCWA conducted a feasibility study on this project estimating costs at over $375 million in 2006 and released a final Environmental Impact Report in 2009 (SCWA 2007). However, despite this progress and support from many growers in the area, the project lacks funding and firmer commitments from both recycled water suppliers and users (SCWA 2009).

In sum, the application of recycled water for agriculture in Sonoma County has been quite successful, and in fact, demand for this water now well exceeds supply. However, the spread of recycled water use for agriculture is being tempered by a number of different factors. Growing water scarcity has created higher demand for water supplies among other users and more and more recycled water is being diverted for higher-value urban uses. The Geysers Project is now using much of the recycled water supply in the area. Efforts to expand recycled water production have been blocked mostly by inadequate funding.

Conclusions

Though the volume of recycled water used in California has more than doubled in the last two decades, there are still a number of barriers hindering it from more widespread use. Water recycling can be significantly cheaper than alternative sources of new water supply, though the initial investment costs can be high. Construction costs for these facilities are often borne by a single entity (e.g., water agency, municipality) even if benefits are provided to many water users through reduced pollution and increased water supply. Moreover, many of the environmental benefits from water recycling programs are difficult to quantify monetarily and therefore, are often excluded from cost-benefit analyses. Better valuing and quantifying of these benefits can play a large role in garnering support and securing funding for recycling programs. Existing funding sources, including the Clean Water State Revolving Funds and the American Recovery and Reinvestment Act 2009, should be targeted at expanding the availability of recycled water to agricultural consumers.

The variety of agencies and authorities necessary for successful implementation of water recycling projects (e.g. wastewater managers, water retailers and wholesalers, cities and counties, regulatory agencies, planning agencies, and the public) poses a number of institutional issues that slow the uptake of water recycling. A mechanism for cooperation among these agencies could promote water recycling in order to provide wastewater treatment, meet regulations and permit requirements, identify and market to customers, and operate and maintain service. We know that in California water demand exceeds supply in many water years, and that this is gap is likely to grow in the future due to a growing population and new pressures, e.g., climate change. Nevertheless, the majority of farmers in California still do not have access to recycled water. There is still much untapped potential to conserve water and protect ecosystems.

References

California Department of Water Resources (DWR). 1998. Draft: The California Water Plan Update, Bulletin 160-98, Sacramento, CA.

California Department of Water Resources (DWR). 2004. Water Facts No. 23: Water Recycling. Retreieved on October 16, 2009 from http://www.water.ca.gov/pubs/conservation/water_facts_no._23__water_recycling/waterfact23.pdf.

California Department of Water Resources (DWR). 2003. Water Recycling 2030: Recommendations of California's Recycled Water Task Force. Retrieved on November 24, 2009 from http://www.sustainca.org/files/WRPuUSA-CA-DWR.pdf.

City of Santa Rosa. 2009a. "Past, Present, and Future." Retrieved on November 24, 2009 from http://ci.santa-rosa.ca.us/DEPARTMENTS/UTILITIES/TREATMENT/TREATMENT/Pages/PPF.aspx>.

City of Santa Rosa. 2009b. "How Recycled Water is Reused.". Retrieved on November 24, 2009 from http://ci.santa-rosa.ca.us/departments/utilities/treatment/treatment/Pages/how2reuse.aspx.

Huss, D. October 27, 2009. General Manager of Sea Mist Farms. Personal Communication.

Monterey Regional Water Pollution Control Agency (MRWPCA). 1987. Monterey Wastewater Reclamation Study for Agriculture. Retrieved on November 13, 2009 from http://library.ceres.ca.gov/cgi-bin/display_page?page=2&elib_id=1106&format=gif.

Sonoma County Water Agency (SCWA). 2007. North Sonoma County Agricultural Reuse Project Environmental Impact Report. Retrieved on October 14, 2009 from http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=2615.

Sonoma County Water Agency (SCWA). 2009. County of Sonoma Agenda Item Summary Report. Retrieved on November 24, 2009 from http://www.sonoma-county.org/Board/meetings/meeting_20090512/meeting_20090512_item_51.pdf.

State Water Conservation Coalition Reclamation/Reuse Task Force. 1991. "Water Recycling 2000: California's Plan for the Future."

Tchobanoglous G. and E. D Schroeder. 1987. Water Quality Characteristics, Modeling, Modification. Addison-Wesley: Menlo Park, CA.

