Innovative Applications in Water Reuse:





Ten Case Studies

Innovative Applications in Water Reuse: Ten Case Studies

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Foreword

The water reuse industry has experienced rapid growth as well as tremendous changes over the last few years. The worldwide need for alternative water supplies due to increasing demand from population growth and other factors is the prime motivation for these changes. Although a number of communities in the United States and abroad have been involved in water reuse for many years, there is a rapidly growing interest in the beneficial reuse of municipal wastewater effluent and other alternative sources of water supply. While several states (e.g., California, Florida, Arizona, and Texas), have practiced water reuse for many years, it is now being recognized as an integral component of water resources management in many other states as well.

As more communities are expanding their water reuse efforts or considering water reuse for the first time, there is an increasing need to share information on successful water reuse projects. The WateReuse Association is committed to supporting the development of new water reuse projects by demonstrating the societal benefits of water reuse, including economic, environmental, and human health benefits. The purpose of this publication is to document the success of 10 diverse water reuse projects in the United States. In response to the need for alternative water supplies, the water utilities that sponsored these projects have embraced the concept of more sustainable water supplies through water reuse. They have accomplished this in a variety of innovative and nontraditional ways.

The WateReuse Association is a non-profit organization whose mission is to advance the beneficial and efficient use of water resources through education, sound science, and technology using reclamation, recycling, reuse and desalination for the benefit of our members, the public, and the environment. The Association supports water projects that increase high-quality water supplies from treated municipal and industrial effluents, stormwater, agricultural drainage, and sources with high salinity such as seawater and brackish water. The Association accomplishes these goals through: 1) sponsoring research that advances the science of water reuse and desalination and supports the Association's commitment to providing high-quality water, protecting public health, and improving the environment; 2) reaching out to members, the public, and local leaders and officials with information that communicates the value and benefits of water reuse; and 3) encouraging more Federal and state support for water reuse, including funding for scientific research and implementation of local projects. More information about WateReuse can be found on the Association's website at: www.WateReuse.org.

This publication would not be possible without the significant efforts of Dr. Jim Crook, the primary author of the case studies. The Association is also greatly appreciative of the cooperation of the water reuse utilities and agencies discussed in the 10 case studies. These utilities and agencies provided much of the underlying information for the case studies and assisted in the review of the summaries. The WateReuse Association is grateful for their efforts. The Association hopes that you benefit from their experiences.

G. Wade Miller
Executive Director
WateReuse Association

Contents

Hampton Roads Sanitation District

Background

Hampton Roads Sanitation District (HRSD), a political subdivision of the Commonwealth of Virginia, is located in southeastern Virginia. HRSD was created by public referendum in 1940 to eliminate sewage pollution in the tidal waters of the Chesapeake Bay. HRSD's service area includes 17 cities and counties of southeast Virginia, an area of over 3,100 square miles with a population of 1.5 million. It operates nine major wastewater treatment plants in Hampton Roads and four smaller plants on the Middle Peninsula having a combined capacity of 231 million gallons per day (mgd).

Water reuse has been a goal at HRSD since the mid-1980s, when the district began discussions with water purveyors to use reclaimed water for nonpotable applications in lieu of potable water. These efforts came to fruition in 1996 when the Amoco Yorktown Refinery (subsequently sold to Giant Industries, Inc.) expressed interest in using reclaimed water. At that time, the refinery was using potable water supplied by the Newport News Water Works as its source of cooling and process water. Projected increases in the cost of potable water led the refinery to seek a less expensive water source. The cost to upgrade treatment at the refinery's own 1.5 mgd wastewater treatment facility represented a large capital investment by the refinery; hence, a logical option was to consider the use of reclaimed water from HRSD's York River Treatment Plant (YRTP), located adjacent to the refinery.

Negotiations were soon underway and a contract between HRSD and the refinery was signed in December 2000. The contract included a 20-year agreement for production and delivery of reclaimed water to Giant Industries' Yorktown Refinery and water quality objectives based on the uses of the water at the refinery. Construction of facilities at the YRTP to produce 0.5 mgd of reclaimed water for use at the refinery began soon after that time, and the project became operational in July 2002. During the first year of operation, reclaimed water use at the refinery averaged about 0.4 mgd, which is 80 percent of the project's anticipated usage of 0.5 mgd. The water reuse facilities are collectively called the James River Water Reclamation Facility.

Project Description

The Yorktown Refinery, built in 1956, processes 60,000 barrels (2.5 mgd) of crude oil per day to produce gasoline, diesel fuel, heating fuel, and other products. The refinery categorizes its nonpotable water as either service water or boiler feed water. Reclaimed water is used for the following service water applications: cooling; crude oil desalting; coke cutting; miscellaneous uses such as rinsing and

York River
Treatment Plant

chemical mixing; charge water for the fire protection system when it is not in use (York River water would be used during actual firefighting); and irrigation of trees.

The source of the reclaimed water is HRSD's York River Treatment Plant (YRTP), located in York County. The influent to the plant is mostly domestic wastewater, as there is little industrial wastewater input to the sewerage system. Not including the addition of sidestream treatment to produce reclaimed water for the refinery, the YRTP has conventional activated sludge secondary treatment, chemical phosphorus removal, and disinfection using sodium hypochlorite. The effluent is dechlorinated prior to discharge to the York River. The wastewater treatment plant has a permitted capacity of 15 mgd and a current average flow of about 10.5 mgd.

The reclaimed water agreement between HRSD and the refinery consummated in 2000 included water quality limits recommended by a committee of regional jurisdictions (including HRSD), the refinery, and the Virginia Departments of Health and Environmental Quality. The reclaimed water limits include the following:

- Reclaimed water quantity: 0.5 mgd;
- Chemical oxygen demand: <40 mg/L;
- Total suspended solids: <10 mg/L;
- NH_3; <2.0 mg/L;
- Phosphorus: <2.0 mg/L;
- Turbidity: <5 NTU;
- Fecal coliforms: <200/100 mL;
- Chlorine residual: ≥ 0.5 mg/L;
- pH: 6.0-9.0;
- Calcium: no significant increase; and
- Sodium: no significant increase.

Water quality data from YRTP indicated that the existing activated sludge treatment process could not consistently meet the ammonia limit during cold weather and could not meet the turbidity limit on a consistent basis. After investigating several ammonia removal processes, biological nitrification using a sequencing batch reactor (SBR) was selected as the most reliable and cost-effective technology to produce reclaimed water for the refinery's applications.

Prior to conception of this project, HRSD investigated the possibility of adding filtration at its wastewater treatment plants to produce water appropriate for reuse applications. Pilot plant studies conducted in 1998 to evaluate the performance of a cloth-membrane automatic backwash disk filter indicated that the filter was capable of reliably producing effluent having turbidity less than 1 NTU. Thus, a cloth media disk filter was selected as the tertiary filtration unit process for the treatment of reclaimed water to be used at the refinery.

The selected reclaimed water treatment train, which provides 0.5-mgd capacity sidestream treatment of primary effluent at YRTP, is as follows: biological oxidation and nutrient removal using an SBR; an equalization tank; disinfection (chlorine is added to the equalization tank); filtration; and final disinfection. The product water is pumped through a 2,800-foot pipeline to a 3.6 million gallon storage tank at the refinery. Primary effluent was chosen over secondary effluent as the source water to the reclaimed water treatment system because the higher BOD concentration in primary effluent results in a stable concentration of heterotrophic and nitrifying bacteria in the SBR, thus ensuring sufficient biomass to produce a settleable floc.

Because YRTP normally nitrifies during the warmer months, it was originally anticipated that the SBR would be operated only in the winter. It has since been determined that it is less expensive to operate the unit year round. The reclaimed water facilities were designed so they could be relocated to another site in the event that YRTP implements full scale nitrogen removal in the future.

The quality of the reclaimed water produced at the James River Water Reclamation Facility is considerably better than that required by the 2000 agreement and easily meets all reclaimed water treatment and quality requirements contained in the most current Virginia Department of Environmental Quality draft regulations for irrigation and industrial uses (i.e., cooling, boiler feed, process water, and fire protection). Average values for selected parameters and constituents in the product water are as follows:

- pH: 7.0;
- Fecal coliforms: <1/100 mL;
- Turbidity: 0.7 NTU;
- Total suspended solids: <1 mg/L;
- Biological oxygen demand: 4 mg/L;
- NH_3: 0.4 mg/L; and
- Total phosphorus: 1.4 mg/L.

Project Benefits

The use of reclaimed water at the Yorktown Refinery results in reduced costs to the refinery for process water while providing a drought proof source of water. At the same time, Newport News Water Works conserves its potable water resources, and HRSD reduces the nutrient load released to the York River, which is a tributary of the Chesapeake Bay.

Funding and Costs

The total capital costs of the project are estimated to be $2.6 million. Approximately $1.6 million of the total will be funded through the Virginia DEQ's Wastewater Revolving Loan Program. This is the first water reuse project funded through this program. The O&M costs for the first year of operation (fiscal year 2003) are estimated to be between $135,000 and $150,000. However, the avoided treatment costs associated with removing 0.5 mgd from the conventional activated sludge process are expected to be as much as $60,000. Thus, the additional cost associated with the new sidestream treatment system, not including existing O&M costs, is anticipated to be about $80,000 to $90,000 per year. Operational costs will be borne by the refinery.

Sequencing
Batch Reactor

HRSD is selling the water to the refinery at cost to recover only the additional investment (capital and O&M costs) incurred to treat and transport the water to the refinery. The current reclaimed water rate of $1.50/1,000 gallons is based on full recovery costs over a 20-year period. The rate will be reevaluated after three years but in no case will exceed the cost of potable water, which currently is $3.25/1,000 gallons.

Potential Future Uses

A potential future use of reclaimed water at the refinery is boiler feed water. Pilot testing concluded that HRSD's reclaimed water could be treated by reverse osmosis (RO) to meet boiler feed water requirements. The refinery has installed RO facilities and is embarking on a one year full scale operation to evaluate the use of RO treated reclaimed water as boiler feed. During this period, all of the reclaimed water produced at YRTP will be used for boiler feed. This use, in addition to the service water uses, ultimately may require expansion of HRSD's facilities to accommodate higher flows and presents issues associated with ability to meet peak demands, maintenance of consistent pH, and disposal of reject water from the RO system. Current and future uses could result in total reclaimed water use at the refinery as high as 1.0 mgd during peak operation.

HRSD also is pursuing the use of reclaimed water from some of its other wastewater treatment facilities. Projects being considered include: providing reclaimed water to the Virginia Department of Transportation (VDOT) for tunnel washing; irrigation at a planned golf course in the City of Norfolk; landscape irrigation at Old Dominion University; using reclaimed water at the Southeastern Public Service Authority's waste-to-energy steam and power plant in Portsmouth; and use at a new gas fired steam plant at the U.S. Navy's naval amphibious base in Virginia Beach.

The VDOT project has the potential for development of a bulk distribution market. HRSD will pursue bulk distribution with landscapers, municipalities, contractors, and others who need large quantities of nonpotable water for irrigation, cleaning, surface wetting, and industrial uses.

For further information, contact: Hampton Roads Sanitation District, 1436 Air Rail Avenue, Virginia Beach, Virginia 23455-3002.

Irvine Ranch Water District

Background

Irvine Ranch Water District (IRWD) was founded in 1961 in the Orange County area of Southern California. This semiarid region receives an average of only 12 to 13 inches of rainfall per year. At the time the District was formed, the area was primarily agricultural. A majority of the property within the District boundaries was owned by The Irvine Company, which began development of the former ranch as a planned community in the early 1960s. About 40 percent of IRWD's drinking water is surface water from the Colorado River and Northern California purchased from the Metropolitan Water District of Southern California. The remaining 60 percent is obtained from local groundwater wells.

