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SELECTION AND IMPLEMENTATION OF NONPOTABLE WATER RECYCLING IN "SILICON VALLEY" (SAN JOSE AREA) CALIFORNIA

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ABSTRACT

South Bay Water Recycling, a nonpotable water recycling project in the San Jose, California (USA) area, was commissioned in 1998 to supply up to 60,000 m^3/day (15 mgd) of high-quality treated effluent to nearly 200 customers for irrigation and industrial use. The project was selected, along with water conservation, as the most effective approach to protecting salt marsh habitat at the south end of San Francisco Bay from degradation due to low-salinity discharge from the San Jose/Santa Clara Water Pollution Control Plant. The project was selected over an outfall discharge based in part on its ability to offset demand for potable water by municipal and industrial customers, including computer-related industries in northern California's "Silicon Valley". Project development began in 1991 with feasibility and conceptual design studies. Preliminary project design and surveying began in 1994, and construction commenced in 1996. The project was completed in July 1998 at a cost of approximately $140 million (US), and consists of a 90 km (60 mile) pipeline with three pump stations and one reservoir. In addition to transmission and distribution facilities, construction included customer retrofits to segregate the nonpotable system from each site's potable supply.

KEYWORDS

Microtunnelling; nonpotable reuse; pipeline; retrofit; sustainability; water recycling.

INTRODUCTION

The San Jose/Santa Clara Water Pollution Control Plant is a 640,000 m^3/day (167 million gallon per day) regional wastewater treatment plant serving a population of 1.3 million people in eight cities and sanitary districts in urban Santa Clara County, the most populous county in northern California. Wastewater is treated to near drinking water quality by primary sedimentation; two-stage suspended-growth activated sludge treatment for removal of carbonaceous and nitrogenous biochemical oxygen demand; multimedia filtration (coal/garnet/sand); and chlorine disinfection. Biosolids are anaerobically stabilized and dried in solar beds prior to reuse as agricultural amendment and landfill cover.

Treatment plant effluent meets all pertinent local and state health standards for unrestricted nonpotable use, including irrigation of playgrounds, full contact recreation and agricultural irrigation of crops intended to be eaten raw. Standards for "unrestricted" nonpotable use are established by the California Department of Health Services and include minimum chlorine contact time (>30 min); reduced turbidity (<2NTU); and reduced concentration of coliform organisms (<2.2 MPN). By reusing effluent instead of discharging it into

San Francisco Bay, the plant will reduce its discharge of effluent within regulatory limits and offset water shortages projected during the droughts that occur frequently in this semi-arid region. To increase the usefulness of the project, facilities were oversized to meet future recycled water demands and pipelines were located to be compatible with future alignments. Completed in July 1998, South Bay Water Recycling (SBWR) facilities include 90 km (60 mile) of transmission and distribution pipeline and three pump stations designed to distribute 60,000 m^3/day (15 mgd) of plant effluent to more than 200 customers for irrigation and industrial use. Prior to delivery of recycled water, existing potable water pipelines at each customer site were physically separated from the new nonpotable system. Planning is now underway to expand the SBWR system to 120,000 m^3/day (30 mgd).

SELECTION OF A WATER REUSE PROGRAM

The project was developed primarily as a means of diverting treated effluent discharged by the San Jose/Santa Clara Water Pollution Control Plant into the south end of San Francisco Bay. In 1989, the United States Environmental Protection Agency (EPA) and the San Francisco Bay Regional Water Quality Control Board determined that salt marsh located downstream of the plant outfall channel had been converted to fresh marsh due to the influence of low-salinity plant effluent. (Total dissolved solids in plant effluent averages around 800 mg/L, well below the 10,000 to 20,000 mg/L TDS of tidal water.) The salt marsh provides habitat for two endangered species, the salt marsh harvest mouse and the California clapper rail. To protect the habitat from further conversion, the EPA and the Regional Board proposed to limit the flows from the plant to less than 450,000 m3/day (120 mgd) during the dry weather period between May 1 and October 31. The plant currently discharges an average of 550,000 m^3/day (140 mgd).

Evaluating discharge alternatives

As lead agency for the eight cities and sanitary districts tributary to the plant, the City of San Jose evaluated a number of options to reduce or divert plant flow. Options evaluated included water reuse, water conservation and construction of a deep-water outfall. After extensive study, City officials adopted a plan combining conservation and nonpotable water recycling to reduce discharge to the Bay. Conservation was primarily achieved through the installation of ultra-low flush toilets using 6 liters per flush, compared to conventional toilets that use as much as 20 liters per flush. The toilet replacement program was estimated to reduce influent flows by as much as 100 liters per day per unit installed. Nonpotable reuse was selected over potable reuse by groundwater recharge primarily due to limitations on the use of the groundwater basin. A requirement to treat all effluent by reverse osmosis prior to recharge significantly increased both capital and operating costs, and would have necessitated an expensive brine disposal system, as well. Nonpotable reuse was also recognized as more readily implemented than potable reuse within the compliance schedule, especially in an area unfamiliar with the use of recycled water.