WateReuse Association of California. 1993. Survey of Water Recycling Potential.

Chapter 7

State and Federal Financing Accelerates Efficiency: Panoche Water and Drainage District and Sierra Orchards

Juliet Christian-Smith

> ***"As a taxpayer, I think it's the best thing my taxes can go to––it's the long term conservation of our food supply."—Craig McNamara, Sierra Orchards***

Introduction

Agriculture is an economic endeavor. It also has great social and cultural importance, but farmers must ultimately make choices about investments based on expected costs and returns. Water efficiency improvements can be costly. For example, conversion to high-efficiency sprinkler or drip irrigation systems can cost up to $2,000 per acre. Initial investments in efficiency improvements can be offset by a reduction in operation costs or increase in crop revenue, but that may mean several years before a grower sees a return on investment. Thus, programs that help defray these upfront costs are critical to provide the right incentives for increased efficiency.

At a federal level, the Farm Bill provides cost-shares to agricultural producers who make water conservation and efficiency improvements through a series of conservation programs, including the Conservation Stewardship Program and the Environmental Quality Incentives Program (EQIP). The 2008 Farm Bill authorizes EQIP funding at $1.2 billion in 2008, rising to $1.8 billion by 2012. At the state level, California voters have repeatedly approved propositions to fund water management and protection. These propositions have helped to fund a variety of financial assistance programs, including low-interest loans to water districts for agricultural water efficiency improvements.

Finally, at the local level some water agencies are implementing new rate structures that allow funds to be collected from excessive water use and re-invested in water conservation and efficiency improvements. It is important that innovative financing options be maintained in the future in order to provide incentives for efficiency at the on-farm and district scale. This is particularly true in California, where much of the local infrastructure is outdated and serves as an impediment to better agricultural water management.

Background

A variety of grant and loan programs along with water rate structures are available that provide financial incentives for agricultural producers and water districts to make water management improvements. This study focuses on several that have provided financing to update irrigation systems and implement best water management practices.

Federal Programs

The federal Farm Bill authorizes several voluntary conservation programs that provide payments to agricultural producers for water and land conservation efforts. EQIP is a particularly important program in terms of agricultural water management. The objective of EQIP is to optimize environmental benefits associated with agricultural production, and it focuses on several priorities areas, including: impaired water quality, conservation of ground and surface water resources, improvement of air quality, reduction of soil erosion and sedimentation, and improvement or creation of wildlife habitat for at-risk species (NRCS 2008a).

This program is administered through the U.S. Department of Agriculture's National Resource Conservation Service (NRCS), which has local offices throughout the U.S. NRCS staff members work with interested agricultural producers to develop environmental improvement plans. These plans become the basis of the EQIP contract between NRCS and the participant. Data from EQIP contracts awarded between fiscal years 2002 and 2008 demonstrate that about 25% of allocated funds address water quality concerns, 19% address soil erosion, 15% address plant condition, and 13% address water quantity (Figure 16).

