HISTORY OF

Orange County Water District

Cover photo: Burris Basin

Table of Contents

Foreword v
Regional Significance of Orange County's Groundwater Basin

Introduction vii
Orange County Water Agencies

Looking Back 1
Water Works and the Spanish Period
Water Works and the Rancho Period
Water Works and the American Period
The Anaheim Colony and the Anaheim Water Company
Birth of Santa Ana, Orange, and Tustin
Anaheim Water Company v. Semi–Tropical Water Company
The Irvine Legacy
Tapping Artesian Groundwater
Arrival of the Railroad
Tri Counties Reforestation Committee
Water Conservation Association
Metropolitan Water District
Orange County Flood Control District
Santa Ana Basin Water Rights Protective Association

Establishing the Orange County Water District 13
Orange County Water District
Irvine Company v. Water Conservation Association
Conservation and Replenishment
World War II and Military Bases
First Report on Water Supply in the Lower Santa Ana Basin
Reducing Overdraft
Responding to Growth: From Croplands to Housing Tracts
Committee of Twelve

Optimizing the Groundwater Basin 25
Replenishment Assessment and Registration
Increased Imported Water in Orange County
The Politics of Spreading Basins
Orange County Water District v. City of Chino, et al.
Basin Equity Assessment
Seawater Barriers
Water Quality in the Watershed
Development of Water Factory 21
Pursuit of New Projects

Increasing Water Supply Reliability 39
Modernizing Orange County Water District
Green Acres Project
Analytical Water Quality Laboratory
Research and Development Laboratory
Improved Recharge Capabilities in the Basin
Stormwater Capture at Prado Basin
Environmental Stewardship at Prado Basin
The Beginning of the Groundwater Replenishment System
Visionary Partnership

Securing a Sustainable Water Future 49
Seawater Intrusion Control
Groundwater Replenishment System
Advanced Water Quality Assurance Laboratory
A Tradition of Innovation
Groundwater Replenishment System Initial Expansion
Recharging GWRS Water
Imported Water Programs
Increasing Stormwater Capture
Addressing Groundwater Contamination
Sound Groundwater Management
Groundwater Replenishment System Completion
Continuing the Tradition of Innovation

Afterword 63

Appendices 65
Historical Timeline—Orange County Water Progress
Locations of District Headquarters
Current Board of Directors
History of Board of Directors
Glossary
Bibliographic and Oral History Works Cited

Attribution 91

Foreword

By Cathy Green, President, Orange County Water District

The Orange County Water District (OCWD, the district) is responsible for managing the Orange County Groundwater Basin, a vast, hidden gem spanning more than three hundred square miles and holding billions of gallons of water located right beneath our feet.

Groundwater is water that accumulates and is stored beneath the surface of Earth in aquifers. Like an underground sponge, an aquifer is a porous mix of sand and gravel that is filled with water. Born of ancient rains and held deep underground, groundwater is Orange County's wellspring—a critically important water resource that is largely invisible and yet saturates the lives and livelihoods of millions of people.

A groundwater basin consists of one or more aquifers surrounded by non–water–bearing material. Inside the basin, the aquifers are divided and shaped by aquitards, clay or silt layers that restrict movement of water between the aquifers. Water enters the groundwater basin by percolation through the ground or by underground flows of water from an adjoining aquifer. The movement of groundwater is extremely slow and is usually measured in feet per year. Water percolates into the basin naturally through rain and river flow. Recycled and imported water also provide a source of supply into the basin and these supplies are diverted into artificially created facilities called percolation ponds.

The water Orange County drinks today may have entered the basin one year, one hundred years, or one thousand years ago…

Regional Significance of Orange County's Groundwater Basin

Orange County's groundwater basin began forming millions of years ago as mountains eroded and ocean and riverine sediments filled a deep valley, trapping Santa Ana River water within layers of sand and gravel. The deepest aquifers of the groundwater basin still contain pristine "fossil water" that fell to the ground thousands of years ago. The water Orange County drinks today may have entered the basin one year, one hundred years, or one thousand years ago, depending on the location and depth of the well.

Orange County's groundwater basin has a safe operating capacity of approximately 500,000 acre–feet. This vast basin reflects an interesting geology. The sandy soil under Yorba Linda, Fullerton, Anaheim, and Orange provides good access for water on the surface to reach deep aquifers while clay layers that underlie other areas impede percolation. These restrictive clay layers limit the reach of OCWD's recharge areas, but they also limit the extent and depth of pollution within the basin.

The water from the Santa Ana River is naturally purified and stored underground without the need for extensive piping networks to transport it. Further, it is not subject to evaporation like water stored in a surface reservoir. Properly managed, the groundwater basin provides a renewable resource for current and future generations, and in times of drought, ensures water reliability that otherwise could be compromised. Responsible management also ensures a basin that provides a solid foundation for city infrastructure, as well as environmental benefits to plants and animals that depend upon rivers, streams, and wetlands.

The Orange County Water District has always viewed groundwater management as a long–term process, and we've made significant investments to increase local water supplies in the basin. Ninety years after its inception, the district continues to be guided by vision and vigilance to ensure water supply reliability for future generations.

It is my distinct honor to serve as president of the Board of Directors. The Board, together with staff, recognizes the pivotal role the district plays in water resource management. Its innovative water supply programs are a testament to its commitment to groundwater stewardship. Please join me in exploring the Orange County Water District's remarkable 90–year history.

La Palma Recharge Basin in Anaheim

Introduction

In 1860, William Brewer, professor of agriculture at Sheffield Scientific School at Yale, accompanied the first geological survey party to study the terrain of California. He kept a detailed journal of his experiences. His early description of the broad riverbed of the Santa Ana River (river) would still be quite accurate if the river had not been confined to a channel in Orange County. Even today during floods, the river appears formidable as it rushes to the sea. One can imagine that, no longer confined by its banks, it could flood the wide coastal plain now covered by asphalt and lined with buildings. The river's floodwater inundated parts of modern Orange County at least five times in the 20th century alone, altering the homes and lives of residents. Yet, for much of every year, it is a narrow, shallow stream that simply disappears into its riverbed about mid–county. As it disappears, however, its waters sink into a groundwater reservoir that is capable of holding some 2.5 to 3 million acre–feet of water (Bailey 1929). Orange County Water District (OCWD, district) hydrogeologists have since mapped and modeled the basin and estimate its total capacity to be 66 million acre–feet (maf), (OCWD Groundwater Management Plan, 2015).

Early in the 20th century, the basin's supply seemed unlimited. By the 1930s, however, the groundwater level had dropped precipitously, indicating the basin was already overdrawn. If Orange County were to continue its economic expansion, the basin supply would have to be replenished and protected. To study the problem, the Farm Bureau and County Chamber of Commerce established a committee of agribusiness and civic leaders. The committee proposed legislation to establish a unique basin–wide management and conservation district for the Santa Ana Valley. As stated in the original 1933 OCWD Act, the new district would monitor and conserve underground supplies in the valley basin and protect local water rights against outside users. While this basic purpose has remained in place, modern technology and science have made OCWD's operation much more complex.

[OCWD's] mission is to provide a... high–quality supply of groundwater procured in an environmentally responsible manner...

The first directors supervised day–to–day maintenance themselves, hiring engineers as needed or retaining attorneys to pursue litigation over water rights against upstream users of the river. By 2002, OCWD's operation had grown to a staff of 186, including scientists, engineers, technicians, accountants, and attorneys. It owned more than 1,600 acres of land for groundwater recharge and had an annual operating budget that exceeded $76 million. Groundwater management policies had expanded to include championing internationally acclaimed wastewater reclamation projects. Now in 2023, supported by a staff of 226 and an annual operating budget of $159.7 million, the district remains at the forefront of groundwater management and protection.

Orange County Water Agencies

Several different kinds of water districts serve Orange County, often with similar names but different responsibilities. Only one—OCWD—manages the groundwater basin of the north and central part of the county. With the exception of treated wastewater for irrigation in the Green Acres Project, OCWD does not directly provide water to anyone. Its mission is to provide local water retailers with a reliable, adequate, and high–quality supply of groundwater procured in an environmentally responsible manner at the lowest reasonable cost.

The Metropolitan Water District of Southern California (MWD) provides imported water from the Colorado River and the State Water Project (Northern California to Southern California). It wholesales this imported water to its Orange County member agencies, including three independent cities, Anaheim, Fullerton, and Santa Ana, and the Municipal Water District of Orange County (MWDOC). MWDOC represents all of Orange County (excluding the independent city members of MWD), acting as a pass–through agency for MWD water sold to its constituent members, and selling additional untreated water to OCWD for groundwater recharge.

Special districts, including Irvine Ranch Water District, Mesa Water District, Yorba Linda Water District, East Orange County Water District, and Serrano Water District, which until recent decades were primarily agricultural water producers, also draw groundwater from the basin. In addition to these districts, cities, private individuals, and water companies also produce water independently from the groundwater basin.

Directly or indirectly, water used in OCWD's service area is tied to the Santa Ana River. Without river flows, north and central Orange County would be dependent on the Colorado River or northern California.

Because of declining river flows, and reducing dependence on imported water, OCWD has invested over $900 million to develop a new 134,000 acre–foot per year (afy) supply of advanced treated recycled water through its Groundwater Replenishment System (GWRS). Also, OCWD has worked with the U.S. Army Corps of Engineers (USACE) to capture stormwater behind Prado Dam and is working with the USACE to develop storm models to implement Forecast Informed Reservoir Operations (FIRO) to potentially capture even more stormwater in the future.

The OCWD has worked diligently over the past 90 years to actively manage Orange County's groundwater basin and develop projects that provide water supply reliability for the 2.5 million people and 19 retail water agencies it serves.

Looking Back

Looking Back

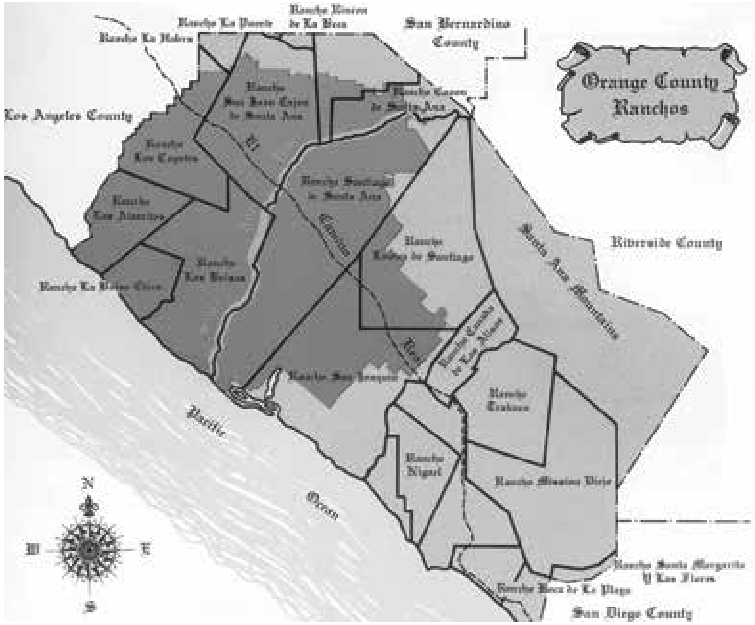
Water Works and the Spanish Period

Beginning in the late 18th century, as their colonies developed, Europeans introduced their concept of community control of irrigation and water management to Southern California. But long before this, Indigenous people, including the Tongva and Maara'yam, lived in this region. They took advantage of abundant water, game, plant foods, and fibers. The river sustained their lives and enriched their culture until missionaries arrived and forever changed their world.

The Spanish clergy were the first Europeans to draw irrigation water from California's streams and springs. According to Spanish law, no individual could claim the right to a stream flow. The right to use water was held in common within a community for the benefit of all and did not supersede the similar right of downstream users. A watermaster, or *zanjero*, was charged with the responsibility of allocating water in proportion to the needs of the people and the quantity available. The *pueblo* (municipality) or irrigation district was responsible for the division of the water, development of water works, and protection of water quality for the stream as it passed by. Thus, formal concepts of communal sharing of water were applied to the river.

In 1810, the Spanish government granted a concession for grazing rights on the 62,500–acre Rancho Santiago de Santa Ana to retired soldier José Antonio Yorba and his nephew, Juan Pablo Peralta. Following the custom of the Spanish government, the rights to graze cattle on the land, rather than the land itself, were granted to the men. Because of its location, the rancho claimed riparian rights to the river flow, confirmed by the United States land commission in 1860. A rancho's rights were subordinate to those of a pueblo. Generally limited to domestic use or watering of livestock, the rancho's water usage could be expanded for crop irrigation or to operate a mill as long as such use did not injure other downstream users. If, however, a rancher turned water onto his land to irrigate and no one complained, his use could be confirmed after a period of time. In the first recorded use of river water for irrigation, Yorba and Peralta diverted water to irrigate their crops and pastureland on the rancho (OCWD 1983).

Old mission house, California, *photo courtesy of ilbusca/iStock*



Orange County ranchos

Water Works and the Rancho Period

When Mexico became independent from Spain in 1821, the influence of the missions began to decline in California. What was once the land of the Maara'yam and Tongva, and later, Spanish missionaries, became the land of Mexican rancheros and some German vineyard owners.

The newly independent nation secularized mission lands in the early 1830s and granted them to settlers. Under the secularization decree, Don Bernardo Yorba, son of José Antonio, received a Mexican land grant to the Rancho Cajón de Santa Ana on the north side of the river. In 1835, Bernardo Yorba built several irrigation ditches on the river in the vicinity of Bedrock Canyon, the narrowest point in Santa Ana Canyon (Hall 1888). Within a year, he was irrigating between 1,000 to 2,000 acres of cropland, vineyards, and orchards (M. B. Scott 1976).

Despite the transfer of land ownership from the missions to the settlers, the economy changed little. Yankee traders came into the region in the late 1820s and early 1830s to trade household goods for hides, which they shipped by ocean–going vessels to the eastern United States. Isolated on the West Coast, the Anglos intermarried with the Mexican ranch families and continued traditional cattle operations on the plains. Because it was so difficult and time–consuming to carry freight beyond the Los Angeles area, there was no outside market for perishables such as meat nor incentive to irrigate more land than needed for food to sustain the local population.

Water Works and the American Period

In 1848, the Treaty of Guadalupe Hidalgo concluded the war with Mexico and made California part of the United States. James Wilson Marshall, a sawmill operator on the American River, discovered gold at the same time, and the rush to California was on. Farmers came to Southern California and purchased rancho land to grow grain and other food crops for hungry miners. Ranchers began to graze cattle for their meat, not just the hides, because it was finally profitable to drive a herd north across the San Joaquin Valley to Sacramento.

The Anaheim Colony and the Anaheim Water Company

Once gold seekers reached San Francisco in the early 1850s, however, they sought additional resources, including wine. Western frontier trapper and tracker–turned–settler William Wolfskill and others began to grow grapes for that market and soon developed extensive vineyards on land that would become part of Orange County. In an effort to expand their production, San Francisco wine merchant John Frohling and his Los Angeles partner, Charles Kohler, looked for people in San Francisco who would be willing to come to the Los Angeles region to grow grapes. At his urging, a group of 50 German immigrants agreed to establish a vineyard colony near the river. The Germans formed a stock company to purchase part of the Rancho San Juan Cajon de Santa Ana, on the north side of the river. Their agent, George Hansen, also secured a right of way across the remaining part of the rancho to the river and the right to fill their ditch from the river with a specific volume of water for irrigation of the 1,165–acre tract. Hansen supervised the laying out of the individual plots for vineyards and households in what became known as Anaheim, a home (*heim*) by the river (*Ana*).

Once the vineyards were established, the colonists took possession of the individual plots of land and established a mutual water company—the Anaheim Water Company—to continue to administer the irrigation works. Each landowner owned one share in the company. This was a pioneering effort to develop a private water company, distinct from later municipal and district operations funded by taxes and bonds (Hundley 1992).

Birth of Santa Ana, Orange, and Tustin

While the colonists on the Rancho San Juan Cajón de Santa Ana had purchased the right to a certain amount of water to irrigate their acreage, there was no volume limit on the riparian rights of the Rancho Santiago de Santa Ana. The original grant stated that Rancho Santiago de Santa Ana had the right to half of the waters of the river that came to it. When Rancho Santiago de Santa Ana was partitioned in 1868, the water rights went with each parcel—along with a right of way for a ditch to the river if the parcel did not border the river. Instead of joining together as the Anaheim colonists did to form a mutual water company to supervise irrigation, the landowners on this rancho dug small individual ditches, which were gradually abandoned.

Mallory's vineyard, 1898, *photo courtesy of Santa Ana Public Library*

Open canal of the Anaheim Union Water Company, *photo courtesy of Santa Ana Public Library*

By the mid–1870s, land developers were already establishing the new communities of Santa Ana, Orange, and Tustin on the Rancho Santiago de Santa Ana. Two of the men who purchased rancho land or took it in payment for services were attorneys A.B. Chapman and Andrew Glassell. Andrew Glassell's brother, William, supervised the creation of Richland (now the city of Orange) some distance from the river. Since this had been rancho land, the development was entitled to water from the river. In order to bring water to the fledgling town, William Glassell widened and lengthened one of the abandoned ditches, constructed a small reservoir, and laid iron pipes to hydrants in the town site (Brigandi 1997). Residents hauled water to their homes and orchards from these hydrants, including one at the Orange Plaza at Chapman and Glassell.

Two years later, the brothers formed the Semi–Tropical Water Company and transferred the ditch, now known as the A.B. Chapman Ditch, to it. The company then extended its lines to Tustin and Santa Ana (Hall 1888).

Anaheim Water Company v. Semi–Tropical Water Company

As people moved into the Riverside area and developed orchards, they used more of the river upstream from the ranchos for irrigation, allowing less to flow down to the coastal plain. While it appeared to Anaheim colonists on the north side of the river that the Semi–Tropical Water Company was taking more of their water, the upper basin diverters were the real culprits. The diminished flow was not a problem in wet years, but 1877 was a dry year and the river ran nearly dry at the ditch intake for Anaheim. Anaheim farmers, accustomed to using as much water as they needed, had to haul water to save their vineyards. As a result, the Anaheim Water Company sued the Semi–Tropical Water Company to regain its volume share of river water.