In the early 1960s water reuse for other than agricultural applications was relatively rare, but the Water District's early visionaries realized that water would be a key component to the viability of the new community. Wastewater came to be viewed as a unique resource rather than something in need of disposal. The Michelson Water Reclamation Plant (WRP) was built and became operational in 1967, supplying the growing community with highly treated recycled water. IRWD merged with the Los Alisos Water District in 2000 and began serving additional customers with recycled water from the Los Alisos WRP.

The main purpose of the water recycling program is to maximize drinking water supplies by reducing the need to use potable water for nonpotable uses. Another purpose is to minimize the amount of treated wastewater that must be sent to a regional wastewater agency for disposal through an ocean outfall.

Project Description

Unlike some projects that serve a limited number of customers, IRWD's recycled water distribution system reaches most of its 133 square mile service area, which has a population of 316,000. While some recycled water distribution lines are retrofitted, common practice at IRWD is to install recycled water lines along with domestic water and sewer lines as new housing or commercial developments are built. Currently, there are over 3,400 metered recycled water connections.

Two facilities, the Michelson and Los Alisos WRPs, treat wastewater to tertiary standards (i.e., total coliforms ≤2.2/100 mL and turbidity ≤2 NTU) specified in the California Department of Health Services Water Recycling Criteria for high level nonpotable uses, such as irrigation of residential property. The Michelson WRP has a capacity of 15 mgd; the Los Alisos Water Reclamation Plant has a capacity of 5.5 mgd. Recycled water is delivered throughout the community through a dual distribution system that includes more than 300 miles of recycled water pipelines, 12 storage reservoirs, and 15 pump stations. Two of the reservoirs are open lakes; the others are pre-stressed concrete or steel tanks. Prior to discharge from the two open reservoirs to the recycled water distribution system, recycled water may receive additional treatment by straining, pressure filtration,

Residence Irrigated with Reclaimed Water

Dual-Plumbed Office Buildings

and/or disinfection. The recycled water storage capacity currently is 656 million gallons.

The primary use of recycled water is landscape irrigation. Eighty percent of all business and public area landscaping in the District is irrigated with recycled water. Landscape irrigation uses include parks, school grounds, golf courses, a cemetery, freeway landscapes, city-maintained streetscapes, common areas managed by homeowner associations, and front and back yards at individual residential dwellings, including large residential estate lots. Recycled water is also used for food crop irrigation, toilet and urinal flushing in 12 dual-plumbed office buildings, and in commercial office cooling towers. Steve Bourke, Landscape Superintendent for the City of Irvine, states that, "We've been using recycled water for more than 30 years with no documented adverse affects. Having recycled water available has been a win-win situation for everybody."

Alternatives to Project

Recycled water now makes up more than 20 percent of IRWD's total water supply, reducing the need to import additional – and expensive – water from the Colorado River and Northern California. The recycled water system also helps make IRWD "drought resistant." During California's frequent drought cycles, drinking water supplies can be curtailed by the state or other entities. These restrictions do not impact the recycled water system.

Problems Encountered

The major problems encountered by IRWD are related to salinity, seasonal storage, and increased maintenance.

Salinity/Water Softeners: IRWD must constantly fight the battle of salinity. With source water (Colorado River) becoming more saline, the District has become increasingly concerned over the addition of more salts into the "closed loop" water reclamation system. Self-regenerating water softeners can add a large amount of salt to the sewer system each year. In addition, regulators attempting to limit non-point sources of pollution (i.e., urban runoff) often suggest that the salty runoff be diverted to the sanitary sewer.

IRWD recognized the salinity issue and enacted rules and regulations in the early 1970s to prohibit the use of self-regenerating water softeners within IRWD boundaries. Exchange tank systems that do not add salt to the sewer system were not prohibited. The City of Irvine was incorporated in 1971, and the prohibition on self-regenerating water softeners soon became an ordinance of the city. The salinity problem reemerged in 1997, when court cases brought by the water softener industry against water agencies elsewhere in California overturned such bans. IRWD continues to work legislatively toward restoring the ability of water recycling agencies to control salinity.

Seasonal Storage: Southern California receives most of its rainfall during the winter months. Since landscape irrigation is the main use of recycled water, demand fluctuates seasonally. In the winter months, more recycled water is produced than can be used. In the hot summer and fall months, the plant capacity cannot produce sufficient water to meet demand. Balancing the seasonal storage issue through the use of open lakes is an ongoing challenge, and finding land in an urban setting to build more seasonal storage is a difficult task. IRWD currently is able to meet year round demand through the use of its numerous storage reservoirs but continually seeks locations for additional recycled water storage to meet expected future demand.

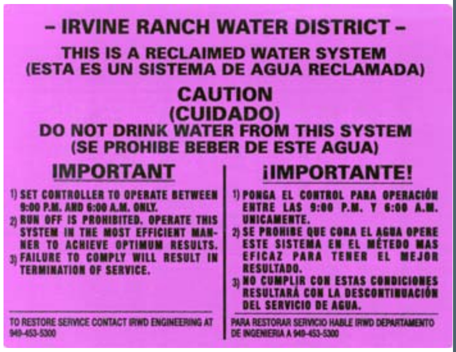
Increased Maintenance: Recycled water systems require more maintenance than drinking water systems. This includes more frequent reservoir tank cleaning, increased control valve maintenance, and potential damage to mainline valve body seats from higher chlorine levels. From a regulatory standpoint, leaks or spills of any amount must be reported to the county health department. Leaks or spills over 50,000 gallons are treated as if they were raw sewage and necessitate notification of the Santa Ana Regional Water Quality Board and extensive follow-up reporting. Also needed is an onsite inspection group to conduct ongoing monitoring to prevent cross connections.

None of the maintenance issues presented by recycled water proved to be major problems, but they did result in equipment and procedural changes to adequately address the maintenance issues. For example, IRWD now specifies a different type of valve seat, which has a higher resistance to chlorine. When dealing with leaks or spills of recycled water, IRWD attempts wherever possible to route the water into a sanitary sewer system instead of the separate storm drain system which flows to the ocean. In other cases, leaked or spilled water is collected and trucked to the sewer system.

Public Outreach

Recycled water generally is very well accepted within the IRWD service area. Because the district has a 35-year track record of successfully and safely providing recycled water to the community, it is not met with resistance by the general public. This is due, in part, to an extensive public education and involvement program via brochures, videos, workshops, tours, and other means that have resulted in community acceptance of water reuse as an environmentally sound method for stretching limited water supplies.

IRWD's public outreach program has included an extensive classroom water education program in local schools for nearly 30 years. The need for water conservation is taught at all grade levels, and the water reuse concept is introduced to students in the fifth grade. In addition, tours of the WRPs and water quality laboratory are regularly held for the general public. IRWD has found that a well informed public is less apprehensive about water reuse.



Costs and Revenues

IRWD has continued to expand and upgrade its reclaimed water program throughout the years, with most of the capital costs financed via the District's internal funding mechanisms. Infrastructure costs are recovered through a combination of property taxes and connection fees. The annual O&M cost of the recycled water system (including treatment and distribution system maintenance) was about $6.6 million for fiscal year 2002-2003. The base recycled water rate is $0.68/100 ft^{3}, which is 90 percent of the base domestic water rate. IRWD uses an ascending block rate structure that severely penalizes excessive water use.

Future Upgrades

The district currently is working on conversion of an existing open reservoir that was formerly used for drinking water storage to provide additional seasonal storage of recycled water. When completed in early 2005, this reservoir will add another 814 million gallons of recycled water storage to the IRWD system.

The District is also in the design phase on the Irvine Desalter Project, which will remove trichloroethylene (TCE) from a plume of pollution migrating from a former military base. Following treatment by reverse osmosis, air stripping with activated carbon filters, and disinfection, the product water will be added to the recycled water system. Beginning in 2006, this project is expected to provide an additional 590 million gallons/yr of water.

Because the IRWD service area is still being developed, there will be a need for additional recycled water in the future. IRWD's master plan calls for the gradual enlargement of the Michelson WRP within its existing boundaries to eventually produce 33 mgd by 2025. Plans call for the eventual expansion of the Los Alisos plant to 7.8 mgd.

For further information, contact: Marilyn Smith, Public Affairs Manager, Irvine Ranch Water District, 15600 Sand Canyon Avenue, Irvine, CA 92618.

Montebello Forebay Groundwater Recharge Project

Background

Southern California is essentially a desert area with limited water resources and an annual rainfall averaging about 15 inches/year. In the early 1900s, local precipitation and runoff was sufficient to replenish the groundwater supply of the coastal basins, which initially was the primary source of water. By the 1950s, increasing demand for water resulted in severe overdrafting of groundwater in the region. Water needs were exacerbated in 1982 by a Supreme Court decision that awarded the State of Arizona surplus Colorado River water, which makes up more than 50 percent of the Metropolitan Water District of Southern California's (MWD) annual withdrawals, raising the possibility of decreased availability of Colorado River water in the future.

The Montebello Forebay Groundwater Recharge Project – the oldest planned indirect potable reuse groundwater recharge project in California – is located in southeastern Los Angeles County and is the primary source of replenishment for the Central Basin, which is the main groundwater basin underlying the greater Los Angeles metropolitan area. Planned recharge of recycled water occurs in an unconfined (non-pressure zone) region of the Central Basin known as the Montebello Forebay. The Central Basin is an adjudicated basin with 85 groundwater pumpers operating more than 400 active wells. Imported water from the Colorado River and State Water Project purchased from MWD provides 55 percent of the water used within the basin, with groundwater accounting for the remainder.

If recycled water was not used for groundwater recharge of the Central Basin aquifer, the Water Replenishment District of Southern California (WRD) would have to purchase an equivalent amount of imported water from MWD for recharge at a much higher price or restrict pumping of the aquifer to prevent overdrafting, which would shift water demand to surface supplies. Surface deliveries could be augmented by seawater desalination, albeit at a much higher cost than either recycled or imported water.

In addition to groundwater recharge, the County Sanitation Districts of Los Angeles County (CSDLAC) uses recycled water for a variety of nonpotable applications, such as landscape and agricultural irrigation, industrial process water, recreational impoundments, and wildlife habitat.

Project Description

The use of recycled water for groundwater recharge began in 1962. Approximately 12,000 acre-feet/year (ac-ft/yr) of disinfected activated sludge secondary effluent from the Whittier Narrows Water Reclamation Plant (WRP) was spread in the Montebello Forebay area of the Central Basin, which has an estimated storage capacity of 780,000 ac-ft. The County of Los Angeles provided funding for the plant, the U.S. Army Corps of Engineers provided the site behind the Whittier Narrows dam, and CSDLAC designed, built, and operated the plant.

Rio Hondo Spreading Grounds

In 1973, the San Jose Creek WRP was placed in service and also supplied secondary effluent for recharge. The San Jose Creek WRP has a capacity of 100 mgd and provides the majority of the recycled water now used for recharge. In addition, effluent from the 13-mgd Pomona WRP that is not reused for other purposes is discharged into San Jose Creek, a tributary of the San Gabriel River, and ultimately becomes a source of recharge in the Montebello Forebay. During the mid to late 1970s, all three plants were upgraded to provide tertiary treatment via filtration as a public health protection measure to protect people recreating in the receiving waters. The WRPs have since been upgraded to include nitrification/denitrification treatment. Recycled water is used along with stormwater runoff and imported surface water (Colorado River and State Water Project water) for recharge.

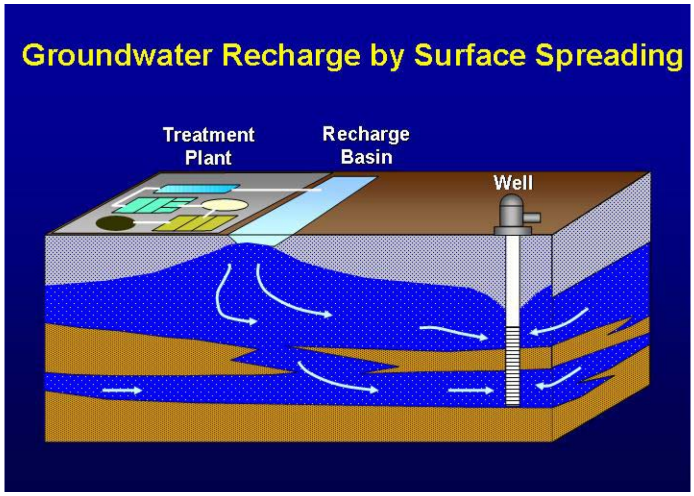
All of the biosolids from the WRPs are returned to one of the major trunk sewers and subsequently treated at the CSDLAC's Joint Water Pollution Control Plant near the coast in Carson, thus eliminating the need for biosolids treatment facilities at the plants. Elimination of treatment of biosolids simplifies operation of the plants, reduces construction and O&M costs, and avoids the potential for odors.