Table 1. Comparison of concept level costs and benefits of diversion alternatives

		Project Costs		Project Benefits			
Project	Flow(m^3/d)	Total ($M)	Unit ($/$m^3$)	Supply	Disposal	Total	Ratio
Outfall	100,000	100	$0.40	0	$0.40	$0.40	1.0
SBWR	80,000*	100	$0.60	$0.20	$0.40	$0.60	1.0
Conservation	50,000**	20	$0.20	$0.20	$0.40	$0.60	3.0

* Total annual reuse is roughly half of annualized seasonal daily flow.
** Estimated flow reduction potential due to conservation measures.

As shown in Table 1, a comparison of the initial cost estimates of the main diversion alternatives reveals some important relationships. Water conservation, though limited in yield, appears to have the highest ratio of benefit to cost when both water supply and wastewater diversion benefits are taken into account. Similarly, the unit cost of the water reuse is higher than that of the outfall alternative, but it is offset by the fact that reuse provides an auxiliary water supply to the community, whereas outfall discharge does not. Local appreciation for the value of recycled water was enhanced by the fact that the alternatives were considered during a prolonged drought (1986-1992), during which time water use was restricted and excessive use was penalized by surcharges. (In fact, the drought was so severe that one partner agency independently implemented a 10,000 m^3/day recycled water system to serve local parks and other sites.)

During the past decade several other water and wastewater agencies in California have adopted a similar context for evaluating reuse projects, recognizing both their water supply and wastewater disposal benefits (Sheikh *et al.*, 1998).

Value engineering

After selecting nonpotable reuse, the City initiated a two-year study to better assess the reuse market within the potential service area. The survey identified over 5000 potential customers, about 500 of whom had significant (>3 m^3/day) water demands. To reach all the identified customers, it was initially proposed to construct the project in phases. Phase 1 was planned to divert approximately 80,000 m^3/day (20 mgd) to more than 100 water users located nearest the plant. Customers in this area were generally smaller than the large parks and golf courses located at the outskirts of the city. Phase 2 was planned to expand the system to reach large remote customers, eventually diverting up to 280,000 m^3/day (70 mgd) through a 400 km (250 mile) pipeline system with an estimated combined cost of $500 million (US).

In view of the high cost and the relatively small customers identified in the Phase 1 area, the project was revised through a value-engineering effort to provide the maximum diversion to the largest customers while optimizing opportunities to expand. A three-day analysis of all project criteria and conceptual designs recommended substantial changes to the project configuration and pipeline alignment to improve its overall effectiveness. In addition to being City standard practice, value engineering was required as a condition of participation by the United States Bureau of Reclamation, which was authorized to reimburse up to 25% of project costs, and the State Water Resources Control Board, which has provided low-interest loans for project construction.

One essential recommendation of the VE team was to construct a single large-diameter transmission line, significantly expanding the Phase 1 service area. The "backbone" design (as opposed to the "branch" system) presented a number of benefits, both structural and operational. By directing the system southward into less developed areas, the Phase 1 system could reach the larger customers and be extended further to the remaining agricultural parcels which fringe Silicon Valley. The southern extension of the SBWR system also approaches the county's largest reservoir – a 100 million m^3 (90,000 acre-foot) lake that may be suitable eventually for indirect potable reuse. In this manner, the Phase 1 facilities were implemented with a view towards providing the greatest long-term potential for water reuse.

In addition to its distinct advantages to overall project cost-effectiveness, the single backbone design also promised to improve recycled water quality by eliminating dead-end pipelines where water is prone to stagnate during periods of relatively low demand. This major revision was adopted without increasing the overall cost of the project. Additional detailed value engineering reviews were conducted on the design of the transmission and distribution pump station, reservoir and all pipeline segments.

CONSTRUCTING A NONPOTABLE WATER DISTRIBUTION SYSTEM

Once the general pipeline alignment was defined through the value engineering process, preliminary design commenced with the aerial survey of the service area and development of design standards. System hydraulics were analyzed repeatedly during the design of the system to ensure that adequate pressure and flow would be provided to all customers. In addition, a number of agreements were developed to clarify services provided by various agencies in designing, constructing and operating the system.

