



U.S. DEPARTMENT OF AGRICULTURE RESEARCH, EDUCATION, AND ECONOMICS MISSION AREA,
THE WATEREUSE ASSOCIATION, AND WASHINGTON STATE UNIVERSITY



FINAL REPORT

Opportunities and Challenges in Agricultural Water Reuse

EDITORS

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UNIVERSITY OF MARYLAND

PUBLISHED JULY 2008



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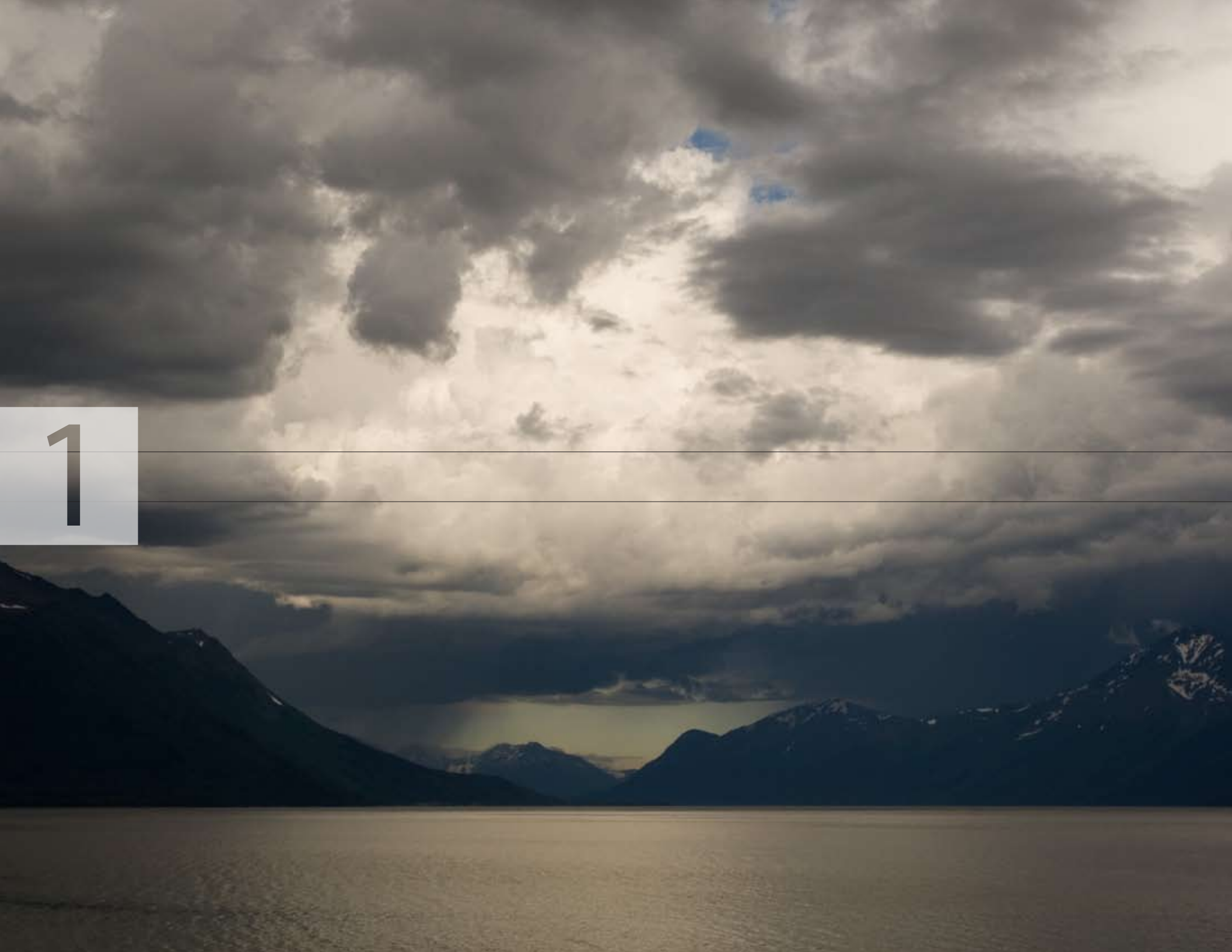
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SECTION 1: Executive Summary

Executive Summary

This report chronicles the events, presentations, and discussions of the Agricultural Water Reuse Joint Specialty Conference held October 29-31, 2006, in Santa Rosa, California.

The report is organized in six sections that follow the conference agenda, culminating in a series of take-home messages and four key recommendations for the U.S. Department of Agriculture (USDA) Research, Education, and Economics Mission Area.

Section Two offers a background on water reuse in agriculture and describes the current status of research, education, and extension program efforts in USDA. Among key observations are the diverse existing programs for research and extension efforts within the Agricultural Research Service (ARS) and the Cooperative State Research, Education, and Extension Service (CSREES). Foremost for both agencies is the opportunity to expand efforts to explore water reuse in agriculture through sound science and effective extension and education.

Section Three details examples of successful implementation of water reuse in agriculture. This section highlights the conference field trip that included stops at a local organic vegetable operation, a dairy operation, and a vineyard. The City of Santa Rosa has worked with these three agricultural operations to provide a high-quality, reliable source of water for irrigation. Section Two of the report continues with examples of effective water reuse in agriculture in California (Santa Rosa and Monterey), Florida, and Hawaii. Examples demonstrate the utility and value of water reuse in agriculture (California and Florida) while highlighting the need to expand options for irrigation water sources (Hawaii).

Section Four focuses on critical emerging issues in water reuse and the regulatory framework that is needed to accompany this source of water for use in agriculture. Producers need sound science to address consumer concerns that water reuse could lead to health concerns—particularly when this water is used to irrigate fresh vegetables. The importance of pathogens and their fate and transport in irrigation water was described. Health concerns related to pathogens and other contaminants were stressed in terms of risk assessment and regulatory approaches that exist to evaluate potential concerns and protect human health from pathogens.

Section Five addresses technologies needed to implement water reuse projects, social and economic issues that arise when projects are implemented, and agricultural productivity associated with recycled water. A critical component of technology development is locating facilities nearer to the end users of recycled water. Poor locations can lead to excessive distribution costs, limiting feasibility of water reuse applications. Public perception is another critical aspect of implementation. Surveys reveal that the public often is interested in the environmental benefits of water reuse but this support comes with concerns about odor, safety, and health. Customers receiving recycled water also have concerns—particularly related to safety, health, and liability. It's critical to overcome the public perception of "toilet-to-tap". Economic analyses reveal that bottom line cost-benefit analyses often do not reflect the full complement

of benefits arising from water reuse. Capturing these additional benefits is critical to demonstrating the economic utility of proposed projects. Finally, agricultural impacts of water reuse are described. Often, impacts include reduced productivity resulting from increased salinity in recycled water. Current research is focused on developing salinity resistant plants and evaluating plant tolerance to salts. This research could lead to irrigation recommendations that would describe how irrigation water could be "reused" sequentially on crops that have increasing salt tolerance.

The final two sections of the report detail discussions of conference participants and highlight Bold Steps for USDA and critical messages learned from the conference.

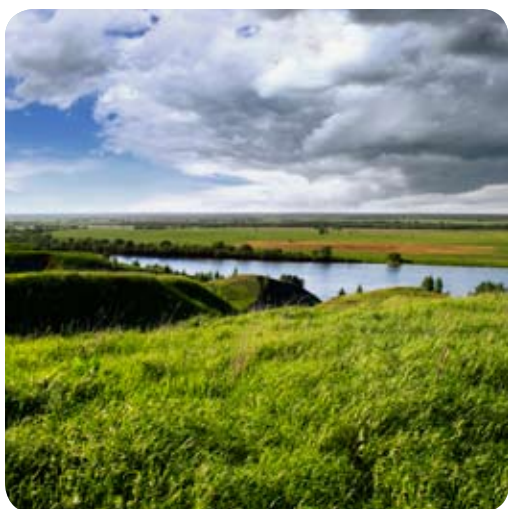
Section Six addresses challenges and opportunities identified by conference participants. Participants divided into four groups defined by key questions or issues highlighted in the conference:

1. Which crop for which place with what water?
2. Reducing human exposure during production and understanding exposure risks for consumption;
3. Improving public perception and acceptance; and
4. Management actions to improve irrigation with recycled water.

Groups were tasked with identifying key challenges that limited implementation of water reuse in agriculture. They also were asked to identify research, education, and extension opportunities that could help expand water reuse in agriculture. Conference participants developed a set of Bold Steps for USDA that culminated in an "implementation map" for these bold steps.

The final section of the report is dedicated to describing the "Take Home" message from the conference. The take home message takes the form of four key recommendations related to water reuse in agriculture:

1. Improve education and outreach on recycled water;
2. Conduct additional research and coordinate existing data on water reuse;
3. Set appropriate standards and develop a certification program for operators; and
4. Improve the role of USDA and other government agencies in promoting water reuse in agriculture.





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SECTION 2: Background

- P 10: AGRICULTURAL WATER SECURITY
- P 11: WATER ISSUES IN AGRICULTURE
- P 13: USDA'S CURRENT OUTLOOK
- P 15: USDA AGENCY ROLES

Agricultural Water Security

In our nation's drier climates and drought-stricken regions, agricultural water users face tremendous pressure to make available additional water sources for municipal and domestic consumption. USDA is attempting to resolve how and where this "new" water will emerge.

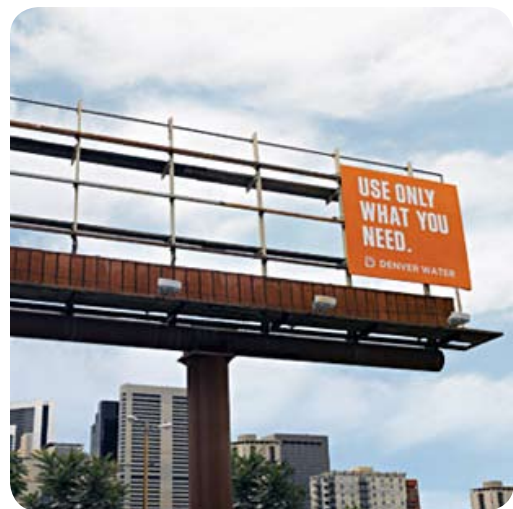
USDA began the search in 2004 by hosting the Agricultural Water Security Listening Session in Park City, UT. This listening session brought together nearly 100 top research, education, and extension professionals with engineers, water managers, and water providers to address how USDA Research, Education, and Economics (REE) programs could help resolve this critical problem. The final report from the Listening Session (Dobrowolski and O'Neill 2005) provided a definition for Agricultural Water Security:

Maximizing the efficiency of water use in agriculture and associated communities to continue or expand the supply of water for domestic water consumption, ecosystem services, energy production, recreation, and aesthetics.

In 2005, REE proposed creating a comprehensive program for Agricultural Water Security that addresses six key themes from the listening session:

- biotechnology;
- irrigation efficiency;
- drought mitigation and preparedness;
- economics and marketing;
- general water conservation; and
- wastewater reuse for agricultural, rural, and urbanizing communities.

These six key themes form the foundation for REE's future program planning on Agricultural Water Security.



Water Issues in Agriculture

Water is critical to maintaining human health and well-being; protecting and sustaining sensitive ecosystems; producing food, fiber, and energy into the future; enhancing recreation and aesthetics; and providing for the long-term security of people and nations.

Providing enough water to meet human demands across the nation is challenging water policy makers—due primarily to water being viewed as a human entitlement, delivered below cost, and used inefficiently (O'Neill and Dobrowolski 2005). Of the 147 countries ranked for water efficiency by the World Water Council, the United States ranked last, where inefficiencies at times reach 50 percent (NCSE 2004). Furthermore, population growth is expanding the demand for water; globally, farmers are irrigating five times more land than at the beginning of the 20th century to feed this growing population. Overall, withdrawals for agriculture doubled and domestic and industrial uses quadrupled between 1950 and 1995 (Postel 1997).

In the United States, population growth and changing values have increased demands on water supplies and watersheds, resulting in water use and management conflicts, particularly in the Western states where populations are expected to increase 30 percent in the next 25 years. Irrigation is the largest consumer of fresh water in the United States, with 42 percent lost due to evaporation, etc. Thermoelectric power generation removes the

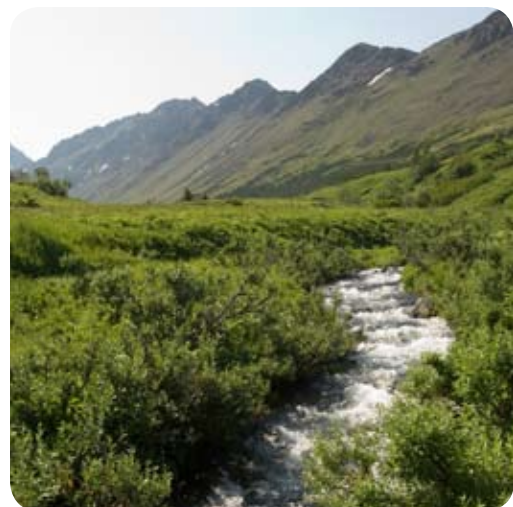
largest proportion of fresh water (52 percent) but much of that water returns to water bodies.

Across the country, agricultural needs often are viewed as being in direct conflict with urban needs and with demands to sustain or improve ecosystem services, recreation, and tourism. Water issues being debated across the nation include enhancing supplies with new storage facilities, expanding existing infrastructure, funding for water reclamation and reuse, and lowering water consumption. As a result, a growing number of communities are seeking federal assistance, actions, and permits related to water supply augmentation through desalination, reservoir expansions, or redirection of operations and water reuse projects—all with program elements that inexorably link to agriculture and USDA (Cody and Hughes 2007).

Much of the potable water that humans use in sinks, toilets, washing appliances, and industrial applications enters the wastewater stream. After treatment, it is discharged to lakes, oceans, and rivers. When this wastewater is intensively treated, it can be returned to the source communities as reclaimed water to irrigate agriculture. Non-potable reclaimed water can offset and preserve potable water supplies for other potentially higher-order uses. For years, wastewater discharges were accepted as a means to maintain minimum in-stream flows. Treatment technology investment required to meet stringent discharge limits resulted in more communities and businesses that targeted other uses for treated wastewater as a means for partial cost recovery. As competition for water supplies intensify, the use and acceptance of reclaimed wastewa-

WATER ISSUES BEING DEBATED ACROSS THE NATION INCLUDE ENHANCING SUPPLIES WITH NEW STORAGE FACILITIES, EXPANDING EXISTING INFRASTRUCTURE, FUNDING FOR WATER RECLAMATION AND REUSE, AND LOWERING WATER CONSUMPTION.

Water Issues in Agriculture (cont'd)



ter for landscape and agricultural irrigation also will increase, leading to a need for dual water systems that are integrated fully into community and rural water supplies (EPA and USAID 2004).

The widening gap between supply and demand is often made up with marginal resources, especially reclaimed municipal wastewater, which is becoming an increasingly important source of water for agricultural in water-short countries like Israel (25 percent of the total agricultural water in 2000, and projected to be 37 percent in 2010, and 46 percent in 2020). The land area in Israel irrigated with treated wastewater is rising continuously—5,100 hectares (ha) in 1975, 16,300 ha in 1985, and 36,300 ha in 1994. Currently, about one-third of the wastewater from the metropolitan Tel Aviv area is treated at a tertiary level, and about 50 percent as secondary or near-secondary treatment. Many advantages arise from the use of wastewater in agriculture, including

- treated wastewater can serve in the long run as a key component to agriculture and might provide for continuity of domestic U.S. agriculture;
- the supply of wastewater is highly reliable relative to quantity (not necessarily with respect to quality) and increases with population growth;
- the cost of treating secondary wastewater is generally low in relation to the cost of fresh water from unconventional water sources (e.g., desalination); and
- the option of allocating wastewater to irrigation is the best and cheapest option for wastewater disposal, from the viewpoint of environmental conservation; accordingly, it can be the preferred disposal alternative for municipalities.