In 1987, a Los Angeles Regional Water Quality Control Board (RWQCB) order permitted the CSDLAC to increase the annual quantity of recycled water used for replenishment from 32,700 ac-ft to 50,000 ac-ft. In 1991, the water reclamation requirements for the project were revised to allow for a maximum recharge of 60,000 ac-ft in any year as long as the running 3-year total did not exceed 50,000 ac-ft/yr or 35 percent recycled water.

As part of the 1987 permit that allowed an increase in the amount of recycled water used for recharge, the California Department of Health Services (DHS) and the RWQCB require monitoring of not only the effluent from the three WRPs contributing to the recharge project, but also bimonthly sampling of six shallow monitoring wells and semiannual monitoring of 19 production wells. This long-term monitoring program has continued to demonstrate that the introduction of recycled water into the aquifer meets all regulatory requirements and has not adversely impacted groundwater quality.

Project Management

CSDLAC operates the WRPs and monitors the recycled water quality. The Los Angeles County Department of Public Works (DPW) operates the recharge facilities (river conveyance and spreading basins), and the WRD is responsible for overall management of the groundwater basin – including groundwater monitoring. DPW has constructed two spreading areas designed to increase the percolation capacity. The Rio Hondo Spreading Grounds have 570 acres of spreading basins available for spreading, and the San Gabriel Coastal Spreading Grounds have 128 acres. Percolation also occurs in



133 acres of the unlined San Gabriel River channel. The WRPs are located upstream of the spreading grounds, allowing gravity flow and existing waterways to transport the recycled water, thus reducing capital and O&M costs.

Under normal operating conditions, batteries of basins are rotated through a 21-day cycle. The cycle consists of three 7-day periods during which the basins are filled, the flow to the basins is terminated, and the basins are allowed to drain and dry out thoroughly. This wetting and drying operation serves to maintain aerobic conditions in the upper strata of the soil and to control vectors in the basins. The vadose zone under the spreading basins (i.e., the sandy loam soil layer extending from the bottom of the basins to the groundwater table in which additional treatment takes place) is variable depending on location but generally is 10 feet thick or more.

Water Quality/Regulatory Requirements

In California, DHS has the authority to adopt water reuse criteria, which are implemented by the RWQCBs via their permit system. DHS has been developing groundwater recharge regulations for a number of years and, although draft regulations have been released, it is unclear what the final criteria will contain upon adoption. It is clear that recycled water used for groundwater recharge will have to meet drinking water standards, very low nitrogen and total organic carbon (TOC) limits, dilution requirements, and not contain measurable levels of pathogens. Also, monitoring of other constituents, such as xenobiotic compounds (e.g., pharmaceuticals and personal care products), will be required by the regulatory agencies. It is noteworthy that the water quality criteria apply to the water after percolation through the vadose zone.

Recycled water produced by the WRPs complies with the primary drinking water standards, and meets total coliform and turbidity limits of 2.2/100 mL and 2 NTU, respectively. Extensive virus and parasite sampling indicates that the recycled water is essentially free of measurable levels of pathogens. Samples taken from monitoring wells within 500 feet of the recharge basins indicate that TOC levels in the groundwater range from nondetectable to about 2.6 mg/L, while the long-term average total nitrogen level (consisting almost exclusively of nitrate) is 4.1 mg/L or less (with nitrite levels being below detectable limits).

The ongoing concern over emerging contaminants and associated health concerns requires effluent monitoring and research beyond what has been done in the past. Development of virus and parasite quantitative analytical techniques, microbial viability studies, evaluation of soil aquifer treatment, and surrogates for health significant organic constituents are just some of the research efforts underway at CSDLAC.

Health Effects Study

A consulting panel was established by the State of California in 1975 to provide information that would assist DHS in the establishment of criteria for groundwater recharge of potable water aquifers. The panel expressed uncertainties regarding potential health effects and recommended that comprehensive health studies be conducted at existing sites. In response, CSDLAC initiated a 5-year, $1.4 million health effects study in 1978 to determine whether the Montebello Forebay Groundwater Recharge Project had an adverse effect on the groundwater or the health of individuals ingesting the groundwater.

At the time the study was conducted, the amount of recycled water spread averaged approximately 26,500 ac-ft/yr or 16 percent of the total inflow to the groundwater basin with no more than 32,700 ac-ft of recycled water spread in any year. The percentage of recycled water in the extracted potable water ranged from zero to 11 percent on a long-term (1962-1977) basis. The data obtained during the study did not demonstrate any measurable adverse effects on the area's groundwater or the health of the population ingesting the water.

The state commissioned a Scientific Advisory Panel on Groundwater Recharge with Reclaimed Water in 1986 to further evaluate benefits and risks associated with groundwater recharge. The panel concurred with the Health Effects Study findings and concluded that the risks, if any, were small and probably not dissimilar from those that could be hypothesized for commonly used surface waters. The panel conditioned its conclusion by stating that the results are "marginal or inconclusive" with regard to cancer because the exposure period was short relative to the expected minimum 15-year latency period for chemically induced cancers.

In an attempt to obtain more definitive health effects data, follow-up epidemiological studies were conducted in 1996 and 1999. They provided no evidence that populations consuming groundwater estimated to contain recycled water in the percentages encountered (zero to 31 percent) in the Montebello Forebay at the time of the studies had a higher risk of cancer, mortality, infectious disease, or adverse birth outcomes than those using other water sources.

Project Benefits

The recharge of more than one million ac-ft of recycled water since 1962 has helped to significantly reduce the cumulative overdraft in the Central Basin. The recycled water provides a new water supply roughly equivalent to the demands of 250,000 people and reduces wastewater discharges to surface waters. Also, the use of recycled water in lieu of imported water for groundwater recharge saves WRD more than $12 million per year in water purchases.

For further information, contact: Earle Hartling, Water Recycling Coordinator, County Sanitation Districts of Los Angeles County, 1955 Workman Mill Road, Whittier, CA 90602.

Monterey County Water Recycling Projects

Background

The Salinas Valley is an agricultural region in northern Monterey County where a wide variety of market crops are grown. Heavy agricultural and municipal groundwater demands beginning in the 1940s led to the development of severe groundwater overdrafting of the underlying aquifers, resulting in seawater intrusion from adjacent Monterey Bay. The intrusion front was advancing inland at a rate of approximately 500 ft/yr. High salt levels in groundwater caused wells near the coast to be abandoned, and agricultural water supply wells and some community drinking water wells were threatened. This was a major factor in the decision to develop a regional wastewater management plan to provide recycled water for food crop irrigation in the Salinas Valley. By using recycled water for irrigation, growers could discontinue pumping from their wells, thus alleviating overdrafting of the groundwater, which amounts to about 16 billion gallons/yr at the mouth of the valley. It is anticipated that the use of recycled water for agricultural irrigation will eventually reduce seawater intrusion by 40 to 50 percent.

The Monterey Regional Water Pollution Agency (MRWPCA) began facilities planning to provide wastewater management services to northern Monterey County, California, in 1975. At that time, water reuse was considered to be an important element in the planning process as a means to reduce groundwater pumping.

Agricultural Reuse Demonstration Study

The 11-year Monterey Wastewater Reclamation Study for Agriculture (MWRSA) was initiated in 1976. The goal of MWRSA was to assess the safety and feasibility of using recycled water to irrigate vegetable crops that may be eaten raw. It included a 5-year demonstration project comparing well water with two different recycled water tertiary treatment trains.

A Task Force comprised of representatives from federal, state, and local governments, the academic community, farm advisors, and local growers provided guidance in the planning and conduct of the study. The California State Water Resources Control Board and the U.S. Environmental Protection Agency provided funding for the study, which cost $7 million.

Various crops (e.g., artichokes, lettuce, celery, broccoli, and cauliflower) were irrigated with three types of water – well water, tertiary treated recycled water that included chemical coagulation and clarification processes, and tertiary treated recycled water using direct filtration. Various side-by-side comparisons of water types, fertilizer rates, and crops were conducted. Study results included the following:

- No pathogenic organisms were detected in the recycled water or produce;
- Poliovirus seeding tests indicated more than five logs removal by the treatment process train;

Crops irrigated with reclaimed water

- Irrigation with recycled water did not adversely affect soil permeability;
- Metals were not found to accumulate in the soils or plant tissues;
- Produce yields, quality, and shelf life were as good, and in some cases better, in crops irrigated with recycled water; and
- Tertiary treatment using direct filtration was determined to be acceptable for irrigation of food crops eaten raw.

Marketing Study

As part of the MWRSA project, a study was commissioned in 1983 to determine the key issues associated with marketability of crops irrigated with recycled water. Interviews were conducted with individuals involved with produce distribution, including wholesale-retail buyers, brokers, and store managers. Responses indicated that produce grown in recycled water would be accepted, labeling would not be necessary, and factual information would be useful to respond to customer inquiries that might arise. The major requirement of buyers was for produce to have a healthy appearance and be aesthetically attractive. Respondents to the market study recommended that response to rumors that might occur regarding irrigation with recycled water should include clear, government-endorsed fact sheets and that support be given to developing an educational information program on the use of recycled water for crop irrigation. A 1997 follow-up study produced similar results.

Field Worker Health

The health status of each person assigned a field task during the field study was monitored through frequent questionnaires and initial and exit medical examinations. Neither questionnaire data nor medical examinations indicated any adverse health effects associated with working in fields irrigated with tertiary treated recycled water.

Full-Scale Facility

Based on the favorable results of the MWRSA study, a decision was made to design and construct a full-scale facility. Design of the treatment plant facilities, called the Salinas Valley Reclamation Project (SVRP) [SVRP conforms to all requirements specified in the California Water Recycling Criteria for recycled water used to irrigate food crops eaten raw] was completed in 1994 along with design of the distribution system, which is known as the Castroville Seawater Intrusion Project (CSIP).

The 30-mgd regional wastewater recycling facility was constructed adjacent to the regional secondary treatment plant to provide tertiary treated recycled water for agricultural applications. Tertiary treatment includes flocculation using polyaluminum chloride or alum and polymers followed by filtration using dual media filters, and disinfection using gaseous chlorine. Diurnal tertiary treatment flow equalization storage is provided. The regional wastewater recycling facility was completed in 1997 and began delivering 20 mgd of recycled water to growers within its service area for food crop irrigation in 1998.

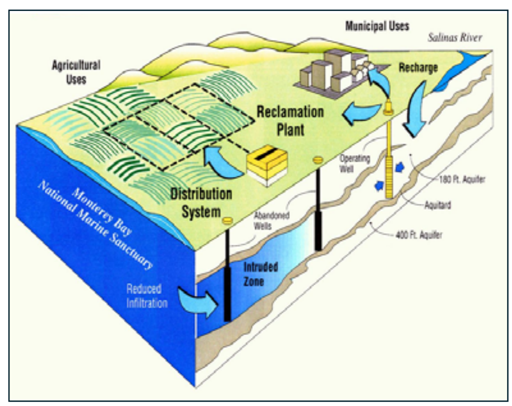
Prior to startup an independent laboratory was hired to conduct a Recycled Water Food Safety Study. The primary objective was to determine if any viable pathogenic organisms of concern to food safety were present in recycled water. A secondary objective was to assess the ability of the treatment processes to remove or inactivate pathogens that might be present in the influent wastewater. Sampling began in 1997 and continues to the present. The study has not detected any *E. coli* 0157:H7, *Salmonella*, helminth ova, *Shigella*, *Legionella*, or culturable natural (in situ) viruses. An extremely low number of *Cyclospora* (one instance), *Giardia* with internal structure (one instance), and *Cryptosporidium* (in seven instances) have been detected in the tertiary treated recycled water.

