

# HISTORICAL EVOLUTION OF WATER RECLAMATION AND REUSE AND OF AQUIFER RECHARGE WITH RECLAIMED WATER IN LOS ANGELES COUNTY, USA

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## ABSTRACT

The need for a dependable water supply is critical in the semi-arid Los Angeles area, where two-thirds of the water supply needs to be imported from hundreds of kilometers away. The County Sanitation Districts of Los Angeles County (Districts) have a long history of activity in pioneering the field of water recycling, culminating in one of the most advanced and widespread programs for the treatment, distribution and reuse of reclaimed wastewater. The Districts' role includes producing the reclaimed water, promoting its use, conducting necessary research and cooperating with other entities who either distribute the water to retail customers or use it themselves.

During 1997, approximately 41 percent of the effluent produced at the ten Districts' water reclamation plants was actively being reused at 376 individual sites, which include 90 parks, 85 schools, 71 roadway greenbelts, 62 miscellaneous landscaped sites (e.g., office buildings, auto dealerships, churches, landfills), 17 golf courses, 20 nurseries, 14 industrial users (e.g., paper manufacturing, carpet dyeing, concrete mixing, cooling towers, toilet flushing, construction), five cemeteries, 11 agricultural sites, a wildlife refuge and two sets of groundwater recharge spreading basins. The number of reuse sites receiving reclaimed water from the Districts has risen 34-fold since 1976, with the greatest increases coming just as the second drought began. The total acreage irrigated with reclaimed water has increased over nine times, from 940 acres (380 hectares) in 1976 to 8,645 acres (3,498 hectares) by the end of 1997, and usage has nearly quadrupled, from 21 to 77.7 million gallons per day (0.92 to 3.40 cubic meters per second).

This paper will discuss the history of water reclamation and reuse in the Districts service area for both direct, nonpotable applications, such as irrigation and indirect, potable applications, such as groundwater replenishment.

## EARLY HISTORY OF WATER RECYCLING

Despite recent technical advances, the principal of water recycling is as old as life itself. Since the advent of the first bacteria and blue-green algae some three billion years ago, nature has been using, cleaning and reusing water countless times. All the water that we have, is all the water there ever was and ever will be. The water molecules that come out of the tap are the same ones dinosaurs drank. Water neither wears out or breaks, it only gets dirty. The idea behind modern water recycling is to collect recently used water, treat it in a manner similar to nature, only faster, and reuse it in place of our scarce drinking water supplies.

The earliest known wastewater collection systems began approximately 5,000 years ago in the Assyrian Empire, located in present day Iraq. Sewers constructed during the Roman Empire are still in existence today. However, during the Dark Ages, the concept of proper sanitation was lost, leading to widespread epidemics. Three hundred years ago, the British reinvented the water closet and sewer system, eliminating a wide variety of water-borne diseases.

Unplanned reuse occurs whenever one city's treated wastewater effluent is discharged into a river which becomes the water supply for the next city downstream. It is estimated that by the time the Mississippi River reaches New Orleans, every drop of water has been used by seven other people. Planned reuse of wastewaters occurred as early as the 1880's in Pasadena, California, when raw wastewater was used to irrigate orchard crops; however, this practice was soon discontinued. In 1904, primary-treated wastewater was used on farmland in the Pomona Valley, east of Los Angeles. This was followed in 1927 by the construction of the first Tri-Cities (Pomona, Claremont and La Verne) plant which produced secondary-treated effluent for reuse.

In the early 1920's, wastewater from the visitors center on the north rim of the Grand Canyon was treated and used for landscape irrigation. Perhaps the most famous of the water recycling projects was Golden Gate Park in San Francisco, which was irrigated with primary-treated effluent from the McQueen Plant from the early 1930's to 1981. The City of San Francisco is currently planning to return more highly treated recycled water to Golden Gate Park in the near future.

## THE NEED FOR WATER

Perhaps the greatest motivation to use reclaimed water is the fact that Los Angeles is essentially a desert, with no major rivers within 100 miles (161 kilometers). In addition to receiving an average rainfall of only 15 inches (38 centimeter) per year, the southern California area is also a highly urbanized area of concrete and asphalt. This not only prevents the natural recharge of rainfall into the regional aquifers, but it channels away runoff to storm drains and concrete-lined flood control channels which rapidly convey it, unused, to the ocean. In fact, it is estimated that during the heavy rainfall of January through March 1993, enough runoff was lost to the ocean to supply the water needs of the entire City of Los Angeles, with a population of 3.5 million, for an entire year. The urban nature of the region also precludes surface reservoirs of sufficient volume to capture storm water. Existing local groundwater supplies are also limited by the lack of local precipitation, recharge capacities of the local spreading grounds, basin overdrafting, sea water intrusion in coastal areas and industrial contamination.

