Reclaimed Water for Citrus Irrigation in Florida

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ABSTRACT

Before 1980, many communities in Florida considered wastewater to be a disposal problem. When it was initially proposed to convert wastewater to reclaimed water for crop irrigation, some citrus growers refused to accept the water because of fears of heavy metals, flooding, or disease. Ultimately, several reclaimed water projects were started, and Water Conserv II west of Orlando has become one of the world's largest agricultural reclaimed water irrigation projects of its type. This project provides irrigation for more than 4300 acres of agricultural crops and two golf courses. The water is chlorinated, is odorless and colorless, and has been used successfully for crop irrigation for 15 years. Excess reclaimed water is discharged to rapid infiltration basins (RIBs). The water meets drinking water standards for a number of compounds including nitrate, sulfate, Na, Cl, Cu, Zn, Se, and Ag. Initial fears that reclaimed water would cause problems were unfounded. In the sandy well-drained soil, excessively high irrigation rates with reclaimed water (100 inches/year) promoted excellent tree growth. Because of a recent severe drought in Florida, attitudes toward reclaimed water have changed. Once believed to be a disposal problem, reclaimed water is now considered to be a valuable resource that can meet irrigation demands. Average statewide reuse flow rates increased by 119% in 11 years, and reclaimed water was being used on 40,152 acres for agricultural irrigation in 2001.

Introduction. As water shortages become more common, competition for water among various sectors becomes more acute. Increasing urban growth, along with agricultural and industrial needs, lead to greater competition for limited water resources. Interest has increased in developing new water resources to meet the greater demand. Florida has relied heavily on groundwater pumping, and concerns have arisen regarding declining aquifer levels. This has led to serious discussions on developing alternate water supplies such as desalination, aquifer storage and recovery, and reclaimed water. Reclaimed water use has evolved in an interesting way in Florida, and the objective of this paper is to briefly discuss one project, Water Conserv II, which illustrates how attitudes toward reclaimed water can change when water supplies get short.

Background. Disposal of wastewater is a problem for many urban areas. In the 1980s, disposal of wastewater effluent was considered to be a growing problem, primarily because of environmental concerns about lake degradation. Urban wastewater disposal had commonly been handled by treating the wastewater to a certain level and then disposing of it in the most convenient or cheapest manner. Usually, this meant discharging the water into a nearby river or lake, spraying it onto a field, or loading it into a percolation pond. Disposal was the primary consideration since the amount of wastewater continued to increase as an unavoidable consequence of population growth. As wastewater volume increased,

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concerns were raised about the effects on discharge sites. This led to consideration of alternate uses such as irrigation. While the idea of converting wastewater to reclaimed water for irrigation was not a new one, using reclaimed water for irrigation was a relatively small-scale activity in Florida before 1980. Eventually, increasing disposal problems led to several large Florida projects set up to reclaim water from wastewater treatment plants for irrigation of agricultural crops or landscape vegetation. Examples include projects in Tallahassee, St. Petersburg, and the Water Conserv II project of Orlando and Orange County (Allhands et al., 1995; Parnell, 1988; Roberts and Vidak, 1994).

Before 1987, Orlando and Orange County each discharged treated wastewater from their treatment plants into Shingle Creek that flows into Lake Tohopekaliga, a lake with high recreational value. Concerns were raised over the potential eutrophication of the lake due to nutrient loading. Thus, the U. S. Environmental Protection Agency required Orlando and Orange County to develop an alternative plan for the disposal of the wastewater they were discharging into Shingle Creek. Several plans for the effluent were proposed, such as: 1) building a pipeline approximately 68 miles long to carry the effluent to the Atlantic Ocean, 2) establishing a "Groundwater Conservation Program" which would inject reclaimed water meeting primary and secondary drinking water standards into the Floridan aquifer, 3) purchasing large tracts of land for rapid infiltration basins (RIBs), 4) increasing the treatment level to convert the wastewater to meet reclaimed water standards and have growers apply it to their citrus groves, and 5) injecting the wastewater into deep wells over 3000 feet deep using high pressure. None of the plans by themselves proved to be acceptable for a variety of reasons. Following further review, a combination of citrus irrigation and RIBs was determined to be effective. This combination was selected and named Water Conserv II.