Schematic of the Water Reuse Concept

The water recycling facility and distribution system are collectively known as the Monterey County Water Recycling Projects (MCWRP). Recycled water is used to irrigate various crops, including lettuce, celery, broccoli, cauliflower, artichokes, and strawberries. During the growing season, supplemental well water is used to meet the total grower demand. Dale Huss, Vice President of SeaMist and OceanMist Farms, typifies growers' satisfaction with the project. He states that, "We've been using project water since 1997 and have seen no adverse effects to our product or our soils. In fact, our yields on artichokes, lettuce, spinach, celery, and fennel are as high or higher as they've ever been."

CSIP distributes recycled water to 222 parcels of farmland in the 12,000-acre service area and includes the following:

- 46 miles of recycled water transmission and distribution pipelines ranging in diameter from 8 to 51 inches;
- 22 supplemental wells to augment recycled water flows at times of peak demand;
- 111 flow-metered turnouts for connection of irrigation piping by farmers;



Schematic of the Water Reuse Concept

- Pressure, conductivity, and flow monitoring stations;
- A centralized control system;
- Three booster pump stations; and
- Cathodic protection for ferrous metal piping.

While there have been no major operational problems related to the distribution system, minor problems include flushing of construction debris from the system, excessive sand in the extracted water of some wells, and a few pipeline breaks. A three-person crew is able to keep the system running on a continuous basis.

The sodium absorption ratio (SAR) of the recycled water is about 4.7, while good quality well water averages 1.7. The combined waters have an SAR slightly above 3.0 – the maximum level desired by growers. While the MWRSA study did not indicate any salt buildup during five years of operation with recycled water, a multi-year salt monitoring program has found that soil SAR and exchangeable sodium percentage are significantly higher in fields irrigated with recycled water but are within the acceptable range for cool season vegetable production. Efforts currently are underway by MCWRA to reduce salt concentration in the wastewater via source control.

Education and Outreach

A Water Quality and Operations Committee was formed in 1996 to gain input from users. The main issues of the growers were related to food safety, marketability, public perception, and water quality. Thus, a proactive education plan was developed in 1997 to address perception issues. Materials were generated to prepare local produce growers and sellers for any questions regarding the safety of the recycled water and produce. An extensive outreach effort directed principally at the local media and public included tours, presentations to service clubs, billing inserts, and school programs. To address the issue of field worker safety, handouts and training videos in both English and Spanish were distributed to all local project growers for their education.

Costs and Revenues

In order to proceed with the project, a partnership was formed between MRWPCA's and the Monterey County Water Resources Agency (MCWRA). Since many of MRWPCA customers have no direct benefit from the project, system operation costs are reimbursed by MCWRA. The Monterey County Water Recycling Projects (MCWRP) was formed by the two agencies in 1992.

The total capital cost of MCWRP was approximately $78 million. Low-interest loans were obtained from the U.S. Bureau of Reclamation (USBR) and the State of California. The USBR loans, for construction of the treatment facilities and distribution, have 40-year terms, while the state loan has a 20-year term.

The total cost to treat and deliver recycled water to agricultural areas is estimated to be about $225/ac-ft ($0.90/1,000 gallons) excluding secondary treatment costs, but including both debt service from low interest loans and operation and maintenance costs for the two components (i.e., tertiary treatment facilities and distribution network) of the MCWRP.

The two sources of revenue for the project are land assessments established by MCWRA – currently $233.41/ac/yr – and a water delivery charge of $0.05/1,000 gallons. The revenue streams provide about $6 million annually and are evaluated and adjusted on an annual basis, as necessary, to cover the operational budget. About $3.5 million of the operations budget is for direct operating costs with the balance for debt service.

For further information, contact:
Robert Holden, Monterey Regional Water Pollution Control Agency, 5 Harris Court, Building D, Monterey, CA 93940.

Orange County Water District

Background

The Orange County Water District (OCWD) in Fountain Valley, California was formed in 1933 to manage northern Orange County's groundwater supply. More than 250 production wells in OCWD's service area supply about 70 percent of the water demand for a population of two million. The remaining demand is met by imported water from the Colorado River and Northern California. Seawater intrusion has been a problem since the 1930s as a consequence of basin overdraft. Seawater intrusion was observed as far as 3.5 miles inland from the Pacific Ocean by the 1960s. Further, a 1963 Supreme Court decision limited the amount California was guaranteed from the Colorado River, thus raising the specter of losing a large quantity of the then currently imported water.

The Orange County groundwater basin contains an estimated 326 billion gallons/year (bgy) of usable water and has an average operating yield of 82 bgy. OCWD's inland surface spreading operations recharge an average of 95 percent of this quantity via approximately 1,000 acres of surface water percolation facilities. Historically, imported water from the Colorado River and Northern California and water from the Santa Ana River have been the source waters for groundwater recharge in the Orange County Forebay.

Water Factory 21

OCWD began pilot studies in 1965 to determine the feasibility of injecting effluent from an advanced wastewater treatment (AWT) facility into aquifers in the Talbert Gap at the mouth of the Santa Ana River to create a freshwater mound that prevents seawater intrusion.

The first permit for the project, issued in 1971 by the Santa Ana Regional Water Quality Control Board, following public hearings and recommendations from the California Department of Health Services (DHS), required that the reclaimed water be blended at least 50 percent with demineralized or deep well water prior to injection. The permit requirements are based primarily on drinking water standards. Other requirements, such as TDS, chloride, and boron, are based on water quality objectives to protect existing groundwater quality.

Construction of the AWT facility known as Water Factory 21 (WF-21) began in 1972, and injection of treated municipal wastewater began in 1976 via 23 multiple-cased injection wells. The project included construction of 31 monitoring wells, five supplementary deep wells, and seven extraction wells. The extraction wells, located between the injection wells and the coast, have not been needed to maintain a hydraulic gradient to prevent seawater

Reverse Osmosis Units

intrusion. Five additional injection wells have been constructed in recent years.

WF-21 receives activated sludge secondary effluent from the adjacent Orange County Sanitation District (OCSD) Plant No. 1. The 15-mgd water reclamation plant's processes originally consisted of lime clarification, recarbonation, ammonia stripping towers, mixed media filtration, granular activated carbon (GAC), chlorination, and blending with deep well water.

The ratio of reclaimed water to blend water was increased to about 67 percent reclaimed water and 33 percent deep well water in 1977 when reverse osmosis (RO) was incorporated into the treatment train (the flow was split 50:50 between GAC and RO). It was found that RO was sufficient to remove nitrogen compounds from the water, and the ammonia stripping towers were taken out of service in 1986. RO and GAC effluent were pumped to a blending reservoir, mixed with deep well water, and injected into four aquifers prone to seawater intrusion using the multi-point injection wells. The bulk of the injected water flows inland to augment groundwater used as a potable supply source. The nearest potable water supply well that receives the reclaimed water is more than 2,000 feet from any injection well.

The WF-21 project, which included a demonstration seawater desalting facility, received approximately $10.2 million in state and federal funding for the $21 million project. The total capital cost of WF-21 was $16.2 million and the total annual O&M cost is about $2.5 million. In 1980-1981, when WF-21 was operated at less than design capacity, the amortized capital cost and O&M cost totaled $1,624 per million gallons. This was estimated to be less than the cost of imported water.

Extensive monitoring has verified that the product water contains no pathogenic bacteria, viruses, or parasites and continually meets all drinking water standards. Within the past few years, N-nitrosodimethylamine (NDMA) and 1,4-dioxane, which are classified as probable human carcinogens, were found in WF-21 reclaimed water, groundwater, and wells subject to extraction of reclaimed water at levels that exceeded the State's action levels of 10 ng/L and 3 µg/L, respectively. OCWD determined that the source of the 1,4-dioxane was an industrial discharger, who immediately changed processes and brought the level into compliance.

The District subsequently modified the WF-21 treatment train to address these compounds and emerging contaminants.

GAC has been eliminated and all wastewater flow now receives RO treatment using thin-film composite membranes. Chlorine has been replaced with UV as the main disinfection process and an advanced oxidation process (AOP) has been added. The AOP entails the addition of hydrogen peroxide prior to UV. The modified treatment train has been shown to be effective in reducing NDMA to an acceptable level and effectively reduces the concentration of other compounds such as low molecular weight organics, pharmaceuticals, and endocrine disrupting compounds.

Green Acres Project

The Green Acres Project (GAP) was designed in the late 1980s to provide reclaimed water for urban irrigation and other nonpotable uses. It went into operation in October 1991. The reclaimed water receives tertiary treatment (secondary treatment, filtration, and disinfection) and is distributed for uses in Fountain Valley, Huntington Beach, Costa Mesa, Newport Beach, and Santa Ana. The reclaimed water meets the California Water Recycling Criteria for uses requiring disinfected tertiary treated reclaimed water.

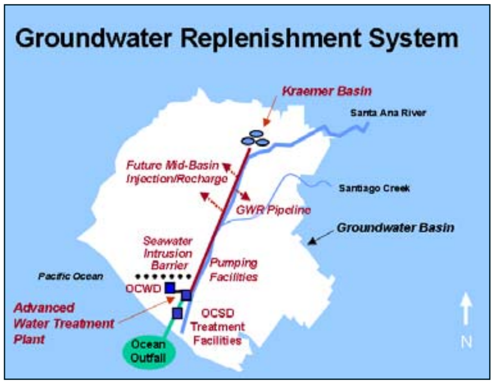
The Green Acres Project provides an average of more than six mgd of reclaimed water for landscape irrigation (i.e., parks, schools, golf courses, etc.) and industrial purposes such as cooling and process washdown through about 32 miles of pipelines ranging in size from six to 42 inches. Use by a carpet dyer was discontinued due to water quality problems that caused occasional spotting of dyed carpets. OCWD is examining ways to resolve the quality issue.

During the winter months, the GAP plant is taken out of service and reclaimed water is supplied by the Irvine Ranch Water District's Michelson WRP. A potential future phase of the GAP project being considered is an extension into central Huntington Beach to serve users with an average of 0.9 mgd. OCWD wholesales GAP water to various water agencies. The capital cost of GAP was approximately $48 million (including assistance for end-user retrofits), and the annual O&M cost is about $0.9 million.

Groundwater Replenishment System

OCWD has continued its tradition of innovation with a new project to help meet the County's future water supply and groundwater quality needs. In the 1990s, OCWD estimated that an additional 45 to 70 mgd could be recharged into the groundwater basin using existing spreading basins in the Orange County Forebay area. A recharge project called the Groundwater Replenishment (GWR) System was conceived to provide a new reliable drought proof water supply at 40 percent less cost than imported water, prevent seawater intrusion, improve groundwater quality, reduce ocean discharge, and defer the need for a new ocean outfall. Detailed design and construction of the GWR System, a joint project between OCWD and OCSD, was approved in 1999. In the first phase of the project, 70 mgd of reclaimed water will be used for recharge.

The source water for the AWT facility will be activated sludge secondary effluent from the adjacent OCSD plant. The GWR system treatment plant will provide further treatment by microfiltration, RO, and AOP. Due to the aggressiveness of RO effluent,



lime will be added to the product water prior to discharge to the transmission pipeline. Monitoring at WF-21 has verified that the treatment provided is capable of producing water that meets all requirements specified by DHS for indirect potable reuse via groundwater recharge, including those related to xenobiotics and other trace organic contaminants. The nearest extraction well is more than 900 feet from the percolation basin, and the retention time underground prior to extraction exceeds eight months.