Approximately two-thirds of the area's annual water supply is imported through three aqueducts that extend between 200 and 500 miles (322 and 805 kilometers) from the Los

Angeles Basin. The delivery capability of each aqueduct is subject to legal, political, operational and climatological factors.

- 1) A United States Supreme Court decision awarded to the State of Arizona over half of MWD's annual diversions of Colorado River water. As the completed Central Arizona Project delivers increasing amounts of water to more and more users, approximately 600,000 acre-feet per year (AFY) [740 million cubic meters per year] could be diverted away from southern California via aqueducts to the major metropolitan and agricultural areas of Arizona. Furthermore, the rapidly growing City of Las Vegas is also looking to expand its diversions of water from the Colorado River as well.
- 2) The Los Angeles City Department of Water and Power's groundwater pumping in the Owens Valley has been halted due to the adverse environmental effects resulting from the lowered water table, and its diversions from streams feeding Mono Lake have been curtailed in order to allow water levels in that lake to rise so that ecosystem can recover. Further diversions of water may be required to alleviate the severe dust and salt storms caused by the historic dewatering of Owens Lake by the City of Los Angeles.
- 3) Following the defeat of the Peripheral Canal initiative in 1982, the State Water Project currently has sufficient facilities to supply only half of its ultimate capacity of water from the main watershed area of the state, the Sacramento Delta. Lack of precipitation and the resulting reduced runoff during the 1987-92 drought prompted reductions in water deliveries to Southern California by up to 80 percent. Environmental concerns over effects of water diversions on the wildlife living in the delta and competition between urban and agricultural users may make such reductions in water diversions permanent likely in the future.

Compounding these threats to the Southern California water supply is the fact that every year the population in the MWD service area increases by another 400,000 people, equivalent to a city the size of Portland, Oregon. The United States Census Bureau estimates that the population of the State of California will increase 52%, from 31.4 to 47.9 million, by the year 2020, prompting increased competition for the State's dwindling water resources. Within the last 20 years, the State of California has been hit by two serious droughts, in 1976-77 and more recently in 1987-92. Mandatory water rationing of at least 20 percent was instituted by water purveyors throughout the state, and, at one point, the California State Department of Water Resources (DWR) anticipated going to a mandatory 50 percent rationing.

Only the extremely wet winter of 1993 brought the water supply situation in the state out of crisis; however, the relief was short lived as the following year was declared "critically dry" by the DWR on April 1, 1994, and the state appears to be heading back into a drought. The State Legislature has long known of the value of water reclamation. The Water Reclamation Law, Chapter 7 of the California Porter-Cologne Water Quality Act, states that: "the people of the State have a primary interest in the development of facilities to reclaim water containing waste to supplement existing surface and underground water supplies and to assist in meeting the future requirements of the State." Furthermore, the State Legislature in 1991 officially adopted the goal of reaching one million acre-feet per year of reuse by the year 2010.

Operators of large landscaped areas such as golf courses and parks departments and water-intensive industries such as those using cooling towers should be well aware of the dire consequences if more draconian conservation measures are ever imposed again. Businesses may shut down and golf courses may lose their expensive investments in landscaping. Many heavy water users have since come to the realization that reclaimed water is still a drought-

proof supply, despite the drought-induced 10% sewage flow decrease. Following the severe 1976-77 drought, several public water purveyors decided to pursue reclaimed water as a supplementary supply to lessen the effects of future water shortages in their service areas. An additional boost for water reclamation come from the most recent drought, which has inspired even more public and private water purveyors to invest in a reclaimed water distribution infrastructure consisting of pump stations, pipelines and storage reservoirs to transport the reclaimed water to a variety of users.