Secondary wastewater contains nutrients such as nitrogen, phosphorus, and potassium, which may save on the use of chemical fertilizers. However, this advantage is conditional on proper quantities and timing of water and nutrients, since bad timing or providing these nutrients in excess may negatively affect yields.

Utilizing reclaimed water reduces or eliminates the demand for potable water, economic consequences during drought, and the need for additional potable water sources and infrastructure; helps maintain freshwater in-stream flows to support ecosystems services; and contributes to a healthy and green environment. California agriculture began using reclaimed water in the 1800s. California established regulations governing the level of treatment, contact with, and use of recycled water. These stringent codes, which require the highest treatment for human contact and parallel pipe infrastructure, help to ensure public and environmental safety.

Currently, four states include water reuse in their official water policies: California (calling it “recycled water”), Florida, Hawaii, and Washington. This report seeks to identify key opportunities and challenges associated with the use of recycled water in agriculture. We hope to build upon the lessons learned from states where recycled water is used in agriculture and we expect to develop and expand the knowledge base to ensure safe, appropriate application of recycled water in agriculture.

USDA's Current Outlook

Merle Pierson, USDA Deputy Under Secretary for Research, Education, and Economics, highlighted actions for USDA in Agricultural Water Security. He stressed informing and engaging the public and stakeholders in the decision-making process regarding water reuse in agriculture.

We should explore opportunities to match available water quality with appropriate water uses; what water is best for which crops in what place? We need to better understand motivations that inhibit public acceptance of water reuse—always employing the best available science to improve decisionmaking and change behaviors.

At the same time, we should engage stakeholders from multiple communities to seek water management solutions and to make appropriate decisions regarding water reuse. Land-grant institutions and other colleges and universities have developed

strong academic programs to address food safety and water quality issues. Today and into the future, the next generation of science and education professionals will need to work on complex issues at the interface between food safety and water quality. Educators also must bring new water management and food safety technologies into the classroom so that students are better prepared to address these topics when they enter the workforce.

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AND EDUCATION PROFESSIONALS
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USDA's focus is proactive. We look to the experts in the scientific, economic, sociology, and policy communities to develop tools that will help solve today's and tomorrow's water reuse problems, supported by peer-reviewed scientific research and science-based education and outreach. USDA is committed to being part of the solution. We recognize that the nation's need to produce the necessary food, fiber, and energy must equal its commitment to protect precious water resources. We are committed to expanding the science base to inform policies. That same commitment will also lead us to better tools and technologies to inform decisionmaking at the individual, community, and national levels.

Potential research, education, and outreach in water reuse technology development that REE might attempt

- study the additional costs to farmers who intend to transition to irrigation with recycled water.
- study the elements that comprise approaches to recycled water pricing for use in irrigation (e.g., conveyance, treatment).
- determine whether social benefits exceed the social cost.
- identify what the recycled water volume contains— concentrations of chemicals, which may be hazardous to agricultural yields and to conservation of soils.
- provide a science basis for regulations (health and food safety) with respect to recycled water use for agriculture.
- programs and projects that focus on two principal methods for reducing drainage salinity problems: 1) reducing the amount of irrigation water applied to crops; and 2) reusing the applied water on subsequent, more salt-tolerant crops.

USDA Agency Roles

Michael O'Neill, CSREES national program leader in the Natural Resources and Environment unit, focused on specific water-related program areas in CSREES that would support efforts to expand water reuse efforts.

The National Research Initiative (NRI) Water and Watersheds Program focus concerns the development of new knowledge related to water quality impairments and water supply/scarcity concerns. CSREES' National Integrated Water Quality Program (NIWQP) has its focus on creating and disseminating knowledge needed to resolve stakeholder- (farmers, ranchers, homeowners) identified water resource issues. Together the CSREES Water Program identifies major water resource issues, then defines and focuses projects to address those critical and time-sensitive

issues. The program provides funding for these projects at the watershed scale for 3–4 years to build a “cohort” of projects around an issue, develops a synthesis of knowledge gained, and identifies the remaining challenges.

As a result of the 2005 Agricultural Water Security Listening Session (Dobrowolski and O'Neill 2005) and subsequent Agricultural Water Security White Paper (O'Neill and Dobrowolski 2005), CSREES chose to build-out three research, education, and extension themes. These three themes (biotechnology, conservation, and water reuse) fit within the research and education challenges (water availability, quantity and quality, water use, and water institutions) described by the National Research Council (2001, 2004) and supported by the U.S. government (OSTP 2004). CSREES' expectations for this conference were the development of new partnerships and opportunities to learn from water reuse professionals,

THE CSREES WATER PROGRAM IDENTIFIES MAJOR WATER RESOURCE ISSUES, THEN DEFINES AND FOCUSES PROJECTS TO ADDRESS THOSE CRITICAL AND TIME-SENSITIVE ISSUES.



USDA Agency Roles (cont'd)

CSREES WILL DOCUMENT IMPACTS AND OUTCOMES BY CHANGES IN ENVIRONMENTAL WATER USE EFFICIENCY, EXPANDED WATER AVAILABILITY, AND HEALTHIER AQUATIC AND ESTUARINE ECOSYSTEMS.

and to identify the need for new technologies linked to the use of recycled water and novel efforts towards water conservation.

CSREES seeks to improve coordination among existing water reuse efforts across USDA and with new partners. Potential federal partners include ARS, the Bureau of Reclamation, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, and U.S. Food and Drug Administration. Non-federal partners should include the WaterReuse Association, land-grant colleges and universities, and other not-for-profit educational groups. Within the Water Program water reuse provides an opportunity to expand the portfolio in the NIWQP.

Evaluation and monitoring effectiveness are critical to maintaining current and seeking additional funding. CSREES will document impacts and outcomes by changes in environmental water use efficiency, expanded water availability, and healthier aquatic

and estuarine ecosystems. Social outcomes will be assessed through public acceptance—adoption of existing and new technologies; behavior change through improved knowledge, attitudes, and behavior relative to water use; conservation; and water reuse. Measures of adoption of conservation and water reuse practices must be developed to record increases in the volume of recycled water delivered to the household and farm level; evaluate changes in the market share of raw water and treated water technologies; and the value of water “saved” through various conservation measures or use of treated water. Other indicators linked to outcomes should identify changes in community involvement toward water use and reuse decisions, changes

in public policies towards water use and reuse, and data from national surveys of per capita water use, both from the National Agricultural Statistics Service and CSREES-supported evaluation studies.



Mark Wertz presented ARS’ water program as focused on integrated, effective, and safe water resources management.

ARS conducts fundamental and applied research on the processes that control water availability and quality for the health and economic growth of the American people and develops new and improved technologies for managing the nation’s agricultural water resources. Problem areas focus on water quality (\$34.5 million), water quantity (\$29.2 million), and watershed management. Agency scientists developed the P-Index. The adoption of this technology has reduced P loadings in water by an estimated 56 million pounds and sediment by 2.1 billion pounds annually with estimated economic benefits to society of more than \$600 million per year. They also produced the SITES 2000 Water Resource Site Analysis Program. The Natural Resource Conservation Service (NRCS) and the U.S. Army Corps of Engineers (COE) also adopted this technology to evaluate the safety of the 11,000 aging earthen flood-control structures.

Existing water quality concerns that are the subjects for research include nitrates, phosphorus, pathogens, salinity, toxic trace elements, and emerging contaminants in water. Efforts are underway to develop technologies to reduce contaminant loading from surface runoff, reduce contaminant loading from drained croplands, and quantify and predict the individual farm and net cumulative water and soil quality benefits at the watershed scale from implementing conservation practices.

ARS programs address water quantity concerns such as drought, water availability and delivery, in-stream flow requirements, dam safety and flood prevention, irrigation efficiency, soil erosion, and stream corridor restoration by developing technology to conserve and effectively use water, nutrients, and energy. Scientists continue to develop technologies to safely reuse degraded water, safely recharge aquifers using recycled water and urban runoff, assess and mitigate the impact of drought on agricultural enterprises, accurately quantify and predict water supply and basin water budgets, and develop knowledge to understand ecosystem requirements and feedback mechanisms in agricultural landscapes.

ARS scientists developed wastewater treatment facilities with the capacity to reduce emissions and improve water quality (Fig. 1). Partnerships with federal and state agencies and universities leverage resources and increase agency impact through participation in interagency working groups, the National Research Council, National Science Foundation committees, and professional societies. These partnerships assist ARS with research efforts in water reuse, drought, sustainability of bioenergy production, and water quality credit trading.

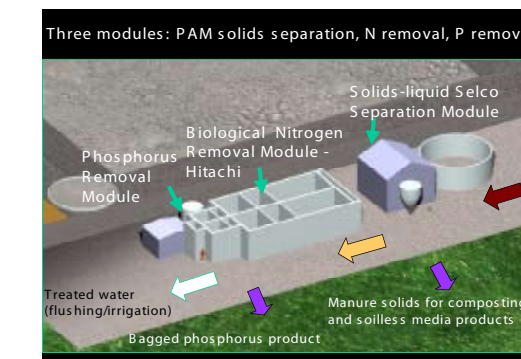


Fig. 1—ARS-designed wastewater treatment facilities with the capacity to reduce emissions and improve water quality.



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SECTION 3: Proof of Performance

- P 20: SANTA ROSA'S 50 YEARS OF AGRICULTURAL WATER REUSE EXPERIENCE
- P 24: USE OF RECYCLED WATER TO IRRIGATE EDIBLE CROPS IN MONTEREY COUNTY, CA
- P 26: RECLAIMED WATER USE ON CITRUS AND OTHER CROPS IN FLORIDA
- P 28: SOLVING AGRICULTURAL IRRIGATION ISSUES WITH RECLAIMED WATER: THE HAWAII EXPERIENCE

Santa Rosa's 50 Years of Agricultural Water Reuse Experience



The mayor of Santa Rosa, **Jane Bender**, welcomed everyone and congratulated the City of Santa Rosa on its efforts in water reuse. "Can we afford not to do these things across the country? Most people are dealing with scarcity that is tied to energy. We must be able to look 40 years down the road. We are all in this together," she said. The City of Santa Rosa has a long history of water reuse. According to **Daniel Carlson**, deputy director for the City of Santa Rosa, the community began recycling water about 50 years ago, with the production of hops.

In the 1950's, Santa Rosa's population was 40,000 with a wastewater flow of 3 million gallons per day (MGD). Most of the water delivered for hop production, about 12 percent of the wastewater flow, had undergone secondary treatment. Between the 1970s and 1990s, Santa Rosa rapidly grew to 100,000 people with 15 MGD wastewater flow. Hops gave way to dairies and other secondary crops, city-owned farms were established, and wastewater storage ponds were built. During this period, about 30 percent of the wastewater flow was used for agriculture.

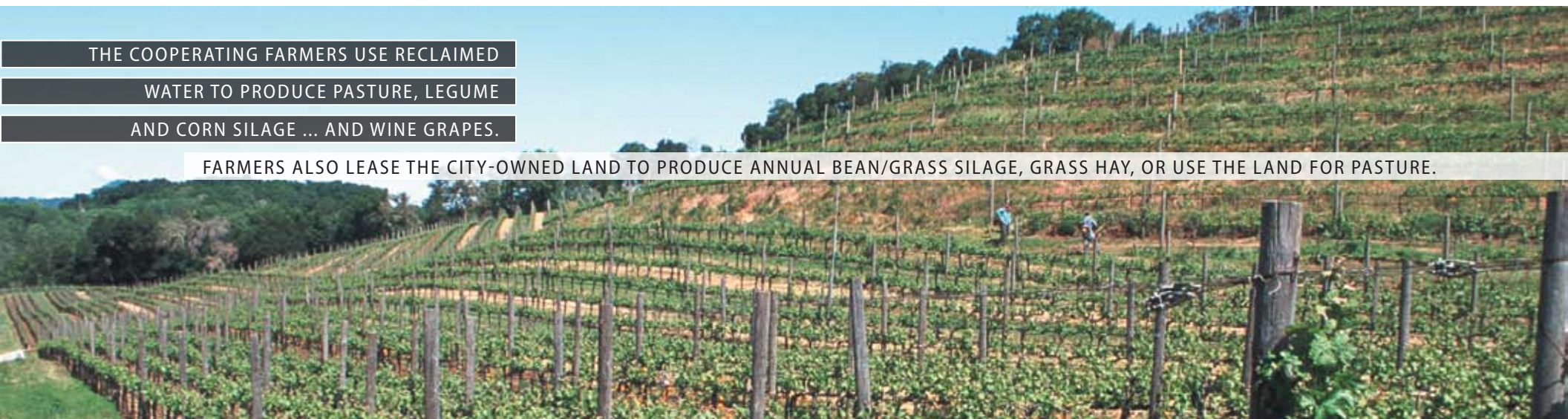
In 1990, Santa Rosa improved its treatment level to tertiary treatment and water recycling. Reuse has continued to increase and now includes edible vegetables, energy production, and the wine grape industry. With a population of more than 150,000 people, reuse of wastewater is now at approximately 88 percent per year. The challenge for the future will be to match the amount of water produced to the demand.

The initial reuse facilities were constructed in the late 1970s and included the Laguna Treatment Plant, an extensive pipeline distribution system delivering recycled water for agriculture to approximately 3,000 acres. Today, the Laguna Subregional Wastewater Treatment Plant and Water Reclamation System provide advanced wastewater treatment and include filtration and UV disinfection. The recycled water meets California Title 22 Wastewater Reclamation Criteria for unrestricted reuse. The Laguna plant produces 20 million gallons of tertiary-treated and UV-disinfected water every day. This water must then be delivered to users or stored. Agriculture irrigation was one of the city's first reuse options and remains a key component of their reuse system. Production water from the treatment plant is unrestricted for any agricultural crop. The system has expanded since initial construction and now consists of 17 storage reservoirs that help provide almost 3 billion gallons of recycled water each year to irrigate about 1,500 acres of city-owned and about 4,500 acres of privately owned land. The privately owned land is operated by 60 individual cooperating farmers, each

has a contract with the city for the use of reclaimed water. The cooperating farmers use reclaimed water to produce pasture, legume and corn silage, hay, turf/sod, a variety of vegetables, and wine grapes. Farmers also lease the city-owned land to produce annual bean/grass silage, grass hay, or use the land for pasture. The combination of city-owned and privately owned land provides operational flexibility during unusual weather years.

In 1997, Gallo Wines partnered with the city on a project that included a storage reservoir, 4 miles of piping and a new 300-acre premium wine grape vineyard that uses recycled water to meet 100 percent of their daily operations. This partnership has proven successful for both Gallo and the city.

Prior to 1990, the City of Santa Rosa paid farmers to use secondary-treated recycled water. Since then, new users are provided the water free of charge or pay the city a nominal amount. Future efforts will focus on additional urban reuse, additional recharge of the Geysers Geothermal Steam Fields, and expansion of agricultural reuse outside of the existing immediate area. The only way to expand the amount of water reused each year is to increase storage and that is being evaluated. The availability of recycled water is helping sustain the agricultural industry immediately adjacent to the urban area. It is anticipated that the future will bring even more crop diversity and system expansion.



THE COOPERATING FARMERS USE RECLAIMED WATER TO PRODUCE PASTURE, LEGUME AND CORN SILAGE ... AND WINE GRAPES.

FARMERS ALSO LEASE THE CITY-OWNED LAND TO PRODUCE ANNUAL BEAN/GRASS SILAGE, GRASS HAY, OR USE THE LAND FOR PASTURE.

Proof of Performance

One of the most effective means of achieving behavior change is through demonstration sites, where innovative concepts are implemented under real-world circumstances.

Conference participants toured three such demonstration sites, where the City of Santa Rosa provides recycled water to a diverse group of agricultural producers who use recycled water in vegetable and flower production, dairy production, and viticulture. These producers found innovative ways to incorporate recycled water into their irrigation schedules to enhance the volume and

reliability of irrigation. The City of Santa Rosa's visionary approach, coupled with the producer's willingness to innovate, has forged a highly successful partnership where recycled water can augment or replace other irrigation sources—and expand available water for the city's citizens.