The majority of the treated water will be pumped approximately 14 miles through a 78-inch diameter pipeline through the Santa Ana River corridor to Kraemer Basin in Anaheim, one of the deep spreading basins used in the Orange County Forebay area. Some of the water, 15 to 40 mgd depending on the time of year, will be diverted to an expanded Talbert Gap Seawater Intrusion Barrier currently served by WF-21; a small portion, as much as five mgd for up to 60 days per year, will be used to supplement OCWD's GAP during the summer months. Some of the treated water may also be made available for irrigation, industrial process water, or other approved uses by connections to the conveyance pipeline in areas located near the Santa Ana River alignment.

The estimated capital cost of the GWR System is $454 million, and the estimated annual O&M cost is $22 million. OCWD received federal and state grants totaling $92.5 million and a State Revolving Fund loan of $145 million. Funding has been provided by several agencies, including the U.S. Bureau of Reclamation, U.S. Environmental Protection Agency, Metropolitan Water District of Southern California, California Department of Water Resources, California Energy Commission, and a California State Water Bond.

The GWR System is supported by an active outreach program to inform water users on the need for the project and the water quality. Currently, approximately $900,000 is spent each year on public information that includes: water user telephone surveys; multiple mailings to each home; print and cable television advertising; and 150 to 180 face-to-face talks to community groups, businesses, hospitals, elected officials and other groups.

Key elements in OCWD's approach to ensuring safe and adequate water supplies within its service area include a commitment to "cutting edge" research, innovation in treatment technology, monitoring of treatment process performance beyond permit requirements, and a close working relationship with regulatory agencies. As stated by Bob Hultquist, Chief of the DHS Drinking Water Technical Operations Section, "OCWD has a long history of technical excellence and expertise that instills a degree of confidence in the District's efforts to protect public health."

For further information, contact: Orange County Water District, 10500 Ellis Avenue, Fountain Valley, CA 92728-8300.

Pinellas County's Reclaimed Water Program

Background

Pinellas County, located on the west-central coastline of Florida, is a highly urbanized peninsular community bounded on the west by the Gulf of Mexico and on the south and east by Tampa Bay. It has an area of approximately 240 square miles, contains 24 separate municipalities, and has a population approaching one million.

The Pinellas County Water System was established in 1935 and soon thereafter began supplying potable water from the Walsingham Reservoir, located in the central part of the County. Wellfields in the northeastern part of the County were added as a water supply source in the 1950s. By 1970, burgeoning population and associated drinking water demands resulted in the need to obtain water supplies outside of Pinellas County. The County experienced a brief building moratorium in the 1970s due to the unavailability of the then existing water sources to sustain new growth.

The first reclaimed water project was initiated in 1975 with irrigation of the Innisbrook Golf Resort. Between 1979 and 1987, the County began to provide reclaimed water to five other golf courses in the northeastern part of the County.

The Pinellas County Utilities Department was formed in 1994 to consolidate all of its public utility services (water, sewer, and solid waste). A 5-year drought in the early 1990s heightened awareness of the need to develop alternate water sources. It was at this time that Pinellas County Utilities created an Alternate Water Sources Department to – among other responsibilities – plan, manage, and administer expansion of the County's reclaimed water system.

In 1998, Tampa Bay Water (formerly known as West Coast Regional Water Supply Authority) entered into a partnership with Pinellas, Pasco, and Hillsborough Counties and the cities of St. Petersburg, Tampa, and New Port Richey to acquire the wellfields of the above mentioned entities and become the wholesaler of potable water in the tri-county area. Pinellas County currently purchases 70 mgd of potable water from Tampa Bay Water at cost for sale and distribution to its more than 107,000 customers and five cities.

Due to the geographic location of several cities, the County's wastewater service areas are divided into two distinct service districts, the north and the south. Pinellas County Utilities owns and operates two regional water reclamation facilities within these districts. The William E. Dunn Water Reclamation Facility (WRF) in the northern part of the county has a permitted capacity of 9.0 mgd and produces an average of 6.5 mgd of treated wastewater, all of which is reused. The South Cross Bayou WRF in the southern part of the county has a permitted capacity of 33 mgd and produces an average of 26 mgd, of which 7.4 mgd is reused.

Landscape Irrigation with Reclaimed Water

North Service Area

Rapid growth of the region in the 1970s produced a wastewater treatment demand greater than the County could initially handle. As a result, several small, independent wastewater facilities using percolation ponds for disposal were constructed by developers to serve golf communities. The County subsequently acquired these small wastewater treatment facilities through agreements that provided for disposal of the effluents within the communities. This was the beginning of the county's north service area reclaimed water system.

In 1991, the William E. Dunn WRF capacity was tripled to nine mgd to replace several small independently created facilities and provide treatment at a single facility, thereby reducing operating costs. The William E. Dunn WRF was designed to meet advanced wastewater treatment (AWT) standards (i.e., five mg/L BOD and TSS, three mg/L total nitrogen, and one mg/L total phosphorus) and meets all Florida Department of Environmental Protection (DEP) water reuse criteria for irrigation of public access areas.

As part of the expansion, a 63-mgd holding pond for storage and a 17-mgd reject pond were constructed at the William E. Dunn WRF. Particulate strainers were added to the outlet line of the storage pond to prevent the release of material that could clog irrigation sprinkler systems. The program required pumping untreated wastewater to the treatment plant and reclaimed water back to the reclaimed water use sites. At that time, there were approximately 450 reclaimed water customers using a total of 3.9 mgd. By 1995, all untreated wastewater was sent to the William E. Dunn WRF; all independent wastewater plants were removed from service by the end of 1997.

The North County system has been expanded to the point where system demands consume all available supplies; thus, additional augmentation water is needed to meet the growing demand for reclaimed water and realize additional potable water savings. In response to this need, Pinellas County entered into an interlocal agreement with the City of Oldsmar in 1998 to purchase 0.8 mgd of surplus reclaimed water, and in 2000 an interlocal agreement with the City of Clearwater for three mgd of surplus water was consummated. The combined capital cost of these interconnects, scheduled to go online in late 2005, is estimated to be $9 million. The Southwest Florida Water Management District (SWFWMD) provides 50 percent of the total project costs.

Currently, there are about 500 residences, seven golf courses, two parks or playgrounds, and seven schools provided with reclaimed water from the William E. Dunn WRF. The residential customers account for less than 10 percent of the reclaimed water distributed in the north county service area, and approximately 73 percent of the reclaimed water produced in the north county service area goes to golf course irrigation. However, the golf courses were on well water prior to receiving reclaimed water; hence, the County does not realize potable water savings by providing reclaimed water to the golf courses. Alternate Water Services is developing strategies to redistribute reclaimed water from the golf courses to residential areas where additional potable water savings would be realized. Upon completion, the system will deliver reclaimed water to 6,400 residential customers for landscape irrigation.

South Service Area

The South Cross Bayou WRF initially had a surface water discharge but switched to deep well injection of treated effluent in the late 1980s. Operational problems led to addition of filtration facilities at the South Cross Bayou WRF. Ultimately, elimination of the deep well injection was required. All deep well injection was discontinued by 2002. The South Cross Bayou WRF underwent a $150 million expansion and upgrade to AWT. The South Cross Bayou WRF, which meets all Florida DEP water reuse criteria for irrigation of public access areas, has an average flow of 26 mgd, of which 7.4 mgd is reused. The remaining effluent is discharged to a tidal creek adjacent to the WRF.

The South County system is undergoing major development and expansion efforts. The north and south barrier island gulf beach communities, areas of the County in which residents were unlikely to access a reliable good quality irrigation water from wells, are a priority area for delivery of reclaimed water. A transmission main from the South Cross WRF to the north and south barrier island beach communities has been constructed, as have distribution pipelines within the five southern communities. The transmission main also will deliver reclaimed water to several mainland areas. The total cost of the transmission/distribution system was $140 million, some of which was offset by a $23 million grant from SWFWMD. One problem encountered resulted from delays in connecting to the system, which led to algae growth in pipelines that caused sprinkler clogging. A flushing program corrected the problem and connection procedures were changed for new additions to the system.

An “interruptible service” strategy has been implemented to bring additional customers onto the reclaimed water system. Interruptible service will provide select commercial customers with reclaimed water at times when there is a surplus supply of the water, such as during wet weather. Two large golf courses have already agreed to augment their current irrigation sources with reclaimed water on an interruptible basis. A special reduced rate and fee structure has been developed for those customers.

In 1998, when St. Petersburg Beach, South Pasadena, and Tierra Verde systems were operational, there were more than 10,000 reclaimed water users on the entire system using 11.8 mgd of reclaimed water.

Implementation program

The initial attempt to implement a water reuse program was through an assessment program to fund construction of distribution systems. Under this program, all wastewater treatment and transmission system costs would be borne by the system in its existing rates. Costs for distribution systems were to be assessed to the benefiting property owners at 100 percent of the cost. This method was time consuming and difficult. The assessment program was ultimately put on hold and replaced by a different approach using an "availability" charge. Under this program, utilities extended the distribution mains and charged all adjacent properties a $7 per month availability charge.

A rate and fee structure was established in 1995. Reclaimed water use by residential customers is not metered. Payment of the flat rate availability charge of $7 per month is mandatory. Irrigation customers pay an additional $2 per month flat rate for unrestricted use of the water. Charges for multi-family and nonresidential metered customers are based on a volumetric rate structure. Metered customers also pay the availability charge plus $0.29/1,000 gallons of reclaimed water received.

Pinellas County has an innovative Contribution-In-Aid of Construction Program to help smaller communities needing financial support to construct water reuse facilities. The County will provide a grant of one dollar for every gallon of potable water capacity saved through construction and operation of a new reclaimed water system. The benefits of this program are realized by obtaining additional potable water capacity for less cost than expanding existing water sources or developing new ones.

By 2002, the number of reclaimed water users had increased to 10,400, who were supplied with 14.7 mgd of reclaimed water. It is projected that there will be more than 28,000 reclaimed water customers by the end of 2007 using 25.9 mgd of reclaimed water and saving 5.7 mgd of potable water.

Several initiatives are being developed that could have a major impact on the operation and maintenance of the reclaimed water system. Some of the issues involve conservation strategies such as metering, day of week use restrictions, tiered rate structures, demand management strategies, and potential indirect potable reuse through wellfield and wetlands recharge.

Costs and Funding

The costs to upgrade the South Cross Bayou WRF to meet Florida DEP requirements for reclaimed water use on public access areas was $150 million. The total capital costs of the north and south county reclaimed water transmission and distribution systems to date is $140 million. Annual operating costs for the entire reclaimed water system are about $1.2 million.

Revenues from the sale of $87 million of revenue bonds issued by Pinellas County, combined with capital improvement program budgeted funds, represent the locally funded portion of the reclaimed water system. In addition, the County received approximately $28 million in grants from SWFWMD. The water management district funded 50 percent of all costs for reclaimed water transmission and storage facilities.

For further information, contact: Pinellas County Utilities, 14 South Fort Harrison Avenue, Clearwater, FL 33756.

San Antonio Water System

Background

For over two centuries, San Antonio, Texas, depended on the Edwards Aquifer for its water supply. In the 1890s, water that used to emerge as natural springflow began to be withdrawn from municipal and private wells. By the 1920s, streams in the area had little to no flow in them in some years, and by the mid-1950s, springs and streams were dry almost all of the time. Upper reaches of streams were completely dry, and most stream flows were due solely to effluent discharged from wastewater treatment plants.

Cemetery Irrigated with Recycled Water

Withdrawals from the Edwards Aquifer were historically based on the right of capture, which allowed any user to withdraw as much water as could be used for beneficial purposes. Demand for water in the 1990s began to surpass the aquifer's safe yield, and legislation was passed to limit aquifer withdrawals to ensure continual springflows. For the first time in its history, San Antonio needed to develop new water resources.