## THE SANITATION DISTRICTS

The Districts are a confederation of independent special districts formed in 1923 to serve the water pollution control needs of nearly five million people in Los Angeles County. The Districts' service area covers approximately 765 square miles (1,980 square kilometers) and encompasses 78 cities and unincorporated territory within the County, with the notable exclusion of the City of Los Angeles. One role of the Districts is to construct, operate and maintain 1,200 miles (2,000 kilometers) of trunk sewers and 11 wastewater treatment plants to collect, treat and dispose of 500 million gallons per day (MGD) [21.9 cubic meters per second ( $m^3/s$ )] of sewage. Ten of the treatment plants in the Districts' system are water reclamation plants that produce almost 190 MGD ( $8.3 m^3/s$ ) of high quality effluent suitable for a variety of reuse applications.

The Districts' first treatment facility was located in the City of Carson, California and is now known as the Joint Water Pollution Control Plant (JWPCP). This facility utilizes advanced primary treatment with partial secondary treatment (going to full secondary by 2002) for disposal to the Pacific Ocean two miles (3.3 kilometers) off shore through two, large diameter (120 and 90 inch [3.0 and 2.3 meter]) outfall pipes. From the plant's inception in 1928 to post World War II, this facility and its subsequent expansions was sufficient to handle the wastewater generated in the Districts' service area in the metropolitan Los Angeles area. However, an economic boom in Southern California followed the war years and was accompanied by rapid population growth in this region. This precipitated the need for more treatment and sewer capacity.

Water reclamation's potential in Los Angeles was recognized as early as 1949 when a seminal study detailed most of the features incorporated in today's reclamation program, such as:

- 1) The construction of water reclamation plants (WRPs), incorporating existing, proven treatment technology, along the Districts' sewer system would be a preferable alternative to increasing treatment at the JWPCP. Economy of scale would be achieved by operating these facilities under one agency, and using the solids handling facilities of the JWPCP instead of constructing and operating such facilities at each reclamation plant.
- 2) Locating the plants upstream of the more heavily industrialized areas in order to treat mostly residential sewage, producing a higher quality effluent. To further improve effluent quality from the reclamation plants, industrial waste would be bypassed around the plants, and an industrial waste pretreatment program would be implemented to prevent toxic wastes from entering the WRPs.
- 3) The reclaimed water produced at these plants would be of such high quality so as to allow its use for agricultural and landscape irrigation, manufacturing, construction and industrial cooling, environmental enhancement, recreational activities, and groundwater replenishment.

Using these principles, the current generation of water recycling projects began the Districts' construction of the prototype Whittier Narrows WRP in 1962. The effectiveness and aesthetic qualities of this facility led to the decision to construct four more WRPs in the Los Angeles basin area. Five other WRPs serve the outlying communities of La Cañada, Lancaster, Palmdale and Santa Clarita. Not only would the valuable resource of water be produced in large quantities from these plants, but it was also determined that this would be more cost effective than increasing treatment capacity at the JWPCP and constructing more and larger sewers to transport the wastewater to that facility. These additional plants were constructed in the early 1970's, with treatment consisting of primary sedimentation (with optional chemical coagulation added later), secondary biological oxidation by means of activated sludge, and disinfection with gaseous chlorine. All five were subsequently upgraded to tertiary treatment several years later with the addition of coagulant dosing and inert media filters. The result of this upgrade was the production of an effluent that meets Federal and State drinking water standards for heavy metals, pesticides, trace organics, major minerals, and radionuclides, and extremely low levels of microorganisms.