QUETZAL FARMS— SANTA ROSA, CA

As you approach Quetzal Farms in Santa Rosa, CA, you can find purple-labeled signs identifying the use of recycled water every 500 feet as you pass the surrounding fields. The owner, Kevin McEnnis, has a successful organic vegetable operation with a

large variety of quality vegetables and some ornamental flowers. McEnnis sells his produce at farmer's markets around the area. McEnnis hires a small number of farm workers who assist in the daily operation. There are approximately 8 to 12 workers who help maintain the high quality crops of sweet peppers, eggplant, zucchini, sunflowers, and other specialty crops. Emitter clogging hazard is slightly higher when irrigating with recycled water, and therefore filtration requirements are increased. His peppers are grown using a disk filter into drip tape with non-clogging emitters.

The City of Santa Rosa provides, at little cost, irrigation assistance through a pump station, a special disk filter, a pressure regulator, and irrigation pipe to distribute the

water at a suitable pressure and location for use on the property. There is a slight salt buildup (recycled water has a TDS of about 425 mg/L) but this does not affect McEnnis' crops or production. McEnnis monitors the water quality on and off his farm each spring and fall. Quetzal Farms maintains very good irrigation practices to ensure that ponded water is minimized to control mosquitoes. Regulatory agencies require groundwater monitoring and the City of Santa Rosa has set up a program to detect if there is movement of contaminants, particularly nitrate due to percolation. The recycled water meets all State of California Title 22 requirements which allow irrigation where vegetables come into direct contact with the recycled water.



KUNDE VINEYARDS— SANTA ROSA, CA

The Kunde Vineyards total 275 acres in the Russian River Valley in central Sonoma County, CA, and is owned by Saralee and Rich Kunde. The Kunde's chose this site because of its cool climate with rich valley soil and plentiful hills. They have the latest in vineyard technology and more than 75 different selections of fruit. The Kunde's can track each vine to its original mother vine through extensive data records. The vineyard has year-round employees who need to be ready and willing to pick at a moment's notice, since delivery is at the pleasure of the winery that purchases the harvest. There are 18 varieties of grapes. At the time of this tour, almost all the harvesting was complete, with approximately 1,800 tons of grapes collected. There were 60 tons remaining for a late harvest. This vineyard primarily grows grapes for three types of

wine: Chardonnay, Merlot, and Zinfandel. This vineyard now sells to more than 46 different wineries.

The vineyard has a well-landscaped pond filled with recycled water. Carefully selected trees and shrubs surround the pond. Prior to becoming a successful vineyard, this land was a working dairy through the late 1980s. There were no vines anywhere on this dairy farm and methane gas was present in the groundwater. The farm had a large manure pit, which the Kunde's emptied and then filled with recycled water to create a pond. They use recycled Santa Rosa water for irrigation and frost control. Leaves are removed to expose the grape clusters to light and air movement that enhances both color, flavor and reduces the conditions for disease development and improves spray coverage. Today, Santa Rosa has made vast improvements in the quality of its recycled water and monitoring wells

were set up here to ensure that groundwater quality is not impacted.

LAFRANCHIE FARM— SANTA ROSA, CA

Arthur Lafranchie's family farm, established in 1962, used water directly from Laguna de Santa Rosa in 1964. Ten years later pipelines were installed, a pond was built, and recycled water delivery began. Between April 1 and October 1, the farm uses approximately 120 million gallons of tertiary-treated recycled water. The City of Santa Rosa treats the water and delivers it through low pressure underground pipes. Without this recycled water, this dairy and others like it would struggle to exist and could be forced to shut down their operations. The City of Santa Rosa provides the farms with recycled water because it is a cost-effective means of disposal. Through this partnership, agricultural open space is preserved by maintaining farms near the city. The issues of recycled water delivery logistics and seasonality, proximity of farms to waste treatment facilities, and whether future treatment plants will be specifically designed to produce recycled water are all relevant to California agriculture today.

Agricultural water reuse also provides a benefit to the public by maintaining local

farms with smaller dairy herds (that vary from 150 to 1,100 head), when compared with Central Valley large-scale (5,000-head) farms. Some farms have onsite storage, but most rely on the city to store the water until they can use it. This farm (and others like it) receives water at a minimum of 60 psi.

The Lafranchie farm uses genetically modified corn to decrease their herbicide usage and improve sustainability. The City of Santa Rosa works as a partner with farmers to help ensure there is no buildup of nutrients in both input and output water.

Farms get recycled water primarily to grow crops, but they also use recycled water for cleaning and washdown of the bedding areas. Reuse water cannot be used in the milking areas. Solids captured during washdown are separated from liquid waste through a screen and then ground into finer particles. The material is then composted and used as a bedding material. The remaining liquid that is pumped to a manure pond serves as fertilizer for the crops irrigated with recycled water. This is necessary because the high level of treatment required for the recycled water reduces its fertilizer value, to about one-third of the crop's requirement. When asked about the partnership with the city, LaFrankie reiterated that it was critical to his farm's survival.

Use of Recycled Water to Irrigate Edible Crops in Monterey County, CA



Robert Holden and **James Heitzman**, of the Monterey Regional Water Pollution Control Agency (MRWPCA), identified water reuse as the key to sustaining their \$3 billion per year agricultural and \$2 billion per year tourist industries in California's Salinas River Valley and Monterey County.

Monterey Regional Water Pollution Control Agency has provided recycled water to 12,000 acres of prime agricultural land around Castroville, in central California, since 1998, with funding through loans from the Bureau of Reclamation and the State Water Resources Control Board.

Within the Salinas Valley, the Castroville Seawater Intrusion Project provides research into a gravity system that delivers treatment plant production water to downstream edible crop farms (e.g., artichokes, lettuce, celery, cauliflower, broccoli, spinach, and strawberries) irrigated by sprinkler, drip, and some furrow irrigation. The experiments began in 1976 as randomized split-plot trials evaluated for microbes and viruses that might have been associated with the recycled water. Researchers found no natural virus detected in the recycled water. When they seeded virus into the production stream, there was a five-log (99.999 percent) removal of the virus during treatment plus about one log (90 percent) further reduction every 3 days after the water was used for irrigation.

The treatment consists of trickling filters and solids contact followed by chemical coagulation/flocculation, granular filtration, and gaseous chlorine disinfection. The water then flows by gravity to 112 turnouts, which provide water to 222 parcels of land.

Since the treatment plant was completed in 1998, no emerging viral or bacterial pathogens (*E. coli* 0157:H7, *Legionella*, *salmonella*, or *shigella*) have been detected in recycled water. The intermittent protozoan cysts that were detected represented a negligible health risk. Maximum *Cryptosporidium*, *Giardia*, and *Cyclospora* were 2.3, 0.3, and 0.034 cysts/L, respectively, as compared to 50/L for illness risk of 1 in 10,000 from drinking one cup of water. Crop quality and yield were unaffected, while some crops experienced some yield increases with the application of recycled water. Workers remained healthy and safe, and heavy metal concentrations were below detection limits as indicated by frequent medical examinations. The conclusion was that food crops irrigated with recycled water could safely be eaten raw. Growers used a combination of signage and a training video to alert the farm workers to the use of recycled water. Growers continue to monitor the fields and production water for pathogens at least 3-4 times per year.

The projects have been very successful, based on several measures. The project is the largest supplier of recycled water for food crop irrigation in the United States. More than 95 percent of the growers within the project area voluntarily use the recycled water. The coliform and pathogen test results show that recycled water compares very favorably with other irrigation waters. Many of the project growers have asked to have the recycled water system extended to land they have which is outside the current project boundaries. Finally, there have been some health issues on crops grown within the project area. Investigators from the Food and Drug Administration and the California Department of Health, once they have seen the coliform and pathogen data on the MRWPCA Web site (<http://www.mrwpc.org>), have immediately concluded that, "It's not the water" and have looked elsewhere for the source of contamination. The project will continue to be successful for three main reasons. First, the Water Quality & Operations Committee meets monthly and has consistently had safety as its number one goal. This committee consists of six growers, the county environmental health director, and the general managers of MRWPCA and of the County Water Resources Agency. Second, MRWPCA samples for more constituents and more often than required by regulation. Finally, there is a proactive approach towards the future exemplified by studying the effects of recycled water on soils, by sampling for emerging pathogens, and by looking at emerging contaminants. The project began with strong community support, but it requires continuous public outreach and education (classroom teaching, civic group presentations, event booths, tours, etc.), to maintain and increase understanding and acceptance of the project.

GALLO SONOMA VINEYARD'S COMMITMENT TO SUSTAINABILITY AND THE ROLE OF WATER RECYCLING

The wine industry is leading the way towards sustainability, according to Jim Collins of Gallo Wine. In California alone, there are currently 17 vineyards on 4,200 farmed acres that are practicing sustainable wine growing. Vineyards today view value chains (Porter 1985) in a much broader and more holistic way. The market is much more environmentally conscious now than in the past decades. The wine industry is constantly seeking new ways to fit into the sustainability trend.

One country that is leading the way in sustainability is Australia, which has a strategy of "sustaining success." The Australian wine industry is committed to the continual improvement of its environmental performance through the use of ecologically sustainable practices in all aspects of its operation. Good stewardship is critical to future success and will ensure that the needs and expectations of a wider community and its customers are met.

The wineries in the United States are also doing their part toward promoting environmental practices throughout the industry. There is a growing sentiment about sustainability certification and a broader worldwide acceptance of these certifications. Ernest and Julio Gallo Winery is a recognized leader in environmental stewardship and was

the first winery in the United States to receive the International Standards Organization's ISO 14001 certification. These standards are incorporated in an environmental management system, used at every level of the operation, and help improve the overall business. Gallo was instrumental in helping to develop and implement the Code of Sustainable Wine Growing Practices. The code promotes sustainable practices that are environmentally sound, economically feasible and socially equitable. These practices include minimizing the use of synthetic chemicals, fertilizers, and pesticides in the vineyard; recycling and reusing processed wastewater; creating new wetlands; and protecting existing riparian habitats to benefit a variety of plants and wildlife. All of these practices are incorporated into the management philosophy of Gallo Vineyards.



Reclaimed Water Use on Citrus and Other Crops in Florida

Phil Cross began by pointing out that, in 2006, Florida’s agricultural industry celebrated 40 years of applying recycled water.

In 2005, 465 domestic wastewater treatment facilities provided 660 MGD of reclaimed water for delivery to 438 recycled water systems. Florida is one of the leading states in using recycled water. Also in 2005, 92 MGD of recycled water irrigated 38,040 acres of agricultural land. While 15.5 MGD irrigated 13,914 acres of edible crops, the majority of the recycled water irrigated 24,126 acres of other agricultural crops. Citrus represents the primary edible crop irrigated with recycled water, but that water also irrigated a wide range of other edible crops, including tomatoes, cabbage, peppers, watermelon, cantaloupe, corn, eggplant, strawberries, pecans, peaches, plums, persimmons, okra, grapes, figs, peas, beans, herbs, squash, and cucumbers.

Farmers began applying treated wastewater in Tallahassee in 1966, and the Water Conserv II (<http://waterconservii.com/>) began in 1986. In 1988, the Reuse Program was inaugurated and, in 1989, Floridians adopted Chapter 17-610 of the Florida Administrative Code (FAC) and finally Chapter 62-610, FAC, in 1993. Florida’s water reuse rules, originated in 1989, are detailed, comprehensive, and consistent with national guidelines. These rules involve slow-rate land application systems, restricted public access, and irrigation of non-food crops, secondary treatment, basic disinfection before use, and setback distances. The use of reclaimed water to irrigate other agricultural crops (such as sod, forest products, pastureland, and feed, fodder, fiber, and seed



EDIBLE CROPS ARE APPROVED
IF THERE IS DIRECT CONTACT
OF IRRIGATION WITH EDIBLE CROPS

AND THE CROP IS PEELED, SKINNED, COOKED OR THERMALLY PROCESSED PRIOR TO CONSUMPTION...

crops) is addressed in Part II of Chapter 62-610, FAC. This part of the rule requires that the recycled water receive, at a minimum, secondary treatment and basic disinfection for irrigation of these crops. Rule 62.610-425 pertains to cattle grazing, outlining 15-day restrictions on milk cow grazing, no restrictions with high-level disinfection, and no restriction on other cattle. Recycled water is approved for non-food crops such as timber, biomass, sod, seed, pasture grass, and hay. Edible crops are approved if there is direct contact of irrigation with edible crops and the crop is peeled, skinned, cooked, or thermally processed prior to consumption with the responsibility for an inventory of crop and recycled water use up to the permit holder.

Approximately 49 percent of the water reuse volume is applied to public access areas such as parks, schools, residential lawns, and golf courses. There are 130 irrigated agricultural enterprises that account for 14 percent of the volume. Groundwater recharge requires 16 percent and an additional 14 percent feeds the industrial requirements. Another 7 percent addresses any other demands for recycled water. Of the 130 agricultural enterprises, 19 are farms growing edible crops using 16 MGD of the total 92 MGD and accounting for 13,914 of the possible 38,040 irrigated farm acres. Recycled water fees ranged from a flat rate per month of free to \$167.67 (average \$64.47) to a per 1,000-gallon charge of free to 70 cents (average 35 cents). These fees are currently under review.

TO DATE, THE APPLICATION OF RECYCLED WATER IN AGRICULTURE HAS ALLOWED THE PRODUCTION OF HIGH QUALITY FRUITS AND NUTS, VEGETABLES, AND FORAGE GRASSES.

The Mid Florida Citrus Foundation was formed in the 1980s as a non-profit organization to act as the research arm of Water Conserv II. Foundation goals focus on: maintenance of a safe and clean environment, evaluation of the long-term effects of citrus irrigation with recycled water, assessment of the economic viability of particular agricultural crops, and promotion of urban and rural cooperation. Water reuse applications up to 100 inches per year show no significant issues, have not promoted weed growth, tend to dilute solids, and maintain a high tree and fruit quality. Fluoride levels in recycled water are too high for seed germination of annual plants—but boron and phosphorus levels did not appear to promote issues with soil pH. To date, the application of recycled water in agriculture has allowed the production of high quality fruits and nuts, vegetables, and forage grasses.



Photo courtesy of NRCS



Solving Agricultural Irrigation Issues with Reclaimed Water: The Hawaii Experience

According to **Chauncey Ching**, water reuse in Hawaii is not an option, but a necessity, since the City and County of Honolulu are projected to run out of fresh water in 2023.

Water reuse in Hawaii’s agriculture is part of a complex set of issues, including but not limited to energy, fragile ecosystems, the needs of and obligations to an indigenous people and their culture, the high cost of production, technology development and testing, education, and linkages to practically all economic sectors. When you add a year-round growing season, rich renewable energy resources, and a small and isolated island state, Hawaii is an ideal venue to address water reuse. The population in Hawaii is steadily increasing as urban development continues on each main island of the Hawaiian chain. Populations are expected to expand significantly through 2025:

	1995	2025	% Change
U.S.	262,765,000	337,815,000	28.6
Hawaii	1,187,000	1,812,000	52.7

Source: U.S. Census Bureau

Water is Hawaii’s most limiting natural resource, from both an agricultural and general economic development perspective. While Hawaii is truly a subtropical paradise, drought is a major concern. Hawaii residents cannot focus their attention only on water as a limiting resource, but they need to address linkages to other resources that condition their future—primarily energy and land. Hawaii’s agriculture is in transition from large-scale plantation agriculture to smaller-scale and more diversified agriculture.

Hawaii has a year-round growing season. Without a vibrant agriculture in Hawaii, Hawaii residents will drown in their waste. Hawaii relies on fossil fuels for electricity more than any other state. Hawaii is the state with the widest range of renewable energy sources. An aging public utility distribution infrastructure increases the attractiveness of small-scale distributed systems. Two of Hawaii’s largest industries, the military and tourism (both of which are controversial), are major users of water and their uses are major factors in water public policy formulation and implementation.