In 1993, the San Antonio Water System (SAWS) adopted a Water Conservation and Reuse Plan that solidified the City's commitment to a water recycling program. Water conservation programs for education, plumbing and landscape retrofits, conservation pricing, and leak detection has resulted in a 31 percent reduction in potable water use since 1986. Current water consumption averages 147 gallons per capita per day. About $4 to $6 million is spent annually for conservation programs. Along with conservation, making more effective use of existing supplies became a key concern, and building a system to deliver recycled water for non-potable uses became a high priority. One stated goal was to maintain adequate flows in the San Antonio River and Salado Creek. Flows in the San Antonio River in the downtown River Walk area had been supplied by wells for decades, and Salado Creek was an impaired stream with high fecal coliform concentrations and low dissolved oxygen levels.

System Development

SAWS owns and operates four major Water Recycling Centers (WRCs) that combined currently produce approximately 116 mgd of tertiary-treated wastewater. Although there is no requirement in Texas that effluent derived from groundwater must be returned to water courses, SAWS has agreed to discharge a minimum of 49 mgd for downstream surface water rights holders. In addition, SAWS has been providing recycled water to the City's municipally-owned electric generating facility for power plant cooling for more than 30 years from the Dos Rios WRC. The plant discharges treated wastewater to the San Antonio River, from which water is withdrawn to cooling water lakes. SAWS contracts for 36 mgd, for which the utility pays about $0.0153/100 gallons.

Cemetery Irrigated with Recycled Water

In 1995, SAWS embarked on an effort to provide the remaining uncommitted wastewater, 31 mgd, to other customers from the Salado Creek and Leon Creek WRCs. Construction of almost 75 miles of pipeline began in 1997. The Salado leg began discharging recycled water in 2000, and the Leon leg was brought online in 2002. The Salado Creek WRC serves the east side of the system and the Leon Creek WRC serves the west side. Interconnections are currently under construction to connect all the facilities. When completed, the Salado Creek WRC will be taken out of service. The City's master plan includes use of recycled water from the Medio Creek WRC on San Antonio's west side. The interconnections will enable recycled water to be delivered to any point in the system from any of the remaining WRCs, thus providing a high degree of reliability and redundancy.

Potential recycled water users were asked to sign a request for service document in 1997. The document confirmed the intention by customers to purchase recycled water from SAWS when such water became available. Potential demand exceeded supply as SAWS allocated an average of 31 mgd of recycled water to be available and about 42 mgd of recycled water was requested by 77 potential customers.

More than 70 percent (i.e., 22 mgd) of the total available volume from the Salado Creek and Leon Creek WRCs currently is contractually committed for recycled water applications. About 45 percent of the total available volume, more than 14 mgd, is online. Uses include industrial cooling water, river maintenance, and landscape irrigation at golf courses, schools, commercial sites, etc.

Potential customers are subject to onsite water use surveys and checks for proper backflow prevention devices and code compliance by SAWS staff. One requirement is a two-way pressure separation testing followed by a dye test of the system prior to connection.

The Texas Commission on Environmental Quality (TCEQ) is the state agency that governs recycled water programs, and its predecessor, the Texas Natural Resource Conservation Commission (TNRCC), was responsible for adopting the State's water reuse criteria. The Texas standards prescribe water quality limits, but do not include specific treatment unit process requirements. SAWS provides "Type I" (i.e., human contact with the water is likely) reclaimed water to its users. Type I reclaimed water requirements include the following:

- BOD: ≤5 mg/L (30-day average);
- Turbidity: ≤3 NTU (30-day average);

- Fecal coliforms: <20 CFU/100 mL (geometric mean); and
- Fecal coliforms: 75 CFU/100 mL (single grab sample maximum).

When complete, the recycled water system will reduce dependence on the Edwards Aquifer supplies – which are now subject to allocations and cutbacks – by 20 percent, thus reserving groundwater supplies for potable use. The goal is to replace 11 billion gallons/yr of Edwards Aquifer water with recycled water. Other benefits include the following:

- A reliable supply of water to industrial and commercial users;
- Acquisition of additional Edwards Aquifer pumping rights by the city through trading for an equal amount of reclaimed water;
- Improvement and enhancement of environmental conditions in the San Antonio River and Salado Creek;
- An unrestricted water source that can be used in times of drought or curtailment of Edwards Aquifer potable water;
- Reduced fertilizer costs due to the nutrients in reclaimed water; and
- Elimination of the Water Supply Fee or the Edwards Aquifer Authority Fee.

Problems

One problem encountered early was water quality deterioration in the distribution system, primarily due to microbial growth in supply lines and tanks resulting from stagnation during startup with low flows. In response, SAWS developed a database to track chlorine levels throughout the system, initiated a program to eliminate stagnation of water in a storage tank by fluctuating water levels in the tank, and installed gas chlorine injection systems at key locations, thus giving SAWS the ability to maintain a chlorine residual of one mg/L throughout the system. Additionally, the system's storage tanks are periodically drained and cleaned to remove suspended solids that settle in the tanks.

During the first few years of operation there were a series of pipeline failures. Most of them were customer related, but failures also occurred on main transmission lines that supplied the Salado Creek Segment (one joint failure) and a portion of the Leon Creek Segment (three joint failures). SAWS was able to maintain service to most of the customers during these incidents by having a potable "backup" supply line – with an air gap – at each major pumping station.

A concern was expressed that high total dissolved solids (TDS) levels, particularly chlorides, could adversely affect vegetation (chlorides in Edwards Aquifer water and SAWS recycled water average 17 mg/L and 150 mg/L, respectively). SAWS responded by incorporating TDS assurance levels in the Recycled Water Service Agreement, as well as assured levels of related constituents, as noted below:

- Ammonia nitrogen: ≤2.0 mg/L;
- pH: 6.0-9.5;
- Total suspended solids: ≤15 mg/L;
- Total dissolved solids: ≤1500 mg/L;
- Sodium absorption ratio: ≤5.0; and
- Residual sodium carbonate: 1.5 meq/L.

A cross connection incident in 2002, where recycled water intended for use at a golf course was introduced into the potable system, was caused by failure to disconnect a potable system valve and pipe that was directly connected to the reclaimed water system. As a result of this incident, SAWS made substantial changes to its procedures to preclude future occurrences. Before allowing a new recycled water service to begin, customer training classes are now conducted with customer workers involved in routine system operation. No system is connected until a 5-step process is completed that ensures complete separation between the recycled and potable systems. After initiation of recycled water service to any new customer, the system is rechecked and tested by SAWS staff.

Stream Augmentation

One of the benefits of the recycled water system has been improved water quality in the San Antonio River and Salado Creek. Extensive laboratory studies in 1996 and 1997 and an extensive San Antonio River sampling program begun in 1997 have confirmed that water quality has improved since discharge of recycled water started. This is evidenced by the return of several pollution intolerant species of fish to the San Antonio River system. Suspended solids levels are generally lower than they were prior to recycled water discharges, while TDS levels have increased. Ammonia nitrogen and phosphorus levels are slightly higher since the addition of recycled water began, but Chlorophyll-a levels are lower due to increased flows. River water at the San Antonio River Walk is clearer, contains less algae, and has fewer odors than before implementation of the recycled water program.

The introduction of recycled water to Salado Creek has begun to restore a healthy aquatic ecosystem. With Salado Creek flowing again, San Antonio is planning a linear park which may include hiking and biking trails, parks, shallow pools, and waterfalls. In 2000, voters approved a proposition to generate $20 million for land purchases along Salado and Leon Creeks for floodways, open space, and hike and bike trails. In its initial phase, almost 20 miles of Salado Creek is targeted for improvements.

Costs and Fees

The potable water rate is $0.098/100 gallons plus a Water Supply Fee (WSF) and Edwards Aquifer Authority (EAA) fee. In 2003, the WSF was $0.094/100 gallons and the EAA fee was $0.0086/100 gallons, resulting in a total cost of $0.20/100 gallons, while the recycled water rate was $0.098/100 gallons, resulting in a cost savings of 51 percent over the potable water rate. Recycled water rates vary slightly based on season and amount of water used. Customers who trade Edwards Aquifer pumping withdrawal rights in exchange for recycled water pay a rate of $0.025/100 gallons; others pay the above stated rates. The total capital cost to date for the recycled water system is $124 million.

For further information, contact: San Antonio Water System, 1001 E. Market Street, San Antonio, TX 78298-2449.

San Antonio River Walk

St. Petersburg, Florida

Background.

The City of St. Petersburg, Florida is a largely residential peninsular community located on Florida's west-central coast. It is bounded on the east and south by Tampa Bay and on the west by Boca Ciega Bay and the Gulf of Mexico. St. Petersburg has a population of approximately 255,000.

In the early 1900s, municipal wells located in St. Petersburg were being pumped for increasingly longer intervals to satisfy a growing population. The resulting seawater intrusion into the groundwater aquifer eventually required the city to seek other sources of potable water supply. In the 1940s, St. Petersburg purchased well fields in western Hillsborough County and Pasco County. By the 1940s the City was treating its groundwater supplies at a water treatment plant located 26 miles north of St. Petersburg. In the early to mid-1970s, St. Petersburg needed additional water but was uncertain if permission could be obtained to develop a new supply. Also, because of rapid population growth, the City's four wastewater treatment facilities needed to be enlarged. Concurrently, the Florida Legislature enacted a bill in 1972 requiring all communities in the Tampa Bay area to either cease discharging to Tampa Bay or treat their wastewater with advanced wastewater treatment (AWT) processes for nutrient removal. The City evaluated the alternatives and based on the cost of constructing and operating AWT facilities, and in consideration of its water supply problems, opted to upgrade its treatment plants to tertiary treatment (i.e., secondary treatment, coagulation, filtration, and disinfection) and implement a water reuse and deep well injection program that would result in no discharge to surface waters.

Reclaimed Water System

The initial portion of the retrofit system went into operation in 1977, at which time the reclaimed water distribution system was limited to serving irrigation water from the City's four water reclamation plants to golf courses, parks, school grounds, and large commercial areas. In 1981, the City applied for grant funding from the U.S. Environmental Protection Agency to expand the reclaimed water distribution system into residential areas. From 1977 through 1987, St. Petersburg spent more than $100 million upgrading and expanding its four water reclamation facilities (WRFs) and constructing more than 200 miles of reclaimed water pipelines. The WRFs range in capacity from 12.8 to 20 mgd.

In 2002, the total average flow from the four WRFs was about 42 mgd, half of which was reclaimed for beneficial uses. The four WRFs supplied 21 mgd of the 54 mgd of water provided by the City's Utility Department. The quantity of reclaimed water used has been relatively consistent for the last 10 years.

The dual water system currently serves more than 10,500 customers throughout the City, including 10,000 residential customers for landscape irrigation. Residential landscape irrigation with reclaimed water

Residential Irrigation with Reclaimed Water

is voluntary in St. Petersburg. Reclaimed water lines are brought into an area when at least 50 percent of the residents in that area petition for service and agree to connect to the reclaimed water system. Reclaimed water also is used for irrigation at 95 parks, 64 schools, six golf courses, and 335 commercial sites. The water also is used for fire protection via more than 300 reclaimed water hydrants throughout the system and for cooling water at 10 sites. In recent years, the system has been expanding at a rate of 300 to 500 new customers per year.

Injection Wells

Deep injection wells are used to dispose of excess reclaimed water and inadequately treated wastewater. The city operates a total of 10 injection wells at the four WRFs. The wells penetrate to a saltwater aquifer approximately 1,000 feet below the land surface. The groundwater contains approximately 22,000 mg/L of chlorides, precluding its use as a water supply. It was hoped that the injected water would form a bubble in the aquifer such that it could be extracted as needed in the future. However, hydrogeologic conditions in the subsurface have thus far thwarted attempts to extract high quality water for reuse through aquifer storage and recovery.

Distribution System

Prior to distribution, reclaimed water is pumped to covered storage tanks at all four reclamation plants. Reclaimed water is delivered through more than 100 miles of trunk and transmission mains ranging from 10 to 48 inches in diameter. Local service is provided through more than 190 miles of small diameter distribution pipe ranging from two to eight inches in diameter. The transmission mains from all four WRFs are interconnected so that reclaimed water flow and pressure can be maintained on the entire distribution network when any one plant is taken out of service. System pressure is monitored at key locations. The reclaimed water system incorporates five City owned and operated booster pump stations and four privately owned and operated booster pump stations to provide reclaimed water for all of the applications throughout the City.