Citrus grove owners initially rejected the plan because of concerns about possible heavy metal contamination, potential virus or disease problems, flooding, and lack of flexibility in water application during periods of high rainfall. Growers also raised concerns over psychological aspects and feared that there might be a degradation of fruit quality from trees irrigated with reclaimed water. Ultimately, Orlando, Orange County, and the growers developed a plan that provided for the establishment of reclaimed water standards, regular monitoring of the water, greater grower flexibility on timing of use, and research on the effects of the reclaimed water on citrus tree performance. In addition to applying the reclaimed water to citrus groves, the project also included the purchase of land for RIBs for disposal of excess water. Water Conserv II has since become the largest reclaimed water agricultural irrigation project of its type in the U.S., and was the first project in Florida to be permitted to irrigate crops for human consumption with this water (McMahon et al., 1989).

At present, the reclaimed water is applied primarily to citrus, but it is also used for irrigation of several other crops. At the Orange County National Golf Center and West Orange Country Club, golf courses with a total of 45 holes have RIB sites incorporated into them and use the reclaimed water for irrigation. At present, over 4,300 acres of citrus, 12 nurseries and tree farms, and two landfills use this reclaimed water for irrigation. One hundred acres of willow is irrigated in a "browse farm" to provide feed for the Walt Disney World Animal Kingdom theme park. A new pipeline has been installed to extend the reclaimed water to additional areas.

Water Treatment, Distribution, and Quality Standards. Two treatment facilities receive the wastewater and process it to meet reclaimed water standards. These facilities were upgraded to meet the stricter water quality standards. In addition to the normal treatment, advanced secondary treatment capability was added to meet high-level disinfection standards. This involves coagulation and filtration facilities similar to potable water treatment plants. Pump stations at both reclamation facilities transmit the reclaimed water through a pipeline about 21 miles long to a distribution center in western Orange County. The distribution center is located in a citrus production area with deep, well-drained, sandy soils. The center can store up to 20 million gallons of water in four large covered concrete tanks. A computerized control system monitors the distribution of reclaimed water continuously. Water is pumped from the distribution center to either grower's fields or to RIBs. Under current conditions, about 60% of the water goes to citrus groves and the remaining 40% goes to the RIBs. This project presently delivers 30 to 35 million gallons per day (mgd). Permitted average daily flow capacity is 44 mgd with ultimate average daily flow capacity of 50 mgd with peaks to 75 mgd. The source of the wastewater is primarily residential properties, restaurants, motels, and tourist attractions in western Orlando and Orange County. There is very little factory or heavy industry input into the incoming wastewater.

During freezes, there is a high demand for irrigation water, and the reclaimed water provided to citrus groves is supplemented with well water for frost protection in order to meet that demand. Most groves are irrigated with undertree microsprinkler irrigation, which can provide some frost protection (Parsons et al., 1982; 1991), as well as normal irrigation for citrus trees.

Under the current contract, growers agreed to accept either 25 or 50 inches of water per acre per year for 20 years. Water is delivered at no charge to the edge of the grower's property at a minimum pressure of 40 psi. Growers can terminate their participation in the 20-year agreement at any time through a buy-out clause by repaying the city and county $3600/acre the first year with the repayment decreasing by 5% each following year. To date (15 years into the project), no grower has chosen to opt out of his contract. This indicates grower satisfaction with the reclaimed water.

The University of Florida established water quality guidelines for citrus trees. They are rigorous and apply only to the Water Conserv II project. The maximum average concentration limits (MACLs) for some elements such as sodium, chloride, barium, chromium, copper, selenium, silver, sulfate, and zinc are more stringent than Florida drinking water standards (Parsons et al., 2001). Water samples are tested monthly for bacteria, virus, and most of the mineral elements. Drinking water standards, Conserv II standards, and typical values are presented in Table 1. The treatment facilities have been required to meet the drinking water standard of 10 mg/L for nitrate nitrogen. In terms of crop mineral nutrition, meeting the nitrate drinking water standard is a disadvantage because this reduces nitrogen supplied to the tree.