In Hawaii, R-1 Water is tertiary treated recycled water that has undergone a significant reduction in viral and bacterial pathogens. This type of treated water can be utilized for spray irrigation without restrictions on use. R-1 is approved for spray irrigation of golf courses, parks, athletic fields, schoolyards, residential properties where managed by an irrigation supervisor, road sides/medians, and for vegetables and fruits that are eaten raw. R-2 Water is disinfected secondary treated recycled water. Spray irrigation is limited to evening hours, and requires a 500-foot

buffer zone between the approved use area and adjacent properties. Food crops that are irrigated with R-2 water must be either irrigated via subsurface systems or, if irrigated with spray irrigation, undergo additional processing before certified suitable for human consumption. R-3 water is non-disinfected secondary treated recycled water. There are strict limitations on its use. Currently, only a couple of ranches use this type of recycled water to irrigate pastures.

Recycled water makes sense for some crops, one of which is the seed industry—a major component of a transformed agriculture. Recycled water is a viable substitute for potable water in selected uses. When Hawaii residents link lessons learned to their island context, they find that recycled water can be an economic driver and not all crops are suitable for recycled water. Hawaii is a natural laboratory in which to develop, test, demonstrate, and evaluate novel approaches to water reuse in agriculture.



WHEN YOU ADD A YEAR-ROUND GROWING SEASON,
 RICH RENEWABLE ENERGY RESOURCES,
 AND A SMALL AND ISOLATED ISLAND STATE,
 HAWAII IS AN IDEAL VENUE TO ADDRESS WATER REUSE.



SECTION 4: Emerging Issues and Regulatory Approaches for Water Reuse

- P 32: EMERGING ISSUES FROM A GROWER'S PERSPECTIVE
- P 33: ARE PATHOGENS A CONCERN FOR RECYCLED WATER?
- P 35: HEALTH ISSUES RELATED TO USE OF RECYCLED WATER ON CROPS
- P 38: CALIFORNIA'S REGULATORY APPROACHES AS THEY PERTAIN TO AGRICULTURAL WATER REUSE

Emerging Issues from a Grower’s Perspective

Food safety and public perception are very important issues on the minds of growers today, according to **Dale Huss** of Ocean Mist Farms. Water quality is declining across the country and it is increasingly more difficult to meet the discharge requirements set by regional water quality boards.

Growers are concerned about increasing business costs due to the lack of good water quality and the added costs to irrigate and pump the water for their crops. Increasingly, water doesn’t have time to recharge and brine seeps into the water system. When you add the high cost of irrigating a crop to a slight change in market demand, long-lasting and devastating financial effects can occur to growers. An example of this demand shift occurred with the recent food safety concerns and the topic of recycled water regarding fresh spinach in September 2006. Recycled water was not implicated, though public perception about the safety of eating spinach resulted in a huge loss to farmers that almost shut down the entire spinach industry. Even 4 weeks after the spinach food safety issue was resolved, demand was only at 25 percent of normal. It may take a few years before the spinach industry can recover. This scare made retailers demand changes in general agriculture profiles and manufacturing programs. Today, all inputs into crops are under a magnifying glass, including irrigated water. Changes are expected to sweep through the industry from coast to coast. One way to deal with public perception is to combat ignorance. There have been many tests and studies about the use of recycled water, but the information is not widely available.

Seawater intrusion is a big concern for growers and further research and outreach could significantly help to reduce soil and water quality degradation. Many growers want to join together because of declining water quality. The key to success in overcoming some of the issues of declining water quality and food safety may be a team approach that has growers and other stakeholders working collaboratively on these issues. True team efforts may help share the increasing costs of declining water quality between the public and agriculture.



ONE WAY TO DEAL WITH PUBLIC PERCEPTION IS TO COMBAT IGNORANCE. THERE HAVE BEEN MANY TESTS AND STUDIES ABOUT THE USE OF RECYCLED WATER, BUT THE INFORMATION IS NOT WIDELY AVAILABLE.

Are Pathogens a Concern for Recycled Water?

Jeanette Thurston-Enriquez examined the pathogens likely to occur in reclaimed water, their reduction by various wastewater treatment practices, pathways of pathogen transmission, and research needs necessary for determining pathogen threats to public health.

A number of health risks can develop when humans come in direct, or indirect, contact with recycled water. These health risks are posed by regulated and non-regulated chemicals, pathogens, and emerging contaminants. Three water quality contaminants, pathogens, pharmaceuticals, and personal care products, have been identified as emerging challenges regarding the application of recycled water for irrigation. Food safety and human health experts have focused on human health effects of pathogens (see Table 1). These pathogens have been found in lakes, streams, rivers, and other water bodies where humans may come in direct contact. Water resource professionals are investigating the source, transport, fate, and persistence of pathogens in water and soil, as well as if these pathogens pose health risks to human populations.

Multiple factors contribute to transmission and persistence of pathogens in the environment. These factors include

- high numbers are shed in feces;
- increased survival in the environment;
- low infectious dose for humans;

- increased resistance to disinfection/treatment;
- multiple routes of transmission; and
- animal and humans can become infected by some waterborne pathogens and, therefore, there are multiple sources of these pathogens.

Hundreds of pathogens may be present in untreated wastewater and we cannot test for them all. Problems arising from testing include a lack of sensitive methods, the high cost, the amount of time required to test, and the need for special training. Nevertheless, we must ask ourselves, “How do we determine if pathogens are present in water?”

Often, levels of indicator bacteria are used to determine the microbial water quality of various water sources. Typically, these indicators attempt to assess the presence or degree of fecal contamination; however, these microbial indicators have deficiencies when used to detect the presence of pathogens. Pitfalls to using indicators as surrogates for pathogen detection include:

- indicator absence ≠ pathogen absence;
- indicator presence ≠ pathogen presence;
- pathogens can re-grow in aquatic environments and water distribution systems;
- presence of indicators is not necessarily indicative of a health threat; and
- no relationship exists between indicators and enteric viruses or protozoan pathogens.

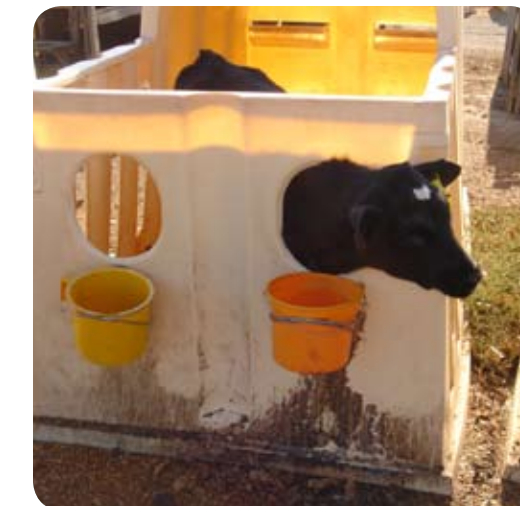


TABLE 1. PATHOGENS FOUND IN UNTREATED WASTEWATER

Pathogen	Disease/ Health Condition
<i>E. coli</i> O157:H7	<i>Diarrhea, kidney failure</i>
Salmonella	<i>Diarrhea, nausea, vomiting</i>
Cryptosporidium	<i>Diarrhea, vomiting, wasting disease</i>
Hepatitis A	<i>Fever, malaise, nausea, jaundice</i>
Adenovirus	<i>Respiratory disease, conjunctivitis, diarrhea</i>

Are Pathogens a Concern for Recycled Water? (cont'd)

TABLE 2. LEVELS OF MICROBES IN UNTREATED WASTEWATER

Microbe (per 100 ml)	Municipal Wastewater
<i>E. coli</i>	104–105
Salmonella	< 8,000
Enteric Virus	< 103
Cryptosporidium	10–103
Entamoeba Histolytica	< 500

TABLE 3. TREATMENT EFFECTIVENESS FOR A VARIETY OF MICROBES

Type of Treatment	% Reduction of Various Microbes
Primary	5–40
Trickling Filters	18–99
Activated Sludge	25–99
Anaerobic Digestion	25–92
Waste Stabilization Ponds	60–99
Tertiary (flocculation, sand filtration, etc.)	93–99.99

Adapted from Geldreich (1996)

Table 2 lists examples of the levels of microbes in untreated wastewater and Table 3 lists the reduction of microorganisms by conventional wastewater treatment practices. When testing wastewater, it is recommended to use a suite of indicators that reflect a broader spectrum of potential pathogens.

Instead of the traditional use of total coliforms or *E. coli*, assessing the presence of more resistant microbes such as enterococci and Clostridium may be better indicators of more resistant pathogens. Also, determination of water quality over time instead of instantaneous samples will reduce the threat of pathogens. The occurrence of pathogens in a given water supply is variable depending on season and environmental inputs.

Concerning reclaimed water treatment, there are many applicable technologies. Examples of these technologies include: ultraviolet light (UV), membrane filtration, ozone, and chlorination. Research shows that UV is capable of inactivating microbial pathogens; however, information on the effectiveness of newer UV technologies to reduce pathogens is lacking. Membrane bioreactors and reverse osmosis were shown to meet drinking water standards and California standards for recycled water. Finally, ozone and chlorination are proven technologies for addressing microbial contamination. However, there needs to be continued work to establish the effectiveness of these technologies as viable options for pathogen reduction.

Reclaimed water can be an important water source for crop irrigation especially in arid climates. Practices that can reduce pathogen transmission during crop irrigation would include

reducing the potential for air transport by irrigating crops with drag tubes or drop sprinkler heads. When using spray irrigation, being conscious of weather conditions that may help to disseminate contaminated water is important. Also, understanding the microbial quality of the water is important for determining the water's best use.

To improve understanding of the health risks involved with pathogens in water, researchers need to determine the fate and dissemination of pathogens in the environment. We also need to improve the ways we detect pathogens in water samples. Since it is not possible to assess the presence of every possible pathogen in a water source, we must develop appropriate indicators to signal their potential presence. Given the high cost of analysis, new sampling strategies must reflect the most appropriate frequency and location for sample collection. We need to assess current and newer treatment technologies for reduction of pathogens in reclaimed water. These technologies, however, must not only be effective at pathogen reduction but must also be economical. Finally, we need to reconsider designation of appropriate uses for impacted water bodies and conduct risk assessments for human health concerns. Research needs include determining pathogen occurrence in recycled water, assessing or developing technologies to reduce pathogens in recycled water in order to achieve recycled water standards, and human risk assessments as a basis for choosing the best use for recycled water.

Health Issues Related to the Use of Recycled Water on Crops

Laura Kennedy acknowledged that among emerging contaminants, unregulated chemicals include pharmaceuticals and personal care products. These and other contaminants pose considerable challenges to determining the health risks because there are no regulatory guidelines or limits, often we have limited toxicity data, and because risks are perceived but not always measured.

Concerns regarding unknown or perceived health risks can be an obstacle for use of recycled water for irrigation of agricultural crops. However, these concerns may not be based on actual scientific or technical reasons. In order to determine whether the use of recycled water on agricultural crops is a legitimate public health concern, the health risks need to be evaluated. Risk assessment is a tool that can quantify the potential for adverse health effects. For decades, regulatory agencies have used risk assessments to make informed, defensible management decisions regarding drinking water, wastewater, and environmental remediation. The key components of any risk assessment are identifying the hazards and estimating realistic exposures to humans in order to quantify the risk. By definition, risk is dependent on both hazard and exposure, so if either the exposure or hazards are sufficiently low, the risk will be negligible.

Several exposure scenarios were presented that could occur by using recycled water on agricultural crops and several approaches to quantify the potential health risks were explored. Exposure to chemicals in recycled water could occur through both direct and indirect pathways. The magnitude of exposure depends on the nature of the exposure and the concentration of the chemical in the water. The health risks, in turn, are dependent on the magnitude of exposure and the toxicity of the chemical. After quantifying the health risks, the significance of those risks are evaluated. One approach is to compare the quantified health risks to an accepted standard risk level. While this approach is straightforward, it may not provide sufficient context for decision-makers. Another approach is to compare the health risks from using recycled water on agricultural crops with health risks from other common activities to provide a relative comparison of risk. These evaluations demonstrate how risk assessment can address concerns about health effects associated with using recycled water on agricultural crops.



CONCERNS REGARDING UNKNOWN OR PERCEIVED HEALTH RISKS CAN BE AN OBSTACLE FOR USE OF RECYCLED WATER FOR IRRIGATION OF AGRICULTURAL CROPS. HOWEVER, THESE CONCERNS MAY NOT BE BASED ON ACTUAL SCIENTIFIC OR TECHNICAL REASONS.

Health Issues Related to the Use of Recycled Water on Crops (cont'd)

TABLE 4. PHARMACEUTICALS IN TREATED RECYCLED WATER

Drug	Secondary		Tertiary	
	RANGE (NG/L)	MEAN (NG/L)	RANGE (NG/L)	MEAN (NG/L)
ACIDIC				
Diclofenac	<10-62	40	<10-110	40
Ibuprofen	<10-320	100	<10-37	13
BETA-BLOCKER				
Metoprolol	9-160	56	<10-130	35
Propranolol	5-33	15	<10-61	21
ANTIBACTERIAL				
Ciprofloxacin	<30-860	230	<30-180	87
Sulfamethazine	<30-500	100	<30-450	110

Sources: Huang and Sedlak 2001; Kolodziej et al. 2003; Grosset al. 2004; Sedlak et al. 2005.

Unregulated chemicals have been detected in wastewater effluents, generally at trace concentrations (Table 4). However, public scrutiny and concern is growing as these emerging contaminants continue to appear in drinking water supplies and other water sources:

“Various medications are detected in drinking water that has been derived from treated sewage. The health risk, if any, is unknown.”—LA Times, January 30, 2006;

“Drug traces found in Grand Rapids drinking water.” —U.S Water News, April 2007.

We know little about the impact of these pharmaceuticals on human health. However, recent investigations show deleterious effects of these or other pharmaceuticals on fish and other aquatic species. New risk assessment tools will explore the potential risk of these unregulated compounds on humans or other species.

The EPA and many states widely use risk assessment studies and practices. Risk assessment also is the basis of regulatory guidelines for drinking water and wastewater. Overall risk is a function of toxicity and exposure: Risk = Exposure x Toxicity. Human exposure, therefore, does not directly result in risk. The overall risk is dependent on concentration, the exposure scenario, and toxicity (a measure of response to different dosages).

What are some possible exposure scenarios that relate to using recycled water in agriculture? Direct exposure poses a risk for agricultural workers. Field workers may come in direct contact with water or plants that carry emerging contaminants. Indirect exposure also can occur for crop consumers when they purchase raw vegetables or fresh-cut vegetables and consume them without proper cleaning. Ecological exposures are considerable and effects are highly variable across species.



FIELD WORKERS MAY COME IN DIRECT CONTACT WITH WATER OR PLANTS THAT CARRY EMERGING CONTAMINANTS.

INDIRECT EXPOSURE ALSO CAN OCCUR FOR CROP CONSUMERS WHEN THEY PURCHASE RAW VEGETABLES...WITHOUT PROPER CLEANING.

Quantifying the risk posed by direct exposure requires knowledge of the concentration of pharmaceuticals in recycled water. Assumptions also must be made regarding the intake, including the number of days per year of exposure, absorption through the skin, and the possibility of incidental ingestion. Toxicity data for dose-response and threshold effects of dosages generally are not available for these compounds.

Quantifying the risks posed by indirect exposure adds complications regarding the concentration in edible portions of crops and assumptions about crop uptake of these compounds. It is possible to use partition models

to separate soil, water, and plant components. Within the plant component, one can further separate potential concentration in leaves, fruit, and roots. Independent evaluations of concentrations in soil and water may include exploring the effects of soil or water chemistry on compounds.