Litigation of the river began with the lawsuit of Anaheim Water Company v. Semi–Tropical Water Company. A lower court decision stated that Anaheim was entitled to a supply of water to fill its main ditch. That decision was appealed to the California Supreme Court, which reversed the lower court's decision and upheld the Semi–Tropical Water Company's riparian rights to the river. The court, however, also recognized riparian rights invested in the Anaheim Water Company, stating that it had equal rights to use the water. Justices remanded the case to the lower court for a final decision, but suggested that instead of continuing litigation, the parties agree to an equitable division of the water and devote their money to "proper development and use of it" (Hall 1888). By the time the case was finally settled in 1883, the Anaheim Water Company had joined with other small ditch owners on the north side of the river to form the Anaheim Union Water Company. Meanwhile, the Semi–Tropical Water Company had been purchased by the Santa Ana Valley Irrigation Company, which was formed to irrigate all the river land on the south side. As a result of these consolidations, two private water delivery companies commanded the flow of the river in the Santa Ana Valley. They continued to supply water to their customers until the 1960s when OCWD purchased the jointly held land, the water rights of the Santa Ana Irrigation District, and the works of the Anaheim Union Water Company to prevent their purchase by upstream users (Pearson 1968).

The Irvine Legacy

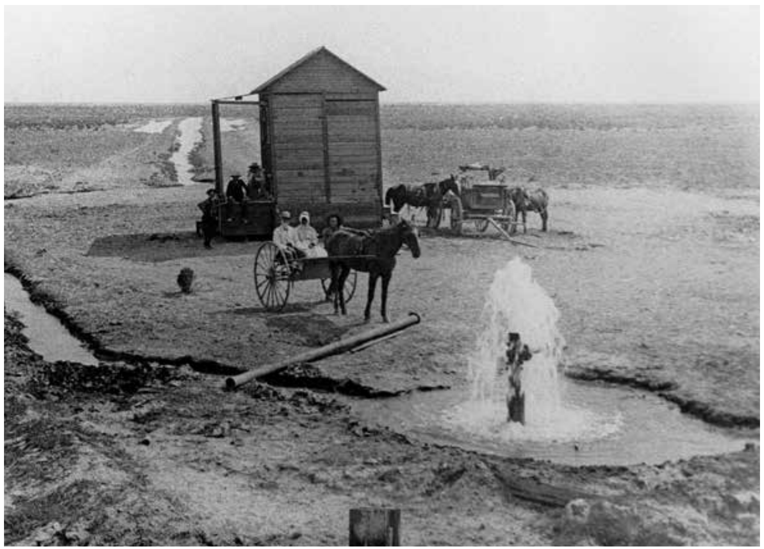
The James Irvine family holds a prominent place in the county's history as well as its water resources. Lured by the Gold Rush, James Irvine I arrived in California in 1848 and worked as a merchant and miner. His success as a businessperson enabled him to invest in real estate, both in San Francisco and what would become Orange County. Timing was everything. The Mexican land grant system dissolved once California entered the Union in 1850. The dons who once held title to vast ranchos found themselves owing property taxes they could not pay. While debt began eroding their wealth, severe drought began decimating their cattle herds. Many had no choice but to arrange for quick sale of their holdings. James Irvine I became a silent partner in Flint, Bixby, and Company, a sheep raising venture based on Orange County land comprised of Rancho San Joaquín and Rancho Lomas de Santiago, and later, Rancho Santiago de Santa Ana. In 1876, Irvine bought out his partners, becoming sole owner of the Irvine Ranch, nearly one–third of present–day Orange County.

His son, James Irvine II, or "J.I.," assumed control of the Irvine Ranch in 1892 and founded The Irvine Company two years later. Aiming to maximize yield without losing control of the land, he established a program of tenant farming on the property. Sheep and cattle ranching gave way to the production of lima beans, citrus, sugar beets, barley, and other crops. The arrival of the railroad enabled the Irvine Company to tap a national market, while the construction of wells enabled it to tap into groundwater. Water was not perceived to be an issue on such a marsh–dominant landscape. However, within 10 years, the water table dropped significantly, and water conservation and management soon became a company priority. Dams and reservoirs, including Irvine Lake, were built on the Irvine Ranch, and water supplies were closely monitored.

Tapping Artesian Groundwater

The presence of groundwater in both the upper and lower Santa Ana River basins made it possible for growers to irrigate off–stream farms with wells. In the upper river basin, water from small tributary streams sunk into the rich, porous soil, filling groundwater basins and reducing the amount of water reaching the river. Irrigation in the upper basin further reduced the flow of water in the lower river basin. So great was the irrigation use in the upper valley, later estimates showed that less than half the mountain runoff reached the river (Bailey 1929). Early on, this was enough water for all, but in later years, the disparity would create conflict among growers in the three counties.

Where the river enters modern Orange County, water is also absorbed into the Orange County groundwater basin, underlying rich farmlands. Citrus ranchers and farmers irrigated from shallow wells sunk as little as 15 feet into the valley below the foothills. Closer to the coast, artesian springs flowed freely across peatlands.



Early artesian well, circa late 1880s, *photo courtesy of Kern County Local History Photograph Collection. Kern County Library, Bakersfield, California*

Called "the Delta of the American Nile" by enthusiastic boosters, the Fountain Valley area was filled with an almost impenetrable tangle of scrub trees, peat bog, and vines (Talbert 1982). Between 300 and 400 flowing artesian wells flooded this lowland area. Springs were fed by the seasonal river runoff and augmented by the flow of Santiago Creek. Although a few hardy individuals farmed the swamp's edges at Westminster, its rich bottomland soil was too moist for cultivation.

Determined farmers had to channel the artesian spring runoff before they could cultivate these swampy coastal regions. Since any drainage channel would have to go all the way to the ocean to be effective, landowners formed a municipal irrigation, or drainage, district to clear large sections of swamp. They assessed themselves to pay construction costs and built a network of large ditches—fed by underground tile drains—to carry excess water to the ocean (Talbert 1982; Osborne 1997). By 1900, they had successfully drained the swamp to raise sugar beets, barley, lima beans, and other crops.

Arrival of the Railroad

In 1887, the Santa Fe Railroad arrived at Santa Ana to break the monopoly of the Southern Pacific Railroad and connect the valley cities directly with the eastern produce markets of Chicago. Valley businessmen joined other Southern California growers to establish the California Fruit Growers Exchange (now Sunkist), further improving market access and increasing profits as the citrus industry expanded in the 1890s. These economic changes brought substantial population growth to the riverbanks and correspondingly, more demand for water, from both the river and the groundwater basin. The changes also meant that the Santa Ana Valley was finally strong enough politically to separate from parent Los Angeles County. In 1889, county lines were drawn along the Coyote Creek and San Gabriel River, carving Orange County out of the southern section of Los Angeles County.

Tri Counties Reforestation Committee

In 1888, there were about 23,500 irrigated acres in Orange County. By 1904, there were 30,000 acres, and by 1912, 50,000 acres. At the same time, water levels in county wells started to drop and farmers began to wonder about their future water supply. A 1905 federal study indicated that the underground supply was being drawn out faster than it was being refilled. Conservation was urged (Works Progress Administration 1936).

In response, citrus ranchers in Orange, Riverside, and San Bernardino counties formed the Tri Counties Reforestation Committee to improve groundwater conditions (*Anaheim Gazette* 1906). The committee's members were among the successful elite of each county. Simultaneously conservationists and progressive businessmen, they wanted to protect and preserve nature to utilize its resources efficiently and expand their own fortunes. They realized that forest cover slowed the flow of the river and allowed more water to sink into the groundwater basin. If they were to maintain or even increase the groundwater supply, they had to protect the forest above the watershed. They began to lobby for federal funds to purchase more forestlands and reforest burned and lumbered areas in the San Bernardino Mountains.

Water Conservation Association

Two years later, in 1909, the committee organized and incorporated the Water Conservation Association to manage water conservation projects in the upper river basin (Baker 1983).

Under the direction of Francis Cuttle of Riverside, the association began to spread, or percolate water in the porous debris beds at the base of the San Bernardino Mountains. Earlier experiments showed that spreading water over permeable soil and gravel beds could increase the quantity of available groundwater in the underground basins. In theory, the water would percolate underground from the upper basin to the lower one or drain by the river from one to the other. The spreading was primarily privately funded. County governments, reluctant to pay for spreading efforts outside their own boundaries, nevertheless jointly funded studies of the flow. By 1930, engineers in the lower basin questioned the value and the quantity of water produced in this manner for Orange County. Eventually, they concluded that the project was not to the county's advantage and recommended that it be stopped.

Metropolitan Water District

The Los Angeles basin population exploded in the 1920s. Orange County's population nearly doubled during that decade to 118,674 people. Until this time, most Orange County communities had enough well water to furnish domestic water without endangering the irrigation supply. Now, however, there was doubt that the water supply could be expanded to serve both. In 1925, water engineer J.B. Lippincott reported to the Orange County Board of Supervisors that the overdraft was about 39,449 acre–feet, that the artesian area had shrunk from 315 square miles in 1888 to 52 square miles in 1923, and that the water table level was dropping 2.5 feet per year (Lippincott 1925). Several breaches in the coastal geologic barrier between the ocean and the groundwater basin were also discovered. When the level of water dropped below the breaches, seawater contaminated coastal water wells and could affect the interior groundwater basins. Orange County officials recommended that the county seek domestic water from outside the groundwater basin and build a flood control and conservation dam at Santa Ana Canyon to control the flow of the river.

Neighboring Los Angeles, undergoing the same kinds of urban pressures, had already built the Los Angeles Aqueduct to bring fresh water from the Owens Valley, over 400 miles away. It was not enough. William Mulholland, director of the Los Angeles Water and Power Department, proposed that the urban region import additional water from the Boulder Dam project, a flood control, irrigation, and hydropower project in proposal before Congress. He envisioned an aqueduct from the Colorado River to Southern California that would bring this water to the thirsty region. The cost, however, would be enormous, so he encouraged other regional cities to join the planning and development process.

The artesian area had shrunk from 315 square miles in 1888 to 52 square miles in 1923, and…the water table level was dropping 2.5 feet per year.

In 1924, the Boulder Dam Association—citizens lobbying for the flood control, irrigation, and hydropower flood project—proposed the affected cities form a new water district to build an aqueduct from the Colorado River to the Los Angeles general area and distribute water to its member municipalities. It authorized another lobbying organization, the California Aqueduct Association, to draft and support state legislation to form the proposed Metropolitan Water District.

Orange County political leaders helped draft the final provisions for the enabling act so the city of Los Angeles would not overwhelm the smaller municipalities in the district. The Orange County leaders insisted on a uniform rate for domestic and irrigation water. They hoped to preclude Los Angeles from charging Orange County cities higher rates to cover the cost of a required trunkline extension into Orange County. Ultimately, it was OCWD that paid for the pipeline as a part of the overall project cost.

While farm interests were suspicious of the motives of Los Angeles and were concerned that the potentially powerful district might try to condemn local groundwater for domestic use, they were pragmatic. Influential growers realized that if domestic water could be brought from outside, there would be more groundwater for irrigation purposes. The enabling legislation for the Metropolitan Water District was passed in 1927.

Cities that had their own municipal domestic water supplies were eligible to join the new district. Anaheim and Santa Ana joined at once. Fullerton joined in 1931 when its city government realized its water supply was inadequate for economic expansion. Orange, the other eligible city in the county, chose not to join at the time, but eventually joined in 1951 as part of MWDOC. It was a decade before the Colorado River Aqueduct was finished and began providing water to the cities. Meanwhile, the civic leaders planned for expansion based on the availability of sufficient imported water. This optimistic view temporarily relieved concern about the future of the groundwater supply.

Orange County Flood Control District

The immediate problem along the Santa Ana River, however, was flooding. Ironically, Orange County faced both a water deficit due to overdrafting of groundwater supplies and a dangerous surplus due to out–of–control flooding during winter storms. The great flood of 1862 virtually marked the end of the ranching period in Southern California because it and the subsequent drought decimated an already weakened cattle economy. The river flooded again in 1916, causing damage to crops and orchards in Orange County. It flooded once more in 1927. Although this flood was smaller than the one in 1916, the damage was greater because the population had doubled and the cultivated acreage in the flood plain had increased.

Demographic changes in Orange County—reflecting those of the rest of Southern California in the 1920s—created new wealth. Men who had come to California during World War I returned with their families to establish small farms and orchards or to work in the new industries of the postwar economy. New residential districts were built on the flood plain. Farmers began to plant in the overflow land of the old river channel in the Anaheim area and in the outwash at the base of the mountains. The value of citrus and ground crops increased as farmers cultivated more acreage. In 1911, for example, the entire citrus crop was valued at about $2.7 million; by 1927 its value increased to over $28 million (Orange County Department of Agriculture 1911, 1927). The discovery of oil in Huntington Beach attracted additional capital and industry to the county in the 1920s. The value of oil production in the county had increased from $6.5 million (1915) to more than $56 million (1927) in less than 15 years due to these major new petroleum strikes (California State Senate 1927). No wonder the 1939 Army Corps of Engineers' report on the potential need for Prado Dam prepared under Major Theodore Wyman, Jr., stated that "Orange County has been said to have the highest per capita wealth of any corresponding area in the country."

The state legislature created the Orange County Flood Control District (OCFCD) in 1927 at the request of the county's mayors. It was designed to provide for control of floodwater and stormwater that have their source outside the district, to conserve such water for beneficial use by spreading, and to protect property within the district from flood damage. The district boundaries corresponded to the county lines, and the County Board of Supervisors served as district directors. The first proposal to fund flood control works on the river was narrowly defeated in 1929, largely because of the opposition of James Irvine and Susana Bixby, influential ranchers who opposed the location of a dam on the river. Two more proposals were defeated or withdrawn in the early 1930s due to the impact of the Great Depression. Finally, after the great flood of 1938 took 34 lives and caused some $14 million in damage to properties in the county, the Army Corps of Engineers built Prado Dam as a federal facility (M. B. Scott 1976).

Santa Ana Basin Water Rights Protective Association

Santa Ana Basin Water Rights Protective Association Water Engineer Paul Bailey's 1929 report on the diminishing groundwater supply in the county was a wake–up call to agricultural interests. Southern California was in the middle of a multi–year drought despite the occasional flooding of its major streams. No longer could growers be sure that imported domestic water alone would ease future shortages; they needed additional irrigation water to continue expansion. Even in depression times, citrus production continued to increase. In 1929, there were almost 44,000 acres devoted to orange orchards. That acreage rose to 48,000 in 1931 and to nearly 54,000 acres by 1935 (Orange County Department of Agriculture 1911, 1927).

The Farm Bureau formed the Santa Ana Basin Water Rights Protective Association to study the political problem of groundwater recovery and produce a solution. Like the earlier water committees, this one was composed of prominent farmers and political figures from throughout the valley, including R.J. McFadden, L.J. Bushard, John Pope, R.A. Chaffee, W.C. Mauerhan, and J.J. Dwyer. H.C. Head and A.W. Rutan were retained as legal counsel. Edson Abel, of the California Farm Bureau Federation, a powerful lobbying group, assisted them on the state level in Sacramento (Lenain 1983). The committee had two major challenges: to improve the condition of the groundwater basin and to prevent "outsiders" from taking water directly from the basin.

The Board of Supervisors of Orange County had given the water–spreading project tacit support since they could not fund the experiments directly, but had contributed to tri–county studies to improve the river flow. As early as 1925, however, J.B. Lippincott warned that the benefits to Orange County had not yet been demonstrated. Upper basin orchards were drawing their water upstream from Orange County, near the mountains. They were using water that might have percolated into the groundwater basin and finally come to Orange County in the normal stream flow. As a result, the anticipated supply was not reaching the lower basin. Bailey demonstrated in 1929 that, despite several years of above–normal precipitation, the river stream had declined in the Prado area and, correspondingly, in north Orange County's groundwater basin. He theorized the reduction was because of the increased pumping in upper basin wells and warned that pumping would further increase because there was still land to be put under cultivation in the Riverside and San Bernardino area (Bailey 1929).

Nevertheless, Francis Cuttle continued the Water Conservation Association's efforts to spread water. Both Riverside and San Bernardino counties began construction of new water spreading facilities near the mountains as the Great Depression began to affect Southern California's economy (*Anaheim Gazette* 1933). While Cuttle saw the new construction primarily as a means to provide jobs for the unemployed, the completed diversion works could have spread most of the flood flow that Orange County relied upon to replenish its groundwater basin. As a result of this understanding, G.A. Elliott, a consulting engineer to the OCFCD, recommended that the county interests discontinue support of the upper basin spreading program (Bailey 1929). Subsequently, the Irvine Company entered into a suit against upper basin users to protect its own rights to a portion of the river flow.

Upper basin users were not the only sources of threats to northern Orange County's water interests. Soon after the Santa Ana Basin Water Rights Protective Association was formed, it rallied against an attempt by the city of Long Beach to buy water–bearing land in the Orange County basin. The association made a formal legal protest to the Long Beach City Council and threatened further legal action if its plans continued (*Anaheim Gazette* 1931). The threat of litigation plus the support of the Board of Supervisors deterred the city. Still seeking outside water, Long Beach joined MWD.

Laguna Beach lay outside the basin, but owned land and water wells on the flood plain between Newport Beach and Huntington Beach. The city was piping water through Newport Beach and Corona del Mar to its residents because it had virtually no other source of domestic water. Basin landowners resented Laguna Beach's use of the local water and considered the city an outsider. Laguna Beach's wells in the basin failed because of encroaching seawater, and the city was forced to import water.

Establishing the Orange County Water District

Establishing the Orange County Water District

The Santa Ana Basin Water Rights Protective Association developed a series of proposals to protect the basin supply from outsiders and to encourage basin–wide conservation. These proposals led to the legislation that created OCWD. The first attempts in 1931 to create a water district stalled in the legislature because of opposition from Orange County cities (Anaheim, Fullerton, and Santa Ana) that belonged to MWD. These cities expected to have MWD water deliveries in the future. Since they were already being taxed to pay for that outside water, they did not want to pay additional taxes for water they might not use. In the 1933 legislative session, the association tried again. This time, the proposal eliminated MWD cities from the district and made several other changes to satisfy objections of the urban residents. Senator N.T. Edwards carried the bill, SB 1201, which was signed into law on June 14, 1933.