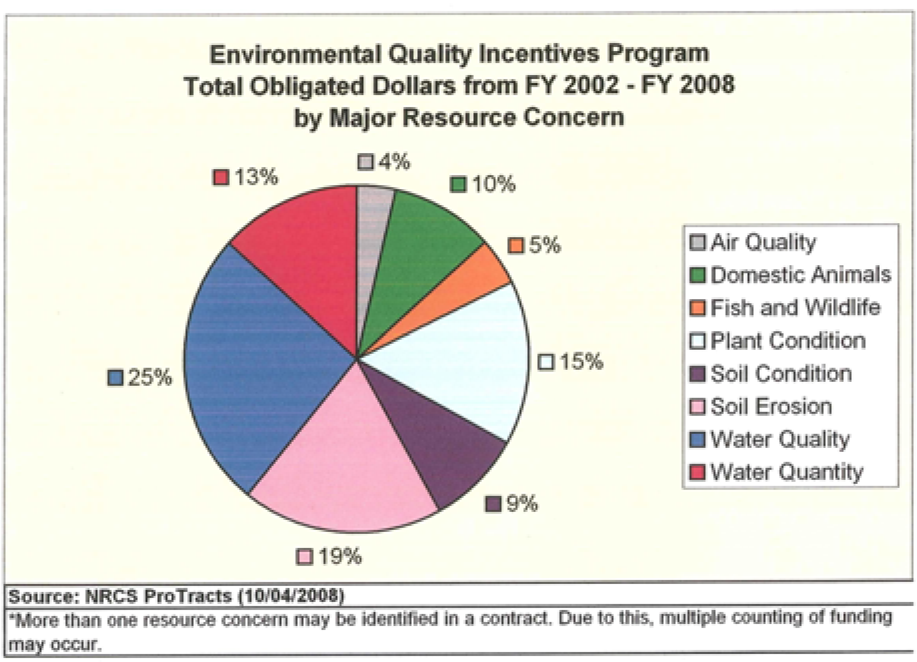


Figure 16. Environmental Quality Incentives Program funding allocation by resource concern, 2002-2008 (source: NRCS ProTracts)

EQIP provides payments for up to 75% of the incurred costs and income foregone of certain conservation practices and activities. However certain historically underserved producers (limited resource farmers/ranchers, beginning farmers/ranchers, socially disadvantaged producers) may be eligible for payments up to 90% of the estimated incurred costs and income foregone. The 2008 Farm Bill established a new payment limit of $300,000 for all program contracts entered during any six-year period, though projects determined as having special environmental significance may, with approval of the NRCS Chief, have the payment limitation raised to a maximum of $450,000.

Another important Farm Bill conservation program is the Conservation Stewardship Program (CSP). CSP payments are based on the level of conservation: the lowest level allows contracts of five years and annual payments up to $20,000; the middle level allows contracts of 5-to-10 years and annual payments up to $35,000; the top level allows contracts of 5-to-10 years and annual payments up to $45,000 (NRCS 2008b). The lowest level requires a plan that addresses at least one resource concern on the part of a farm, the middle level requires a plan that addresses at least one resource concern on the entire operation, and the top level requires a plan to address all resource concerns on the entire operation. Only a fraction of EQIP and CSP applications are funded nationwide; this means that each year we turn away thousands of farmers who are interested in improving their soil and water management practices. According to the American Farmland trust, "In 2004, there were over 180,000 applications from farmers for EQIP financial assistance. Three out of four—totaling $2.09 billion—were unfunded" (AFT 2007).

State Programs

California has largely relied on voter-approved bond measures to fund a series of water conservation programs over the last decade (Table 8). The California Department of Water Resources (DWR) and the State Water Resources Control Board (State Water Board) have run multimillion dollar bond-funded programs which have provided grant and low-interest rate loan money to many local agencies for integrated regional water management, water conservation, water recycling, distribution system rehabilitation, groundwater storage, water quality improvement, conjunctive use projects, and drinking water treatment. These programs are intended to encourage local agencies to adopt water management practices which have a statewide as well as a local benefit. Over $18.4 billion in grants and low interest loans have been authorized via state-issued bond programs since 1996 (Table 9). Propositions 204, 13, and 50 have been particularly important in terms of funding agricultural water efficiency improvements. For instance, in 2005 almost $400,000 of Proposition 50 funds were allocated to the Panoche Drainage District to install a subsurface drainage collection system and to plant approximately 270 acres of salt-tolerant crops to be irrigated with the recycled subsurface drain water in order to improve water quality in the San Joaquin River and the Bay Delta. This case will be discussed further below.

Table 9. California voter approved bonds that have provided funds for water management since 1996 (source: DWR 2009)

Title	Proposition	Total amount (in million $)
The Safe, Clean, Reliable Water Supply Act of 1996	Proposition 204	$995
The Safe Drinking Water, Clean Water, Watershed Protection and Flood Protection Act of 2002	Proposition 13	$1,970
California Clean Water, Clean Air, Safe Neighborhood Parks, and Coastal Protection Act of 2002	Proposition 40	$2,600
Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002	Proposition 50	$3,440
Safe Drinking Water, Water Quality & Supply, Flood Control, River and Coastal Protection Bond Act of 2006	Proposition 84	$5,338
Disaster Preparedness and Flood Prevention Bond Act of 2006	Proposition 1E	$4,090
Total		$18,433

District-wide Improvements

Most irrigated areas throughout the world are partly or fully supplied from collective delivery systems (Goussard 1996). These systems provide benefits but can also limit the farmer's ability to efficiently manage water resources. In California, there are three primary methods of delivering water to farmers in California: rotational, arranged ordering, and on-demand. The most common of these systems, rotational and arranged ordering, can present significant challenges to effective water management, and therefore represent an important area for improvement.