Finally, we can explore the relative risks posed by alternative routes for pharmaceutical contact. These relative risks evaluate possible contact through diet, drinking water, or airborne compounds. (Fig. 2)

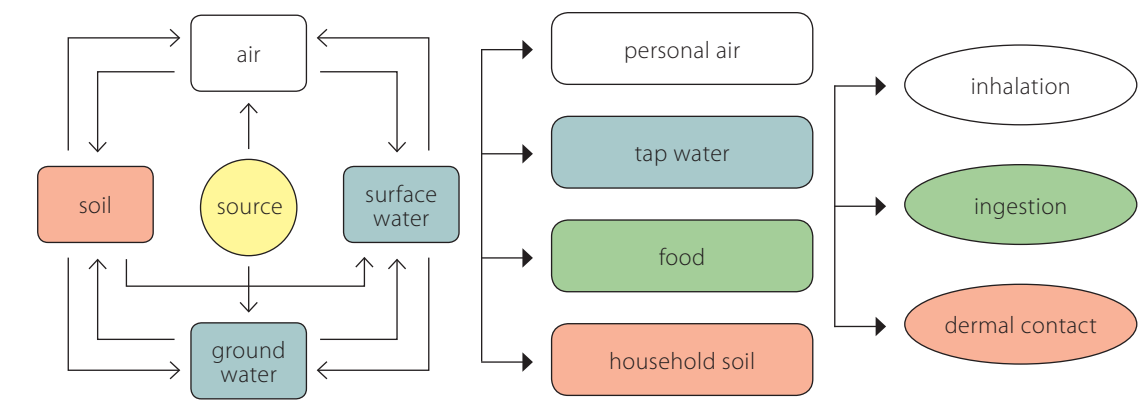


Figure 2. Exposure Scenarios (from CalTOX, A Multimedia Total Exposure Model For Hazardous Waste Sites, McKone, 1994).

California’s Regulatory Approaches as They Pertain to Agricultural Water Reuse

TABLE 5. CRITERIA DEVELOPMENTS SINCE 1977.

Date	Regulatory Approach
1977	Criteria based on best available treatment for highest exposure use and proportionally less treatment as exposure is reduced
1977	Pomona Virus Study (PVS)
1980s	Developed guidelines for discharge treatment based on risk analysis—consistent
1988	Direct filtration policy based on PVS
1990s	Two microbial risk assessment papers (Tanaka et al. 1998, and Asano et al. 1992) indicate risk associated with various uses is < 10 ⁻⁴
Since 2000	Latest CCR Title 22 WRC—accommodates new filtration and disinfection technologies and implements the PVS and a 10 ⁻⁴ risk goal

California has a broad range of regulatory approaches to ensure the safety of water resources in areas where recycled water is applied, according to **Robert Hultquist**, California Department of Health Services.

Table 5 lists some major regulatory developments of the past 30 years. The California Water Recycling Criteria (WRC), established in the 1970s, were based on best available treatment for the highest quality (relatively unrestricted use) irrigation water and on proportionally lower treatment requirements as public exposure is reduced and restrictions on use increase. In the 1980s, California developed guidance for the treatment of wastewater discharges based on a risk assessment that validated the WRC for the various irrigation uses. In the 1990s, two microbial risk assessment papers (Tanaka et al. 1998, and Asano et al. 1992) indicated that the annual risk of infection from consuming crops irrigated with reclaimed water meeting the WRC was less than 10⁻⁴ (one in 10,000). California adopted this level as the maximum level of acceptable risk when preparing the last version of the WRC. California recognizes that this is a relatively stringent risk goal, but considers it achievable and appropriate for a controllable public exposure.

A key consideration is that the WRC address only public exposure related directly to the reclaimed water or to the crop. They do not address occupational exposure or threats to the environment.

California has specific criteria for recycled water applied to agricultural products. In general, criteria for agricultural irrigation water differentiate between crops eaten raw, food crops not irrigated with recycled water, nursery stock and pasture, and those crops that have no direct food contact, such as vineyards (Table 6). The reliance on restricting the type or end use of the crop, method of irrigation, timing of harvest, and method of harvest for lower levels of reclamation treatment/quality is problematic. Crops have been embargoed pending the results of microbial monitoring when growers disregard the restrictions. California agencies may lose confidence in the regulatory approach if numerous violations occur.

Most states do not have irrigation water standards for recycled water. Three states have notable standards for recycled water used in irrigation (Table 7).

What is an acceptable risk of infection? The acceptable risk goal is a policy decision set by each jurisdiction. California established a water recycling criteria of 10⁻⁴ annual risk of infection for all uses. State and federal drinking water goals and World Health Organization guidelines for recycled water for agricultural irrigation cover additional considerations for risk infection. Examples of acceptable risks involve 10⁻⁶ (one in one million) daily risk of infection, or 10⁻³ (one in one thousand) annual risk of infection.

What are the most effective criteria to prevent or minimize risk of infection when using recycled water in agriculture? Criteria should be science-based and should achieve the stated risk goal. Effective criteria address treatment and quality, recognize operational limits, focus on reliability of standards, and promote regulator, health agency, medical community, public, and policymaker confidence. Use area restrictions are problematic for expanding recycled water for agricultural irrigation. Moreover, criteria address only direct exposure to recycled water or the crop—more information is needed to develop criteria for indirect exposure. Crops irrigated with recycled or discharge impaired water are shipped across state and international boundaries. Individual jurisdiction recycled water standards have not been reconciled with this commerce.

Finally, there is a need to reconcile differences among standards developed for individual jurisdictions. These differing standards produce serious challenges for agricultural producers and the consuming public.

TABLE 6. CRITERIA FOR AGRICULTURAL IRRIGATION

Agricultural Product or Use	Treatment Level	Quantitative Standards
Crops eaten raw with recycled water contact	Secondary, Filtration, Disinfection	turbidity < 2 NTU average; 450 CT or 5-log virus reduction; ≤2.2 total coliform/100 mL median; 23 total coliform/100mL in 1 sample/mo.; ≤ 240 total coliform/100 mL always
Surface irrigation of food crops with no recycled water contact	Secondary, Disinfection	≤2.2 total coliform/100mL median; 23 total coliform/100mL in 1 sample/mo.
Nursery stock, sod farms, pasture for milk producing animals	Secondary, Disinfection	≤23 total coliform/100mL median, 240 total coli/100mL in 1 sample /mo.
Surface irrigation of seed crops, fiber, fodder (not food) crops, pasture for animals not producing milk, tree farms, vineyards and orchards with no food contact with recycled water	Secondary	

TABLE 7. BEST FOOD CROP IRRIGATION WATER STANDARDS

Colorado	Texas	California
Primary, secondary, and effective filtration	Primary, secondary, and effective filtration	Primary, secondary, and effective filtration
Disinfection to an acceptable risk	20 fecal coliform/100 ml	126 E. coli/100 ml 2.2 total coliform/100 ml

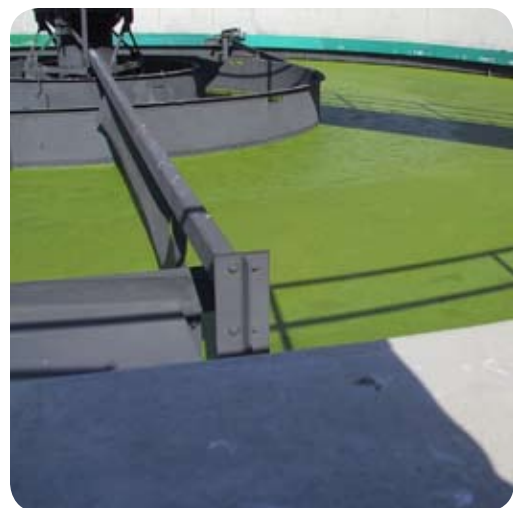


Photo courtesy of NRCS



SECTION 5: Critical Issues in Project Development

- P 42: THE ADEQUACY OF TECHNOLOGY TO ACHIEVE WATER QUALITY GOALS
- P 43: MANAGEMENT OF PUBLIC PERCEPTION
- P 45: ECONOMICS OF WATER REUSE
- P 49: SOIL SALINITY ISSUES AND FARMING SUSTAINABILITY RELATED TO CROP YIELD AND QUALITY



The Adequacy of Technology to Achieve Water Quality Goals

George Tchobanoglous, University of California–Davis, evaluated the adequacy of technology to achieve water quality goals by outlining important considerations related to water reuse.

He focused on treatment process design, facility design, and location. He elaborated the sodicity issues associated with waste treatment streams and provided a perspective on the future of agricultural reuse. Removal of the conventional constituents: biological oxygen demand (BOD), total suspended solids (TSS), nutrients, and pathogens occurs through conventional and membrane bioreactor technologies. Tchobanoglous described sequencing batch reactors and the BIOLAC® process, with the caveat that the depth of the clarifier and the clarifier design are critical to wastewater TSS removal—deeper is better. Critical stages of membrane bioreactor function are primary wastewater filtration and tailwater disinfection by both chlorine and UV. California has set “Not to Exceed” discharge limits related to disinfection efficacy. These limits are:

TABLE 8. DEFINITION OF NOT TO EXCEED DISCHARGE LIMITS

Exceedances Per Year	Probability Percent
6	98.3
3	99.2
0.33 ²	99.9

² Recommended average frequency for acute and chronic criteria.

The importance of variability in the selection of design values relates to the efficacy of removal. Before disinfection and after cloth media filtration, design principles have included other efforts to remove total dissolved solids (TDS) that include nanofiltration and electrodialysis. The sodicity of inflow water can affect the efficacy of nanofiltration. Reverse osmosis can remove trace constituents and TDS. Reverse osmosis, however, has its own difficulties—stability of the process, the influence of sodicity, and special constituents, such as boron and brine management.

Removal of TDS from production water will reduce the potential discharge of sodic waters into irrigation canals, streams, and groundwater. TDS could be removed from treated wastewater or removed at the household level. Use of potassium instead of sodium chloride for softener regeneration, using exchangeable ion exchange canister softening units, or a combination of measures could help the TDS discharge load.

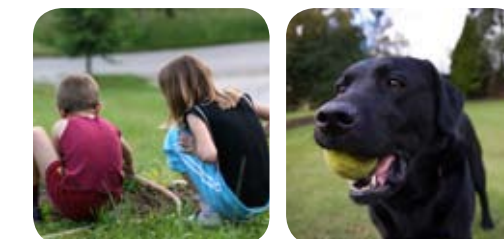
Taking the perspective of the future of water reuse in agriculture—with new TDS requirements, treated wastewater is suitable for agricultural irrigation. Treatment plant location is a fundamental problem, as inappropriate siting of treatment plants leads to high distribution costs. In the future, satellite and decentralized treatment will become more common and combined wastewater management options will include irrigation and groundwater storage.

Management of Public Perception

Influencing public perceptions about recycled water use is a challenge, stated **Mark Millan** from Data Instincts™. People do not automatically believe the scientific basis for using recycled water;

there is a “yuck” factor that is not easily overcome and there are often lingering doubts about safety and water quality. There appears to be an instinctive mistrust of government when it comes to issues of potential environmental and health risks that may be associated with recycled water. This leads us to wonder if we can effectively manage people’s perceptions about irrigating food crops and school playfields. Public outreach firm Data Instincts™ conducted water reuse surveys in three California cities and found 67 percent of respondents reported no concerns about the area’s recycled water projects. Ninety-two percent of the survey respondents believe using recycled water will have an overall positive effect on their community—with greater potential environmental benefits, potable water offsets, and conservation. Communities did raise some concerns in follow-up

interviews regarding water quality, public safety, and impact to children’s health when playing on grass irrigated with recycled water. They were also concerned about potential odors during irrigation, possible health and environmental effects of both pathogens and pharmaceuticals; potential crossed pipe connections with potable water sources and possible tainting of potable supplies; as well as risks to pets, birds, and wildlife. Potential customers of recycled water have water quality concerns that include issues of safety, smell, bacterial content, and how the recycled water may affect equipment. A significant question revolves around public perceptions of the usage of recycled water. Residential areas and school officials were far more concerned about public reaction than other potential users. Homeowners have perceptions about water reuse that



COMMUNITIES DID RAISE SOME CONCERNS IN FOLLOW-UP INTERVIEWS REGARDING WATER QUALITY, PUBLIC SAFETY, AND IMPACT TO CHILDREN’S HEALTH WHEN PLAYING ON GRASS IRRIGATED WITH RECYCLED WATER.

Management of Public Perception (cont'd)

their property values may decrease. Transparency in communication and proactive outreach are critical. Using a customer relationship management approach educates and supports users and significantly helps overcome the stigma that highly treated reclaimed wastewater used in agricultural fields was recently sewage. In-depth meetings with new users and also communicating with their local community about this new water source are two ways to build trust. Creating demand without “selling” recycled water is key—it is important to not hide anything, but be honest and explain the water dilemma. Help users be familiar with emerging studies and provable facts. A question to be answered is, “Does trust trump disgust?” Can we manage perceptions about the use of recycled water for agricultural irrigation? Can we help the public understand the complexities of reclaimed or recycled water quality in terms of risks relative to other hazards we face?

Water reuse purveyors need to provide water branding and education, explain relative risk, and where they are heading, in terms of demand and recycled water usage. Commercial usage is often understated, but communities want to know that the water is safe to use and will not harm their natural environment. Purveyors need to educate the communities that they will be assigning the right water to the right users in a safe way—recycled water can be useful in certain areas and for certain purposes but is not meant to be used everywhere.

In 1987, the Monterey Regional Water Pollution Control Agency (MRWPCA) conducted an extensive study in Monterey County, CA, to demonstrate that recycled water was as safe as well water when used to irrigate food crops. However, the concern from the grower’s perspective is ongoing. Fear of public perception about the use of recycled water for irrigating their food products is unsettling at times for growers. In Redwood City, CA—even though many experts said recycled water is completely safe for landscape irrigation—a small group of citizens still struggled with the concept, with much of their concern based on emotion rather than science.

As more recycled water projects are implemented, new agricultural users fear episodes like the recent *E. coli* scare involving spinach grown in the Salinas/Hollister, CA, area. No grower or producer wants to be in the position of Natural Selection Foods, the company that grows and packages fresh greens in San Juan Bautista, CA. What, if anything, can assuage the concerns of potential users? Lawrence Jaffe, a grape grower who uses recycled water in Sonoma County, CA, believes that, “Recycled water has proven itself safe. The stigma lies mainly with farmers, since consumers do not generally question the source of irrigation water.” Is he right? Perceptions about water quality are critical to public acceptance. Being customer-centric and responsive to customer perceptions and educational needs can lessen the headache for potential agricultural recycled water users.



PURVEYORS NEED TO EDUCATE THE COMMUNITIES THAT THEY WILL BE ASSIGNING THE RIGHT WATER TO THE RIGHT USERS IN A SAFE WAY—REUSE WATER CAN BE USEFUL IN CERTAIN AREAS AND FOR CERTAIN PURPOSES BUT IS NOT MEANT TO BE USED EVERYWHERE.

Economics of Water Reuse

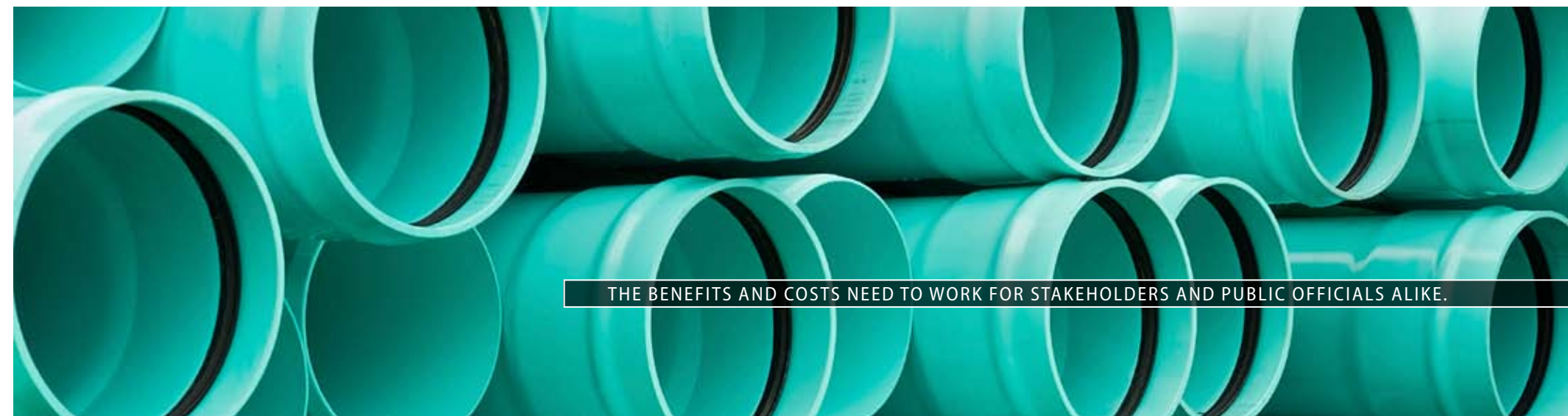
Bob Raucher, Stratus Consulting, Inc., described the economic analysis of sustainable water reuse as an economic framework, recently completed and published for the WateReuse Foundation (WRF project 03-006).

