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SECTION 5: Critical Issues in Project Development

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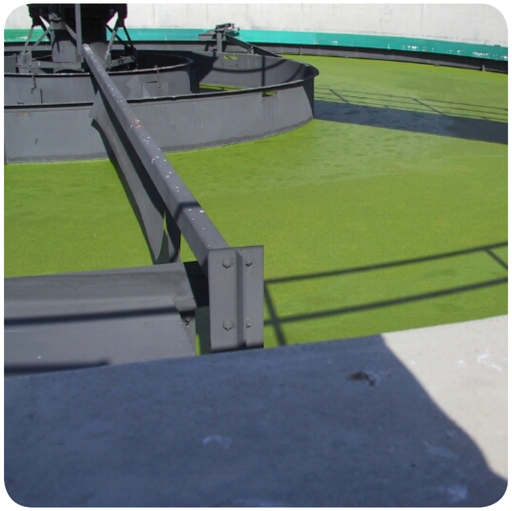
The Adequacy of Technology to Achieve Water Quality Goals



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

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Management of Public Perception (cont'd)

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.

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.

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).

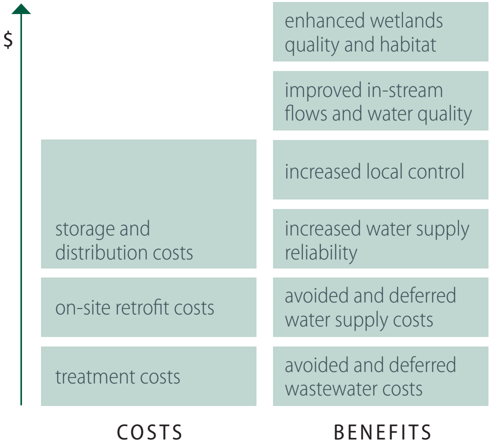

Fig. 3. Counting All of the Benefits of a Water Reuse Project

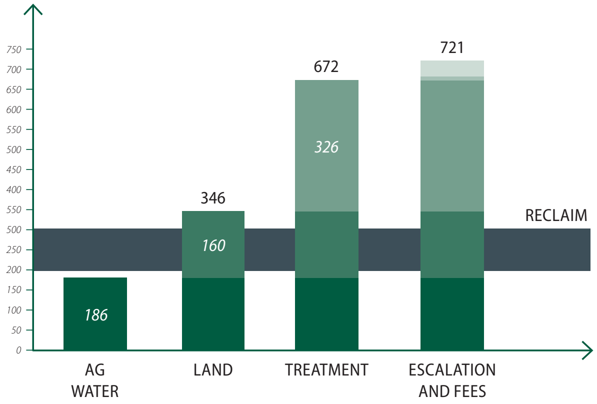

Fig. 4. Apples-to-Apples Baseline Comparison of Reclaimed Versus Agricultural Water

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)

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 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.

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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.

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

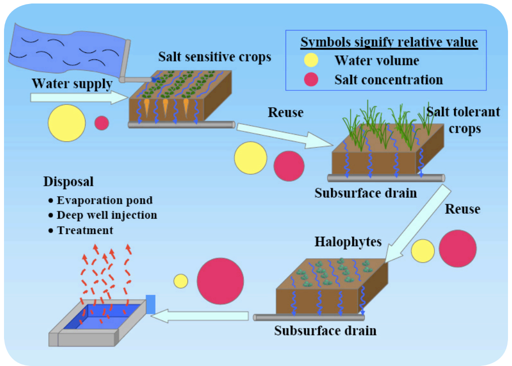

Figure 5. Schematic Plan for Multiple Sequential Uses of Drainage Water for Maximum Utilization of the Resource and Reduced Drainage Volume.

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

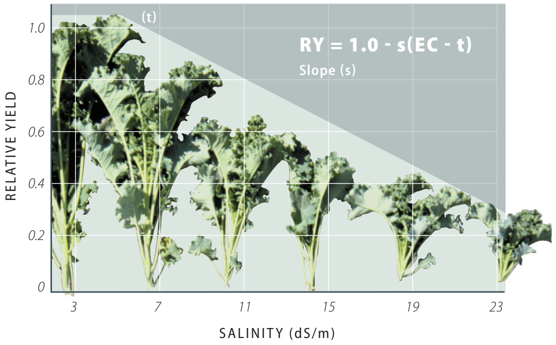

Figure 6. Relative Yield of Kale as a Function of Soil Salinity

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.

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

Common Name	
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	
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.

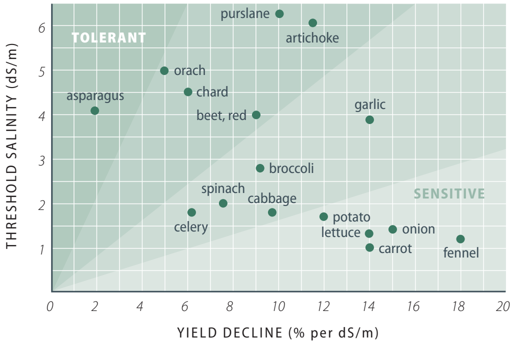

Figure 7. Salt Tolerance of Leafy Vegetables. Threshold value is EC level (dS/m) at which there is no yield loss.

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