With fixed rotational deliveries, water is delivered according to a schedule, e.g., once every two weeks, whereby an irrigator must take the whole supply of water available. These systems provide the least flexibility to the farmer, who is not able to schedule irrigation based on crop water demand or changing weather conditions but must apply water when it is delivered. With arranged ordering, the irrigator requests water for a particular date and time. Water is then delivered to the irrigation system within 1-to-48 hours from the time that the order is received, depending on system capacity. Arranged ordering is less rigid than rotational deliveries, although it does not allow the irrigator to adjust deliveries based on short-term changes in weather conditions or soil moisture. With on-demand delivery, irrigators can precisely schedule irrigations and alter the amount of water applied. Thus, on-demand delivery provides irrigators with the needed flexibility to respond to changing conditions.

In California, water is predominantly delivered through gravity-fed canals designed and constructed in the early and mid-20th century (AWMC 2008). Nearly 80% of these water systems fail to provide water to farmers on demand (Figure 17). Rather, water is primarily available on an arranged ordering system. Water deliveries for nearly half of those areas subject to an arranged ordering system must place orders 24-to-48 hours in advance, thereby limiting the irrigator's ability to respond to changing weather conditions. About 5% of those surveyed were delivered water based on a fixed rotation and therefore must make water orders up to two weeks in advance of watering.

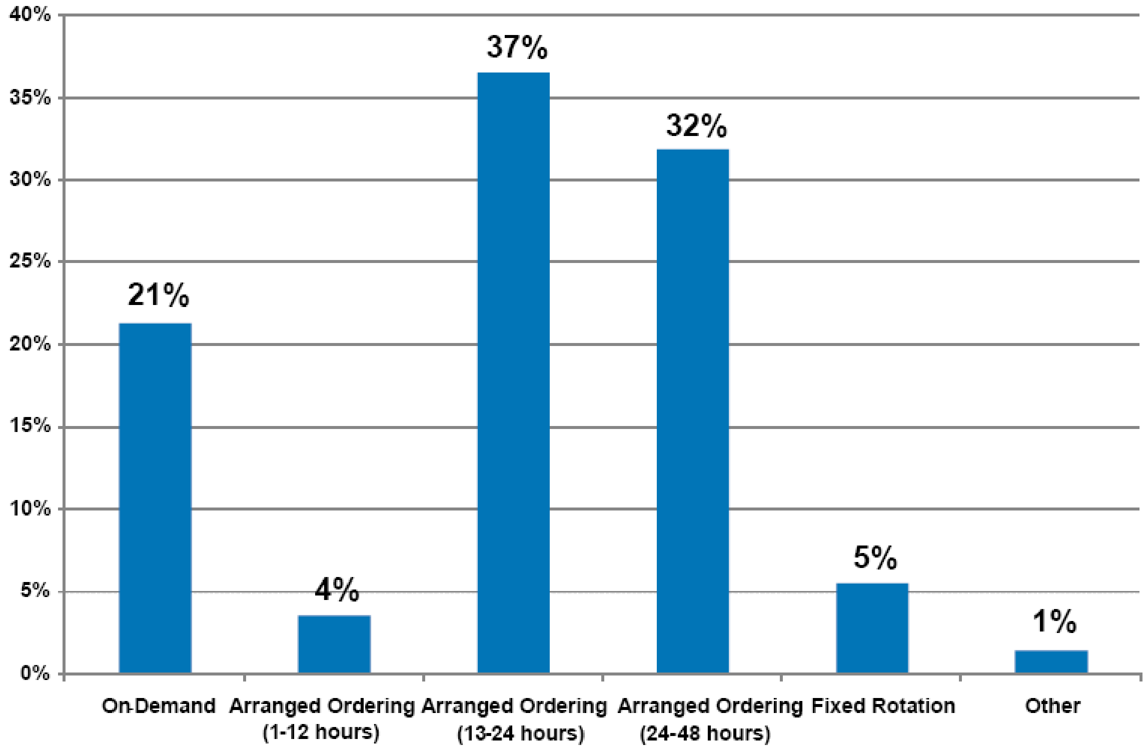


Figure 17. Water-delivery systems in California

Panoche Water and Drainage District

Panoche Water District serves about 38,000 acres in the Central Valley near the city of Firebaugh, and Panoche Drainage District serves another 44,000 acres, overlapping with some of the Water District's land. The District receives water from the Central Valley Project via the Delta Mendota Canal and the San Luis Canal and delivers this to over 500 farms. Typical crops in the district include almonds, tomatoes, cotton, wheat, asparagus, pistachios, and alfalfa.