The project’s objectives include developing an economic framework that includes and describes all the relevant benefits and costs of reuse; ensuring broader recognition of all the applicable benefits (and costs) of water reuse; and working with stakeholders, public officials, and water agency professionals. Working with these groups, it is critical to develop a “common parlance” for benefits (and costs), so that technicians (economists and engineers) do not talk past public officials, customers,

constituencies, and stakeholders. The benefits and costs need to work for stakeholders and public officials alike.

The economic framework is, in essence, a tool to help water agencies and other water sector professionals conduct a benefit-cost analysis (BCA) of reuse or desalination investments. The economic framework is thus designed to help water managers identify, estimate (to the degree feasible and meaningful), and effectively communicate the full range of benefits associated with water reuse projects or related activities.

One of the core economic issues associated with water reuse includes the understanding of whether new water supplies from reuse are worth the high cost. From a financial cash flow perspective, reuse projects may not seem fiscally sound—high costs mean high cash outflow and revenue streams are



THE BENEFITS AND COSTS NEED TO WORK FOR STAKEHOLDERS AND PUBLIC OFFICIALS ALIKE.

Economics of Water Reuse (cont'd)

FOR MANY REUSE PROJECTS, THE BENEFITS (I.E., VALUE) TO SOCIETY MAY OUTWEIGH THE COSTS. ECONOMIC BENEFITS ARE NOT THE SAME AS REVENUES. ECONOMISTS ARE EMBRACING A BROADER, “SOCIAL COST” PERSPECTIVE THAT REFLECTS FULL “VALUE” OF REUSE OR OTHER OPTIONS.

limited (and often net revenues may be negative). Revenues are often limited because purveyors are hamstrung with current potable price structures (given pressures to price recycled water below the price of potable water and potable supplies are often underpriced) and recycled water sales volumes often are limited due to the siting of potential customers relative to the location of treatment plants.

For many reuse projects, the benefits (i.e., value) to society may outweigh the costs. Economic benefits are not the same as revenues. Economists are embracing a broader, “social cost” perspective that reflects full value of reuse or other options. In terms of social cost accounting, there is a broad range of benefits and a large, diverse set of beneficiaries. When benefits are greater than costs, identifying benefits and beneficiaries may be difficult; and some key beneficiaries may be outside of the

rate paying area. Water reuse may generate many important types of benefits. When there is a large suite of benefits, many may not be well recognized or are obscured, and/or hard to quantify and value (full social cost accounting). By contrast, costs are usually obvious. Benefits may include local control, drought proofing, in-stream flow improvement, reduced wastewater discharge, and creating wetlands. Positive externalities become a valid basis for seeking cost sharing and subsidies. Some benefits are dispersed across political or district jurisdictional boundaries with some beneficiaries not engaged in the deliberations. A disconnect exists between those who benefit and those who pay.

These factors make it very difficult to justify or build public/political support for reuse or desalination projects that, in reality, often have many important net social benefits to offer. Raucher

discussed the types of benefits that may be especially relevant for reuse projects, and reviewed the potential high value of some of these reuse project benefits.

The concept of a Triple Bottom Line (TBL) can be a useful approach for trying to reflect a broad array of all benefits (and costs). The following three bottom lines are identified to reflect:

- financial results (cash flow, revenues and costs);
- social outcomes (e.g., employment, equity); and
- environmental (e.g., instream flows, fisheries).

In essence, a TBL equals an initial step of a social benefit-cost analysis, identifying all benefits and costs, both internal and external. Australia and New Zealand are places where the TBL is routinely applied to water projects—they run and regulate their water and wastewater agencies as if they were a business, even though these entities are owned by the public sector and serve a public trust.

Products of the WRF project include a user-friendly toolkit with guidance (a “why” and “how to” user’s guide), case studies as practical examples, templates, and a spreadsheet model. The intent of these products is to be generic, but focused and practical. Each reuse project has unique properties, so the model is not a plug-and-play, or a one-size-fits-all model. Rather it is a “framework” or “tool” to organize, develop, and communicate credible analyses of benefits and costs (<http://watereuse.org/Foundation>).

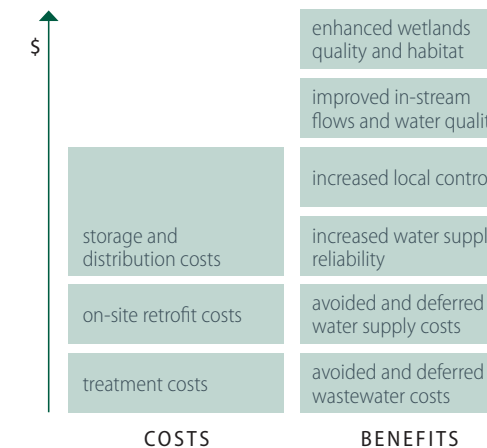


Fig. 3. Counting All of the Benefits of a Water Reuse Project

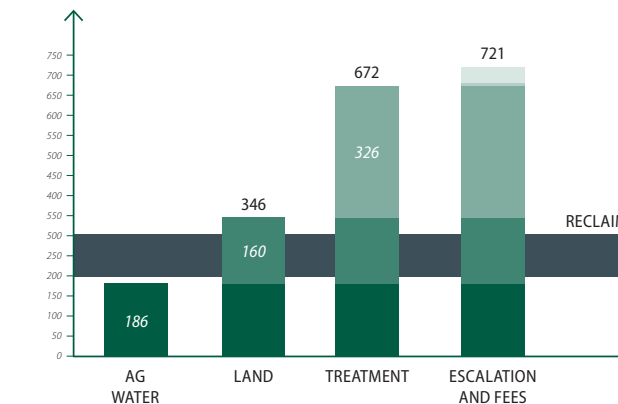


Fig. 4. Apples-to-Apples Baseline Comparison of Reclaimed Versus Agricultural Water

A critical key to a good economic analysis is to ensure proper definition of the baseline of “without project” versus “with project.” Defining the baseline can be challenging—for example, there is a growth and development requirement element in defining a baseline that reflects likely future realities. It is a complex issue of where alternative water supplies would come from, and what it would really cost. Or, baseline equals what happens if more water is not added to the community supply portfolio. Stakeholder baselines may reveal disagreement over core assumptions or goals (e.g., growth).



Economics of Water Reuse (cont'd)



The Implications of Recycled Water Use for Organic Certification

Kevin McEnnis stated that the organic movement during the 1960s was a reaction to public distrust of science. Organic farming is one of the largest growth sectors in agriculture, growing 20 percent per year. Farmers choose organic farming because they are interested in sustainability and consumers choose organic products because they are interested in food safety for themselves. McEnnis stated that recycled water is easy to use in organic farming—but different certification boards have different attitudes towards its use. No regulation exists for water in the national organic program—but organic standards can change. “We need to show the public that we are on top of it—and come up with a very transparent process,” he said.

Some key sources of value (benefits) of reuse include postponed or avoided costs (cost offsets) compared to baseline water supply and/or wastewater control options; portfolio management and supply reliability; diversifying risk across water supply options; local control (compared to imported supplies); positive externalities (environmental and social benefits); preserving and enhancing freshwater stream flows; and wetland restoration or creation.

Potential benefits to agricultural users of recycled water include increased reliability of source water for irrigation. With recycled water, farmers are independent of drought cycles, independent from import or extraction limits, and reuse may bypass or ease infrastructure bottlenecks. Farmers could potentially feel less pressure to sell or transfer water rights to urban users, and recycled water sources may enable the sale of valuable source water assets. In addition, farmers could benefit from the fertilizer value of recycled water.

How do economists value increased reliability relative to drought insensitivity? It becomes part of the “portfolio management” approach. Perhaps a 50 percent premium should exist for reclaimed versus some drought-sensitive river water sources. Reuse may also be considered greener to use even if reclaimed costs more dollars per acre-foot. One indication of the value of added reliability is based on urban area householders’ willingness to pay more

POTENTIAL BENEFITS TO AGRICULTURAL USERS OF RECYCLED WATER INCLUDE INCREASED RELIABILITY OF SOURCE WATER FOR IRRIGATION. WITH RECYCLED WATER, FARMERS ARE INDEPENDENT OF DROUGHT CYCLES, INDEPENDENT FROM IMPORT OR EXTRACTION LIMITS, AND REUSE MAY BYPASS OR EASE INFRASTRUCTURE BOTTLENECKS.

to avoid drought-related water use restrictions. This value could reach perhaps \$100+ per year per household, which translates to perhaps \$4,000 per acre-foot or higher. The drought reliability value to agricultural users is unknown.

Recycled water often is relatively expensive, but it often provides some relatively unique, yet important, types of benefits. Some of these benefits may have very high values. Agricultural users may realize particularly important benefits. When trying to identify the value of water reuse, a financial analysis perspective is too limited and a broader economic or TBL perspective is needed.

Soil Salinity Issues and Farming Sustainability Related to Crop Yield and Quality

Increasing demands on our fresh water supplies means that irrigated agriculture will need to reuse drainage water and treated municipal and industrial wastewaters for irrigation, according to **Don Suarez**, ARS Riverside.

These waters are usually higher in salinity (primarily sodium and chloride) than the initial fresh waters. The water generally contains increased levels of alkalinity (thus elevated pH) and often contains elevated concentrations of minor elements, such as boron, that may adversely affect crop growth. Drainage water reuse reduces the volume of drainage water requiring disposal (Fig. 5). It reduces the area affected by shallow water tables, optimizes land productivity, and reduces nutrient and

contaminant discharge. Water quality issues associated with reuse include organic contaminants (pharmaceuticals, pesticides, etc.), pathogens (bacteria and viruses), and inorganic components. Inorganic components are also an issue for infiltration and/or crop yield where elevated pH (typically above 8.5), elevated alkalinity (resultant from decomposition of organic residues in the treatment process), increased salinity (especially Na and Cl) (Fig. 6), lower Ca/Mg ratio, higher sodium absorption ratio (SAR), higher nitrate concentrations, presence of colloids, and potentially toxic ions (e.g., B, Mo, and Se).

Despite limitations, proper crop selection and management practices enable beneficial reuse of these waters with minimal reduction in yield. Where winter rains and leaching occur, soil salinity is reduced during the early stages of crop growth, which are generally the most salt-sensitive stages. Advances in

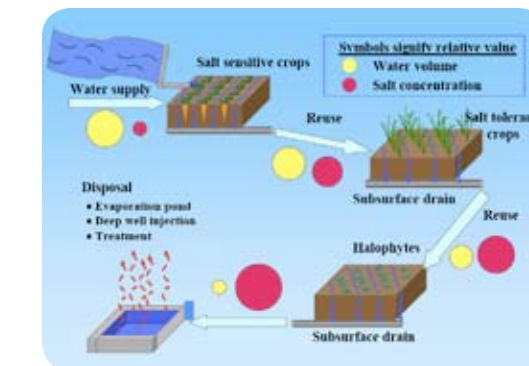


Figure 5. Schematic Plan for Multiple Sequential Uses of Drainage Water for Maximum Utilization of the Resource and Reduced Drainage Volume.



Soil Salinity Issues and Farming Sustainability Related to Crop Yield and Quality (cont'd)

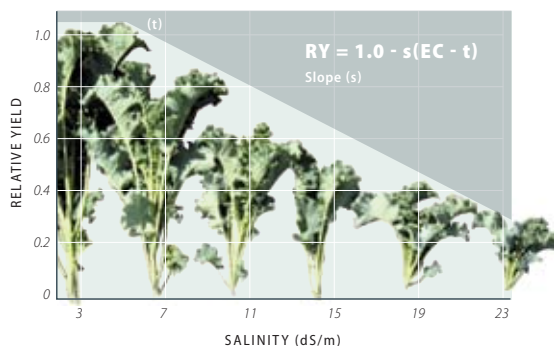


Figure 6. Relative Yield of Kale as a Function of Soil Salinity

knowledge of plant salt response suggest that increased salt tolerance can be developed for salt-sensitive and moderately salt-tolerant crops, such as rice and tomatoes, and that high quality forage can be grown with saline water.

Traditional plant breeding and molecular techniques are particularly promising where yield reduction relates to specific ion toxicity to sodium and chloride. Crop selection should be based on profitability rather than relative yield loss. Because salt-tolerant crops are generally lower-value crops, and often lower-yielding crops, it should not be assumed that they are optimal for irrigation with moderately saline waters. Despite some yield loss, moderately salt-tolerant crops, such as alfalfa, may out produce more salt-tolerant crops, such as wheatgrass, at salinities up to 15 dS/m. Increased product quality may be among the benefits of moderate salt stress to crops.

Many plants adapt to salt stress by accumulating more secondary metabolites, such as soluble solids, sugars, organic acids, and proteins, thus increasing quality and marketability. For example, salinity stress increases the sugar and dissolved solids content of tomatoes and melons (Table 8); increases the content of beneficial antioxidant compounds in strawberries; and increases the oil and lesquerolic acid in lesquerella (Table 9). Sustainable reuse of these waters will require careful monitoring of field conditions. New remote sensing technology can provide rapid and inexpensive detailed field salinity assessments and evaluate the need for amendments. Reuse of these waters provides not only beneficial utilization, substituting for high quality waters, but also minimizes the environmental impact associated with direct discharge of wastewaters.



MANY PLANTS ADAPT TO SALT STRESS BY ACCUMULATING MORE SECONDARY METABOLITES ... THUS INCREASING QUALITY AND MARKETABILITY.

FOR EXAMPLE, SALINITY STRESS INCREASES THE SUGAR AND DISSOLVED SOLIDS CONTENT OF TOMATOES AND MELONS...

TABLE 8. FRUIT AND VEGETABLE CROPS - CONSTITUENT IMPROVED BY SALINITY

Common Name	Constituent Improved
Eggplant	Increased sugars, improved post-harvest firmness
Melon	Increased TSS, firmness, improved post-harvest firmness
Onion	Reduction in bulb pungency
Pear	Increased TSS, higher % healthy, disease-free fruit
Pepper	Increased lycopene
Squash	Increased TSS, fruit firmness
Strawberry	Increased sugars, color, flavor
Tomato	Increased TSS, Vitamin C, β-carotene, sugars, phenolics, firmness. Increased acidity. Improved fruit shape index (more spherical fruit)
Watermelon	Increased TSS, glucose, fructose and sucrose

In crop growth experiments conducted by ARS scientists using saline water, chard, salad greens, kale, and pac choi all have potential for use in drainage water reuse systems, provided salinity is moderate and irrigation practices are appropriate. Irrigation with moderately saline water did not affect vegetable nutrient quality or consumer acceptability.