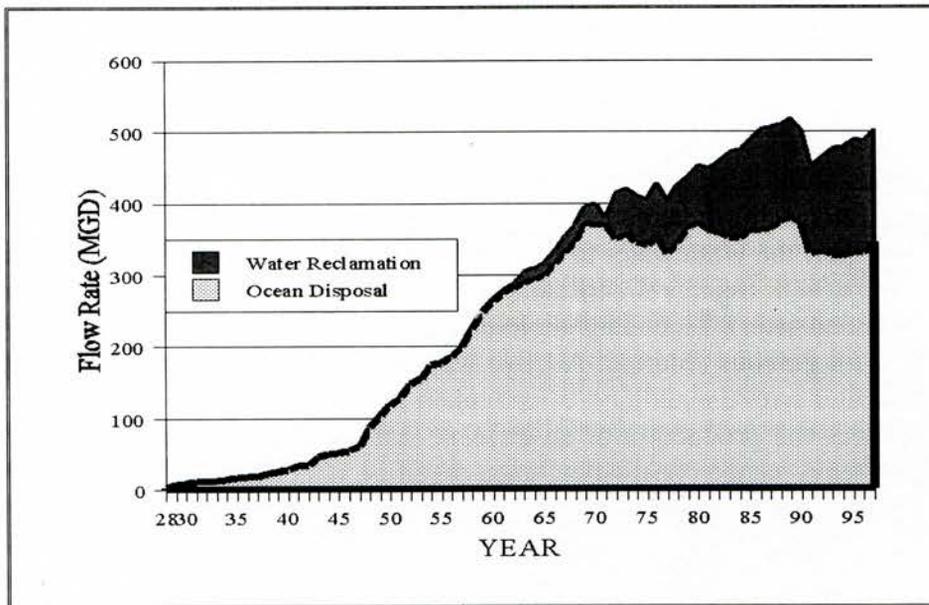
The Districts' WRPs were scattered geographically throughout the JOS to better handle locally produced wastewater. Therefore, they can supply reclaimed water to a greater number of communities. It continues to be the Districts' intent to construct additional treatment capacity at the WRPs, instead of for ocean disposal at the JWPCP, in order to make additional reclaimed water supplies available for reuse. It can be seen in Figure 1 how a drought-induced decrease in sewage flow is taken from the ocean disposal treatment facility, while the water reclamation facilities continue to produce the same amount of effluent. This stability of flow ensures that users of reclaimed water will not be required to reduce their usage during potable water shortages.

## **GROUNDWATER REPLENISHMENT**

Following the Districts' 1948 study on the potential for water reclamation, a second study followed in 1956 which outlined a plan for constructing water reclamation plants, upstream of the Districts ocean disposal plant. As previously mentioned, the first of these plants was the Whittier Narrows WRP. This plant was specifically designed for the reuse of the effluent for groundwater replenishment. The facility was located in an area behind the Whittier Narrows flood control dam, so there were no other buildings or residences nearby that might have been impacted. It sat alongside the Rio Hondo, directly upstream of spreading basins that were constructed to conserve storm flows for replenishment of the Central Basin aquifer, the main groundwater supply for metropolitan Los Angeles. The river was to be used to convey the treated effluent to the spreading grounds for recharge, thus eliminating any construction of transmission or usage facilities for the reclaimed water.

The need for management of the groundwater basin became obvious by the 1950's as overpumping of the Central Basin by 900,000 AF (1,111 hm<sup>3</sup>) had dropped the water table precipitously, increasing pumping costs and allowing for seawater to intrude into the aquifer at various points along the coastline. In 1959, the Water Replenishment District (WRD) was formed to actively manage the basin by limiting pumping and providing for supplemental recharge water. The Whittier Narrows WRP was a part of the WRD's plan to manage the groundwater by purchasing the entire amount of reclaimed water produced by this facility for recharge. Additional Districts' WRPs were constructed and contributed reclaimed water for recharge in 1966 (Pomona), 1971 (San Jose Creek Stage I), 1983 (San Jose Creek Stage II) and 1993 (San Jose Creek Stage III).

Figure 1. Joint Outfall System Flow Diversion to Reclamation, 1928-97



Reclaimed water for groundwater replenishment has the distinct advantage of being exactly where it is needed, so that long, extensive aqueducts are not required. And reclaimed water is available when it is needed for spreading, 24 hours a day, 365 days a year, even during the hot, dry summer months when imported water supplies are limited and storm flows are non-existent. And because there are no time-of-use restrictions as with parks and other public landscaped areas receiving reclaimed water (i.e., irrigation only at night), the recharge program can take advantage of the peak effluent flows which occur during the middle of the day, and which would otherwise be wasted.

Replenishment of the groundwater with reclaimed water was regulated by two state agencies: the Regional Water Quality Control Board (RWQCB) and the Department of Health Services (DHS). The amount of reclaimed water that was permitted to be used was limited to 32,700 AFY, which was determined to be the amount of effluent that had historically entered the groundwater from other sources. Health authorities were reluctant to increase the amount of reclaimed water recharging the underground drinking water supply due to concerns over increased exposure of the populace to synthetic chemicals which might be potential carcinogens. The drought of 1976-77 prompted the health authorities convene a panel of experts to discuss the health aspects of groundwater replenishment with reclaimed water. From this discussion, the Districts initiated its Health Effects Study. This study was to examine all facets of groundwater recharge with reclaimed water, including flow modeling, virus monitoring, toxicology and epidemiological studies, etc. Completed in 1984, the study showed that the proportion of reclaimed water used for replenishment had no measurable impact on either groundwater quality or human health. The epidemiological portion of the study, conducted by the University of California, Los Angeles, found that the evaluation of health and vital statistics data for the period of 1969-80 showed that residents of the area that received reclaimed water experienced no increased rates of infectious diseases, congenital malformations, infant and neonatal mortality, low birth weight, cancer incidence, or deaths due to heart disease, stroke, stomach cancer, rectal cancer, bladder cancer, colon cancer, or all cancers combined, when compared to residents of two control areas that did not receive reclaimed water (Nellor et al, 1984).