The water is chlorinated which provides virtually complete removal of viruses and bacteria. The water is colorless and odorless. Florida regulations presently state that only indirect contact methods such as drip, subsurface, or ridge and furrow irrigation can be used to irrigate the "salad crops." Any type of irrigation method can be used to irrigate tobacco, citrus, or other crops that will be "peeled, skinned, cooked, or thermally processed" before human consumption (York et al., 2000). Most of the oranges in Florida are processed for juice, but some do go to the fresh market.

<u>Reclaimed Water Research at Water Conserv II.</u> Growers have now used Water Conserv II reclaimed water successfully for over 15 years. At the request of growers, studies were initiated to determine the effects of this reclaimed water on citrus trees. The first studies were conducted in commercial groves to make comparisons between reclaimed and well water (Zekri and Koo, 1990). In these plantings, growers using reclaimed water commonly used more water than those using well water. Hence, soil water content was usually higher in the groves using reclaimed water. Appearance of trees irrigated with reclaimed water was usually better than the trees irrigated with well water (Koo and Zekri, 1989; Wheaton et al., 1996).

Table 1. Florida drinking water standards, typical well water values, Conserv II maximum average concentration limits (MACL), and typical values in Conserv II water. All values are in mg/L except for pH, EC, and SAR.

	Drinking water Max. Contam. Level (mg/L)	Well water typical values (mg/L)	Conserv II water MACL (mg/L)	Conserv II water typical values (mg/L)
Arsenic	0.05	–	0.10	<0.005
Barium	2	–	1	<0.01
Beryllium	0.004	–	0.1	<0.003
Bicarbonate	–	–	200	105
Boron	–	0.02	1.0	<0.25
Cadmium	0.005	–	0.01	<0.002
Calcium	–	39	200	42
Chloride	250	15	100	75-81
Chromium	0.1	–	0.01	<0.005
Copper	1	0.03	0.2	0.002-0.05
EC (umhos)	781	360	1100	720
Iron	0.3	0.02	5.0	0.01-0.37
Lead	0.015	–	0.1	<0.003
Magnesium	–	16	25	8.5
Manganese	0.05	0.01	0.20	0.006-0.042
Mercury	0.002	–	0.01	<0.0002
Nickel	0.1	–	0.2	0.01
Nitrate-N	10	3	10	6.1-7
pH	6.5-8.5	7.8	6.5-8.4	7.1-7.2
Phosphorous	–	0.01	10	1.1
Potassium	–	6	30	11.5
SAR	–	0.6	–	2.5
Selenium	0.05	–	0.02	<0.002
Silver	0.1	–	0.05	<0.003
Sodium	160	18	70	50-70
Sulfate	250	23	100	29-55
Zinc	5	0.02	1.0	0.04-0.06

Since disposal of wastewater was of concern early in this project, it was important to determine if citrus could tolerate high application rates of reclaimed water. In research plantings, very high rates were applied to two citrus varieties, ‘Hamlin’ orange and ‘Orlando’ tangelo trees on four rootstocks. In addition to normal rainfall of approximately 48 inches/year, these trees were irrigated with rates of up to 100 inches/year (~2 inches/week). Application of 2 inches/week of reclaimed water in a 20-acre experimental planting significantly increased canopy volume and fruit yield compared to 0.3 inch/week of well and reclaimed water applications (Parsons et al., 2001). Because of the scheduling method used, the lower irrigation rate did not provide adequate water for optimum tree growth and production. The excessive irrigation diluted the juice soluble solids somewhat, but because of the greater total fruit production, total soluble solids per acre were increased at the 100-inch irrigation rate (Parsons et al., 2001).

Weed growth was excessive because of the high reclaimed water irrigation rate (Parsons and Wheaton, 1992; Zekri and Koo, 1993). Such growth has been controlled with proper herbicide use and mowing.

Irrigation with reclaimed water increased soil P, Ca, Na, and pH (Parsons and Wheaton, 1992; Zekri and Koo, 1993). Most fibrous roots are located in the top three feet, and much of the Na in the soil was leached below this depth. This reclaimed water supplies all the P, Ca, and B required by trees in central Florida soils. While levels of some elements have increased in the soil, they have not built up over the years (Zekri and Koo, 1993). This lack of buildup is attributed to low soil organic matter, low cation exchange capacity, and leaching rainfall. Leaf P and Ca levels were also increased. Leaf levels of Na, Cl, and B were elevated but remained below toxic levels.