TABLE 9. SELECTED CROPS CONSTITUENT IMPROVED BY SALINITY

Common Name	Constituent Improved
OIL SEED	
Crambe	Increased oleic acid content
Evening Primrose	Increased oil content, beneficial reduction of fatty acid ratios
Lesquerella	Increased lesquerolic acid (industrial oil)
Stock	Increased linolenic acid (omega-3)
Sunflower	Increased oleic acid
ORNAMENTAL	
Carnation	Sturdier stems, larger flowers
Chrysanthemum	Shorter, sturdier stems
Lisianthus	Sturdier stems
Stock	More compact inflorescences, sturdier stems
GRAIN AND FORAGE	
Alfalfa	Increased protein, total digestible nutrients
Wheat	Increased protein and baking quality

Research needs to focus on plant response in terms of yield and quality to irrigation waters of differing ion composition. For example toxic element uptake [such as boron (B), selenium (Se), molybdenum (Mb), and arsenic (As)] as it relates to water composition and competing ions; interactions among salinity, nutrients, ion composition, and toxic elements related to the prediction of yield, pH effects on crop yield and quality, and soil physical properties, long-term predictions of salt transport/loading, including B, Se, and Mo, and optimal management practices when using a combination of fresh and recycled water for irrigation.

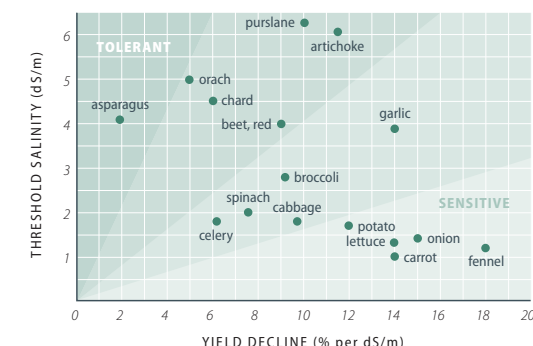


Figure 7. Salt Tolerance of Leafy Vegetables. Threshold value is EC level (dS/m) at which there is no yield loss.



6

OPPORTUNITIES AND CHALLENGES IN AGRICULTURAL WATER REUSE | FINAL REPORT

SECTION 6: Challenges and Opportunities

- P 55: WHICH CROP FOR WHICH PLACE WITH WHAT WATER?
- P 57: REDUCING HUMAN EXPOSURE DURING PRODUCTION AND UNDERSTANDING EXPOSURE RISKS FOR CONSUMPTION
- P 59: IMPROVING PUBLIC PERCEPTION AND ACCEPTANCE
- P 61: MANAGEMENT ACTIONS TO IMPROVE IRRIGATION WITH RECYCLED WATER

Challenges and Opportunities

During the course of the listening session, participants provided input and ideas on topics critical to success in using recycled water for agriculture. Participants chose one of four breakout sessions to discuss issues around specific topics. Each group focused on a specific question and identified some challenges, opportunities, and specific policies or actions that USDA might make or take.

In general, many research, education, and/or outreach challenges were raised around the topic of water reuse for agriculture. Participants felt that USDA should take an integrated approach to water quality management and suggested interdisciplinary teams and approaches. Some of the identified research needs are basic, while others lend themselves to more applied approaches with considerable involvement by various stakeholder groups (producers, consumers, markets, wholesalers, retailers, and regulators were some key groups mentioned throughout the sessions). All breakout groups identified many educational needs for the different stakeholder groups above.



Which Crop for Which Place with What Water?

Participants were excited about the opportunity to augment water supplies and alleviate pressure on water resources through use of recycled waters. Being able to accurately and easily match the qualities of different waters with options for tolerant crops in the most appropriate locations has great potential for agriculture. Discussing challenges around this question helped to elucidate some of the opportunities for USDA.

More research is needed to investigate both plant tolerances to waters of varying quality and particular constituents in the water with potential plant toxicities. The group also cited a need to set base standards for plant growth tolerances and production. Research on salt tolerant plants would increase options for growers who use recycled water in their production operations. It could also lead to identification and development of salt collecting crops for water treatment and recycling purposes. There are questions surrounding maintenance of soil quality

regarding salts and other constituents and the fate and transport of these constituents not taken up by crops. There were also questions about data on the quality of recycled water, specifically in comparison with other irrigation water quality. There are challenges to develop effective and efficient recycled water quality testing parameters and more rapid procedures based on sound science. From earlier presentations on pathogens and health risks, participants recognized that water testing should focus on risk assessment and pathogenicity.

KEY QUESTION:
IN ORDER TO BE SUCCESSFUL WITH RECYCLED WATER, WHICH CROP IS BETTER SUITED FOR WHAT LOCATION AND WHAT QUALITY OR SOURCE OF WATER SHOULD BE USED?



RESEARCH ON SALT TOLERANT PLANTS WOULD

INCREASE OPTIONS FOR GROWERS WHO USE RECYCLED WATER

IN THEIR PRODUCTION OPERATIONS.

IT COULD ALSO LEAD TO IDENTIFICATION AND DEVELOPMENT OF SALT COLLECTING CROPS FOR WATER TREATMENT AND RECYCLING PURPOSES.

Which Crop for Which Place with What Water? (cont'd)

Therefore, research on pathogens in recycled water and the fate and transport of these organisms needs to be addressed. Finally, more research is needed on how to handle, and what to do with, the brine resulting from recycling and treating waters for reuse.

Applied research and outreach need to focus on decision support to enable informed decisionmaking and enhance adaptability and diversity in agricultural production operations. For example, the participants viewed the quality of the recycled water as a primary driver for decisions. However, several breakout groups discussed decision support and educational information regarding crop production options in the context of the quality of different waters available and related plant tolerances.

Participants discussed educational challenges and opportunities, including the need to learn and share information about successes and failures of water reuse in agriculture. A clearing-house for this type of information was recommended to help reduce barriers to expanding the use of recycled water in agriculture. Although a separate public perceptions group focused on perception and acceptance (see below), this group also addressed these challenges and suggested several opportu-

nities for extension education. Group members noted that the three major challenges might be public/consumer acceptance, producer acceptance, and purchaser/wholesaler/retailer acceptance of using recycled water in agriculture, particularly related to food/fresh market crops. It appeared to the group that there are noticeable differences in regional or state acceptance of water reuse for agriculture. Other opportunities for USDA include educational and extension programs addressing crop diversification in agricultural systems using recycled water and ways to make these decisions easier and more informed to increase the adaptability of agricultural systems given the pressures on water supplies. There was discussion about opportunities to use recycled waters on new types of crops, including bioenergy crops, turf production, or lawn and landscaping irrigation in residential situations. Expanded dialogue and cooperation between USDA and EPA were recommended.



ACTIVE MANAGEMENT REQUIRES MATCHING APPLICATIONS BASED ON IRRIGATION SYSTEMS, CROPS PRODUCED, AND SOIL OR GROUNDWATER CONSIDERATIONS, WHILE TAKING INTO ACCOUNT THE LEVEL OF TREATMENT AND THE QUALITY OF RECYCLED WATER.

Reducing Human Exposure During Production and Understanding Exposure Risks for Consumption

Participants in this group expressed a wide range of thoughts and suggestions to USDA during this breakout session. In general, there was great enthusiasm in this group—as well as in others—about the opportunity to increase available water supplies and water management using recycled water, thus increasing sustainability. A goal identified for USDA is to make recycled water the best available source of water for irrigation.

The group discussed at length significant opportunities for education and enhancing public understanding, including water reuse and water management in general. These opportunities should include finding creative ways to communicate, exploring new outlets for communication, and comparing recycled water to other irrigation water sources. Workers, supervisors, growers, trade groups, retailers, and consumer agencies are among the many groups to target for future educational opportunities. Improving scientific understanding about human exposure and risk and risk assessments are necessary to reduce uncertainty and to increase our ability to address concerns or perceptions about worker safety, food safety, and to test effectiveness of best management practices (BMP).

More research is needed to understand the exposure risks associated with water reuse. The group described “fear of the unknown” as a challenge and stated that research and data can address those concerns. Funding for research on these issues for water reuse was an opportunity targeted by this group. They also felt there were opportunities to partner with other agencies or organizations on this research. Some specific research topics included addressing new or growing threats, such as pathogens and other emerging contaminants (e.g., pharmaceuticals and hormones), constituents or potential contaminants in recycled water (e.g., trace elements), protection against health threats and BMPs for production, processing, and environmental protection (e.g., do buffers help?), and quality control and packaging considerations. Additional research topics included risks to humans (e.g., exposure routes), effects on wildlife, and soil accumulation and standards for cropland protection (from trace constituents or contaminants). The group recommended comparative risk analysis (recycled water vs. other water sources) to provide context for interpreting communication about risk. There is a need for independent review to address credibility challenges towards the science basis and alter inaccurate perceptions.

Numerous opportunities for education and outreach were discussed. The public needs to be more aware of the benefits of using recycled water; however, the stigma associated with recycled water use, consumer confidence, and public perception issues are major challenges. There is a great need to gain the confidence of consumers and decisionmakers through science-based education, clear and effective risk communication,



Photo courtesy of NRCS

**KEY QUESTION:
WHEN AND WHERE IN THE FOOD
PRODUCTION AND CONSUMPTION
PROCESS ARE THE POINTS OF RISK?**

Reducing Human Exposure / Understanding Exposure Risks for Consumption (cont'd)



transparency, and honesty. One suggestion was to bring any doubts and criticisms into the process/discussion and to partner with those who raise concerns. The group felt that more funding was needed to establish extension agents for recycled water, that funding for water reuse extension programs was a priority, and that a network of these agents should be formed. The need for credibility and reliability, strong science basis, and clear and effective communication and education campaigns fits in well with the role of extension.

Summarizing existing information and data will be critical to producing educational materials. Several target audiences were noted for educational programs and outreach, including workers, supervisors, growers, trade groups, retailers, and consumer agencies. Participants discussed specific challenges related to work forces and reducing human exposure, including low scientific literacy, limited education, and language barriers (meaning that people in the water industry tend to use technical language that workers and consumers may not understand). Workforces tend to be maintained over long periods—sometimes across generations. Educating workforces where multiple generations continue to work together in the fields allows for generational transference and provides for long-term retention. Training supervisors and growers/managers/owners would be critical elements to a successful education program for agricultural water reuse.

Some challenges or approaches to reduce exposure during production include signage, restricted access and waiting periods (if necessary), personal protective equipment, sanitation facilities for workers, and site supervision. For consumers, education on what to wash (in terms of produce) can reduce exposure risks. In addition, quality control measures and packaging considerations can help reduce risks to consumers.

Additional opportunities for recycled water users could include irrigation for golf courses or rangelands. These applications have a lower risk for workers and involve non-food crops, much like the mention of bioenergy crop irrigation in another session or the use of recycled water in the bioenergy production process. The group discussed using the media to deliver messages, but noted that, in the interest of accuracy, the media needs to understand the material. Participants also suggested that local spokespeople could help to encourage public understanding among their peers. They identified a role for USDA in outreach, stating that USDA needs to take the lead on recycled water, partner with other agencies and organizations, and encourage use of recycled water through incentives and science-based policy-enabling implementation. USDA should also help develop standards for croplands under cultivation to prevent contamination. Participants noted that irrigation water is not regulated and that transparency is needed in the regulatory process and in dialogue among agencies.

Improving Public Perception and Acceptance

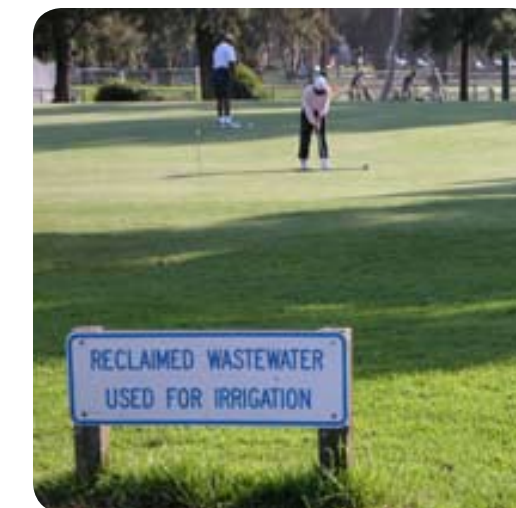
This group was excited about using recycled water to offset the use of fresh water sources, the economic benefits, and benefits to communities. However, addressing perceptions and behaviors is a major challenge. It was clear that in each breakout session, no matter the topic,

all conference attendees ultimately noted that the greatest challenge for water reuse in agriculture might be the perception and willingness of the public to accept its use to produce their food. There are several specific challenges and opportunities related to perception and acceptance of this technology and water resource for agriculture, and this breakout group was both creative and strategic in its suggestions. Most suggestions involved targeting educational opportunities to specific groups to increase their knowledge and understanding of the facts, or improving the perception of recycled water through outreach programs.

Several groups discussed partnerships and collaboration to improve effectiveness in addressing public perceptions and acceptance. Working closely with the agriculture community and farmers was strongly suggested. Closer and more regular collaboration with the media was another repeated suggestion in this group. Partnerships were recommended with USDA and between USDA and non-governmental groups (which some suggested might seem more trusted by the public), as well as with state and regulatory agencies. The group's final summary recommended more regional cooperation on educational programs.

Group participants noted specific challenges and opportunities dealing with funding for water reuse programs. Funding could be applied in several ways, including educational programs, outreach efforts, media campaigns, research needs and risk assessment, or for certification of or planning for irrigation water sources. Some of the suggested educational opportunities were to increase awareness of water resource issues in general for the public, for officials and decision-makers, and for members of the media. Public outreach and education were recommended before and during the planning stages for water reuse projects. This kind of early engagement was seen as critical regarding formation of perceptions and acceptance of uses. An informational show or DVD could be produced and used to tell the story and successes of recycled water use. Educating buyers and consumers of the benefits of using recycled water is critically important to perception and acceptance. There was also discussion about school programs, including tours of water reuse facilities, to educate children and their parents.

Participants recommended standardizing terminology and coordinating water resource messages for educational and outreach efforts. A general paradigm shift is needed to influence public perceptions and willingness to accept recycled water. Recycled water should be seen as a resource, not as a waste. This applies to regulatory approaches as well.



A GENERAL PARADIGM SHIFT IS NEEDED TO INFLUENCE PUBLIC PERCEPTIONS AND WILLINGNESS TO ACCEPT RECYCLED WATER. RECYCLED WATER SHOULD BE SEEN AS A RESOURCE, NOT AS A WASTE.

Improving Public Perception and Acceptance (cont'd)



KEY QUESTION:
HOW DO WE BETTER UNDERSTAND
WHAT THE PUBLIC FEARS?

Participants saw a need to overcome negative messages in the media and felt that, in some circumstances, the “issues were getting hijacked.” Given the focus of this session, much discussion centered on the media and the messages they provide to the public. Communication should be ongoing, not just during times of crisis. Communication must be science-based, should report relative risk, and should not involve speculation; in times of crisis, it is very difficult to overcome negative portrayals or inaccurate accusations—people remember these messages. One way to overcome a negative portrayal is for USDA to release comments that correct the record of facts once the crisis is understood. Non-governmental groups, which may have greater public trust, could help with this as well. To build public confidence and trust there needs to be transparency and to partner with trusted groups. Independent, third-party review or endorsements from environmental or health and safety groups would build credibility and reinforce the science on the issue. Public research could serve as an unbiased source of information, but more funding is needed for public research on recycled water and its properties or on risk assessment. Lastly, certification of recycled water and other irrigation water could reassure both agricultural producers and consumers.

Development of rapid response and outreach teams comprised of regional outreach and technical experts, state agencies, and local stakeholders could respond in crises and serve as a media resource. In other situations, they could share success stories, collaborate on outreach strategies, or assist in formulation of simple, clear policies.

Management Actions to Improve Irrigation with Recycled Water

This group discussed actions and approaches related to some of the challenges to implementing the use of recycled water for agriculture. In general, the group identified integrated approaches for water quantity and quality management, as well as for soil salinity management.

Groundwater concerns and potential issues associated with recycled water use need to be addressed, including development of guidelines to assess groundwater. Active management of salt buildup related to total dissolved solids in recycled water is necessary to prevent problems and other considerations that might include crust formation and runoff from raindrop impact,

and drainage water management and leaching into groundwater. Regional salinity task forces could provide management of soil and groundwater concerns. One advantage noted by this group was the nutrient value of recycled water used for irrigation. Many of the farmers that interacted with conference participants pointed this out as a positive feature.