Up until the mid-1980s, drainage water from the area was collected in the Kesterson National Wildlife Refuge. When it was discovered that high concentrations of selenium in the drainage water caused deformities in wildlife (Deverel et al., 1984; Presser and Barnes, 1984), the state and federal government mandated a series of strategies to decrease the quantity and improve the quality of discharged drainwater (San Joaquin Valley Drainage Program, 1990). Driven in part by this regulation, the District has implemented a variety of innovations over the last decade and has become a leader in water conservation and efficiency.

> ***"The district is continually making improvements to the water distribution system to reduce water losses and increase water delivery reliability and flexibility, making improvements to its drainage water management and reuse projects, and implementing policies to promote efficient water use and corresponding reductions in drainage flows." –Marcos Hedrick, Water Master***

Some of the projects and policies the District has implemented include a pre-irrigation tiered water-pricing program to encourage farmers to more carefully manage water deliveries in order to reduce drain water volume and selenium load. The program has been in place since 1996, and sets the maximum amount of pre-irrigation at nine inches per acre. If a grower exceeds this amount the water rate doubles. Marcos Hedrick, reports that the program has been extremely effective: "Notices were put out and all of our growers have pretty much stayed under [nine inches per acre for pre-irrigation]" (M. Hedrick, Panoche Water District Water Master, personal communication, October 27, 2009).

The district has also improved their water conveyance systems in order to increase the responsiveness to growers' water demands, allowing water to be regulated and applied precisely to meet crop needs. This has included lining irrigation canals and installing new turnouts on the San Luis Canal to increase water delivery flexibility. In addition, the district has made low-interest loans available to farmers for the purchase of gated pipe, sprinkler, and drip irrigation systems to enhance water management and reduce drain water volume.

> ***"The state's low-interest loan program [for irrigation system improvements] has been very fruitful and we hope to do more in the future because there is still quite a bit of demand for drip systems."***
>
> **–Marcos Hedrick, Panoche District Water Master**

Many of these programs were partially funded through state grants and loans. For instance, funds for the low-interest loan program were made available by the State Water Resources Control Board. Since the program's inception in 1996, farmers within the district boundaries have spent approximately $5 million dollars for improved irrigation equipment, and today nearly 70% of the district uses high-efficiency irrigation systems. State funding has greatly accelerated the installation of on-farm and district-wide water efficiency improvements.

On-Farm Improvements

While there have been significant improvements in terms of on-farm water management practices over the last several decades, there is still great room for more. The last statewide survey of on-farm irrigation methods was conducted in 2001; it found that almost 60% of irrigated acreage in the state is still flood irrigated (Figure 18). Flood, or gravity, irrigation has a lower average efficiency in comparison to other methods, particularly sprinkler and drip.[6] While some crops are most well-suited to flood

[6] Efficiency is defined here as the volume of irrigation water beneficially used (equal to evapo-transpiration) divided by the volume of irrigation water applied minus change in storage of irrigation water.

irrigation, e.g., rice, other crops have seen significant yield and quality benefits associated with switching to more precise irrigation technologies, e.g., orchards and vineyards. Yet, more than 20% of both orchards and vineyards were still flood irrigated in 2001. It is likely that these percentages are decreasing; however cost is often listed as a major impediment by farmers. Therefore, a wider availability of loans, grants, and tax incentives can speed implementation.