Because the nitrate-N level is low (less than 10 mg/L), the amount of nitrogen extracted from this reclaimed water is unknown. In a small grower test, young trees that were given no fertilizer and irrigated only with Water Conserv II reclaimed water took 2 to 5 years to show nitrogen deficiency symptoms and yield declines (Ross, 1993, pers. comm.). Other work in the Vero Beach area showed that reclaimed water alone did not provide adequate nutrition for young grapefruit tree growth (Maurer and Davies, 1993). Preliminary data showed that high application rates of reclaimed water maintained yield for one year, but yields declined in the second year without additional fertilizer application (Wheaton et al., 1996).

Have Attitudes Changed? Attitudes in Florida toward reclaimed water have changed since the mid-1980s. Once considered to be an urban disposal problem with no beneficial use, treated wastewater effluent was discharged into a water body or spray field as a low cost method of disposal. Environmental concerns ended such disposal. Growers were initially opposed to the Water Conserv II project because of fears about salts, heavy metals, odors, contaminants, flooding, disease, and potential tree damage. Once water quality standards were established and the initial fears of flooding, disease, and tree damage were proved to be unjustified, research went on to show that reclaimed water had no adverse effects. Sufficient flexibility was also given to growers so they could acceptably manage their water in a region that has quite variable rainfall.

The water management districts in Florida have encouraged the use of reclaimed water by funding a number of projects. Reuse capacity in Florida increased noticeably in the 1990s (Fig. 1, Fla. Dept. Environ. Protec., 2002). Utilities initially wanted to encourage the use of reclaimed water since disposal was of primary interest. Hence, many utilities gave reclaimed water to users on a low or no cost basis (Ferraro and York, 2001). Unlimited use was commonly allowed. In the 1980s when utilities had abundant supplies, the low fees encouraged the inefficient use of reclaimed water. Many customers used more reclaimed water than was necessary for proper irrigation. A severe drought in 2000 that lasted into the spring of 2002 caused some reuse systems to run low in reclaimed water. This angered some