System design

As designed and constructed, the pipeline ranges in size from the 2740 mm (108-inch) diameter effluent diversion pipeline down to 100 mm (four-inch) diameter laterals. The program management team, with the assistance of SBWR program consultants Montgomery Watson Americas, specified materials and methods for construction of the pipeline. Standards provided for the optional use of concrete, steel or ductile iron pipe for large diameter segments (700 mm and greater) and steel, ductile iron or PVC for smaller diameter pipes. Other design standards covered issues such as backfill and trenching, acquisition of permits and mitigation of hazardous materials or cultural artifacts encountered during construction. Agreements were negotiated with nine different design firms (seven private firms and two public agencies) to develop final plans and specifications for fifteen separate construction packages.

In addition to conveying effluent by gravity from the treatment plant to the transmission pump station, the diversion structure was designed to provide supplementary disinfection. Chlorine injectors located at the head end of the structure allow operators to dissolve gaseous chlorine into the effluent, and the capacity of the diversion pipeline (about 8000 m^3) provides detention time in excess of ninety minutes at peak flow.

The transmission pump station pressurizes the flow throughout the system with eleven constant- and variable-speed vertical turbine pumps ranging in size from 0.175 to 0.644 m^3/s (15,000 to 50,000 m^3/day). Two booster pumps provide additional pressure to deliver flow, and a 15,000 m^3 reservoir located at the furthest point on the system provides storage to accommodate peak demand. Due to the seasonal nature of landscape irrigation, and the fact that many customers restrict their irrigation to non-daylight hours, a peaking factor of 2.0 was incorporated into system design, such that the average daily system demand can be distributed in twelve hours or less. As constructed, system capacity can be increased to 200,000 m^3 /day (80 mgd) at its furthest distribution point by the planned addition of pumps at the transmission pump station the extension of certain parallel lines near the midpoint of the system.

One pipeline segment, transecting several downtown neighborhoods, required special attention to mitigate for traffic, dust and noise during construction. Rather than employ open cut methods, the program opted for less intrusive microtunnelling construction to install a 3 km (2 mile) run of 1060 mm (42-inch) diameter pipe under existing utilities. Neighborhood meetings continued throughout construction, and provided a forum for addressing both resident and project needs without costly or time-consuming litigation or political intervention.

Table 2. Interagency agreements required for SBWR implementation

Agency	Cost Allocation	In-Kind Services	Wholesaler-Retailer	O& M	Rebate
San Jose	x	x	x	X	
Santa Clara	x	x	x	x	
Milpitas	x	x	x	x	
Agencies[1]	x				
SJWC[2]			x		
SCVWD		x			x
USBR		x			x

[1] Including West Valley Sanitation District; County Sanitation Districts 2-3; and Cupertino, Burbank, and Sunol Sanitary Districts.
[2] San Jose Water Company, an investor-owned utility operating within the city limits of San Jose.

Institutional arrangements

Implementation of the system required the support of a number of stakeholders (Lindow *et al.*, 1997). Key among these were the water retailers whose customers switched to recycled water when the system became operational. Consensus was also required among each of the agencies responsible for the SJ/SC WPCP, especially the three cities through which the pipeline alignment runs and in which right-of-way was needed. Other agreements were required to operate the utility after completion, and for funding the project. For example, the United States Bureau of Reclamation (USBR) was authorized by Congress to fund 25% of eligible costs, and the Santa Clara Valley Water District (SCVWD) which agreed to subsidize the City at the rate of about $0.10 per cubic meter of recycled water supplied. To formalize participation of these agencies, agreements were drafted and the terms ratified by all parties. A list of interagency agreements required for implementation of the project is shown in Table 2.

In addition to the allocation of project costs in the "Master Agreement" with the partner agencies, another set of agreements was executed with the cities of San Jose, Santa Clara and Milpitas to provide services like right-of-way acquisition, permitting and construction inspection. Each city selected a different role in the program, ranging from plan review (Milpitas) to actual pipeline construction (Santa Clara). Public works staff contributing to this effort were compensated according to terms set out in "In-Kind Services" agreements, which specified the services to be provided by each city, their pay rates and overhead. Similarly, municipal water service companies in each city elected to take responsibility for the operation and maintenance of the pipeline within their jurisdiction, and were awarded contracts for this service through the "Operation and Maintenance" agreements.

Involving the municipal jurisdictions in construction management became one means of expediting the program, and each city cooperated fully in meeting program goals. The program management effort was complicated by the need to administer more than a dozen separate construction contracts. However, this burden was offset by rapid implementation, since multiple contracts provided many crews to work on several project elements simultaneously, with the added benefit that smaller regional engineering and construction firms were able to participate in the project.