Orange County Water District

The bill as passed formed a district within Orange County of about 156,000 acres, excluding MWD cities and part of the Irvine holdings. The new district had broad powers to protect the basin water supply. It was expected to provide the following:

- Management of the groundwater basin
- Conservation of the groundwater supplies, including both quantity and quality of the water, and
- Protection of Orange County's water rights to the natural flows of the river (Wesner 1973)

These obligations meant that the new district was to function as a litigator for basin water rights; to import water from outside the watershed for basin replenishment; and to control, conserve, and reclaim flood and stormwater for beneficial use in the basin (OCWD 1983). Its activities would be funded by an ad valorem tax on real property within the district. Unlike the flood control district, which was directed by the County Board of Supervisors, this new district had a board of seven directors, each representing a subregion within the district. The directors were elected within each division on the principle of one vote per each $100 of assessed valuation of property owned, so that each property owner would have a voice in proportion to their financial interest in the district. Nothing like that had been tried before (*Anaheim Gazette* 1933). Undoubtedly to forestall hostile challenges, OCWD supporters instituted a friendly suit against its levy and taxation provisions, and the legislation was upheld in court (*Los Angeles Times* 1934).

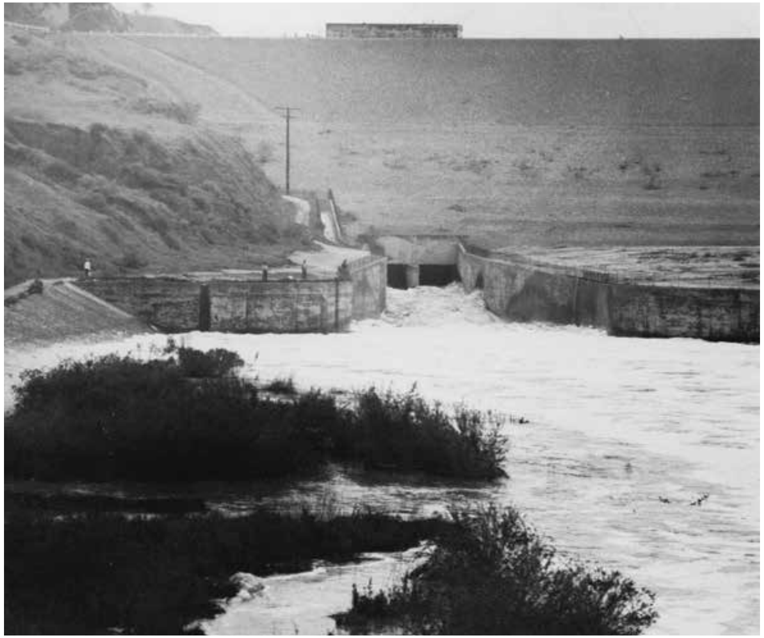
The first directors of the new district were Roy Browning, Frank B. Champion, William Schumacher, William C. Mauerhan, William Wallop, C.A. Palmer, and Willis Warner. Warner, later a multi–term member of the Orange County Board of Supervisors, was elected president of the board.

Original OCWD Board of Directors, circa 1933

Almost immediately, the directors discovered that they needed to amend the enabling act if they were ever to seek outside water. In the haste to pass the original bill, a section that would allow them to get water from outside the basin had been inadvertently dropped. Before they could rally the support needed to amend the bill, they had to agree not to take water from the Mojave Valley, located on the eastern side of the San Bernardino Mountains. The water was plentiful there, and the region had not developed as fast as had been expected. As a result, Mojave Valley did not use all of its water for crops. Water specialists in the Los Angeles region had already considered condemning water rights in this valley as well as for the Colorado River in their search for imported water, so the political interests were alert to the possibility of a takeover. Mojave legislators threatened to block the bill unless it specifically stated that OCWD would not file for water rights on the valley's water. The bill was amended so that Mojave water rights could not be affected. To the relief of the OCWD directors, the bill passed.

Irvine Company v. Water Conservation Association

It took a couple of years for OCWD to organize itself and prepare to take on litigation responsibilities for the basin. Finally, in 1937, OCWD directors intervened in the Irvine suit against water spreading by the upper basin water users. James Irvine II, as the largest landowner in the county, had initiated the suit to protect his own water interests. It was obvious, however, that if his interests were protected, those of the rest of the basin would be as well. Farm Bureau leaders thought that the suit was the proper responsibility of the entire basin, not just James Irvine, and that James Irvine should be reimbursed for his court costs. In 1936, both sides agreed to a five–year study of the river flow to be conducted by a three–person panel of experts. This study was to be the basis for a decision on the amounts of water to be allocated to each of the parties involved. OCWD, wary of litigation, sought arbitration of the issues as the preparations for court continued. In a 1940 letter, James Irvine argued for arbitration. "I know of nothing more indefinite, intangible, with definite undiscernible, excessive costs than a nice, juicy water lawsuit," he wrote to Dian Gardiner, secretary of OCWD. "In my opinion no opportunity should be lost at any time to come to any reasonable compromise


Water passing through Prado Dam on its way to Orange County

settlement in any water issue." The agreement, reached in 1942, reduced the amount of water that could be spread in the riverbed, Mill Creek, and Lytle Creek basins upstream to ensure that Orange County would have water from the river (M.B. Scott 1976). It also placed monitoring and administrative responsibilities on the defendants (Blomquist 1992). Although this was not the final litigation on the river, it set the limits and conditions for future spreading and secured Orange County's rights to the stream flow.

During the study period, there were several years of above–average rainfall, resulting in an increased river flow and percolation into the groundwater basin. Experiments suggested that management of the spreading areas could increase the percolation, and OCWD continued to buy river land for that purpose. Flood control was the primary purpose of Prado Dam when it was completed in 1941. Holding back water increased the amount available for percolation into lands below the dam owned by OCWD. The dam, however, was constructed with ungated openings to avoid involving the federal government in local water rights issues; consequently, for many years it was impossible to hold back water for seasonal storage (Osborne 1997).

Conservation and Replenishment

In addition, to increase the recharge capability of the riverbed, the OCWD directors began conservation projects along the river in conjunction with the flood control district and private landowners. As property became available in the riverbed, OCWD purchased it to use for replenishment experiments. OCWD added heavy tractors and trucks to its fleet to sculpt the riverbanks and clear brush as strategies to improve percolation in the gravel beds. OCWD also built a double–row iron fence along the riverbank, planting willows between the rows to prevent soil erosion on the riverbanks. These small–scale experiments gave OCWD engineers the confidence to begin spreading operations on a large scale in the late 1940s and 1950s.

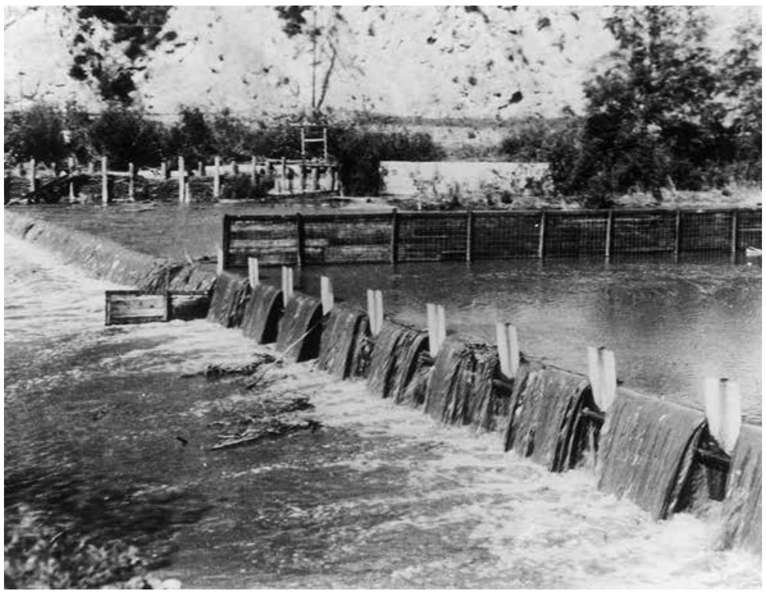
World War II and Military Bases

Even before the Irvine suit was settled, a potentially more fundamental problem developed. When war engulfed Europe, the United States began preparations to support the Allies. In 1940, the Army began construction of Camp Haan, an anti-aircraft camp outside Riverside, near March Field. Riverside proposed to supply the new camp with water from its wells, which were in the upper river basin. This basin supplied the rising stream of the river into Orange County, and, according to a 1940 memorandum of protest from Paul Bailey, about two-thirds of the water that reached the county. Since upper basin use, still under adjudication, was already imperiling the Orange County supply, this new demand further threatened the county's orchards and field crops. Although OCWD was supportive of the efforts of the military to meet the crisis, it was cognizant of the intrabasin water shortage and determined to protect its water rights for local irrigation. Bailey suggested bringing Colorado River water to the base via MWD pipelines instead of pumping precious groundwater. He and OCWD's attorney, A.W. Rutan, lobbied strenuously in Washington to convince the Army to use MWD water as soon as the pipeline connection could be constructed.

According to the exchange of letters between Bailey, Rutan, and the Army, the final agreement between the Army and the city of Riverside allowed the use of a maximum amount of basin water for a brief time until MWD could deliver Colorado River water. It specifically said that this was an emergency allotment for the wartime effort, not an entitlement to the future use of basin water. Since MWD rules required an entity to be a member of the district to receive water service, MWD directors also had to declare a wartime emergency to permit delivery of Colorado River water to the Army (Oshio 1992). Instead of becoming a problem for OCWD because of its use of groundwater, Camp Haan became an early opportunity for MWD to sell its surplus water and demonstrate to a skeptical population that Colorado River water was fit for domestic use.

At the beginning of World War II, Orange County was still a sparsely settled agricultural region. War brought county land to the attention of the military seeking new bases along the coast. The Marines chose El Toro as an air base. "It was perfect—few and far away neighbors, close to the ocean so pilots could practice

El Toro air base (1962), *photo courtesy of Great Park Design Studio* carrier landings, within range of desert bombing ranges and near Camp Pendleton" (Soja 1992). Editors of the *Laguna Beach South Coast News* were only too aware of the increasing burden of the military bases nearby in the thirsty region. A September 22, 1942 editorial spoke of the necessity of furnishing water to the military and concluded: "A shortage of water here would immediately curtail the war effort at one of its vital centers" (Oshio 1992). In 1942, cities along the Orange County coastline formed the Coastal Municipal Water District and annexed to MWD to ensure their domestic supply and thereby reduce the burden on the valley's groundwater basin. Once again, OCWD supported MWD with



Upper Santa Ana River headgate

lobbying efforts. When the federal government first rejected MWD's plea for a pipeline to reach the new coastal district, pragmatic OCWD spokespeople intervened and convinced skeptics that the pipeline was critical. Rationed materials were then made available for construction of the pipeline from Santa Ana to the coast.

First Report on Water Supply in the Lower Santa Ana Basin

By the war's end, the cities of Anaheim, Fullerton, and Santa Ana, and the Coastal Municipal Water District all had connected to the MWD system and were receiving domestic water. Nevertheless, a new study (Gleason 1945) showed that approximately 123,500 acre–feet per year were still being pumped from the groundwater basin. After calculating the typical natural replacement, the groundwater basin was still being overdrawn by about 12,000 acre–feet per year. As Bailey had predicted, when groundwater was drawn down below sea level by the overdraft, seawater filtered into the coastal areas and threatened to pollute the entire groundwater basin. Several coastal wells had already been contaminated and abandoned, so the fear of contamination was warranted. It was imperative that OCWD act to replenish the groundwater basin just to maintain the status quo.

Even more discouraging than the overdraft situation was the realization that Orange County might not have water available for industrial expansion. Without adequate water supplies, the county was limited in its ability to attract new industries first drawn to the county by the prospect of less expensive acreage. OCWD directors threatened that if the overdraft were not corrected, they would have to oppose postwar expansion and industrialization to protect the current water users (OCWD directors 1945). George Gleason, who prepared a report for OCWD and the California Department of Water Resources, made several recommendations in his study for improvement, which he described as "akin to 'scraping the bottom of the barrel.'" Nevertheless, he suggested that OCWD might be able to salvage the 12,000 acre–feet per year shortfall through wastewater conservation behind Prado Dam, improvement of the percolation basins below the dam, increased efficiency in the use of irrigation water, and reclamation of sewage water.

Under a seven–point program, OCWD directors began to implement these recommendations to improve the quantity and quality of the groundwater. Among the study programs were agreements with the California Department of Water Resources to sample and analyze the quality of water in the basin and to study evaporation and transpiration below the dam. Other studies involved the reclamation of wastewater and better irrigation techniques. On a proactive note, OCWD maintenance crews constructed barriers in the river to prevent channelization, thus allowing the percolation of water over a broader area of the river. Finally, OCWD encouraged other cities in the county to take more of their water directly from MWD and formed a committee to figure out how to increase the supply of imported water (Poland 1947).

Still, this was not enough. Postwar growth demanded even more water than engineers had anticipated. In little more than a decade, the population of Orange County doubled to 270,000. Significantly, crop acreage dropped, and industrial development increased. By 1952, of the total estimated need for 250,000 acre–feet of water per year, 80 percent was for industrial and domestic use, while 20 percent was for irrigation purposes—exactly the opposite of the pattern in the 1920s (Crooke 1967). If the overdraft was not halted, accumulated water might be used up in the foreseeable future. To make matters worse for water planners, the county entered a long drought period in 1945, and water levels, which had been high in 1944, began to drop once again. Predictably, during the next decade, water levels in the district's 3,500 pumping wells dropped an average of 38.5 feet, and ocean water intruded three to four miles into the Fountain Valley area (Crooke 1967).

Reducing Overdraft

OCWD directors had hoped that natural replenishment would fill the basin, but clearly, they had to obtain outside water and limit production from the basin by adjudication or other means. MWD was finally delivering water to Orange County through its new pipeline, but only members regularly received it. OCWD was not a member agency, and because it did not retail imported water, did not qualify to become one. Even if OCWD could obtain emergency supplies to halt the overdraft, it did not have enough money from its property tax funds to purchase the needed quantities.

Legally, the directors could put a special assessment for replenishment before the voters and hope they would allow it, but a special assessment was a temporary levy, and replenishment was a long–term endeavor. Not only were the directors unsure of their approval, but they also knew that the assessment could not be temporary. Property owners within the district who were also within MWD's area would, conceivably, be paying for the Colorado River water twice—through their taxes for the MWD system, and for replenishment through OCWD. And finally, because all property owners within the district paid the ad valorem tax whether or not they produced groundwater, use of the tax to purchase water appeared to subsidize groundwater pumpers at the expense of nonpumping property owners (Blomquist 1988).

Housing in Orange County was growing

Other means of financing the replenishment had to be identified for the long term. The alternative was to lose the groundwater, suffer possible subsidence, and fund an extensive and expensive above–ground pipeline feeder system for imported water (Blomquist 1988). In the immediate water emergency, MWD agreed to sell some water for replenishment. The County Board of Supervisors paid for the deliveries from OCFCD funds in 1948–1949, 1950–1951, and 1951–1952, but other means of financing the replenishment had to be located for the long term.

At the time, imported water was readily available from MWD. MWD was eager to protect its right to Colorado River water in anticipation of a future legal challenge, so it was able to secure and deliver surplus water to Orange County (Blomquist 1988).

The delivery actually met one of MWD's goals, to use surface water to replenish groundwater supplies in the general region (Oshio 1992).

George Osborne, manager of the OCFCD at the time, vividly recalled the first deliveries of MWD water. "This water was introduced upriver at Arlington where the transmission line from Lake Matthews crosses the river. They opened the valve and the water sprayed out several hundred feet and fell into the river. That was the initial delivery of water to Orange County" (Osborne 1997). The water, however, was not actually used for replenishment. Anaheim Union Water Company and the Santa Ana Valley Irrigation Company diverted it to serve their customers. In turn, the two water companies refrained from pumping an equivalent amount of water from the basin.

Responding to Growth: From Croplands to Housing Tracts

Mid–century Orange County was a different place from Orange County of the 1920s and 1930s. Until the war years, the rural landscape was mostly farmland and oil fields dotted by independent towns. In the north, citrus was king. Citrus ranchers made comfortable lives from a few acres of lemon or orange trees. In the plains, prosperous truck farmers planted a variety of crops for market. Petroleum fields in the Huntington Beach and Fullerton areas brought transient wealth to those communities.

After the war, though, the pace quickened. A few housing tracts were built in northern Orange County for workers commuting to Los Angeles. More housing followed new freeways into the orchards and open countryside. Los Angeles' economy was booming from the wartime aircraft industry. The city was already congested. Land costs within the central industrial and commercial areas had begun to spiral upward. By the mid–1950s, the aerospace industry began to take shape throughout Southern California. To compete in the new industry, major aircraft companies established large branch plants outside the urban center, many of them among the remaining orange groves of northern Orange County. Land was less expensive than in Los Angeles, and there was plenty of it for industrial uses (A.J. Scott 1986). The land only lacked sufficient water to attract these new industries.

Although Orange County leadership was politically cautious, it was profit minded. Farmers saw that the days of agriculture were drawing to a close. The "quick decline" disease had begun to attack citrus orchards, and they were becoming less profitable. Groundwater in other orchards had fallen below the level of their pumps. In Irvine, for example, it dropped to 60 feet below sea level (Owen 1997). While the pumpers could set their pumps even lower into the basin, this deeper pumping process required more energy and was more expensive. Raw land values were increasing rapidly and, as it had been in the 1920s, water was still a critical part of land values. If owners wanted to get top dollar for their property, they would have to ensure a constant supply of water for urban and industrial uses. There was strong talk of adjudicating the basin to determine each pumper's rights or stopping new pumpers from taking water out of the basin (Owen 1997). The groundwater basin had to be stabilized or economic expansion would be sharply limited.

Committee of Twelve

In spring of 1952, the Farm Bureau and the Associated Chambers of Commerce recognized that OCWD had to be able to replenish the groundwater basin with imported water if the county were to reach its maximum growth potential. The Orange County Water Basin Conservation Committee was created in June 1952 to investigate the possibility of recommending a procedure for raising funds for the purchase of outside water to replenish the underground basin. All users of the common supply were to be included in any formula offered (OCWD directors 1952). Their objective was threefold: to protect the groundwater from seawater intrusion, to replenish both the annual and long–term overdraft with imported water, if necessary, and to find a way to pay for it (OCWD directors 1952). The committee became known by its informal name: the Committee of Twelve. Some of the most influential people in business and agribusiness served on it.