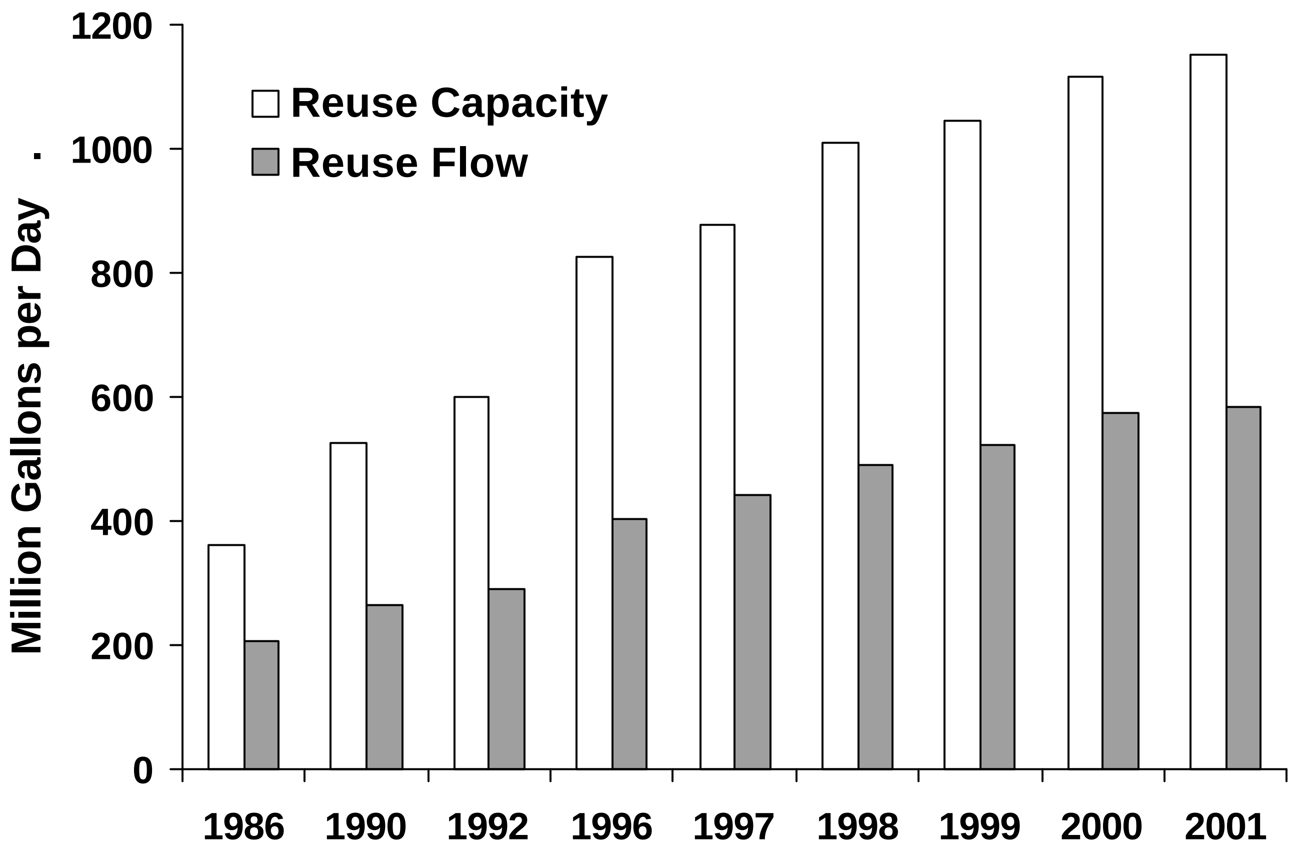

Fig. 1. Florida reuse invertory

customers who had been promised unlimited quantities of reclaimed water as a low cost, drought-proof water supply. Metering of reclaimed water will probably become necessary to improve efficiency of use.

Earlier wastewater systems were designed for effluent disposal and reuse was not of interest. One example is in southeast Florida where the low-cost way to deal with effluent was to dispose of it to surface water bodies or deep well injection. Ferraro and York (2001) point out that "It is interesting to note that Dade and Broward Counties account for about 24 percent of the state's population and about 27 percent of the state's permitted domestic wastewater treatment plant capacity. However, these two counties, which make extensive use of ocean outfalls and deep well injection systems, account for less than four percent of the state's reuse capacity." More recently developed treatment facilities can better incorporate reuse into their plans.

With the recent drought, public acceptance of nonpotable reuse has been relatively high. Reclaimed water has now become recognized as a water resource of some value. Procedures to encourage more efficient use for conservation of reclaimed water will need to be set up.

Summary. The benefits of Water Conserv II are now apparent. Orlando and Orange County benefit by meeting the mandate for zero discharge of effluent into surface waters. Withdrawal from the Floridan aquifer for irrigation has been reduced. Recharge of this aquifer has been accelerated due to the application of reclaimed water to the RIB sites. Because reclaimed water has been used safely and effectively, some groups and agencies are promoting the use of reclaimed water as a way to make up for water shortages. The recent drought in central Florida lasting up to the spring of 2002 has greatly increased interest in water reuse. Statewide reuse flow increased by 119% to 584 mgd from 1990 to 2001. By 2001, agricultural reclaimed water irrigation reached a total of 40,152 acres (14,621 acres of edible crops and 25,531 acres of other crops) (Fla. Dept. Environ. Protec., 2002).

Reclaimed water is no longer considered to be a disposal problem, but a limited resource of value. Quality of the water, along with supply and demand forces, will ultimately determine how much reclaimed water is used for irrigation or other purposes. Some growers still have a concern that there is a psychological stigma attached to reclaimed water that may damage the market reputation of Florida citrus which has rested on its quality over the years. Nevertheless, initial opposition to use of reclaimed water has decreased as demand for the water has increased. In the case of Water Conserv II, reclaimed water has been used in a productive and environmentally safe manner in a successful cooperative effort between growers and government agencies that has solved problems for both and proven the value of reclaimed water as a resource.

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