All potable water services located in areas where reclaimed water service is provided are protected with cross-connection control backflow assembly devices. Top loading double check valve assemblies are used at residences. Cross-connection control provisions for commercial uses are based on the degree of hazard the facility presents.

A typical residence in St. Petersburg uses about 30,000 gallons of reclaimed water per month during peak demand periods. The average irrigation rate is 1.5 inches/week. The average home discharges approximately 6,000 gallons of wastewater per month into the sanitary sewer system. Thus, it requires about five

Reclaimed Water Injection Well

sanitary sewer customers to provide an adequate supply to one reclaimed water customer during peak demand periods.

Water Quality

The Florida Department of Environmental Protection (DEP) water reuse criteria for residential and public access irrigation require that wastewater receive secondary treatment, filtration, and disinfection such that the fecal coliform level is below detectable limits in 75 percent of the samples analyzed over a 30-day period and does not exceed 25 fecal coliforms/100 mL at any time. A minimum total chlorine residual of 1.0 mg/L is required after at least 15 minutes contact at peak hour flow. The regulations also specify a maximum BOD limit of 20 mg/L, a TSS limit of five mg/L prior to disinfection, and continuous monitoring of turbidity and chlorine residual. St. Petersburg's Water Reclamation Facilities consistently meet all Florida DEP criteria.

System Problems and Solutions

Pressure: During the first few years of operation, it was discovered that the installation of backflow assemblies on residential services presented thermal expansion problems in plumbing systems when pressure built up by the hot water heater created a discharge at the hot water heater's temperature and pressure relief valve. To rectify this condition, the City provided pressure relief regulating devices to property owners for installation on an external spigot so that the discharge would occur outside the structure rather than inside the homes. Other recommended solutions involved installing expansion tanks or flushometers in toilets.

Chlorides: In about 1985, St. Petersburg began receiving complaints from some residential homeowners claiming damage to ornamental plants and trees caused by irrigation with reclaimed water. Chloride levels in the reclaimed water were, at times, as high as 700 mg/L due to infiltration of seawater into sewers near the coast. Research conducted by the City found that chloride levels above 400 mg/L in irrigation water for an extended time period damages salt-sensitive species of plants. The problem was solved by reducing seawater intrusion through an infiltration/inflow correction program, by mixing high chloride reclaimed water with reclaimed water containing low concentrations of chloride, and by diverting some reclaimed water containing very high chloride levels to the deep wells for disposal. Reclaimed water chloride levels are now kept below 400 mg/L and complaints have ceased.

Inadequate Supply: Although approximately 50 percent of the effluent is injected into deep wells for disposal on a yearly basis, there are times when the demand for reclaimed water exceeds the supply. Demand increases substantially during the hot, dry spring months when wastewater flows are at a minimum and occasionally stresses the supply. The City addressed this problem by providing additional storage, which proved to be marginally successful, and by imposing a moratorium on distribution expansion until a solution has been developed to maintain current service levels. Other measures being considered include: metering the reclaimed water to control overuse; restricting irrigation during critical periods; developing an aquifer storage and recovery system to seasonally store reclaimed water and recover it for use during high demand periods; and developing informational programs to further educate the public about proper use techniques and lawn management.

Educational Outreach

Adult educational programs include public forums that address water issues, water conservation booklets and videos, weekly taped television broadcasts, online water conservation information via a website, annual public recognition awards, and community events promoting water reuse and conservation. A youth education program has been created to provide water conservation education through schools and youth agencies.

Funding, Costs, and Subsidy

Residents who hook up to the system pay the cost of extending distribution lines to serve them, which typically ranges from $500 to $1,200 per customer, through a Voluntary Assessment Program. The total connection charge is $295 – a $180 tapping fee and $115 for a backflow prevention device on the potable water line. Reclaimed water costs $11.36 for the first acre and $6.51 for each additional acre or portion thereof. The flat fee rate structure does not encourage water conservation, and most residents use more reclaimed water than necessary for proper irrigation. The reclaimed water rate for commercial customers who are metered is $0.33/1,000 gallons; however, not all commercial customers have reclaimed water meters.

The total capital cost of the program to date is about $135 million. Of this total, U.S. EPA provided $100 million to upgrade the four treatment plants and construct the distribution system, and the City contributed $20 million. The remaining $15 million is recoverable through the Voluntary Assessment Program, $11 million of which has been recovered to date. The current annual operating cost is $5.2 million. System revenue is $1.6 million; the remaining $3.6 million is subsidized by the City's water and wastewater utilities, each of which pays half of that cost.

Benefits

While the initial impetus for developing the dual system was to avoid costs associated with upgrading treatment to reduce nutrient levels in effluent discharged to receiving waters, reclaimed water use is now an important component of St. Petersburg's overall water resources management. Because of the lowered demand for potable water, the need to develop additional potable water supply sources has been postponed and may not be needed at all if current water usage trends continue.

For further information, contact: Joseph V. Towry, Assistant Director, Water Resources Department, 1635 Third Avenue North, St. Petersburg, FL 33713.

Water Conserv II

Background

In 1979, a citizens group filed a lawsuit against Orange County, Florida and the City of Orlando to stop discharge of treated wastewater to Shingle Creek. At that time, effluent from the County's Sand Lake Road Wastewater Treatment Facility (since renamed the South Regional Water Reclamation Facility) and the City's McLeod Road Wastewater Treatment Facility (since renamed the Water Conserv II Water Reclamation Facility) was discharged to the creek, which flows into Lake Tohopekaliga. The citizens group contended that the effluent discharges were contributing to degradation of the lake and its fish habitat. The citizens group won the case, and an injunction was issued against the City and County to cease discharge of effluent into Shingle Creek by March 1988. This occurred at a time when a growing population in the region required expansion of both wastewater treatment plants.

During a lengthy evaluation process nine project alternatives were investigated. These included continued discharge to surface waters with advanced treatment and phosphorus removal, shallow well injection, citrus irrigation, rapid infiltration basins (RIBs) to recharge the Floridan aquifer, deep well disposal, combined citrus irrigation and RIBs, on-lot disposal (with combined citrus irrigation and RIBs), and ocean disposal. The selected alternative was combined citrus irrigation and RIBs, which was determined to be both cost-effective and innovative. Thus began the Water Conserv II project, a cooperative water reuse project by the City and County and the agricultural community.

The project initially encountered strong resistance from area citrus growers and residents. The growers' concerns centered on potential adverse effects of irrigating with reclaimed water, while the residents' concerns focused on health and environmental issues. The citrus growers agreed to accept the reclaimed water after they were provided initial research data on citrus production and fruit quality indicating that irrigation of citrus with the reclaimed water would be beneficial to growing citrus. The City and County also agreed to provide funding for research on the long term effects of irrigation with reclaimed water. As incentives to the growers to participate in the project, reclaimed water would be provided to the growers at no cost for the first 20 years at a pressure suitable for microsprinkler irrigation, and the water would be provided during freezing conditions for frost protection. The residents accepted the project after assurances were provided through an interlocal agreement between the City and County and after the County adopted several resolutions to address the residents' concerns.

Construction of facilities began in 1983, and a contract operator was hired for operation and maintenance of the project. To remain in control of day-to-day activities, the City and County implemented a cost-plus-fixed-fee budget for the contract operator.

Rapid Infiltration Basins

Project Goals

Project goals include:

- Elimination of surface water discharges;
- A reliable, cost-effective supply of reclaimed water for agricultural and other customers;
- Conservation of groundwater supplies;
- Groundwater recharge via a system of RIBs;
- Funding for research (through the Mid-Florida Citrus Foundation) to develop management practices for the profitable reestablishment of citrus in the Central Florida area and evaluate the economic viability of irrigating non-citrus crops with reclaimed water;
- Evaluation of agricultural crops for economic viability; and
- Evaluation of reclaimed water for golf course irrigation.

Project Description

The project, located in western Orange and southeast Lake Counties, began operation in December 1986, more than 1½ years ahead of the court-mandated deadline. The City's and County's water reclamation facilities both provide advanced wastewater treatment (i.e., secondary treatment followed by filtration and high level disinfection). They produce a total of approximately 42 mgd of reclaimed water which meets all of the Florida Department of Environmental Protection's (DEP) requirements for public access reuse, such as irrigation of citrus, open access areas, and residential lawns. About 35 mgd of the reclaimed water produced is sent to Conserv II, and the remainder is beneficially used in the City's and County's individual reclaimed water systems serving urban areas. Florida DEP treatment process requirements and water quality limits for Water Conserv II agricultural and landscape irrigation applications include the following:

- Secondary treatment, filtration, and high level disinfection;
- No detectable fecal coliforms/100 mL in 75 percent of the samples analyzed over a 30-day period;
- Fecal coliforms: ≤25/100 mL at any time;
- CBOD5: ≤20 mg/L;
- Total suspended solids: ≤5 mg/L; and
- Chlorine residual: ≥1.0 mg/L after at least 15 minutes contact at peak hour flow.

Reclaimed water is pumped from the water reclamation facilities to the Conserv II Distribution Center in western Orange County. The water is then distributed to customers or to the RIBs through a network of distribution pipes ranging from six to 54 inches in diameter. The system is capable of handling up to 75 mgd. The entire process is monitored and carefully controlled by supervisory control and data acquisition (SCADA) computers located at the Distribution Center.

Orange County and the City of Orlando own 5,250 acres for existing and planned RIB expansions. There currently are seven RIB sites that collectively contain 65 RIBs having from one to five cells (135 total cells with a total bottom percolation area of about 200 acres). The RIBs, which provide aquifer storage capacity and wet weather storage for excess flows during rainy periods, were selected based on percolation capacity. The current total capacity of the RIB system is 22 mgd. Agricultural and commercial customers use 60 percent of the reclaimed water, with the remaining 40 percent going to the RIBs. Operation of the RIBs is controlled through a computerized management system known as the Groundwater Operational Control System, which provides the ability to forecast the impact on the groundwater system of loading an individual or groups of RIBs at prescribed rates and duration.

Rapid Infiltration Basins

Reclaimed water is served to 87 customers for agricultural and landscape (e.g., golf courses, residential property, a browse farm for Walt Disney World's Animal Kingdom, and other landscape areas) irrigation, soil compaction at landfills, soil cement production, and washdown water at an animal shelter. The agricultural customers include more than 4,300 acres of citrus, eight tree farms, four fruit and vegetable growers, and nine indoor foliage and landscape nurseries.

The system was originally designed to serve 12,000 to 15,000 acres of citrus groves, but devastating freezes in the 1980s put several citrus growers out of business and forced others to move their operations to potentially warmer climates in south Florida. The availability of reclaimed water for freeze protection in the late 1980s helped in the survival of many groves. However, more than 11 times the average daily flow rate for irrigation is needed for freeze protection. Supplementary flow is primarily provided by 25 wells connected to the distribution system that produce a total of about 80 mgd. In addition, there is a total of 38 million gallons of storage capacity at the reclamation facilities and Distribution Center. The demand for water during freeze conditions is a major factor in not pursuing additional agricultural customers that require water for freeze protection. System operational costs during freeze conditions average $15,000 to $20,000 per day. During a normal winter season, water for freeze protection is needed for about 3-4 days.

Future Upgrades or Expansions

Permitted and planned expansion will increase the project reuse capacity from 68 to 81 mgd. The expansion includes an increase in irrigation capacity from 46 to 53 mgd and RIB capacity from about 22 to 28 mgd. Diversification of the system will continue with future additions of a large sand mining operation, an additional golf course, residential irrigation, and a major regional/municipal interconnect for landscape irrigation.