The membership list read like a county business and political "who's who": Glen Allen, prominent in MWD and OCWD policy–making; Courtney Chandler, mayor of Santa Ana, the county seat; J.W. Crill, president of the OCWD board; W.B. Hellis, representing the Irvine Company; John Murdy, incoming state senator; Walter Knott of Buena Park, owner of Knott's Berry Farm; industrialist H.H. Kohlenberger of Fullerton; Charles Pearson, mayor of Anaheim; Walter Schmid, representing the still–powerful Farm Bureau; Ross Shafer, prominent water and land consultant; E.T. Watson, representing the Santa Ana Valley Development Company, owner of the conservation lands behind Prado; and Roy Seabridge, mayor of Huntington Beach and member of the OCWD Board of Directors (OCWD directors 1952).

The members of the Committee of Twelve were not developers. For the most part, they were farmers who wanted to be able to sell their land for the highest return (Owen 1997). They believed a common pool of water in the basin was worth more to the land than a limited, individually adjudicated share of the current groundwater supply. That meant they had to manage the water rights differently than other districts in the region, which had gone to court to adjudicate individual rights.

Over a period of four months, the committee arrived at a proposal. According to Howard Crooke, who soon would become the first OCWD secretary–manager, the committee reached two conclusions in its deliberations. One was that they did not want to adjudicate the basin's water because the action would lead to a "philosophy of scarcity." The process of adjudication was long and involved litigation of the quantity of water each producer was entitled to receive. Langdon (Don) Owen, who later became the second secretary–manager of OCWD, recalled that the thinking at the time was that if each producer took the rights to a certain quantity of water as an individual, they would get only about 25 percent of the water they needed. If, however, the producers did not establish individual rights, but functioned as a group, they would be able to manage and replenish the basin so that *all* had more water (Owen 1997). The second conclusion was that equitable financing for importing water to replenish the groundwater basin was the most practical solution to having adequate water for landholders and inhabitants alike (Crooke 1965).

These politically conservative individuals made several socialistic recommendations that were incorporated into a revision of the OCWD Act. In doing so, they set a new course for OCWD. They set aside their individual property rights concept in favor of a basin–wide use policy in which they would share the surplus in wet years and the shortage in drought. Identified as a policy of surplus rather than shortage, it meant that every producer in the future would have an equal right to pump as much water as they could beneficially use, but that each would also have the obligation to pay the costs of replacing their yearly extractions to continue making the basin as productive as possible (Owen 1997). Howard Crooke and the others who promoted the new concept knew that everyone could not get all they needed from the basin, regardless of how much additional water they could produce in common action. They expected to purchase MWD or other imported water to make up the difference.

This was a difficult concept to implement, further complicated by opposition from all sides. Traditionally, groundwater basins were adjudicated among the users. The idea of a non–adjudicated common pool basin was difficult to reconcile. Farmers feared they would lose agricultural water to the cities if they did not establish rights to it, and cities feared they might not obtain any legal right to the groundwater without adjudication. Nevertheless, the committee recommended the common pool approach without adjudication, a policy that has continued until today.

Up to this point, the three MWD member cities from Orange County had been excluded from OCWD. These cities, however,

OCWD Board of Directors, circa 1971

were pumping about 50 percent groundwater. If they remained outside the district, they could not be required to pay for the replenishment water. On the other hand, the three cities did not want to pay OCWD for replenishment water through ad valorem taxes because they were already paying for MWD water in their property tax rate. A method of assessment had to be developed to include the cities without double taxation.

Since the district had been primarily an agricultural entity, voting was on the basis of property value. An early proposal from the committee had suggested a popular vote for the directors. If that happened, urban interests could easily outvote the agricultural interests. OCWD counsel, A.W. Rutan, expressed the property owners' viewpoint in a letter to the Board of Directors on December 29, 1952: "Personally, I do not like a popular vote in districts of this kind. Persons owning no property are too willing to vote large bond issues and assessments which the property owners have to pay." As a result of his influence, the voting policy remained unchanged for the time being.

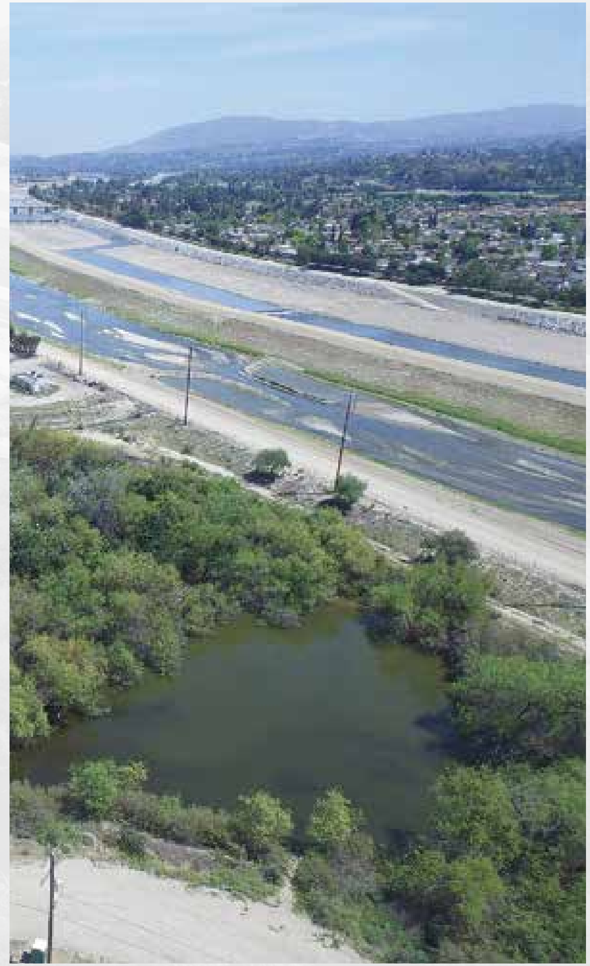
The committee members proposed changes to the law that addressed most of the general legislative concerns. Membership was extended to cover MWD cities as individual units within the district. Each city's governing board was permitted to name a director who would serve the same length term as the elected directors from the different geographic subregions. Voting outside the cities would continue to be by property value, but there would be no direct vote within the cities. Technically, while city residents had no direct vote on their choice of director, they did elect the city officials who appointed them. By the middle of the 1960s, however, large parcels of agricultural land had been purchased by outside interests intent on developing them commercially, and there were many more homeowners within the district subregions. Voting by property value was no longer a protection for agriculture or other local small property owners, but instead reflected different outside interests. The method of electing directors was modified by amendments to the Act in 1967, which put the vote in compliance with the general election voting laws (California Codes n.d.). After this, directors were elected in the geographic regions on the basis of one vote per registered voter. The cities of Anaheim, Fullerton, and Santa Ana, however, continued to appoint their representatives.

To meet the three cities' objections to double taxation and to put the burden of payment on those who used the groundwater, the committee proposed a gross pump tax on future water production. Under this concept, everyone paid alike, on the basis of the amount of water they produced, regardless of when they began to pump from the basin. There would be no special protection for those who had been in the basin for a long time, nor special reservations for newcomers. The committee rejected an ad valorem tax to pay for imported water to meet future overdrafts, but agreed that the current landowners, whose land had appreciated greatly in the past decade, could be taxed to add enough water to the basin to replenish the current overdraft (Owen 1997).

The proposed amendments set up a two–tier tax system: an ad valorem tax to cover OCWD's expenses in setting up the new system and to pay for enough water to slow the seawater intrusion, and a "pump tax," called a replenishment assessment (RA), based on each pumper's yearly extraction to pay for water to replace the estimated future annual overdraft (Weschler 1968). Beginning in 1954, each pumper, or producer, was required to register its well(s) with OCWD, maintain records of the amount withdrawn during the year, report that figure, and pay a tax (the RA) in proportion to the amount of water used. The tax would be established after completion of an engineer's report that indicated how much water had been used in the previous year, estimated the amount that could be extracted safely, and calculated how much water would have to be imported to maintain the groundwater at a safe level. For the first time, the entire basin supply was placed under the management of a single water entity. Although each of the producers was free to use the water needed, each producer was now responsible to a governmental agency for documenting all extractions. Because a producer would pay a tax on what it removed, based on the condition of the entire basin, the producer was forced to consider how its efforts affected the groundwater supply.

State Senator John Murdy, a member of the committee, introduced the bill amending the OCWD Act in the 1953 legislative session, and it became law in June 1953, to be effective in 1954.

Optimizing the Groundwater Basin



Optimizing the Groundwater Basin

Replenishment Assessment and Registration

Until this time, there had been little need for either a permanent office staff or an administrator. The board met regularly and managed its business by committee. Secretarial support was often provided by someone in a member's personal office, and expert advice was provided by consultants. By 1952, conditions had changed, and district responsibilities had multiplied. Permanent staff were needed. The OCWD Board of Directors hired its first full–time administrator and secretary in 1952–1953. Thelma Willoughby became a full–time office manager/secretary in 1952, and Howard Crooke became secretary–manager in 1953. Both, according to later manager Neil Cline, were critical to the early success of the new structure. Crooke was the "rough and ready" personality who implemented the amendments, convincing producers to support the concept of pooled resources. Willoughby was the gentle diplomat and organizer who often dealt with disgruntled producers in the district office and helped them understand the new regulations. Although the board had received applications from several qualified engineers for the position of secretary–manager, its members decided against hiring a technical expert to manage OCWD. They looked instead for someone with administrative ability, diplomatic skills, and a close familiarity with the local conditions. The board's general feeling was that they could hire an engineer when they needed that expertise (OCWD directors 1953).

By 1952…permanent staff were needed. The OCWD Board of Directors hired its first full–time administrator and secretary.

Crooke was from Garden Grove and had managed a Sunkist citrus warehouse. He had no engineering training, but was a farmer, with a farmer's instinct on how to manage water. Neil Cline characterized him as a gruff person, a deep thinker. "He could be quite charming," he said, "but was very businesslike, very goal–oriented, and a genius" (Cline 1997). Crooke had the persuasive ability to convince the ranchers that their land was of limited value with a water scarcity problem, but with an adequate water supply had limitless value. If they were to sacrifice their individual rights for the good of all, they would all benefit. He made them realize that this was a good business decision, and a good farming decision (Cline 1997). Apparently, no one really believed Crooke when he started out promoting the program, but by the force of his personality, he succeeded. His successor, Don Owen, said that Crooke convinced the skeptics that the pump tax would be used for the purchase of water only. "I can buy neither the pencil nor the eraser to audit this account out of the pump tax," Crooke would say "I can only buy water." Even after the amendments passed, there was disagreement over the mechanics of a pump tax. Charles Pearson tried to smooth feelings after a particularly heated meeting. "It [the amendments] is a new theory, sort of a trial and error proposition, and that is the way we have to accept it..." (OCWD directors 1954). As Crooke and the Committee of Twelve had hoped, the efforts to increase production were successful and instrumental in promoting Orange County's urban development. Crooke made the following comments about the cost of importing MWD water for replenishment in the basin and alternate use:

> *Payments made by the people of Orange County to The Metropolitan Water District of Southern California in the form of water charges and taxes for the entire period from the formation of MWD in November 1928 to July 1, 1963 total $61.5 million. In the eleven–year period from 1954–55 to 1964–65, the taxable assessed valuation of the area of the Orange County Water District increased by $1.1 billion. Actual values of these properties in this same period increased more than $3.8 billion. The $61.5 million in payments to MWD are but 1.6% of the increase in actual values of these properties that have taken place. This is cheap insurance, indeed, for the development of an area that could not have occurred without a water management program that guaranteed a firm and adequate water supply* (Crooke 1967).

Increased Imported Water in Orange County

In 1951, several more Orange County cities—Huntington Beach, La Habra, Orange, Placentia, Seal Beach, and Tustin (Oshio 1992)—realized that they, too, would have to join MWD and purchase domestic water to serve their expanded populations. MWD's policy was that cities could join as geographic groups, which included the surrounding rural areas. The cities, therefore, formed the Orange County Municipal Water District, soon renamed the Municipal Water District of Orange County (MWDOC). MWDOC promptly joined MWD, representing the cities and most of the underrepresented portions of the county as a pass–through agency to obtain MWD imported water. Once MWDOC became a member, OCWD purchased imported water indirectly from MWD through MWDOC.

OCWD's policy for the period from 1954 to 1964 was to fill the groundwater basin in an attempt to keep out the seawater and ensure an adequate supply of fresh water. Crooke acted swiftly because there were already out–of–state challenges to California's entitlement to Colorado River water, and no one was certain how long MWD would have a surplus to share. After the first replenishment assessment (RA) was collected in 1954, OCWD began to purchase MWD water in large quantities for replenishment. In 1954, OCWD purchased 50,000 acre–feet of water from MWD at a cost of $500,000. OCWD spent $3,247,136 to purchase 234,789 acre–feet in 1963 at the peak of the program (Blomquist 1992).

The Politics of Spreading Basins

It took several years of spreading to make a difference in the water levels. In 1956, the water dropped to its lowest point, as much as 40 feet below sea level, and seawater intruded three–and–a–half miles inland (Blomquist 1992). Then, the basin began to recover. By 1964, the overall water level had reached 1944 levels; however, the aquifer had shifted as a result of subsidence and pumping patterns. While the water level in the forebay (the area where spreading took place) was 50 to 80 feet above the 1944 level, seawater was able to intrude into some of the coastal areas where the level was still below sea level (Blomquist 1988; Weschler 1968). Worse, if OCWD continued to add water in an attempt to block the intrusion, it would recreate the swampy conditions that gave the Fountain Valley area the appellation of "Gospel Swamp." Like the rest of the valley, that area had been extensively developed with homes and businesses. OCWD did

Storm flow spilling over a drop structure en route to ocean

not want to be seen as responsible for a long–abandoned artesian well bubbling up in someone's backyard because the basin overfilled. The OCWD engineer's report said that the basin was probably as full as it could be and recommended that spreading be reduced even though seawater intrusion continued (Weschler 1968). Subsequently, the basin equity assessment (BEA) and basin production percentage (BPP) programs were established to control the quantities of groundwater throughout the basin.

In the mid–1950s, when OCWD began to prepare its recharge basins to capture as much imported water and natural flow as possible, no one realized the consequences of massive water spreading to properties near the spreading grounds. The plan was simply to prepare percolation basins to handle the additional water. Because of the strong economic climate, there was a demand for the sand and gravel that would be removed to create these basins.

Two freeways were being built through the county at that time, in addition to other major construction projects in the region. They all required enormous amounts of fill materials. Commercial sand and gravel companies excavated pits 40 to 50 feet deep in the porous ground adjacent to the river to provide base materials for the heavy construction. As OCWD began to add water in the river spreading grounds in Anaheim, water would seep into the gravel pits and hamper operations. The result was conflict with the owners. Owen recalled that "these people played very rough. Howard [Crooke] could stand like a bulldog if he had to." OCWD fought desperately to establish its rights to spread water in the forebay and resisted the opposition of the sand and gravel people

Sand and gravel mining at Burris Pit, 1974

to any spreading. In addition, the district worked closely with George Osborne, then manager of the flood control district, to improve flood control works, permit wider spreading operations, and improve public safety (Owen 1997).

When they first began to improve the spreading beds in the Anaheim forebay, Crooke planned to have sand and gravel pits dug by district personnel and their extracted material sold. That would have put OCWD in competition with private companies. The potential competitors protested, stopping Crooke's original approach. Instead, the sand and gravel operators removed the sand and paid OCWD 10 to 15 cents per ton for the material. As OCWD continued to spread water, it purchased additional sand and gravel property in the forebay area and excavated additional spreading basins. Crill Basin, purchased in 1957, was one of the first. Later named Anaheim Lake, it became a popular fishing spot.

With this purchase, OCWD began a new policy. It treated the sand and gravel removal as a public works contract, setting conditions and specifications for the operation. Everything was done under a bid contract. This way the district could enforce performance, and most importantly, increase the price of the material to $1.42 per ton. OCWD purchased the land for $20,000 an acre and received $45,000 in revenues from the sand and gravel contract revenues. With this kind of return, OCWD could afford to purchase even more gravel land for percolation and continue the spreading operations (Owen 1997).

At the same time, OCWD began spreading MWD water to recharge the basin it also began another suit against the upstream users to protect its rights to the Santa Ana River flow. This suit, originally filed in 1951, was against the four major upstream cities—Riverside, San Bernardino, Colton, and Redlands—to limit their water production and protect the river's flow into Orange County (Blomquist 1992). Like Orange County's cities, these cities had grown during the war years because of the military bases nearby. As they expanded, their use of groundwater increased, in part because none had joined MWD to get outside water. OCWD sued to force a declaration of the rights of these cities to water, and to ensure that they take only the amount stipulated. The case finally reached court in 1957. It was determined that the cities had a right to the amount of water they used in 1946 at the start of the five–year period before the initial suit was filed. Their water use was scaled back, and OCWD's share of the water increased.

The case was last appealed in 1961, but the basic judgment held (Blomquist 1992).

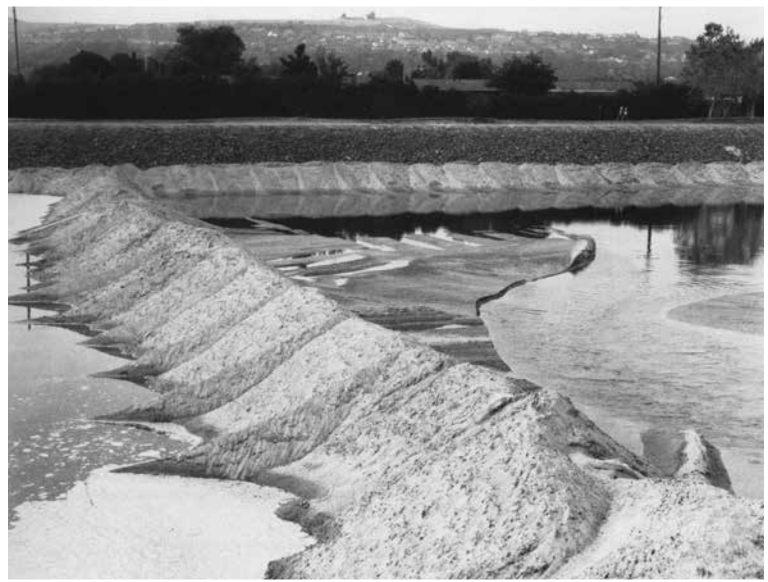
Orange County Water District v. City of Chino, et al.