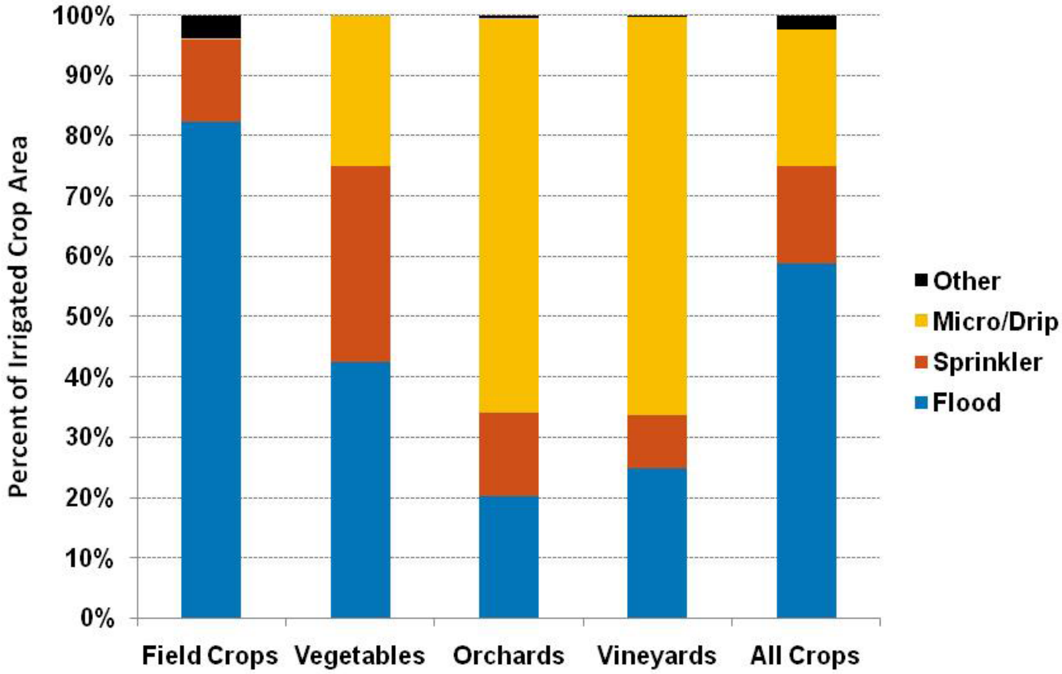


Figure 18. Irrigation technology by crop type, 2001
Note: These data are based on a survey conducted in 2001 and published in 2005. More recent statewide data are not yet available. "Other" includes subsurface irrigation where underground pipes or open ditches are blocked to force water into a crop root zone (based on data in Orang et al. 2005).

Sierra Orchards

> ***"As a farmer I think of myself first and foremost as a conservationist and environmentalist. Protecting our nation's land, water, and air resources are my most important goals."***
>
> **–Craig McNamara, Sierra Orchards**

Craig McNamara has owned and operated Sierra Orchards in Winters, California for nearly three decades (Figure 19). As an organic walnut farmer, member of the California Board of Food and Agriculture, and recipient of the Leopold Conservation Award, McNamara believes that "conservation has to be a critical part of what we're doing on the farm and as citizens of California." Sierra Orchards employs a number of innovative water management practices including buried drip irrigation on all new plantings, tailwater recovery ponds, and sediment trapping ponds.

Salas et al. (2006) found that the average efficiency for flood, sprinkler, and drip irrigation were 73%, 78%, and 89%, respectively.

In addition, McNamara manages for multiple benefits, looking to maximize habitat opportunities on-farm and minimize sediment inputs. He has created over two miles of hedgerows and riparian habitat on the farm. In order to stabilize the creek banks and eliminate soil erosion, they have planted over ten acres of native upland oak forest. Efforts to restore the watershed have been greatly enhanced by partnerships with willing organizations: Center for Land-Based Learning, Audubon California Landowner Stewardship Program, local Resource Conservation Districts, the Solano County Water Agency, the Community Alliance with Family Farmers, the Xerces Society, and the local Putah Creek Stream Keeper.

While the cost for these improvements exceeds tens of thousands of dollars, Sierra Orchards was able to receive matching funds through federal Farm Bill conservation programs, including the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (C. McNamara, Owner and Operator of Sierra Orchards, personal communication, June 8, 2009). These programs defray the costs of implementing critical on-farm water conservation practices.

Figure 19. Craig McNamara at Sierra Orchards in Winters, California

For instance, the land preparation and labor required to install drip irrigation systems and to restore 15 acres of upland riparian habitat cost around $150,000, yet through a combination of federal and state grant programs McNamara's out-of-pocket expenses were approximately $25,000. McNamara described the Conservation Stewardship Program as "one of the greatest acknowledgements that we have received…This funding partially compensated us for the voluntary conservation efforts that we had undertaken on our farm over the past 20 years."