Following this study, a Scientific Advisory Panel was convened to examine these results. In the 1987 Report of the Scientific Advisory Panel on Groundwater Recharge with Reclaimed Wastewater, the State Water Resources Control Board and DHS concluded that they were comfortable with the continuation of the current groundwater replenishment project and with the safety of the product water and they felt that the risks, if any, were small and probably not dissimilar from those that could be hypothesized for commonly used surface waters. In response to this report, the RWQCB and DHS permitted the annual amount of reclaimed water used recharge to be increased by 53%, to 50,000 AFY (62 hm<sup>3</sup> per year). In 1991, these agencies permitted the amount of reclaimed water recharged in any one year to be increased to 60,000 AF (74 hm<sup>3</sup>), with a three-year running total limit of 150,000 AF (185 hm<sup>3</sup>).

As a follow-up to the epidemiological survey done for the Health Effects Study, the Rand Corporation issued a report in 1996 entitled Groundwater Recharge with Reclaimed Water - An Epidemiological Assessment in Los Angeles County, 1987-1991. The purpose of the assessment was to investigate the reported rates of cancer, mortality, and infectious diseases, and compare them to other areas which receive none, more, or less reclaimed water in their groundwater supply to see if there were any significant differences. The epidemiological study concluded that after 30 years of groundwater recharge with reclaimed water, the rates of cancer, mortality, and infectious disease of the persons receiving groundwater containing reclaimed water, are similar to a control area which receives no reclaimed water, and to other areas where reclaimed water percentages are higher and lower. The results provided no evidence that reclaimed water has an adverse effect on health.

Long-term monitoring of the groundwater of shallow wells located in the spreading grounds (Table 1) has also indicated no degradation of the groundwater due to the recharge of reclaimed water. The distance shown is the lateral distance between the bottom of the nearest spreading basin to the uppermost perforation in that monitoring well's casing.

The DHS is currently revising their requirements for groundwater replenishment with reclaimed water based on the Districts' experience over the past 35 years. Additional quantities of reclaimed water may be permitted to be recharged only after additional treatment (e.g., reverse osmosis, activated carbon) is utilized to remove total organic carbon. Such advanced treatment is currently used at two locations in Southern California for processing reclaimed water for use in seawater intrusion barriers.

Table 1. Shallow Well Monitoring Summary, August 1988-December 1997.

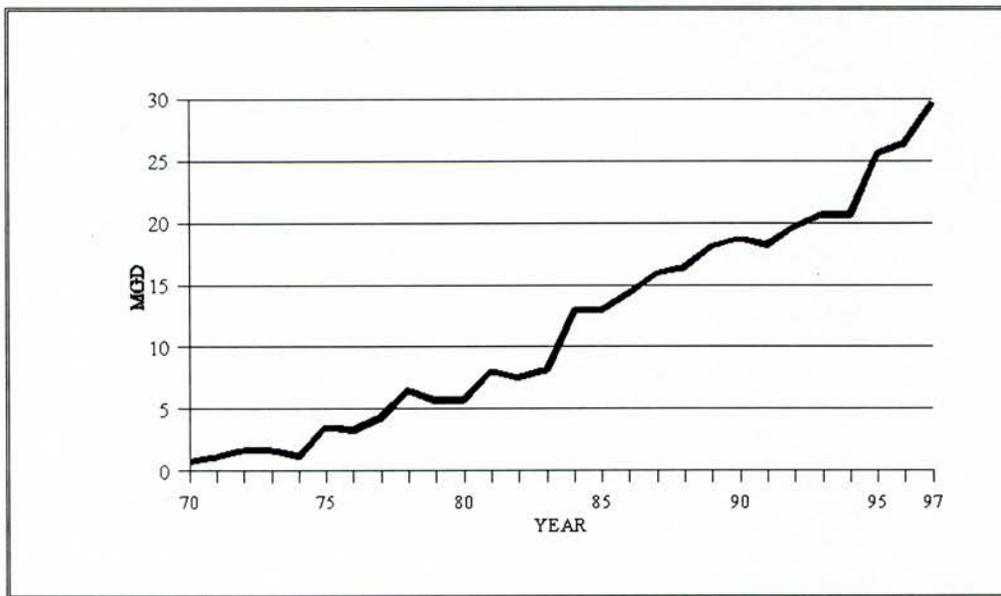
Constituent	Well Number						
	2909Y	1590AL	1581P	1582W	1620RR	1612T	1613V
Distance, feet	112	168	106	61	70	60	70
Total N, mg/l	2.17	2.45	3.43	2.12	3.82	4.57	3.31
TDS, mg/l	391	429	460	307	548	527	514
COD, mg/l	< 8	< 9	< 9	< 9	< 12	< 9	< 12
TOC, mg/l	< 1.62	< 2.21	< 1.37	< 1.57	< 2.25	< 2.06	< 2.14
Non-Volatiles, µg/l	< 0.02	< 0.70	ND	< 0.30	< 0.02	< 0.02	< 0.01
Pesticides, µg/l	< 0.02	< 0.02	< 0.13	ND	ND	< 0.05	< 0.02
Volatiles, µg/l	< 0.20	< 0.43	< 0.13	< 0.35	< 0.64	< 0.23	< 0.08