Two years later, the inflow of water at Prado Dam from the Santa Ana River decreased due to upstream use (Blomquist 1992). This necessitated a new and larger–scale suit. In 1963, OCWD filed suit again, this time to require an adjudication of the entire upper basin and ensure a minimum level of water for Orange County, regardless of the use and needs of upper basin pumpers. The case, OCWD v. City of Chino, et al., was really aimed at all water producers above Prado Dam. Negotiations were held and the final settlement came in 1969.

The stipulations generally allocated the natural supply of water between the basins and left individual rights within the basin for users of the water basins to determine internally. OCWD was given the rights to conserve and store stormwater behind Prado Dam in Riverside County, and all parties agreed that water that passed through their treatment facilities and into the river must meet the water quality standards of the Santa Ana Regional Water Quality Control Board. The settlement stated that pumpers on the upper basin had to ensure that an average of 42,000 acre–feet of base flow reached Prado Dam annually. Further, it stipulated that the volume required would be adjusted for quality using a formula based on the quantity of total dissolved solids in the water. The new rules were to be administered by a joint Watermaster Committee made up of representatives of each of the major districts above Prado Dam and OCWD. This committee would compile a yearly report of the water flow and quality (Superior Court of the State of California 1969).

The district needed more land for spreading operations by the close of the Chino suit. It already owned Anaheim Lake and six miles of riverbed stretching from Imperial Boulevard to Ball Road, managing it in conjunction with the OCFCD for spreading and flood control. However, additional spreading grounds did not come without conflict.

Construction continued throughout the north county at a steadily increasing rate. Manufacturing had eclipsed agriculture



Reconstructed sand levee in the river

and become the county's major industry. Many of the major aerospace and aircraft employers had built plants in the Fullerton and Anaheim areas. Land prices in the best percolating areas of the river were escalating because the properties were ideally suited to small businesses that served major industries. If OCWD could not acquire enough open acreage before industry developed, the spreading program would be constrained. To be successful, OCWD had to contend with landowners who considered giving their land away just to have construction that would bring more business into the area.

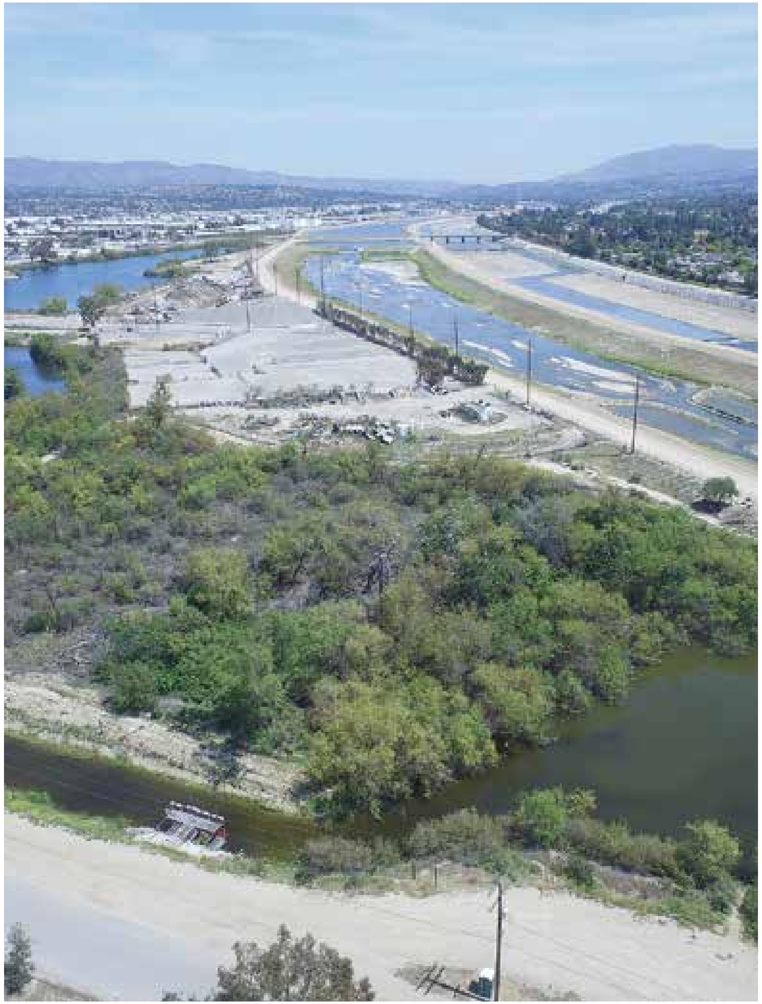
The district purchased 95 acres on the north side of the river for a percolation basin, now known as Warner Basin, in 1966. Ten years later, in 1976, they purchased a portion of the Kraemer property near Anaheim Lake and the flood control district's Miller Retarding Basin to complete a series of interrelated storage basins. At the same time, the district purchased Burris Pit, near Ball Road, and enlarged it as a recharge and conservation basin (Blomquist 1988). In 1983, OCWD purchased two sand and gravel pits along Santiago Creek for additional recharge capacity. These were joined with Burris Pit by a pipeline so that additional river water could be transferred from Burris to the Santiago Creek Recharge Basin.

As OCWD accumulated land along the river, it came in conflict with county residents. Anaheim citizens did not want to see the river changed or turned into a gravel pit. They wanted the area to remain undeveloped for recreation. People in other areas were disgruntled that OCWD was spending all of its money in the forebay area without seeming to benefit them. The district realized that the protests could lead to stoppage of all spreading programs. To forestall this and provide benefits for the entire district population, OCWD directors dedicated 10 percent of the sand and gravel gross revenue to recreational activities along the river (Owen 1997). Several years after the purchase and filling of Burris Pit, a creative concessionaire developed a golf driving range over it, complete with distance markers set on islands, and floating golf balls. These recreational facilities, developed with the financial assistance of OCWD, are open to the public. In addition to the water–oriented recreation sites, OCWD worked with the OCFCD to build trails along the riverbanks as part of the countywide equestrian, hiking, and biking trail system (Cline 1997). Today, these trails remain an important, well–traveled feature in the river landscape.

The newly acquired basins gave OCWD added recharge capability but did not address the problem of how to balance the use of water throughout the district. Producers could draw as much water as they needed, regardless of location, since there were no restrictions on pumping. That meant a pumper in the coastal area could pump the groundwater below sea level, allowing seawater to reach the basin, while in another area, a producer might not pump enough to permit adequate recharging.

Basin Equity Assessment

OCWD produced a plan to regulate the pumping (Osborne 1997). The district thought the groundwater basin should be used in conjunction with MWD supply. If customers would purchase MWD water during the year, and use groundwater primarily for



Aerial view of the Santa Ana River

peak–need periods, the groundwater basin could be used to store water for emergency drought periods when imported water was scarce. Owen described the outcome of this concept as a bathtub in which you could raise and lower the water level at will. In a period when water was plentiful, OCWD could add to the basin supply, conserving additional water against a dry period when producers would draw heavily on it and lower the level. All the persuasive powers that OCWD could muster were needed to convince the cities to cooperate in a conjunctive use program by taking at least 50 percent of their water from MWD, since it was more expensive than groundwater (Owen 1997).

The OCWD Act was amended in 1969 to implement this pumping regulation proposal. The district envisioned that each year, engineers would determine how much water could be safely pumped from the basin to meet the estimated total needs of the district. In most years, this figure was less than the total estimated need, which had to be made up with imported water. The estimate of water to be pumped from underground versus that to be imported is expressed as a percentage figure, the basin production percentage (BPP). While producers were theoretically obligated to take water in that ratio, OCWD did not necessarily expect them all to do so. In some cases, as in the coastal area, OCWD may want one producer to pump less than the stated percentage. In other cases, a producer may not be able to obtain MWD water and therefore would have to pump all groundwater.

Historically, imported water costs more than groundwater, so providers were reluctant to purchase more than they required to meet their obligations. If the BPP were to work, the cost of imported water would have to be subsidized so producers would use it instead of groundwater. In order to make the cost equitable for those who take imported water, OCWD would assess producers who pump more than the BPP based on the difference between the cost of the additional groundwater pumped and the cost of an equivalent amount of MWD water purchased. This assessment is known as the basin equity assessment (BEA). To this day, OCWD determines which water retailers cannot pump the maximum groundwater percentage—or which ones it wants to produce less from groundwater—and pays them the difference in cost from the fund established by overproducers' assessments. Theoretically, the total cost for every water retailer in the district is based on the same ratio of groundwater and MWD water (Owen 1997).

This program came about not only because of OCWD's vision, but also because of the flexibility of the District Act. The legislature could amend it when it was necessary to adjust or devise new management programs. This program, as well as others that changed district operations, was a result of a management decision, not users' decisions. If, according to Owen, individual producers had the choice to limit production or pay district assessments, their cooperation might not be extended.

Still, the metaphor of a bathtub had a flaw. The sides of a tub are all the same level. In reality, the "bathtub" of the Santa Ana Valley groundwater basin had breeches along its coastal front. Even when OCWD engineers could theoretically raise and lower the level, they had to "patch" the hole in the coastal walls before they could actually control the basin. There was a geological barrier at the coastal edge of the basin that had openings in at least two places, the Alamitos Gap, near the mouth of the San Gabriel River, and the Talbert Gap, in Fountain Valley. Seawater could seep into the basin through these gaps if the freshwater level were not maintained about sea level.

Seawater Barriers

In 1965, OCWD began a joint program with the Los Angeles County Flood Control District to maintain a freshwater barrier at Alamitos. The seawater intrusion at this gap affected both Orange County and the central basin of Los Angeles County, including the Long Beach area. As a barrier against the sea at the mouth of the San Gabriel River, OWCD placed 26 injection wells in the area to force fresh water into the basin. Water for these injection wells originally was secured jointly through Los Angeles County Flood Control District and OCWD from MWD (Blomquist 1992).

Talbert Gap required a different solution. Studies began in 1965 to plan for protecting this barrier area (Wesner 1973). It would have required nearly six times the quantity of water to create an adequate barrier similar to the one at Alamitos.

Water Quality in the Watershed

In 1967, representatives of the three major water agencies upstream met with OCWD to develop a joint program for improvement of water quality (OCWD directors 1967). Subsequently, the OCWD board authorized a joint powers agreement between OCWD, Chino Basin Municipal Water District, Western Municipal Water District (Riverside area),

Aerial view of Water Factory 21, circa 1971

and San Bernardino Valley Municipal Water District to "create a self–help agency which will conduct a water quality management program study for the Santa Ana River watershed" (OCWD directors 1967). The Santa Ana Watershed Planning Authority obtained start–up grants and initial funding from the four districts in 1968 to plan a basin–wide program that addressed buildup of total dissolved solids. The study recommended treatment plants, desalters and a brine line to the ocean to carry off residual wastewater. Since no district was willing to embark on a project of this size alone, the authority was recast as the Santa Ana Watershed Project Authority (SAWPA). In 1972, it began building the pipeline that now stretches from San Bernardino to Fountain Valley (Cline 1997). Projects of SAWPA continue today with desalting plants and other water quality facilities.

Development of Water Factory 21

In the 1960s, the shared sentiment of most water planners was that there might not be surplus water for Southern California beyond the next 20 years. Mindful of the possibility, OCWD urged the development of additional local water, knowing it would take 20 to 30 years to perfect the technological processes (Environmental Coalition of Orange County 1975; Owen 1997). To do so, however, the district had to develop a program that would be politically acceptable throughout the basin and still provide extensive protection for the coastal barrier. A plan was conceptualized to create a program that would add storage capacity to the basin because it gave the flexibility of raising or lowering the water level at will without the danger of seawater breaching the gap. This approach was acceptable because it emphasized that the entire basin was to benefit from the cost of stopping seawater intrusion in the coastal areas (Owen 1997).

The district's plan consisted of two sets of wells, one for injection, and the other for extraction. Extraction wells were placed about two miles inland, to pull the seawater out of the aquifer. This caused a depression in the groundwater basin level. At the same time, injection wells, placed four miles inland, added water to the basin. Because of the depression, the fresh water tended to flow toward the ocean, forming a mound of water as a barrier to seawater intrusion. By careful monitoring, engineers would be able to determine how much water to inject to maintain the slope of the basin.

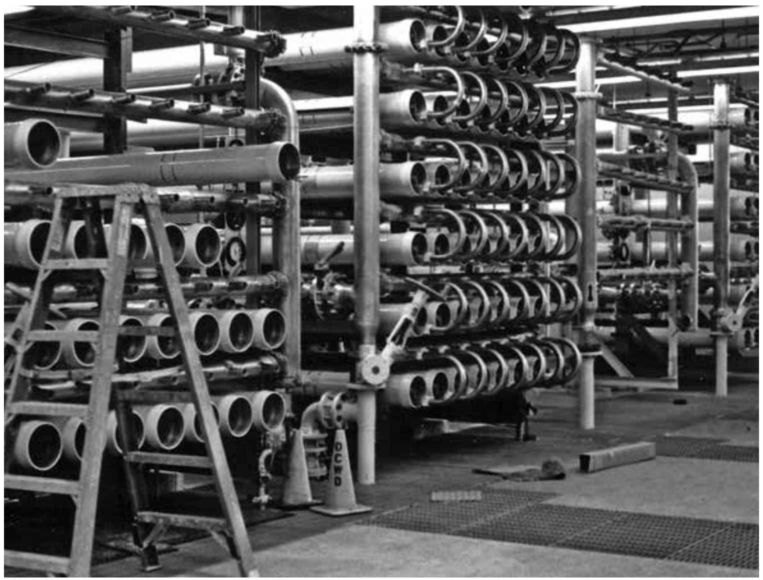
Although OCWD could have purchased expensive MWD water, at least for the time being, the district decided to develop a multimillion–dollar treatment plant to provide wastewater that had been brought to drinking water standards for injection. This water was still expensive, but it was cheaper than building a pipeline from MWD connections to its destination in Fountain Valley (Owen 1997).

There had been talk as early as 1929 about trying to process wastewater for replenishment, but the technology had not been developed. Finally, in the mid–1960s, district engineers decided to consider treating wastewater for injection along the coast at Talbert Gap. The directors purchased land next to the sewage treatment plant for a pilot plant to conduct experiments in tertiary treatment of the wastewater before it was injected and to monitor the experimental injection wells. Meanwhile, Howard Crooke retired from OCWD and Don Owen, his assistant, became secretary–manager. Owen hired Neil Cline, a geologist he had known when both were working for the California Department of Water Resources, as his assistant to oversee the injection experiments. Owen and Cline thought they would be able to inject treated wastewater into the barrier where it would mingle with the other waters and be diluted. The first experiments found that the treated water was too saline and did not dilute but stayed in a mass (Cline 1997). Experiments continued for several years under the supervision of the State Department of Health. Finally, by 1971, both OCWD and the health department were satisfied with the advanced treatment's capacity to remove organics and, together with deep well fresh water or desalinized seawater, form the barrier mound of fresh water.

The timing of the pilot plant was auspicious. The Department of the Interior's Office of Saline Water (later the Office of Water Resources and Technology) was interested in developing a joint desalinization project in Southern California and had talked to MWD about building a desalter plant. At the time, MWD showed less interest than OCWD because of the costs. OCWD was interested since the experimental plant would be one more way to develop water for the barrier project and offered the potential of additional potable water for the future. Jointly funded by the federal government and OCWD, the project began in 1971 with construction of an advanced recycled water treatment plant and desalter. The technical operation process was almost too much for the general audience to comprehend, although most welcomed the potential for more fresh water. In a 1975 article, Owen recalled how the project got its name, "Water Factory 21."

According to Owen, he had been invited to discuss this project at a League of Women Voters meeting in Newport Beach. He began by saying something like, "The plant consists of a seawater desalting module that will combine two flash distillation methods, vertical tube evaporation and multi–stage flash, and a wastewater reclamation plant using lime coagulation, clarification and solids settling, ammonia stripping, recarbonation, mixed/media filtration, carbon adsorption, and chlorination." One woman in the front said, "What?" Owen repeated his description, which was no more enlightening the second time through. The woman said, "But what does it do?" Owen replied that it cleaned up sewage and made fresh water out of ocean water. "Oh," the woman said. "It's a water factory." Owen liked that, and though he says he was met with initial opposition, that became the project's name. The "21" was added to connote the plant's futuristic technology and implications (Environmental Coalition of Orange County 1975).

The prototype wastewater treatment plant went into operation in April 1975. In June, the desalter unit was completed and put into operation by the federal government. Although designed for a five–year pilot study, it operated for less than a year before the project was canceled (*Los Angeles Times* 1976). Cline recalled that almost from the beginning, the directors knew the joint project was doomed for several reasons. The first was an increase in operation costs. The desalter was designed to clean 15 million gallons per day (mgd), but even though it was only producing 3 mgd in the demonstration phase, it used the same amount of fuel as if the plant were in full production. Overall fuel costs had gone up dramatically as a result of the 1973 Oil Embargo, making the demonstration concept less practical. The economy was faltering, and federal programs were reduced or phased out, as funds became difficult to secure. Of the eight federal desalinization projects testing different methods of operation, five were canceled, including this one (*Huntington Beach Independent Review* 1975). As of April 30, 1976, the Fountain Valley plant's operation was halted, and the plant placed in standby condition.



Reverse osmosis plant inside Water Factory 21, circa 1990

Withdrawal of support by the federal government left OCWD in a difficult position. The directors had committed funds not only for the desalting plant, but also for the wastewater treatment plant, which was now operating. Confident in the availability of demineralized seawater, OCWD had planned to have 30 mgd of reclaimed water, including the desalted seawater, for injection into the barrier. Now, OCWD had to find another way to get higher quality water to blend with the wastewater. Cline remembered the political battle he fought to get federal funding to continue the desalter. He recalled wryly that he was unsuccessful in getting the administration to continue the project even though millions had been spent on it. "It came down to an advisor to President Ford saying, 'We regret the local inconvenience.'" (Cline 1997).