In 1993, McNamara began working with local schools, and in 2001 created a nonprofit organization, the Center for Land-Based Learning, now headquartered on his property. The Center engages youth in learning experiences on the land that foster respect for the critical interplay of agriculture, nature, and society. Today, the Center for Land-Based Learning reaches thousands of high school students in 13 counties throughout the state, teaching them about on-farm conservation practices through hands-on activities. Close to 2,000 people of all ages visit the Center's headquarters, called the Farm on Putah Creek, each year.

Conclusions

When Congress passed the 2008 Farm Bill on June 18, 2008, it promised to increase funding for the most important and popular program in farm country to prevent water pollution and tackle other priority conservation problems. The Environmental Quality Incentives Program (EQIP) was to be funded at $1.337 billion dollars in fiscal year 2009–an increase of $320 million over the fiscal year 2007 funding. Just 29 days after the 2008 Farm Bill became law, the Senate Appropriations Committee proposed to fund EQIP at only $1.052 billion, which is $285 million less than what was promised in the 2008 Farm Bill. In California alone, that would amount to a loss of over $15 million that would have defrayed costs for agricultural improvements (Cox 2008).

In addition, the recent financial crisis has been particularly severe in California: state programs are being cut, and many bond-funded projects are on indefinite hold. While it is difficult to consider more funding, or even continued funding, at this moment, we are also facing on-going drought and changes in the timing and availability of water associated with climate change. Significant investment in our state's water infrastructure is unavoidable. It is critical to focus this investment not only on large supply but also on the localized distribution, conveyance, and application of irrigation water, where there is still great proven potential for increasing water quality and decreasing water demand.

References

Agricultural Water Management Council (AWMC). 2008. A Smaller Footprint: Managing Our Resources. Retrieved on February 13, 2010 from www.agwatercouncil.org.

American Farmland Trust (AFT). 2007. “Environmental Quality Incentives Program.” Retrieved on Febraury 15, 2010 from http://www.farmland.org/programs/campaign/documents/AFT_EQIPbriefing_WebMar07.pdf

Deverel, S.J., R.J. Gilliom, R. Fujii, J.A. Izbicki., and J.C. Fields. 1984. Areal distribution of selenium and other inorganic constituents in shallow ground water of the San Luis Drain service area, San Joaquin Valley, California: A preliminary study: U.S. Geological Survey Water-Resources Investigations Report 84-4319, p. 67.

Cox, C. 2008. “State by State EQIP Cuts.” Environmental Working Group. Retrieved on February 7, 2010 from http://www.ewg.org/conservation/report/State-by-State-EQIP-Cuts.

Goussard, J. 1996. Interaction between water delivery and irrigation scheduling. In: FAO/ICID (eds.) Irrigation Scheduling: From Theory to Practice: Proceedings of the ICID/FAO Workshop on Irrigation Scheduling. Rome, Italy, 12-13 September 1995. FAO Technical Papers, Water Reports 8.

Hedrick, M. October 27, 2009. Panoche Water District Water Master. Personal Communication.

McNamara, C. June 8, 2009. Owner and Operator of Sierra Orchards. Personal Communication.

Natural Resources Conservation Service (NRCS). 2009(a). Farm Bill 2008, Fact Sheet: Environmental Quality Incentives Program. Retrieved on February 13, 2010 from http://www.nrcs.usda.gov/programs/farmbill/2008/pdfs/EQIP_factsheet.pdf.

Natural Resources Conservation Service (NRCS). 2009(b). Farm Bill 2008, Fact Sheet: Conservation Stewardship Program. Retrieved on February 13, 2010 from http://www.nrcs.usda.gov/farmbill/pdfs/csp_fact_sheet-080709.pdf.

Orang, M.N., R.L. Snyder, and J.S. Matyac. (2005). Survey of Irrigation Methods in California in 2001. Bulletin 160-05. Sacramento, California: Department of Water Resources.

Presser, T. S., and I. Barnes. 1984. Selenium concentrations in waters tributary to and in the vicinity of the Kesterson National Wildlife Refuge, Fresno and Merced Counties, California: U.S. Geological Survey Water-Resources Investigations Report 84-4112, 26 p.

U.S. Department of the Interior and California Resources Agency. 1990. San Joaquin Valley Drainage Program : draft final report. Washington, D.C.: U.S. Government Printing Office. Retrieved on February 12, 2010 from http://ia310833.us.archive.org /2/items/sanjoaquinvalley01sacr/sanjoaquinvalley01sacr.pdf.