Well 1581P replaced by Well 1582W in December 1990. ND = Not Detected

## NONPOTABLE APPLICATIONS

The use of reclaimed water for more direct, nonpotable applications, such as irrigation and industrial process supply, did not start with as much enthusiasm as did the groundwater replenishment activities. While groundwater recharge relied on existing flood control and water conservation facilities and gravity for transport of the water from the WRP to the point of reuse, direct users required the construction of a parallel water delivery infrastructure of pumps, pipes and storage tanks, along with energy, to move the reclaimed water. Literally every potential reclaimed water use site is already served with domestic water. As a result, the biggest incentive to use reclaimed water, which is the absence of any kind of water supply, is missing. During times of water surplus, the potential for future interruptions in the domestic water system is simply ignored, a case of "out-of-sight, out-of-mind." Although rationing and increased water costs had very severe consequences during the droughts of 1976-77 and 1987-92, the domestic water connections were physically still there. Figure 2 shows the increase in the usage of reclaimed water for direct nonpotable applications from 1970 to 1997, while Figure 3 shows the increase in the number of sites receiving reclaimed water.

Figure 2. Increase in Direct Nonpotable Reuse, 1970-97



Therefore, the marketing of reclaimed water has to overcome an obstacle that never confronted the domestic water system: competition from another source with infrastructure already in place. The concept of water recycling, by necessity, must rely on the voluntary commitment from all of the parties involved. These parties include the agencies who produce the reclaimed water commodity, the various layers of purveyors and the end user who must ultimately accept the reclaimed water and apply it. Any break in this chain results in reclaimed water not being used. It was not until the drought of 1976-77, that water purveyors, who also have the responsibility to deliver reclaimed water as well as potable water, did not see the need for investing in reclaimed water infrastructure. However, during and immediately following this drought and the subsequent drought of 1987-92, there was significant activity by numerous forward-looking public water purveyors in regards to planning, designing, constructing and operating reclaimed water distribution systems.

The evolution of distribution systems for reclaimed water has occurred in several discreet steps that have built on the steps before. The first generation of reuse systems consisted of large, individual users located adjacent to the WRP. Generally, a small pump was placed at the final effluent forebay or one of the WRP's pumps (e.g., washwater pump) was used to deliver reclaimed water through a short run of pipe to the user. These users were either golf courses or large parks whose irrigation systems were already isolated or could be readily isolated from the potable water system originally supplying the site.