USE OF INCENTIVES TO FACILITATE CUSTOMER RETROFIT CONNECTIONS

Another program standard specified the location of nonpotable recycled water pipelines relative to existing potable pipelines. These standards were based on California Department of Health Services (DOHS) regulations that require both vertical and horizontal offsets from potable pipelines. To connect the SBWR system to the more than 200 identified customers, all sites with existing potable service had to be retrofit for recycled water supply. The retrofit process consisted of a number of steps:

1. mapping the existing water distribution system;
2. designing modifications to isolate nonpotable and potable uses;
3. obtaining approval for retrofit design from local and state agencies;
4. contracting for retrofit construction;
5. inspecting the work in progress; and
6. checking the completed nonpotable systems for potable cross-connections.

Recycled water customers requiring system retrofits for connection included city and county parks; public schools, college and business campuses; cemeteries and golf courses; certain industries (including cooling towers); and some urban farmland. The program provided customers a dual incentive to connect to the SBWR system. First, the program reduced the wholesale price of recycled water to ensure that the retail price to the average landscape customer would be 20% to 30% cheaper than potable water. Second, the program paid up to 0.40 $US/m^3/day to qualifying customers for part or all of the cost of modifying customer irrigation systems to segregate the new nonpotable system from the potable supply.

Pricing incentives

As the wholesaler, the City sets the price at which recycled water is sold to the water retailers. The retailers in turn add their mark-up for administrative costs and lost revenues to determine the final retail price to the customers. To ensure that the retail price is attractive to the customers, the City established a two-stage pricing structure. The basic wholesale rate was set at about 0.19 $US/ m^3 (240 $US/acre-foot), equal to the current cost of potable water prior to treatment. The wholesale cost was reduced still further through a rebate that varied depending upon the type of use. For example, the wholesale cost of water used for landscape irrigation was reduced by an additional 0.05 $US/m^3 to allow for occasional over-watering to flush salts from the soil. Industrial customers received an even larger rebate, in recognition of the additional costs of treating higher salinity recycled water for industrial use. As shown in Table 3, after wholesale discounts were passed on to the retail customers, the resulting retail rate was 20-30% lower than the corresponding retail potable rate. For a customer using 300 m^3/day, this represents savings of about $US10,000 per year.

Table 3. Retailer pricing for potable and nonpotable water in SBWR service area

	Landscape Rates ($/m³)			Industrial Rates ($/m³)		
	Potable	**Nonpotable**	**Discount**	**Potable**	**Nonpotable**	**Discount**
Wholesaler*						
SBWR (w/o	$ 0.25	$ 0.19	25%	$ 0.25	$ 0.19	25%
SBWR (w/rebate)	$ 0.25	$ 0.15	40%	$ 0.25	$ 0.20	92%
Retailer						
San Jose	$ 0.52	$ 0.37	29%	$ 0.48	$ 0.24	50%
Santa Clara	$ 0.38	$ 0.30	21%	$ 0.38	$ 0.30	21%
Milpitas	$ 0.68	$ 0.54	21%	$ 0.19	$ 0.16	20%
SJWC	$ 0.45	$ 0.35	22%	$ 0.45	$ 0.22	51%

* Wholesale potable water rates set by Santa Clara Valley Water District

Retrofit incentives

Various retrofit funding arrangements were available to meet the needs of different customers. For example, a grant program offered larger customers up to 150 $US/m3/day to construct retrofits required to connect to the SBWR system. To obtain the grant, customers met certain criteria related to proximity to the system and quantity of use and entered into an agreement with the City to construct the retrofit and use recycled water. Other customers (including some public agencies) preferred to have the City contract for and supervise the retrofit work on their site. Still others, especially farmers cultivating undeveloped property by lease agreement, elected to perform the retrofit work themselves in exchange for free water usage in an amount equivalent to the value of the retrofit cost. In all, the program developed four standard approaches to funding retrofit costs (Table 4), and frequently combined two or more funding strategies for a single customer.

Table 4. Variety of funding arrangements in SBWR retrofit program

Customer Type	Program Grant	Program Loan	"Equivalent Water"	On-Site Construction
Landscape (Large)	x	x		
Landscape (Small)			x	x
Urban Agriculture			x	x
Public Schools	x			x
County Parks	x			x
Industrial	x			

CURRENT STATUS AND CONCLUSIONS

South Bay Water Recycling began operation on October 29, 1997 with the dedication of the Transmission Pump Station and 30 km (20 miles) of distribution line to some thirty customers. The remaining pipeline segments were completed in July 1998. Flows are projected to reach 50,000 m^3/day (12 mgd) by the end of the current dry weather season, and will approach 60,000 m^3/day by May 1999. Planning is now underway for expansion of the system to 120,000 m^3/day by 2002 through extension of the pipeline to additional urban landscape and agricultural customers. A master plan for the South Bay Water Recycling system has as its objective supply of up to 400,000 m^3/day of recycled water by 2020, and may include such options as export to agricultural areas, potable reuse through reservoir addition and environmental applications such as streamflow augmentation.

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