Although he was able to get some Congressional support and a little more funding, the seawater plant was obviously dead.

Pursuit of New Projects

Resilient district engineers settled on a method of improving the quality of wastewater for injection. They turned to reverse osmosis (RO), a process not used before in wastewater treatment. In this process, water is passed over a series of membranes that filter out salts and other impurities, leaving water that meets drinking water standards. OCWD engineers believed that they could blend the treated water with water drawn from deep wells to produce a blend suitable for injection into the water table. The pilot operation, however, produced only 5 mgd of the water required for injection, and an activated carbon adsorption process was used to purify the remainder of the wastewater component.

In an interview, Bill Dunivin, Water Factory 21 plant manager, remembered the years of research that perfected the operations. "This was an entirely new concept," he said (Dunivin 1997). Visitors came from around the world to examine the new plant and learn about the technology OCWD was developing. At first, the cost was high (over $1,000 per acre–foot), but by 1996, it had come down to within a few dollars of the cost of imported water. The initial cost of reclaimed water was a concern, but the planners expected it to be high in the beginning and anticipated that it would decrease as new technology became available. What is noteworthy about this research effort is that Water Factory 21 had provided the freedom to research a variety of technologies. Further, the cooperation of the water industry manufacturers who supplied experimental materials for testing was outstanding.

Reverse osmosis (RO) membranes

Water Factory 21 had become the success its proponents anticipated. After five years (1976–1981) of experimentation, a Stanford study stated that "no evidence was found that would indicate that this reclaimed municipal wastewater would pose a significant health risk if used as a source of municipal water supply" (OCWD directors 1983). In 1991, OCWD reached its ultimate goal when it received a permit to inject undiluted product water from Water Factory 21 into the groundwater basin. These endorsements were important to the future of the project. Both Fountain Valley and Huntington Beach drew their domestic water from the basin in the vicinity of the injection wells. The treated wastewater had to meet municipal standards because it was likely to mingle with groundwater in the cities' wells.

In 1978 when the California State Ballot Proposition 13 passed, restricting the rate of increase of property tax and rolling the level backwards, many public agencies were devastated. Orange County Water District funding, however, came from the replenishment assessment (RA), as well as the ad valorem tax, so OCWD had an untouched source of money to continue operation. The District Act was amended to permit use of the RA for *all* purposes instead of just the purchase of imported water. Under the old method of assessing the ad valorem tax, OCWD had estimated its yearly needs and set a rate accordingly. After Prop 13, the rate was set as a portion of the one percent tax rate allowed on real property in the county, regardless of what the anticipated expenditure was.

During this wet period, OCWD did not spend as much on imported water as it had projected. The current projects had been built, and there was a lull in new construction. As a result of these factors, OCWD accumulated reserve funds that could be used to fund new projects.

Serving punch made with reclaimed water to guests touring Water Factory 21, circa 1980

Increasing Water Supply Reliability

Increasing Water Supply Reliability

Modernizing Orange County Water District

William Mills, a private consultant and former employee of the California Department of Water Resources, was the board's ultimate choice to succeed Cline in 1987. Mills recognized that OCWD needed a long–term improvement plan to continue the programs that had been previously started. He made several changes to modernize OCWD's operations, including changing his title from secretary–manager to general manager, creating a finance department, and integrating a complex computer system for data management. Under his direction, OCWD developed an eight–point plan for groundwater management. The plan provided for: "water quality monitoring, contaminant cleanup, regulatory agency support, toxic residuals removal, hazardous waste management, technical information, public disclosure, and periodic evaluation of overall policy effectiveness" (OCWD 1994). Slightly modified, these points have continued to guide district planning.

To carry out his goals, Mills developed a capital improvement plan that identified "a couple hundred million dollars" worth of facilities to be built within the next five or six years to increase the amount of groundwater that could be pumped. His financial plan increased the revenue base of OCWD by raising the RA. "With the stability of a higher revenue base, OCWD secured additional outside funding for the planned improvements" (Mills 1997). The ultimate benefit of this capital improvement plan was the capacity of OCWD to slow down increases in water costs for retail water agencies by reducing their necessary purchases of more expensive imported water.

Green Acres Project

Having proved it was possible to treat wastewater for injection, OCWD began another program to develop tertiary treated wastewater for urban irrigation use. Until this time, county golf courses, public parks, and landscaping were watered with drinking water because the treated effluent—or outflow—from the sanitation district did not meet water quality standards for reuse. The Green Acres Project was designed in the mid–1980s to provide this reclaimed water for use within five miles of the plant. Operational in 1991, the plant initially provided water for nearby Mile Square Park. Secondary treated wastewater was piped from the Orange County Sanitation District (OCSD, OC San) to the adjacent OCWD reclamation plant in Fountain Valley, treated to a tertiary level, and piped out for use. Since this time, additional reaches of pipe have been installed to serve Santa Ana and other cities beyond the five–mile range (Orange County Water District 1991). Since 1991, the Green Acres Project has provided an average of 4,000 acre–feet of water a year to customers in Fountain Valley, Costa Mesa, Newport Beach, and Santa Ana.

Analytical Water Quality Laboratory

The permits that allowed OCWD to build Water Factory 21 required an increase in the sophistication of staff to meet the challenges of developing and monitoring the new project. The proposal called for "a highly qualified operation and maintenance staff of about 14 persons including one superintendent, eight operators, one chemist, and four maintenance men" (Wesner 1987). Laboratory services—initiated in response to the needs of Water Factory 21—continued to expand, monitoring water quality at wells throughout the district.

Dr. Yvonne Shen, a research chemist trained at the University of Massachusetts, established the first of two labs—the water quality lab—in 1973. This lab was planned to monitor the water quality of river water and the demonstration injection wells of Water Factory 21. When the EPA rules for water quality became more stringent, requiring extensive testing for more chemical contaminants, OCWD took over that responsibility from the Orange County Health Department and added it to the work of its lab. The workload increased dramatically, and other technicians were hired to assist. In 1991, the lab processed 176,900 analyses for a network of over 400 monitoring and production wells. The water quality lab's responsibilities continued to increase, as did the size and level of sophistication of its testing equipment. It earned a high level of accreditation from the State of California for complete chemical, physical, and microbiological analysis of groundwater and wastewater. As a result of this approval and recognition, the lab's technicians conducted testing not only for OCWD and its producers, but also for OC San facilities as well

The Advanced Water Quality Assurance Laboratory

(Shen 1997). To meet this growing demand, OCWD added 1,000 square feet of space and acquired new equipment, including four new high–performance water–testing instruments. OCWD chemists use these and other instruments to test for new contaminants at very low detection levels (e.g., parts per trillion).

Research and Development Laboratory

OCWD's research laboratory is another dynamic contributor to the future of water technology. Like the water quality lab, it grew out of the need for research for Water Factory 21. David Argo, former district engineer, recruited Harry Ridgway, a post–doctoral research scientist at the University of California, Irvine, to study the problem of a fouling layer (slime) on RO membranes. Argo and Cline decided that district management needed to set up a second research lab. OCWD directors were skeptical at first, but established an annuity to fund the lab, and Ridgway was hired to continue research on RO membranes (Cline 1997). Since then, the research laboratory has expanded to include other scientists and state–of–the–art equipment. Its projects have included continued RO membrane studies and other bacteria–related research such as percolation enhancement in the recharge basins and biological treatment of groundwater contaminants (Orange County Water District 1995, 1996). Additional research focused on advanced oxidation processes (AOP) like the ultraviolet light (UV)/hydrogen peroxide process used with GWRS, sediment removal by prefiltration before percolation of river water, fouling of both microfiltration (MF) and reverse osmosis membranes by nanoparticles, and factors affecting the mobilization of metals in aquifer materials by low ionic strength waters such as RO product water.

OCWD's research laboratory is another dynamic contributor to the future of water technology.

It was at this lab in Fountain Valley where OCWD first tested MF as a potential technology, prior to the use of RO. This led to the design of an integrated membrane system. Both technologies were proven to be successful in the water purification process. In fact, Water Factory 21 was the first–ever application using RO on municipal wastewater.

Improved Recharge Capabilities in the Basin

When the Orange County Water District v. City of Chino, et al. decision was handed down in 1969, it was a mixed blessing. Orange County was assured of a water supply for recharging and production. OCWD facilities, however, had to be improved to take advantage of the additional base flow and storm flow that would come downriver from Prado Dam.

A major project envisioned by OCWD engineers was to develop storage basins at Santiago Creek and construct a pump station and pipeline to connect them to Burris Pit so that additional water could be transferred there. Former Forebay Operations Manager Alan Flowers recalled that the project cost about $25 million but paid for itself in water—saved water that OCWD did not have to purchase for recharge (Flowers 1997). When finished in 1991, the system added another 25,000 acre–feet of capacity to the basin, bringing OCWD's total recharge capability to between 300,000 and 400,000 acre–feet per year.

The Santiago Creek project had an unexpected natural bonus for nearby residents, despite additional cost and frustration for OCWD management. Since the new basins would inundate small, isolated wetlands within the basin, engineers had to include a mitigation project. OCWD directors authorized nearly $200,000 to pay for planting, irrigation, and other measures to create a wildlife habitat on a 16–acre island between the two basins (Fonley 1997).

Over the years, OCWD's research has included work with the recharge basins themselves. Initially, in each of the percolation basins, beginning with Anaheim Lake in 1962, water infiltrated quickly. Gradually, however, the silt from the Santa Ana River flow collected in the basins, retarding infiltration. Cleaning became a yearly task as the managers emptied the basins to scrape the accumulated solids that were preventing infiltration. Since the process was time consuming, it could not be done easily during the winter months when the operators expected a storm flow. As a result, water infiltration declined when it was needed most to capture the heavy flow. Precious water was also lost during the process because once a basin was emptied for cleaning, there was no way to hold the water or transfer it from one basin to another.

The first step taken to correct this problem was building a maze of pipes linking the different basins in the forebay area. As one basin required cleaning, its contents could be shifted to another. High– powered submersible pumps were also installed in each basin to empty it quickly. Soon, operators could empty, clean, and refill the recharge basins during the winter as well as the summer to increase infiltration by as much as 40 percent.

Along with purchasing land, OCWD's infrastructure investments have maximized the recharge capacity of its facilities. For instance, the addition of two inflatable rubber dams across the river channel in the early 1990s increased recharge capacity. These replaced earthen levees that had been built to capture normal runoff and direct it into the recharge basins. However, when storm flow was high, these levees washed out and could not be replaced until the water level went down enough to bring heavy equipment into the riverbed. Valuable replenishment water was lost in the interim. The rubber dams deflate during storms and can be raised again in 30 minutes to capture runoff once the flow has decreased. The dams allow water to be diverted from the active river channel into the district's complex system of channels and pipelines that distribute water into the various groundwater recharge facilities. The cost to purchase the first dam, constructed in 1992, was recovered within its first year of operation. The increased amount of stormwater captured offset this cost.

Other improvements include multiple pumping stations, miles of pipelines, numerous valves, flow meters, water level sensors, and a sophisticated computerized control system that allows the system to be monitored and controlled remotely. With these facilities, OCWD can recharge river water, imported water, stormwater and GWRS supplies.

OCWD operates and maintains one of the world's most advanced–managed aquifer recharge systems to replace the water that is pumped from the basin by local water agencies, cities, and other groundwater users. The location of the recharge system, the cities of Anaheim and Orange, is determined by the geology of the land. The naturally coarse–grained soils in these cities are conducive to surface water percolation and aquifer recharge operations.

Recharge basins are extremely important in the management of groundwater supplies and OCWD realized early on the need for constructing additional basins to maintain a reliable and adequate water supply. The district took an opportunistic approach to acquiring land. When land was available, OCWD purchased it.

Stormwater Capture at Prado Basin

Prado Dam in Riverside County was originally conceived as a flood control dam, with water conservation being an incidental secondary purpose. Although it is still a critical point in flood protection in the lower Santa Ana basin, its importance for conservation has increased. For many years, two private water companies, Anaheim Union Water Company and Santa Ana Valley Irrigation Company, owned land behind Prado Dam for conservation. Ditches dug in the overflow lands helped relieve waterlogged conditions by increasing the flow through the dam's ungated opening (Osborne 1997).

The Santa Ana River in the Prado wetlands

OCWD owns about 2,150 acres of bottomland behind Prado Dam that can be flooded for conservation purposes. During the 1970s and early 1980s, OCWD began working toward a proactive water conservation program. The basic concern was that flood control and water conservation require opposite management techniques. Flood control managers want to keep the flood land behind a dam as free of water as possible, to prepare for an unexpected heavy runoff. Water managers, on the other hand, want to store as much water as possible behind the dam, releasing it slowly so that it can be infiltrated in spreading grounds and saved as groundwater. OCWD directors authorized $600,000 in 1986 to study the feasibility of conservation consistent with flood control at Prado.

Environmental Stewardship at Prado Basin

The study, completed by the USACE in 1988, indicated that seasonal storage would not jeopardize flood control at the dam (Orange County Water District 1991). Conservation could take place between March 1 and September 1, while flood control efforts would take precedence between November 1 and

February 28 (Van Haun 1997). Environmental studies followed to determine the impact on wildlife in the proposed storage area. Finally, in 1991, OCWD, the USACE, the U.S. Fish and Wildlife Service (USFWS), and The Nature Conservancy reached an agreement to allow storage and mitigate and alleviate anticipated damage to wildlife habitat. Under the agreement, OCWD set aside land for habitat for an endangered songbird, the least Bell's vireo, and contributed $900,000 for habitat management and other land conservation projects. In spring 1991 alone, some 40,000 acre–feet of high–quality water were saved from runoff by storage behind the dam (Orange County Water District 1991). Had OCWD needed to purchase that amount of water to replenish the basin, the total cost would have been far greater than the cost of the conservation project.

Jim Van Haun, former associate general manager, remembered that OCWD had seriously considered giving up on the conservation project in 1986 when the least Bell's vireo was listed as a federal and state endangered species. Prado Basin had the second largest population of these small songbirds and its population had dropped to 19 nesting pairs. Since their migration period from Mexico to Prado, where they nested, was mid–March, these few pairs would be directly affected by the proposed conservation plan. OCWD directors finally decided to try to "live with the Endangered Species Act" and continued the study. According to Van Haun, biologists discovered that the bird population decline was due more to an incursion of brown–headed cowbirds, not necessarily the loss of habitat alone. Cowbirds lay their eggs in the nests of other birds, like the least Bell's vireo, and leave. The diminutive vireo parents are left raising a large and aggressive cowbird nestling that starves and crowds out the vireo nestlings.

Endangered songbird, the least Bell's vireo, *photo by Benjamin Smith*

The immediate solution was to build and install Australian cowbird traps. For several years, OCWD spent $35,000 to $40,000 each year trapping cowbirds. Dick Zembal, OCWD natural resources director, who at the time served as USFWS deputy field supervisor, and Martin Rigby, former assistant general manager of OCWD, collaborated to develop a recovery plan. By setting cowbird traps and changing mowing patterns of fields behind Prado Dam, the least Bell's vireo population rebounded. Since first being listed as an endangered species in 1977, the population of vireos at Prado Basin has grown from 12 territories to 610 territories in 2022. As a result, OCWD has been allowed to expand the area it seasonally floods for conservation. Overall, the good results from trapping, while costly, saved millions of dollars worth of water and provided the basis for a permanent water conservation agreement (Van Haun 1997).

Subsequent to the decision to trap cowbirds, researchers found that an invasive species, *Arundo donax* (giant cane) had overrun the birds' habitat. OCWD, USFWS, and the USACE entered a cooperative agreement to remove this plant throughout the upper watershed. OCWD's share of the cost was $1 million. In March 1995, just a few days after the environmental impact statements were completed and approved to allow additional storage behind the dam, a storm came up and the dam filled, saving $3.2 million worth of water for use in Orange County (Van Haun 1997).

OCWD provided the leadership to form a team with seven other agencies to develop the Santa Ana River Conservation Trust Fund. Its unique concept of depositing funds into a trust dedicated to solving a regional problem provides the opportunity for broader solutions with more lasting results. By 2002, the Trust Fund had funded the removal of 600 acres of *Arundo* from the watershed. Ten years later, more than 5,000 acres had been removed. Currently, OCWD continues to collaborate with its partners, including the Santa Ana Watershed Association, SAWPA, and the USACE to control *Arundo* in the watershed.

Through its water quality research program, OCWD scientists and engineers discovered other benefits of the Prado conservation program. The water that reaches Prado Dam is degraded because of nonpoint source pollution upstream. Under terms of the Chino decision, this water had to meet certain water quality standards when it reached Prado Dam. Even before the conclusion of the lawsuit, the water agencies realized that the water quality of the river was continuing to deteriorate in the watershed.

Routine testing led scientists to another means of improving the water quality at the dam site. Behind the dam was a 450–acre constructed wetlands consisting of 50 linked pools through which half of the baseline flow of the river passed. This was originally operated by a concessionaire as a waterfowl hunting area. Water quality engineers discovered that the water passing through these ponds was of a higher quality than other water reaching Prado, indicating that the series of ponds naturally removed some of the nitrate and other compounds accumulating in the urban flow. As a result of these studies, OCWD modified the pond system to increase the flow in and out of each pond. It deepened individual ponds, widened and deepened the main diversion channel to the pond system, and improved the conveyance system between ponds. With these modifications, OCWD increased the rate of flow from 60 cubic feet per second (cfs) to 200 cfs, thereby allowing more river water to flow through the ponds (Orange County Water District 1995). The wetlands have proven to be very effective at removing nitrate from the river water. In fact, they remove up to 2,000 tons of nitrate per year.

The Beginning of the Groundwater Replenishment System

The early 1990s were marked by drought and groundwater levels were low. Concerned that the existing amount of water injected into the seawater barrier was inadequate, OCWD staff recommended that injection volume more than double to 35 mgd to ensure that groundwater levels could be lower in the basin without risking seawater intrusion. It was determined that newer technologies could be explored to replace the existing treatment process used by Water Factory 21. This would lead to overall lower treatment costs.