Much of the discussion and questions focused on the need to develop national standards for the quality of recycled water and for other irrigation water sources. Any such standards must address crop/plant/industry and environmental needs; developing these standards would require a collaborative agency approach. Standards must be science-based. There are many research needs to develop and monitor the standards, and educational needs to implement and manage them. Agencies to be involved in this should include EPA, USDA, USDO, Bureau of Reclamation, and the Food and Drug Administration.

KEY QUESTION:
HOW DO WE MANAGE THE DELIVERY,
STORAGE, AND USE OF RECYCLED
WATER ACROSS GROWING SEASONS
AND YEAR ‘ROUND?



STANDARDS MUST BE SCIENCE-BASED. THERE
ARE MANY RESEARCH NEEDS TO DEVELOP AND
MONITOR THE STANDARDS, AND EDUCATIONAL
NEEDS TO IMPLEMENT AND MANAGE THEM.

AGENCIES TO BE INVOLVED IN THIS SHOULD INCLUDE EPA, USDA, BUREAU OF RECLAMATION, AND THE FOOD AND DRUG ADMINISTRATION.

FINALLY, A MAJOR RECOMMENDATION FROM THIS GROUP CHARGED USDA TO DEVELOP AND ISSUE A POLICY ON THE USE OF RECYCLED WATER AS A RESOURCE FOR AGRICULTURE.

Management Actions to Improve Irrigation with Recycled Water (cont'd)

However, it was noted that farmers are averse to regulations. An alternative approach is for USDA to offer voluntary certification of irrigation water. A minimum level of standards would help to increase confidence in the use of different water qualities in different situations and might make these decisions easier and the public more willing, while also ensuring environmental protection. A survey of existing state standards and a database of irrigation water uses would be starting points for such an effort. Development of such national standards might also necessitate development of rapid, accurate, and effective testing technologies (a research need) for pathogens and other important water quality constituents either for regulatory requirements or to aid in irrigation management decisions (such as which water can be used in what circumstances).

Some other considerations related to regulation were raised. Standards and regulations must be applied in a consistent and logical manner. For example, questions were raised as to why low quality irrigation runoff is permitted to leave a site, but recycled water requires a National Pollutant Discharge Elimination System permit. Other questions related to how water boards apply anti-degradation policies, and about environmental and social justice. There is also a need to address water rights (in the West) to maintain surface water flows and quality.

Operationally, there are challenges and opportunities as well. Operational and monitoring standards would help to assure the quality of recycled waters for agricultural users. Developing site management guidelines for different irrigation applications would be helpful to managers making these decisions and ensure proper and responsible use. Active management requires matching applications based on irrigation systems, crops produced, and soil or groundwater considerations, while taking into account the level of treatment and the quality of recycled water. This is a major research need and must include an integrated approach to whole system optimization.

Finally, a major recommendation from this group was for USDA to develop and issue a policy on the use of recycled water for agriculture. This policy should emphasize the "value" of water and the value of recycled water as a resource. It should also note the opportunity to supplement diminishing water supplies in many parts of the nation and take credit for the triple bottom line when using recycled and reclaimed waters to increase the sustainability of U.S. agriculture.



DOCUMENTATION AT DAY TWO OF THE SANTA ROSA AGRICULTURAL WATER REUSE CONFERENCE, OCTOBER 30, 2006





7

SECTION 7: Bold Steps for USDA

Bold Steps for USDA

Each key question posed to participants in the discussion breakouts led to setting goals that were slightly out of reach to push USDA into reaching exceptional and proactive results. These bold steps are designed to be captured as measurable actions that result in success and provide a basis for accountability.

The Bold Steps Illustration (see next page) summarizes the responses from the four breakout sessions and the Take Home Message Section expands and summarizes these action steps.

When asked, “What should USDA do to expand its efforts in water reuse?” our panel discussants, Dan Carlson, representing municipal water and wastewater management; Keith Israel, regional water and wastewater management; Mark Millan, social and behavioral management; and Trevor Suslow, university research, outreach, and education, identified specific actions and responded to audience questions.

From the municipal water and wastewater management perspective, USDA should endorse the use of recycled water as a “safe available source for irrigation (SASI).” USDA–REE should help promote a federal consensus that recycled water is key to the security of our national resources. And finally, the REE mission area could provide funding for both planning and construction of recycled water facilities for agricultural reuse projects.

With respect to regional water and wastewater management, USDA should convene an annual recycled water workshop. As part of that workshop, one day might focus on discussions where regulators and irrigators could define the issues and research needs related to the use of recycled water. Based on a survey and review of food crop irrigation using both recycled and other waters, USDA needs to publish a white paper on crop irrigation water with the focus on suggested best management practices and a comparison of irrigation waters. Research studies about the use of recycled water for food crops should be a priority for funding from USDA.

From the social and behavioral management aspects of recycled water, USDA needs to provide funding towards public outreach, education, and developing a common language to explain water reuse issues—particularly towards public/consumer acceptance, producer acceptance, and purchaser/wholesaler/retailer acceptance of using recycled water in agriculture, expressly related to food/fresh market crops. REE could partner with the WateReuse Association to support farmers and communities that use recycled water. USDA should support research, outreach, and education efforts to communicate “relative risks” from emerging contaminants.

Key research needs in the safe use of reclaimed water on edible horticultural crops included an expansion of the database on re-growth potential, greater research to understand irrigation source blending, and groundwater recharge issues. USDA could help fund the determination of differential consequences of use in complex production systems where human bacterial pathogens are likely and/or possible. Other critical avenues for research include a reassessment of current safety assumptions for Df (filtered and disinfected) and Udf - 2o (unfiltered, disinfected secondary treated): 23-rule treatment uses for tree crops and seed crops and the development of science and data-based end-user and consumer awareness outreach using qualified and group appropriate communicators.

No regional coordinating committee exists that covers recycled water use for irrigated agriculture. Participants suggested that Congress establish a water caucus to move the application of recycled water in agriculture forward. In areas where programs are ineffective, we might have more support and success if recycled water was used by large farms in well-known and established farming regions, such as the Central Valley of California. Participants felt that there might be a unique opportunity to provide more support for water reuse research in the new farm bill and that the negative perceptions might change, “if people knew that the USDA supported recycled water.”





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SECTION 8: Take Home Message

- P 71: RECOMMENDATION 1: IMPROVE EDUCATION AND OUTREACH OF RECYCLED WATER
- P 72: RECOMMENDATION 2: CONDUCT ADDITIONAL RESEARCH AND COORDINATE EXISTING DATA
- P 73: RECOMMENDATION 3: SET STANDARDS AND DEVELOPING A CERTIFICATION PROGRAM
- P 74: RECOMMENDATION 4: IMPROVE THE ROLE FOR USDA AND OTHER GOVERNMENT AGENCIES

Take Home Message

One of the keys to water sustainability is the addition of recycled water—with the understanding that the resource is limited and that we use it to leverage other resources, voiced **Richard Katz**, chair of the California’s Recycled Water Task Force. How do we do a better job of introducing recycled water into the mainstream—with public acceptance and understanding?

The public must believe that the process, from wastewater treatment to food safety, is not compromised. By 2020, 20 percent of the water budget in California needs to come from desalinated and/or recycled water. We need to get the message out, be completely transparent, and engage local stakeholder participation, understand local needs and desires, and be consistent. Short, catchy phrases such as “showers to flowers” might be useful to help educate the public and state legislators.

Several important themes emerged during the breakout sessions of the Agricultural Water Reuse Conference. Each session discussed the need for improving public education of recycled water in agriculture. The potential benefits and perceived risks to society should be properly evaluated and clearly understood so that farmers, retailers, consumers, and politicians will support and accept the practice of water reuse. There is a need for additional research and a compilation of existing data to be made available to the industry and the public. Once the research, data, and facts are organized, improved outreach is vital to the overall acceptance of recycled water in agriculture. USDA and other government agencies can take an important step by helping to set standards, develop certification, and improve communications about the use of recycled water. The following recommendations contain consistent themes that emerged from all of the breakout sessions.

Recommendation 1: Improve Education and Outreach of Recycled Water

Improvements in education and outreach are essential to achieve a wider acceptance and use of recycled water around the country. Public misunderstanding and fears are based on a lack of understanding and effective outreach in the use of recycled water—the public needs to understand the science.

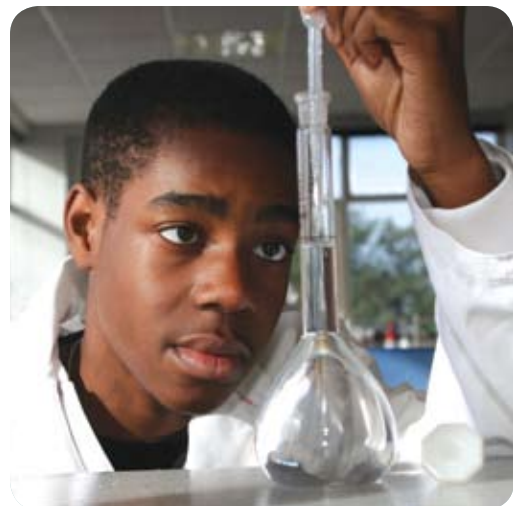
Without appropriate outreach and education, the public will continue to view recycled water as a waste, not as a resource. Misconceptions and wrong public branding of recycled water can change through better coordination of the media message, enhanced educational programs for public officials, schools, and consumers. Improved communications between politicians, scientists, engineers, planners, consumers, and farmers regarding updates and research will enhance public acceptance. Working with the media will help get the message out to the community. The need to use recycled water and its benefits to the environment and climate will reach more people and have a greater impact. Outreach through more focused activities and proper use of the media will help build trust and confidence and get the science-based message out to the public.

Actionable Strategies:

- Help fund education and outreach to growers, wholesalers/retailers, and consumers that facilitates the exploration of water reuse possibilities.
- Promote water reuse education at both ends of the spectrum—fund the development of programming for K-12/higher education and regulators, legislators, and other key officials emphasizing public perception issues.
- Fund the creation of an informational DVD to relate the recycled water story—e.g., “not all wastewater is waste.”
- Support funding for extension faculty with appointments in recycled water as part of the solution to water availability problems.
- Assist extension in partnership with farmers, to channel the recycled water message through the appropriate media outlets (e.g., blog, iPod, game, etc.).
- Study the additional costs to farmers, financial or real, in transition to irrigation with wastewater (e.g., salination).
- Study the elements that comprise approaches to wastewater pricing for use in irrigation (e.g., conveyance and treatment).
- Do social benefits exceed the social cost (The Compensation (Kaldor-Hicks) Principle)?
- Assist extension and others to establish state and local water reuse advisory groups that would share success stories, identify issues (e.g., salinity), and inform decision-makers.



Recommendation 2: Conduct Additional Research and Coordinate Existing Data



Although research on water reuse in agriculture has been done over the years, new research is needed to identify gaps in data such as salt tolerances of plants, new or unknown threats, best management practices for production and processing, and identifying the right water for certain crops. Additional funding should be dedicated to meet these research needs.

A large amount of data exists but there is no coordination of this data. A clearinghouse should be established to make the data accessible to stakeholders. Salt build-up needs to be better understood. Research in ways to improve salinity management will help to address crop and environmental needs. More in-depth research on the plant tolerances, base standards, and a clearer understanding of pathogens in both soil and water should be adequately researched. This information should be accessible to, and easily understood by, farmers and consumers.

Actionable Strategies:

- Promote a comprehensive review of research into the use of recycled water by the National Academy of Sciences.
- Help to prioritize water reuse at the national level by promoting collaboration among federal water agencies.
- Assist with the creation of a comprehensive database with information about recycled water as part of the total water volume used for irrigation. This database must be summarized, independently reviewed, and available to inform policy.
- Identify and utilize existing information concerning issues with recycled water from experienced nations.
- Fund efforts to address critical issues surrounding recycled water, such as salinity tolerance in plants and associated plant-based remediation through discovery and integrated research.
- Provide funding for programs and projects that focus on two principal methods for reducing drainage salination problems. They are: reducing the amount of irrigation water applied to crops and reusing the applied water on subsequent, more salt-tolerant crops.
- Identify the barriers to recycled water use, e.g., issues of recycled water distribution and the logistics of constructing water treatment plants near a customer base.

Recommendation 3: Set Standards and Developing a Certification Program

Currently, there are no national standards for any source of irrigation water—farmers are sometimes concerned about potential pathogen spikes in non-recycled surface water.

In order to improve the quality and find the best use of recycled water, there needs to be national standards in place and an improved monitoring system. Operation and monitoring standards can help to assure the quality control of recycled water. A good starting place would be to conduct a survey of existing state standards and then develop national standards that address both crop and environmental needs.

Actionable Strategies:

- Identify what the wastewater volume contains—concentrations of chemicals, which may be hazardous to agricultural yields and to conservation of soils. Wastewater may cause groundwater contamination by chlorides, nitrates, sodium, boron, and other contaminants. Farmers feel that recycled water is an asset—but they are not always sure what blend they are receiving.
- Fund the identification and research the critical indicators towards establishing national standards, based on existing state and local standards, that insure the use of recycled water with appropriate crops, worker and consumer safety, and soil and water quality.
- Promote federal collaboration among the water agencies to work towards the development of a beneficial use policy.
- Based on existing state and local standards, fund efforts to identify an appropriate suite of best management practices associated with food production and processing to prevent contamination.
- The only existing regulations with respect to wastewater quality are public health oriented, and even these are not properly observed. Coordinate research to provide the scientific underpinning to national wastewater quality standards for agriculture.



Recommendation 4: Improve the Role for USDA and Other Government Agencies

USDA has a unique opportunity to take the lead in coordinating with other government agencies in terms of conducting more research, starting an outreach committee, and developing curriculum and 4-H programs. Through dialogue and better communication between government agencies and stakeholders, USDA can help lead the efforts on building a unified message.

Along with EPA and the Department of Energy, USDA can help standardize the language and develop certification for water reuse. The actions of government agencies should be transparent so that confidence and trust can be built. USDA and other government agencies can work to change this perception. Mandatory programs and regulation of irrigation waters will provide consistency throughout the states. Setting standards for croplands under cultivation to protect them from any contamination will reduce risks and improve the acceptance of recycled water. USDA should provide endorsement of recycled water and make it the best available water source for irrigation.

Actionable Strategies:

- Take the lead to promote water management with recycled water as a critical component, which transcends political and social boundaries—connecting urban, rural, environmental, and agricultural uses at the watershed scale.
- Efficiencies gained through the use of recycled water might translate into greater ecosystem services (e.g., instream flows) within a watershed. Ecosystem services are quickly becoming the currency as to how some agencies measure the outcomes of their efforts.
- Coordinating the use of recycled water could expand flexibility in decisionmaking, and provide greater incentives for use through water marketing.
- Rigorously organized and coordinated follow up and control of water with proper quality sampling is required, regarding the chain commencing with fresh water supply to households and industrial plants, as ending with the use of wastewater in irrigation.
- Cooperatively funding the research to underpin the certification of green technology in farming and food production.



DISCUSSION AT DAY TWO OF THE SANTA ROSA AGRICULTURAL WATER REUSE CONFERENCE, OCTOBER 30, 2006



SECTION 9: References

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PANELISTS AT DAY ONE OF THE SANTA ROSA AGRICULTURAL WATER REUSE CONFERENCE, OCTOBER 30, 2006

10



OPPORTUNITIES AND CHALLENGES IN AGRICULTURAL WATER REUSE | FINAL REPORT

SECTION 10: Conference Handouts

[WATER REUSE IN AGRICULTURE CONFERENCE BROCHURE \(PDF\)](#)

[KEY CONSIDERATIONS FOR GROUP DISCUSSION LEADERS HANDOUT \(PDF\)](#)

[SUPPORTING INFORMATION KIT FOR WATER REUSE FACILITATORS \(PDF\)](#)

[WATER REUSE IN AGRICULTURE GROUP DISCUSSION GUIDANCE HANDOUT \(PDF\)](#)

[PARTICIPANT LIST \(PDF\)](#)



United States Department of Agriculture Cooperative State Research, Education, and Extension Service

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