Project Funding and Costs

Conserv II capital costs expended as of 2003 total $277.7 million, and the current annual operating cost of the distribution system is approximately $4.8 million. Operating costs are split between Orange County (60 percent) and the City of Orlando (40 percent) based on flow contributed. Project costs do not include capital and operating costs for the Water Conserv II Water Reclamation Facility and South Regional Water Reclamation Facility. The

U.S. Environmental Protection Agency originally provided grant funding of about $100 million for the project; the remaining costs have been borne by the County and the City.

Project Benefits Realized

Environmental benefits associated with the project include: elimination of discharge to environmentally sensitive surface waters; reduction of demand on the Floridan aquifer by eliminating the need for well water for irrigation; replenishment of the Floridan aquifer with reclaimed water via RIBs; and establishment of a preserve within the RIBs for endangered and threatened species of plants and animals.

Research coordinated through the Mid-Florida Citrus Foundation, a nonprofit organization and the research arm of Water Conserv II, has yielded significant data. Some of the important findings to date include the following:

- Citrus on well-drained sandy soils can tolerate up to 100 inches/yr of reclaimed water for irrigation; a small reduction in juice solids due to the high irrigation rate is offset by an increase in fruit production;
- Tree condition and size, crop size, and soil and leaf mineral aspects of citrus trees irrigated with reclaimed water are as good as, if not better than, groves irrigated with well water;
- Fruit quality from groves irrigated with reclaimed water is similar to that from groves irrigated with well water;
- Boron and phosphorus are present in adequate amounts in reclaimed water and can be eliminated from the fertilizer program; and
- Reclaimed water maintains soil pH within the recommended range; thus, lime no longer needs to be applied.

Freeze Protection using Reclaimed Water

Water Conserv II has provided the following benefits to citrus growers: a dependable long term source of irrigation water that is not subject to water restrictions during droughts; elimination of installation, operation, and maintenance costs associated with well or surface water pumping systems; enhanced freeze protection capabilities; increased crop yields; and better tree growth. As one of the growers states: “We have three-year-old trees that are almost six feet tall. We have been able to produce bigger trees with more fruit because we have increased our growing capacity.”

For further information, contact: Al Castro, Utilities Section Manager, Reclaimed Water Section, Water Reclamation Division, Orange County Utilities, 8100 Presidents Drive, Suite A, Orlando, FL 32809 or Thomas L. Lothrop, Wastewater Division Manager, City of Orlando, 5100 L.B. McLeod Road, Orlando, FL 32811.

West Basin Municipal Water District

Background

The West Basin Municipal Water District (WBMWD), formed in 1947, is a public agency that wholesales imported potable water and recycled water to local cities, water companies, private companies, and investor owned utilities. WBMWD's service area encompasses 200 square miles in southwest Los Angeles County, California. WBMWD provides 80 percent of the potable water used in its service area to more than 850,000 people; the remaining 20 percent is local groundwater pumped by retail water agencies.

In the early 1990s, about 80 percent of the water used in southern California was imported. WBMWD purchased State Water Project and Colorado River water from the Metropolitan Water District of Southern California (MWD) for resale to its customers. It was around this time that WBMWD began considering alternative sources of water supply to the region due to the prospect of a dwindling supply of imported water caused by environmental concerns and anticipated future allotment cutbacks. In addition, extended droughts that occur from time-to-time and a lack of emergency storage facilities to assure reliable deliveries during droughts made it more imperative for WBMWD to diversify its water supply portfolio. Recycling treated municipal wastewater and desalinating seawater were identified as the most viable alternatives available to supplement WBMWD's water supplies. WBMWD pursued water recycling as the most economical choice that would also give the District the opportunity to treat wastewater to different levels depending on end use. WBMWD embarked on a large scale conservation and recycling program in the early 1990s to improve water supply reliability and reduce the region's dependence on imported water. Consistent with its mission to "obtain and provide a safe and adequate supplemental supply of high quality water to our member agencies, including the communities, businesses, and residents they serve, in an efficient, effective, and economical manner," plans were underway to establish WBMWD as one of the leaders in water recycling.

The goals of the recycling program are to reduce dependence on imported water by 50 percent, provide an alternative drought proof local water source, reduce the volume of treated wastewater discharged to Santa Monica Bay by 25 percent, and prevent further saltwater intrusion of the groundwater basin. In addition to providing recycled water to customers for diverse applications, the overall program includes education, conservation, and resource planning.

Various agreements were necessary to proceed with the proposed project. An agreement was needed with the City of Los Angeles to purchase secondary effluent from the Hyperion Wastewater Treatment Plant (HTP). Another agreement was

Satellite MF/RO Treatment Plant

needed with MWD for their local project rebate of up to $250/ac-ft (i.e., 70,000 ac-ft for 25 years, a financial commitment of over $200 million). Both agreements were approved and construction of the first phase of the project was initiated in 1992 and completed in late 1994. Delivery of recycled water began in 1995.

In 2002, an average of 24 mgd of recycled water was used for a variety of applications, including landscape irrigation, industrial cooling and boiler feed water, commercial applications, and groundwater recharge. The treatment processes have been specifically designed to produce water that meets the specific needs of the end user; thus the term “designer water” was coined to describe the five different qualities of recycled water produced at the West Basin Water Recycling Plant (WBWRP).

Project Description

Phase I of the project consisted of a pump station at HTP, a 60-inch force main, a recycled water treatment plant, and a distribution system. Secondary effluent from HTP is pumped five miles from the 90-mgd pump station to the WBWRP in El Segundo, California, for further treatment prior to reuse.

The WBWRP produces five different qualities of recycled water, all of which meet the treatment and water quality requirements specified in the California Department of Health Services (DHS) Water Recycling Criteria for the different recycled water applications. The quantities of recycled water (2002 annual data converted to daily averages), types of treatment, and uses of the water are as follows:

- 2.5 mgd of disinfected tertiary treated recycled water for irrigation;
- 7.4 mgd of nitrified and disinfected tertiary treated recycled water for industrial cooling makeup water;
- 6.5 mgd of recycled water that has undergone tertiary treatment, lime treatment, reverse osmosis (RO), and disinfection for groundwater recharge;
- 5.8 mgd of recycled water that has undergone microfiltration, RO, and disinfection for low pressure boiler feed water; and
- 2.4 mgd of recycled water that has undergone microfiltration, RO, disinfection, and second pass RO for high pressure boiler feed water.

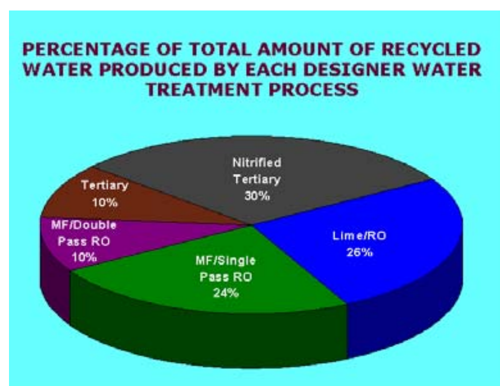
Tertiary Treatment for Nonpotable Uses: Tertiary treated recycled water is used for industrial cooling water and a variety of irrigation uses. The tertiary treatment train at the WBWRP consists of coagulant addition using ferric chloride, flocculation basins, anthracite mono-media filters, and disinfection using sodium hypochlorite. The finished water is stored in a five million gallon storage reservoir from which it is pumped to a 75-mile long distribution system for industrial and commercial applications and irrigation of parks, golf courses, schoolyards and other landscape areas. Phase I had an initial treatment capacity of 15 mgd, which was expanded to 30 mgd after completion of the Phase II expansion.

Nitrified Water: A portion of the tertiary treated water receives additional treatment to remove ammonia, which causes corrosion in industrial cooling towers that have copper-based alloys. Nitrification to convert the ammonia to nitrate takes place in biofilters at satellite package plants. Sodium hypochlorite is then added to assure complete destruction of the ammonia and for disinfection purposes.

AWT for Recharge: The West Coast Basin Barrier Project, operated by the Los Angeles County Department of Public Works, was constructed in the 1950s and 1960s to inject imported MWD water into a series of wells along the coast to halt or reduce seawater intrusion into the potable groundwater basins. There are more than 150 injection wells that, in total, inject an average of approximately 20,000 ac-ft/yr into the aquifers, although as much as 40,000 ac-ft/yr has been injected in some years.

Three parallel treatment trains with a total capacity of 7.5 mgd produce recycled water for the barrier. In Phase I of the project, two identical treatment trains were built to treat a maximum of 5 mgd of recycled water for recharge. Treatment of HTP secondary effluent by these trains includes decarbonation to remove CO_2 and raise the pH, chemical coagulation and clarification using lime to precipitate magnesium and other chemical constituents from the water and provide disinfection, recarbonation to lower the pH, filtration using tri-media filters (anthracite, garnet, and sand), addition of sulfuric acid for pH adjustment and a scale inhibitor to prevent deposition of salts on the RO membranes, RO treatment, decarbonation for pH adjustment, disinfection using sodium hypochlorite, and lime addition to stabilize the water.

During the Phase II expansion, a third treatment train with a capacity of 2.5 mgd was built. In this train, treatment of HTP secondary effluent includes sodium hypochlorite addition, straining, microfiltration, addition of sulfuric acid and a scale inhibitor, RO, decarbonation, disinfection using sodium hypochlorite, and lime addition. The product waters from all three treatment trains are then combined, blended with MWD potable water, and pumped to barrier wells for injection. The recycled water is subjected to extensive monitoring and meets all treatment process and water quality requirements specified by the California DHS in its most recent draft groundwater recharge criteria. The reject water (concentrate) from all RO units is discharged into the HTP's 5-mile secondary effluent outfall pipeline for disposal.



RO for Industrial Boiler Feed Water: WBMWD supplies recycled water to a Chevron refinery in El Segundo for both low pressure and high pressure boiler feed water and to an Exxon Mobil refinery for boiler feed water. Because minerals and other constituents cause scale and foaming problems in boilers, they must be removed from the water. Therefore, treatment similar to that used for barrier injection (i.e., microfiltration, RO, decarbonation, and disinfection) is used at the WBWRP to produce water for the Chevron refinery and at a satellite treatment plant to produce water for the Exxon Mobil refinery.

Because higher quality water is required for high pressure boiler feed, some of the water (after the first pass RO treatment and disinfection) passes through RO a second time (second pass) to remove more dissolved solids from the water. About 5.8 mgd that has received single pass RO treatment is produced for low pressure boiler feed, while an additional 2.4 mgd receives second pass RO treatment for high pressure boiler feed. Product water is pumped to a storage tank at the nearby Chevron refinery in El Segundo. Reject water from the RO processes is discharged to the HTP outfall line. Product water from the satellite MF/RO plant in Torrance is pumped to the Exxon Mobil refinery.

Funding

Funding for Phase I facilities capital construction costs of about $200 million was obtained from WBMWD water revenue bonds, U.S. Bureau of Reclamation grants, and State of California low interest loans. By 2003, total capital costs (including land) expended for all phases of the project were approximately $365 million. The operating cost of the project was $14.8 million for the fiscal year ending 2002.

WBMWD sells imported water to its customers for $510/ac-ft, while the price of recycled water charged to customers varies according to the level of treatment the water receives. Tertiary recycled water is sold for 25 to 40 percent less than imported water. Nitrified water is sold for 20 percent less than imported water. AWT recycled water is sold for 10 percent less than imported water. Users of single and double pass RO water for low pressure and high pressure boiler feed are charged a rate equal to, or slightly higher than, imported water.

Public Information Programs

WBMWD has an extensive ongoing public outreach program. A proactive children's education program, called the Planet Protector Explorations, was developed to heighten public awareness in the entire community. The outreach efforts work in tandem with construction, recycled water marketing, conservation, and school education to inform the public. WBMWD's Speakers Bureau targets local cities and civic and environmental groups that that are affected by WBMWD's recycling project. These programs have been instrumental in capturing the support and enthusiasm of the residents, educators, students, and businesses and industries.

For further information, contact: West Basin Municipal Water District, 17140 S. Avalon Blvd., Carson, CA 90746-1296.

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