In 1995, the district began pilot testing new technologies, including MF, a new membrane material for the RO system, and UV light. MF had not been used to treat wastewater before. It was used for surface water treatment and for various treatments in the industrial sector. The district pilot–tested several manufacturers' products. It then decided to continue testing on a larger scale with three manufacturers, U.S. Filter Memcor, Pall, and Zenon, to determine which operated best and had the lowest lifecycle costs. At the same time, the district evaluated three different RO membranes manufactured by Hydranautics, Dow/Filmtec, and Koch/Fluid Systems, which used a new membrane material (polyamide thin film composite) that operated at much lower pressures and higher salt rejection than the previous cellulous acetate RO membranes. The district also evaluated the performance of UV light technology produced by Trojan Technologies, Calgon Corporation, and Wedeco.

Conducted over the course of three years, this pilot testing provided data to the regulators that indicated that the processes were effective. Further, the data enabled the district to evaluate which technology provided the overall lowest costs in terms of capital, operations, and maintenance.

Visionary Partnership

While OCWD was pilot testing various treatment technologies for possible use in an expanded seawater barrier project, OC San was facing the challenge of having to build a second ocean outfall five miles off the coast of Huntington Beach. Needing to address 100 mgd of flow relief, it approached OCWD to see if it would be willing to build an expanded project. No longer facing the need to build the outfall, OC San was willing to contribute half the capital costs of OCWD's expanded seawater barrier project. The two agencies decided that such a project could be developed and proposed an advanced treatment plant with an ultimate capacity of 130 mgd along with a 14–mile pipeline. This pipeline would pump water from Fountain Valley, where the treatment facility was located, to recharge basins in Anaheim, as well as 15 new injection wells to expand the seawater barrier.

The two agencies began moving forward on this visionary project. In 1997, OCWD Directors Phil Anthony, Don Owen, and Irv Pickler met with OC San Directors George Brown, Norm Eckenrode, and Peer Swan in a newly created ad hoc committee. Two noteworthy actions were taken at this meeting. Committee members agreed to prepare a request for proposals to hire a public affairs firm and develop a scope of work for the environmental tasks that needed to be undertaken. During the following three years, the agencies launched a public affairs campaign, and in 1999, issued a preliminary design contract with Camp Dresser & McKee, Brown and Caldwell, and Tetra Tech.

Securing a Sustainable Water Future

Securing a Sustainable Water Future

Seawater Intrusion Control

Guided by its mission to safeguard the groundwater supply for Orange County, OCWD has constructed critical water infrastructure that includes seawater intrusion barriers. OCWD has used injection wells successfully at the Talbert Barrier, located in Huntington Beach and Fountain Valley. Beginning in 1999, the district began strengthening this barrier with construction of its Talbert Gap Seawater Intrusion Barrier. OCWD constructed several injection well sites—two in 1999, one in 2000, two in 2003, and eight in 2004–05. The addition of four new well sites at the west end of the barrier and four to the southeast helps prevent seawater from going around the existing Talbert Gap Seawater Intrusion Barrier. Further, these wells have more than doubled the barrier's annual injection of 100 percent purified recycled water, allowing coastal water utilities to access even more groundwater without damaging the basin. The Talbert Barrier provides enormous value to local water utilities—without it, seawater would intrude several more miles into the basin, contaminating production wells, reducing the freshwater capacity of the basin, and limiting the amount of water that could be produced each year.

Since 2010, the district has also been investigating the nature and extent of seawater intrusion in the Sunset Gap area beneath the Naval Weapons Station in Seal Beach. Here, basin aquifers are connected to the ocean and are relatively shallow. OCWD's investigation has found that brackish groundwater approaches active city production wells. To further understand the flow paths and extent of seawater intrusion in the Sunset Gap, OCWD installed multi–depth monitoring wells at 12 locations in Huntington Beach and Seal Beach and as of 2023, has plans to install more. Using data derived from these wells, the district developed a computer groundwater model to evaluate a potential future seawater intrusion barrier.

Groundwater Replenishment System

Two public agencies, OCWD and OC San, shared the vision to do what was once unthinkable—purify wastewater into high–quality drinking water. While this concept had been thought of by others, it had not been successfully implemented. This quest for innovation is nowhere more evident than in the cutting–edge Groundwater Replenishment System (GWRS) project. The GWRS is the world's largest advanced water purification system for potable reuse. It takes treated wastewater that otherwise would be discharged to the Pacific Ocean and purifies it using a three–step advanced treatment process. Applying microfiltration, reverse osmosis, and ultraviolet light with hydrogen peroxide, this innovative process produces high–quality water that is superior to all state and federal drinking water standards. After post–treatment stabilization, this water is injected into a seawater barrier and pumped to recharge basins where it naturally percolates into the groundwater basin.

OCWD Board of Directors at the GWRS Initial Expansion groundbreaking ceremony

In 2001, the Boards of both OCWD and OC San voted overwhelmingly to move forward and begin detailed design of the first phase of GWRS with a target goal of producing 72,000 acre–feet per year of purified water, enough to serve nearly 600,000 people. The cost was projected at $481 million.

Part of developing GWRS involved the construction of the $300 million Advanced Water Purification Facility. It is here that 70 million gallons of secondary–treated wastewater are transformed each day to near distilled water quality. After undergoing microfiltration, reverse osmosis, and ultraviolet light with hydrogen peroxide, the purified water is then placed into the groundwater basin.

The GWRS project received significant attention from outside agencies that recognize the applicability of this technology to many other communities. Several grants and low–interest rate loans were received by many local, state and federal agencies, including an annual Local Resources Program (LRP) operational subsidy of $121 per acre–foot over 23 years that amounted to $86.2 million, provided by the Metropolitan Water District, $67 million in grants from the 2000 California State Water Bond including $37 million from the State Water Resources Control Board (SWRCB) and $30 million from the Department of Water Resources (DWR), $20 million from the U.S. Bureau of Reclamation (USBR) through its Title XVI program — and more.

Construction of this monumental project began in 2002. Online in January 2008, the GWRS became one of the most celebrated civil engineering and water projects in the world. Beyond its global recognition, the project proved to be a critical source of supply for Orange County, helping bring a new, drought–proof local water source to the communities served by OCWD. The GWRS is the ultimate expression of OCWD and OC San's long–term goal of developing a dependable water supply from a resource that formerly was wasted to the ocean.

In addition, a robust education and outreach program was developed and implemented to build upon the public's trust and earn overwhelming support for this unprecedented water recycling project.

At the request of the district, the National Water Research Institute (NWRI) established an Independent Advisory Panel (IAP) for GWRS in 2004. Inspired by the success of the earlier

NWRI Santa Ana River Monitoring (SARMON) Scientific Advisory Panel, the GWRS IAP was intended to provide guidance to the district, state regulators, and the public regarding GWRS operations and water quality. At the time, the size and extent of the GWRS project represented an unprecedented use of technologies such as reverse osmosis and advanced oxidation treatment for municipal potable reuse. Furthermore, water quality issues, such as the occurrence of trace levels of pharmaceuticals and personal care products in conventionally treated wastewater, had just emerged in the scientific and public consciousness. The IAP review of the project helped confirm that the GWRS recycling process contained multiple robust treatment barriers to chemical contaminants and pathogenic microorganisms. The NWRI GWRS IAP continues to meet regularly and provide ongoing

Bottles of GWRS purified water

guidance. This has helped the district update required GWRS monitoring and operating plans, as well as inform the district's applied research efforts on treatment optimization and efficiency.

Advanced Water Quality Assurance Laboratory

OCWD's Advanced Water Quality Assurance Laboratory opened in 2009, expanding the district's existing water quality lab. Home to chemists, lab technicians, quality assurance staff, and water quality monitoring personnel, the laboratory handles over 400,000 analyses of approximately 20,000 water samples each year. Regular monitoring of water quality represents an understated contribution vital to the health of water supplies. Core monitoring programs supported by the laboratory include Title 22 drinking water compliance for the groundwater producers, GWRS operational and permit compliance monitoring, and testing across the groundwater basin and watershed to document ambient conditions and impacts of various potential sources of contamination. The laboratory also supports the district's applied research activities.

Reflecting sustainable design features, the new laboratory building was constructed with locally manufactured materials with recycled components and low emissions of volatile organic compounds. Landscaping consists of drought–resistant plants irrigated with recycled water.

The work in the water quality laboratory involves meticulous recordkeeping and adherence to strict quality control practices. The lab is accredited by the state of California's Environmental Laboratory Accreditation Program (ELAP) for more than 240

Fields of Testing (FOTs) and has also earned United States Environmental Protection Agency (USEPA) approval to perform drinking water analyses during all the Unregulated Contaminant Monitoring Rule (UCMR) programs. Renamed the Philip L. Anthony Water Quality Laboratory in 2018, the state–of–the–art laboratory has gained a reputation as one of the premier water quality laboratories in the world.

A Tradition of Innovation

OCWD has fostered a tradition of innovation to overcome both water supply and water quality problems. Early efforts focused on the evaluation of the best means for restoring percolation at the district's recharge basins as they were becoming clogged with fine particles of silt and clay after capturing stormwater runoff, as well as the use of "T" and "L" levees in the Santa Ana River to spread out river flows across the entire channel to maximize percolation and minimize downcutting into the riverbed. The 1960s development and 1970s initial operation of the groundbreaking Water Factory 21 project, predecessor to today's GWRS, required creative thinking and planning, as the injection of recycled water into a potable aquifer had never been previously attempted anywhere in the U.S. The district carried out a program to test the best technologies available at the time to improve the quality of treated wastewater supplied by OC San, such that both injection well performance and potable quality in the aquifer could be maintained. Following the abolishment of the federal Office of Saline Water and associated withdrawal of federal government support for the seawater desalination component of Water Factory 21, the district had to pivot to find a source of demineralized water for the project. OCWD rapidly tested and implemented wastewater reclamation to drinking water standards using reverse osmosis technology, an unprecedented application of such treatment at this scale.

With the onset of Water Factory 21 operations in the late 1970s, the district recognized the need for an ongoing applied research program to optimize the operation of the cutting–edge facility. A Research Laboratory and Research & Development (R&D) Department were established, initially focusing fundamental research on observation, measurement, quantification, and mitigation strategies for reverse osmosis membrane biofouling. An early research partnership with Stanford University led to the discovery that reverse osmosis not only was effective at removing salt from wastewater, but also a wide range of organic molecules. Subsequent efforts focused on wetlands treatment, microfiltration, and ultrafiltration membranes as pre–treatment ahead of reverse osmosis, and optimization of chemical addition at the GWRS facility. More recently, the district's applied research has focused on new methods for efficiently measuring microbiological and organic contaminants, GWRS treatment process optimization, and treatment technology evaluations for PFAS removal and destruction. The current mission of the R&D Department is to conduct applied research that supports the district's operational, regulatory, and water quality objectives. R&D staff are committed to seeking innovative means to develop and evaluate new or improved processes and methods, often through collaboration with universities and topic experts.

Groundwater Replenishment System Initial Expansion

In the 2000s, faced with declining river flows from the Santa Ana River and continued cycles of drought in the region, OCWD recognized the importance of continuing to provide a local, reliable water supply. In 2011, shortly after the GWRS facility became operational, OCWD's Board of Directors approved construction of an initial expansion to the facility that would bring water production up to 100 million gallons a day, enough to serve 850,000 people. The project cost $142 million and received $1 million in state grants, and a $137 million Clean Water State Revolving Fund (CWSRF) loan from the SWRCB.

To support the expansion, construction of additional treatment facilities at the Advanced Water Purification Facility site in Fountain Valley began, including expansion of the microfiltration, reverse osmosis, and ultraviolet light treatment processes. Supporting equipment such as pumps and electrical and additional post treatment systems were also a part of the expansion, though a significant portion of the infrastructure was already in place. In addition to creating a reliable local source of water, the project reduces the amount of treated wastewater discharged to the Pacific Ocean, helps protect Orange County's coastline, and provides all these benefits with fewer greenhouse gas emissions compared to importing water.

With construction complete a few years later, officials gathered to dedicate the facility in 2015. Leading up to the 10th anniversary of the GWRS in 2018, a robust public outreach campaign was implemented. In 2016, OCWD and OC San co–sponsored Assembly Bill 2022 which Governor Brown signed into law in 2016. This legislation allowed the bottling of advanced purified demonstration water to support educational outreach efforts. OCWD and OC San were the first in the Western Hemisphere to bottle and share such water.

Treating wastewater with ultraviolet light with hydrogen peroxide

Beginning in March of 2017, staff of OCWD and OC San took bottles of GWRS purified water on a year–long tour in California to share information about water reuse and provide a taste to audiences who otherwise would not have the opportunity to try it. Staff distributed 13,000 bottles at various events from San Diego to Sacramento, sharing literature and quenching the thirst and curiosity of thousands of people.

OCWD and OC San also challenged social media influencers and the media to #GetOverIt and take a taste test, which these groups promoted. The agencies created these campaigns to help overcome "toilet–to–tap" misconceptions and gain support for water reuse for future infrastructure and program investments on the public's behalf.

At the tour's end in February of 2018, and in celebration of its 10th anniversary, the GWRS was declared "officially amazing" when OCWD and OC San succeeded in setting the Guinness World Records™ title for the most wastewater recycled (100 million gallons) to drinking water in 24 hours.

GWRS product water

Recharging GWRS Water

On average, OCWD's surface water recharge system puts 250,000 acre–feet per year of water into the groundwater basin. Over the years, the district has expanded its recharge system, which now includes more than two dozen separate facilities that cover more than 1,000 wetted acres. A number of these facilities are recharge basins that range in depth from 5 to 150 feet. Other facilities include the Santa Ana River channel and Santiago Creek. Sources of water percolated by the recharge system include Santa Ana River base flow, storm flow, local surface water runoff, imported water, and GWRS water. OCWD's recharge activities are foundational to meeting the water needs of north and central Orange County, approximately 400,000 acre–feet per year.

One of the principal methods for recharging the groundwater aquifers involves supplying GWRS water to four of the district's spreading basins: Kraemer, Miller, La Palma, and Miraloma Basins in Anaheim.

Percolation rates with cleaner sources of water, such as GWRS, are more than four times the rates achieved with Santa Ana River water. Water in the Santa Ana River contains suspended solids, typically comprised of inorganic silts and clays that clog the basin surface during infiltration.

Kraemer Basin consists of 31 acres and has a maximum storage capacity of 1,170 AF (381 million gallons) with a maximum recharge rate of approximately 300 AF (97 million gallons) per day. The average recharge capacity in this basin is 19,000 acre–feet per year (AFY), (6 billion gallons per year).

OCWD purchased two separate pieces of property and constructed the Miraloma and La Palma recharge basins between 2010 and 2016. Located on the north side of Miraloma Avenue just east of Kraemer Basin and south of Miller Basin, the first property is 13 acres. It is dedicated to only receiving GWRS water from a 14–mile pipeline from the advanced water treatment plant located in Fountain Valley.

The second property, La Palma Recharge Basin, is a 17.7–acre site located along La Palma Avenue. It was previously part of a larger Boeing facility and conveniently located adjacent to the GWRS pipeline. La Palma Basin is the district's newest recharge facility and, like Miraloma Basin, is devoted solely to recharging GWRS water. Favorable geology at the site and ultra–pure water from the GWRS have resulted in the district's highest percolation rates measured so far.

In 2017, $9.1 million in Proposition 1 funding went toward OCWD's Centennial Park Mid Basin Injection (MBI) Project, which injects purified GWRS water to replenish the principal aquifer of the Orange County Groundwater Basin. This site has an injection capacity of 10 million gallons per day to refill the groundwater basin, equivalent to the water needs of 85,000 people. It provides operational advantages to the district as well as benefits to the Orange County region while addressing statewide water challenges by creating an additional local water storage mechanism.

Imported Water Programs

While OCWD emphasizes the significance of local water resources, imported water accounts for a modest proportion of the district's water supply portfolio. OCWD has coordinated the management and operation of the groundwater basin with the availability of imported water supplies from the Colorado River and northern California. The Metropolitan Water District imports and manages available water supplies for the region. Each year the district typically purchases 20,000 to 60,000 acre–feet per year of untreated MWD water to recharge the groundwater basin.

The district and MWD entered a historic contract in 2003 whereby MWD can store up to 66,000 acre–feet of water in the Orange County Groundwater Basin through a Conjunctive Use Program (CUP). The district received approximately $33 million in initial compensation which was used to construct water supply facilities around the basin.

In 2017, the district and MWD entered into a cyclic storage agreement which allows MWD to pre–deliver up to 100,000 acre–feet of water in the basin. The district must pay for the water within five years at the prevailing MWD wholesale rate. All of these programs help the district increase the overall water reliability of its service territory.

In 2021, OCWD and regional water agencies worked together with MWD to reach a historic agreement, the Santa Ana River Conservation and Conjunctive Use Program (SARCCUP) to better prepare the region for future droughts and promote water use efficiency in Orange, Riverside, and San Bernardino counties—an area serving millions of customers.

SARCCUP is a first–of–its–kind regional groundwater banking program between several agencies within the Santa Ana Watershed and MWD. The Santa Ana Watershed Project Authority helped distribute more than $55 million of grant funding from California Proposition 84 to support the program.

The $150–million–SARCCUP program will provide a collaborative, watershed–scale approach toward groundwater basin management, replenishment, and water transfers. Under the agreement, SARCCUP will store up to 137,000 acre–feet of storage in six groundwater basins. The regional water agencies will also collectively plan for droughts while also restoring wildlife habitat and assisting with the development of regional water use efficiency programs.

OCWD…worked to reach a historic agreement…to better prepare for future droughts…

Increasing Stormwater Capture

The district continues to implement an "all of the above" approach when it comes to water management and remains prepared to maximize water supply for the region during wet or dry times. Local stormwater capture is important because it lessens demand on imported water supplies, which are more costly and less reliable than groundwater.

Building upon its longstanding partnership with the U.S. Army Corps of Engineers at Prado Dam, the district has increased stormwater capture efforts, which has proven to be an effective and economically viable solution to the region's water challenges without compromising the safety of the dam. Should there be multiple storms each year, this helps OCWD bank a significant amount of water to help mitigate future droughts and ensure sufficient supply in the long term.

The district remains committed to working with the Scripps Institution of Oceanography at the University of California, San Diego to develop predictive models for atmospheric rivers. An atmospheric river is a relatively long and narrow region in the atmosphere that transports the bulk of water vapor outside of the tropics. Forecast Informed Reservoir Operations (FIRO) is a research and operations partnership that uses data from watershed monitoring, and modern weather and hydrologic forecasting, specifically the study of atmospheric rivers, to help water managers selectively retain or release water from reservoirs in a manner that reflects current and forecasted conditions.