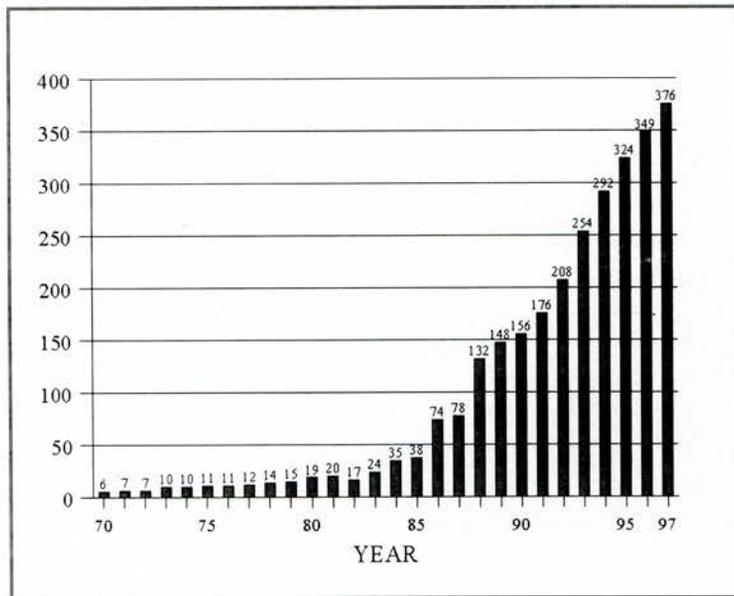
The second generation of reuse systems involved a single municipal water purveyor supplying numerous sites within the city's boundaries, again surrounding the WRP. The additional capital cost incurred by these systems were offset to some degree by the larger amount of reclaimed water that could be delivered. These cities took advantage of the fact that many of their potential reclaimed water customers, such as parks, golf courses, street medians, were already owned and operated by the city itself, which made marketing of the reclaimed water much simpler. The cities that embarked on their own reclaimed water distribution systems were those who were recipients of very expensive imported water supplies. The use of reclaimed water allowed for reduced purchases of the more costly potable water, while permitting their city-owned facilities to maintain their green appearance even during the next drought.

In the mid-1980's, a number of municipal water agencies began examining reclaimed water systems for their own service areas. However, in many cases, either the municipality did not possess the financial resources to accomplish this, or the municipality was located too far away from the WRP. This situation gave rise to the third generation of reclaimed water systems. Regional water wholesalers, who originally delivered imported water to retail purveyors, began constructing reclaimed water delivery systems through the service areas of numerous retail water purveyors. The regional agency constructs the delivery line right up to the end user, and, in some cases, assists the user with any on-site retrofits to allow for reclaimed water use. Reclaimed water is actually sold from the Districts to the regional wholesaler, who sells it to the retail purveyor, who sells it to the end user. These cooperative, regional systems allow the smaller retail purveyors to maintain their customer base while participating in water reclamation. This regional system permits the maximum usage of reclaimed water while enjoying economy of scale.

The fourth generation will consist of these regional systems, which originate at different WRPs, interconnecting with one another, allowing for increased reliability and operational flexibility, and enhanced system pressures and flows. It is anticipated that, over the next few years, several systems will be interconnected so that there will be an unbroken string of reclaimed water pipelines stretching between all of the Districts' JOS treatment plants. This same process will extend reclaimed water interconnection into the adjoining jurisdictions of Orange County and the City of Los Angeles, so that eventually, the reclaimed water system will become as ubiquitous and far-reaching as the potable water system.

In some ways, the practical applications of water recycling have outpaced the regulations for its use. The initial requirements for water reuse were promulgated in 1978 and are contained in Title 22 of the California Water Code. The DHS is currently updating these regulations to take into consideration the fact that water recycling has gone beyond the landscape irrigation and body contact recreation contemplated by Title 22 and is now being used for various industrial processes, livestock watering, fire fighting, toilet flushing in non-residential structures and even snow-making. The upgrade of the Districts' WRPs to tertiary treatment in the mid-1970s has provided a reclaimed water supply that can be used for literally any application short of direct potable supply.

Figure 3. Increase in Number of Reuse Sites, 1970-97



## SUMMARY

The Sanitation Districts of Los Angeles County have operated a successful wastewater reclamation program since the early 1960's. However, this success has not been attained overnight. Rather, it has required a combination of water shortages, progressive water purveyors, cooperative end users and time to reach the current high level of reuse. Nor has this expansion progressed smoothly and evenly. spurts of reuse development activity have been interspersed with quiet times of studying, planning and marketing. Simultaneous efforts in expanding direct nonpotable uses, such as irrigation, and indirect potable uses, such as groundwater replenishment, have yielded continuous progress in expanding the use of reclaimed water and the conservation of valuable potable water supplies. As with many endeavors, there is no clear end-point to these efforts. A ever-growing population and limits on natural water supplies will ensure that the expansion of water recycling will continue unabated into the foreseeable future.

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