Through the FIRO project, OCWD is working with the USACE to update its water control manuals to increase water storage levels at Prado Dam by capturing stormwater up to reservoir pool elevation of 508 feet above mean sea level (amsl) whenever it rains. This could add 7,000 acre–feet of water annually into the groundwater basin, creating a new supply for approximately 60,000 people per year. In addition to increased water supply, this study recommends restoration of more than 600 acres of valuable riparian and associated habitats within the Prado Basin. Restoration of this critical wildlife corridor will improve aquatic and riparian ecosystems by removing non–native vegetation in Prado Basin, planting native plants, and restoring a portion of Chino Creek.

The Prado Dam FIRO project is an example of the continued partnerships between federal, state, and local agencies. The FIRO program has shown that by better utilizing emerging technologies in observations and forecasts to create an adaptive strategy, OCWD can improve water management, not only during the wet years, but also during drought conditions.

Addressing Groundwater Contamination

Key to managing a healthy groundwater basin is ensuring water quality. OCWD's commitment to exceptional water quality requires comprehensive knowledge of groundwater quality. Given this commitment to protect and enhance the quality of the groundwater basin, the district's Philip L. Anthony Water Quality Laboratory implements a proactive, diverse, and comprehensive groundwater and surface water monitoring program to continually generate real–time data.

Groundwater is typically high–quality within the basin. Recharge basins and the streambed of the Santa Ana River improve groundwater quality through natural percolation. Purifying recycled water to near–distilled water quality at GWRS not only increases the water supply quantity, but also enhances the quality of the water in the groundwater basin.

However, releases of industrial chemicals have impacted an area in the North Basin near the cities of Fullerton, Anaheim, and Placentia and the South Basin near the cities of Santa Ana, Tustin, and Irvine. Groundwater plumes created by past manufacturing are spreading and threaten to impact the basin. Consequently, several municipal drinking water wells have been removed from service. OCWD is proactively seeking ways to clean up the pollution in a united effort with state and federal regulatory agencies. The initial cleanup efforts are focused on cutting off and preventing the spread of contamination before it travels further into the main aquifer that supplies hundreds of potable supply wells.

In September 2020, the Orange County North Basin Superfund Site was listed by the United States Environmental Protection Agency (EPA) as a National Priorities List (NPL or Superfund) site. The goal of the Superfund listing is to get contamination

Inland spreading and percolation basins contained and mitigated and to compel parties responsible for the contamination to implement and pay for the cleanup.

The district also responds quickly and efficiently to address issues related to emerging contaminants like PFAS. OCWD has successfully gained laboratory accreditation for analytical testing, pilot testing of effective treatment techniques, and construction of treatment plants that remove PFAS from local groundwater supplies.

PFAS are a group of thousands of manmade chemicals that are used in consumer products such as Teflon pans, stain–resistant carpets, waterproof clothing, and fast–food packaging. Due to their extensive and prolonged use in commerce and industry, PFAS are being detected in water sources throughout the United States, including Orange County's groundwater basin. Much of this water is affected by treated wastewater discharges and stormwater runoff from upstream communities in San Bernardino and Riverside counties via the Santa Ana River.

While not responsible for releasing PFAS into the environment, OCWD nevertheless took swift action to explore this emerging contaminant. It is committed to finding ways to remove it from local water supplies. In February 2019, OCWD's laboratory became the first public agency laboratory in California to achieve state certification to analyze PFAS in drinking water. OCWD launched the nation's largest pilot testing program in December 2019 to test treatment techniques and begin the long–term restoration of the local drinking water supply.

In 2020, as a result of state officials lowering health advisory levels for two legacy PFAS chemicals, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS), dozens of wells operated by several of OCWD's member agencies were taken out of service. OCWD's efforts to address PFAS in Orange County also included a multi–faceted communications plan that provided rapid and transparent information to a multitude of stakeholders.

In the OCWD service area alone, the current PFAS response cost is estimated to be at least $1 billion in capital and operating costs for wellhead treatment over 30 years, and it is likely to increase. OCWD has committed to funding 100 percent of design and construction costs and 50 percent of operations and maintenance costs for these treatment facilities. To support this costly effort, OCWD is actively pursuing all possible funding opportunities, including litigation to hold the manufacturers of PFAS accountable. OCWD received a $131 million federal Water Infrastructure Finance and Innovation Act (WIFIA) loan from the EPA, which is expected to save the district approximately $26 million over alternative financing options.

In June 2021, the county's first PFAS treatment facility came online in Fullerton. By 2024, 36 treatment facilities will be online. OCWD has continuously shared its research and findings with the broader water, technology, and research industries, paving the way for others to implement cost–effective PFAS removal programs in their communities. Working collaboratively with its project partners, OCWD has prepared extensive reports and publications detailing the results of the PFAS treatment study.

Sound Groundwater Management

The district works proactively to manage, protect, and expand its groundwater operations. It excels in its groundwater management because it simultaneously explores strategies related to water recycling, recharge operations, technological advances, and stormwater capture. Together they all contribute to sound groundwater management.

In 2019, the California Department of Water Resources (DWR) approved an alternative to a Groundwater Sustainability Plan for the Orange County Groundwater Basin, as the district demonstrated how it has already achieved sustainable groundwater management. The approval of the plan is a testament to OCWD's tremendous stewardship of the basin since 1933. As other California agencies worked to meet requirements of the Sustainable Groundwater Management Act (SGMA) of 2014, DWR showcased OCWD's plan as an example of a basin that is already sustainably managed.

Groundwater Replenishment System building

As a regional water leader, the district continues to work with south Orange County water agencies to study new options to provide water from the groundwater basin during emergency events.

For most south Orange County agencies, nearly 100 percent of their drinking water supply is imported from MWD and these agencies don't benefit directly from the Orange County Groundwater Basin. Building on its history of being a good neighbor and allowing groundwater to be moved to the southern part of Orange County as the district has previously done during emergencies, OCWD is working to consider a new program to provide additional water supplies during emergency events or shutdowns of the imported water system.

Groundwater Replenishment System Completion

From its initial conception, the roadmap to GWRS included strategic expansions over the years. During the final expansion, OCWD and OC San faced a formidable challenge pertaining to moving water from OC San's second wastewater plant, Plant No. 2, which is located nearly four miles away in Huntington Beach. This required construction of new conveyance facilities, expanded infrastructure, and a vision to reimagine GWRS' existing design to accept and treat more water, which arrives at the plant with higher salt and organics concentrations. The priority was to ensure this goal could be met, while still creating a high–quality water supply that meets all state and federal drinking water standards.

The final expansion has resulted in the production of 130 mgd and the recycling of 100 percent of OC San's reclaimable wastewater flows. Recycling 100 percent of OC San's reclaimable flows is an industry first and unheard of with other wastewater recycling projects. The path to 130 mgd came with challenges that OCWD met and resolved. These challenges were addressed effectively with innovation, sound science, engineering, and applied research, where staff implemented solutions to optimize efficiency, use less energy, and produce more water from Plant No 2.

GWRS maximizes water reuse efforts in the region. By producing more water, the GWRS provides a drought–resilient supply, benefiting not only the Orange County region, but also the entire state. Ultimately, GWRS means importing less water from Northern California and the Colorado River.

The $284 million GWRS final expansion project included many different construction components, such as the Advanced Water Treatment Facility expansion, a new pump station, two flow equalization tanks, a pipeline rehabilitation, and modification of OC San's headworks to be able to segregate reclaimable and non–reclaimable flows.

Funding is through a variety of sources, including OCWD's successful efforts to obtain a low–interest rate loan of $135 million from the EPA's WIFIA and two CWSRF loans in the amount not to exceed $186 million from the SWRCB. The project also received more than $8 million in state grants.

In January 2023, the GWRS celebrated its 15th "crystal" anniversary, apt recognition for a facility that produces crystal–clear water. By this time, the facility had achieved production of more than 400 billion gallons of water since 2008. In April 2023, officials gathered to dedicate the completion of the GWRS through the final expansion.

Tours and tastings continue to be offered to the public. Since its inception, the GWRS has welcomed more than 60,000 visitors. It has also garnered more than 80 awards, including the prestigious American Society of Civil Engineers (ASCE) 2009 Outstanding Civil Engineering Achievement Award for the year's most outstanding national engineering project and the Stockholm 2008 Industry Water Award for the year's most outstanding international water project. OCWD was awarded the 2014 Lee Kuan Yew Water Prize, an international honor presented to the district for its pioneering work in groundwater management and water recycling, as well as its achievements in public policy and community outreach. The district also earned the 2017 Governor's Environmental and Economic Leadership Award (GEELA), given to OCWD for making contributions to conserving California's precious resources, protecting and enhancing the environment, and strengthening the state's economy. In 2023, the GWRS was recognized as Outstanding Water/Wastewater Treatment Project and Project of the Year by the ASCE Orange County chapter.

The district completed its GWRS program goals by constantly innovating and testing new technologies, and it hasn't taken its foot off the pedal. OCWD continues to test new technology such as flow–reversal reverse osmosis (FR–RO) to evaluate if the GWRS can create even more clean water. The current GWRS has an 85 percent recovery rate to meet the current production goal of 130 mgd. Enhanced water recovery technologies like FR–RO could increase the recovery rate to as high as 95 percent, potentially squeezing even more water out of the system. Looking ahead, OCWD will also conduct further studies and continue working with regulators and stakeholders to identify opportunities to bring more water to the GWRS to be recycled, resulting in less ocean discharge in the future and an enhanced water supply portfolio.

Continuing the Tradition of Innovation

From the early days of Water Factory 21 to today, sound research gave OCWD a worldwide reputation for supporting a culture of innovation that still exists. Expert staff, combined with increasingly sophisticated water quality testing, provides the confidence needed by the health and regulatory community and the general public to allow OCWD to continually push the frontiers of water reuse.

OCWD has a long history of supporting research on both the technical and water quality aspects of water purification. Realizing that research was integral to its goal of becoming a leader in water recycling, an Engineering Research Center was constructed as part of the GWRS project, where new technologies could be installed and evaluated on a pilot basis. Today, this testing facility continues to evaluate new membranes and processes and efforts continue to grow at OCWD to tackle challenges associated with emerging water treatment technologies.

Driven by its tradition of innovation, OCWD continues to be a worldwide leader in the water industry. Thanks to visionary leaders, and dedicated and talented staff, OCWD has earned its outstanding reputation in groundwater management, water reuse, and water supply reliability.

Afterword

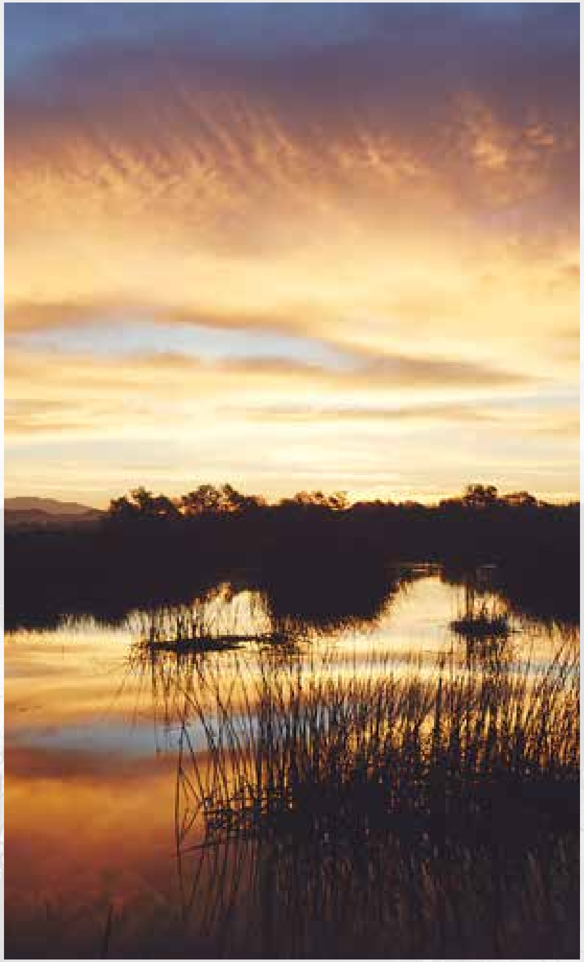
By Michael R. Markus, P.E., D.WRE, BCEE, F.ASCE, General Manager, Orange County Water District

This book details the tremendous achievements of the Orange County Water District over the past 90 years. These accomplishments have made the district a global leader in groundwater management and recycled water. This would not have been achieved without the vision and leadership of the past and present Boards of Directors. These leaders have shaped the decisions and policies that have made the district what it is today. They have understood the need for investments in water infrastructure and the impact of these investments on Orange County's economic vitality.

The district has faced challenges in the past and met them head–on with innovation and foresight. This same spirit will need to continue because future challenges loom on the immediate horizon. These challenges will include decreased flow in the Santa Ana River due to recycling and groundwater extractions in the upper Santa Ana River watershed, decreased stormflow due to drought cycles, and potential shortages of imported water. All of these issues affect the supply of water into the groundwater basin and eventually could lead to a decrease in pumping out of the basin.

Even though the challenges will be great, I am confident that the district staff will rise to the occasion and produce creative solutions in finding additional ways in which to maximize the potential of the groundwater basin. The district has always been recognized for its "tradition of innovation" and high–caliber staff. With the combination of the leadership of the Board of Directors and the ingenuity of the staff, the Orange County Water District will continue its preeminent reputation well into the future.

Appendices



Historical Timeline
Orange County Water Progress

1769	Father Serra camps in Santa Ana Valley
1776	Mission San Juan Capistrano is established
1848	California's gold rush begins, Alta California ceded to U.S.
1850	California achieves statehood
1861	Start of 43–day historic flood
1862	Irvine Ranch is established
1870s	Major cities in Orange County are established
1889	Orange County is established
1916	Historic flood, Santa Ana River is rerouted to present location
1928	Metropolitan Water District of Southern California (MWD) is established, Santa Ana and Anaheim represent Orange County as founding member cities
1931	Fullerton joins MWD as third member city from Orange County
1932	Construction of Colorado River Aqueduct begins
1933	Orange County Water District (OCWD) is established to manage the groundwater basin
1938	Historic flood (Orange County covered by 3 feet of water)
1941	Construction of Prado Dam is completed by U.S. Army Corps of Engineers
1941	Colorado River Water Aqueduct is completed
1941	Coastal Municipal Water District is established, annexed to MWD as a member agency the following year
1949–1950	OCWD first purchases imported water from MWD
1951	Orange County Municipal Water District (OCMWD) is formed and annexed to MWD as a member agency
1952	Orange County Water Basin Committee establishes new water management policies
1954	Anaheim, Fullerton, and Santa Ana are annexed to OCWD
1954	OCWD establishes replenishment assessment (RA) to bring in revenue to purchase imported water to fill the groundwater basin
1957	OCWD purchases its first recharge basin, Crill Basin (later named to Anaheim Lake)
1961	Additional replenishment assessment is established for non–agricultural groundwater pumping to bring in revenue for capital projects
1965	Alamitos Barrier is operational
1969	Stipulated judgment resolves Santa Ana River water disputes
1969	Historic flood

1969	OCMWD changes name to Municipal Water District of Orange County (MWDOC)
1969	Basin Equity Assessment (BEA) and Basin Production Percentage (BPP) are created to assist OCWD in managing the groundwater basin
1972	Santa Ana Watershed Project Authority (SAWPA) is formed
1973	OCWD establishes its first water quality lab
1975	First northern California water deliveries to Orange County
1975	Water Factory 21 is operational
1978	Proposition 13 is enacted, restricting use of ad valorem tax
1983	Water Advisory Committee of Orange County (WACO) is established
1991	Green Acres Project is completed and begins operation
1991	Arlington Desalter becomes operational
1995	OCWD reaches historic agreement with the U.S. Army Corps of Engineers to store Santa Ana River flows behind Prado Dam
1995	Expansion of Prado Wetlands is complete
1996	Proposition 204 Water Bond passes
1996	A $20 million grant for the Groundwater Replenishment System (GWRS) is received from the U.S. Bureau of Reclamation through its Title XVI program
1997	GWRS joint board committee is formed to discuss preparation of required studies, governance issues, and public outreach
1999	Santa Ana River base flows peak at 158,637 acre–feet a year (afy) and begin a steady decline to approximately 75,000 afy over the next 20 years

1999	Environmental Impact Report (EIR) for GWRS is certified
2000	Proposition 13 Water Bond passes
2001	Coastal Municipal Water District is part of MWDOC
2001	Chino Desalter is operational
2001	OCWD and Orange County Sanitation District (OC San) approve design and construction of GWRS
2002	OCWD receives Proposition 13 grant in the amount of $37 million from the Southern California Integrated Watershed Program and SAWPA
2003	Department of Water Resources awards a $30 million Proposition 13 grant for GWRS
2003	OCWD enters into program allowing MWD to store imported water in the groundwater basin
2004	Water Factory 21 ceases operations
2004	OCWD and OC San break ground on the GWRS
2006	Voters approve Proposition 84, the Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006
2008	GWRS begins operation
2009	Advanced Water Quality Assurance Laboratory opens
2011	OCWD breaks ground on initial expansion of GWRS
2012	Advanced Water Quality Assurance Laboratory earns full certification from the Environmental Protection Agency (EPA) to monitor unregulated constituents of emerging concern (CEC)
2013	OCWD celebrates 80th anniversary and 5th anniversary of GWRS

2014	Proposition 1 Water Bond passes
2015	GWRS initial expansion is completed and begins operation
2016	Governor Brown signs AB 2022 into law, allowing the bottling of advanced purified drinking water to support educational outreach efforts
2017	OCWD develops cyclic storage agreement with MWD that allows pre-delivery of up to 100,000 acre–feet of imported water into the groundwater basin
2018	GWRS earns Guinness World Record title for greatest volume of drinking water produced from recycled wastewater in 24 hours (100 million gallons)
2019	OCWD breaks ground on final expansion of GWRS
2020	EPA identifies Orange County's North Basin as a Superfund site
2020	OCWD receives $131 million low–interest WIFIA loan to help finance per– and polyfluoroalkyl substances (PFAS) treatment plants
2021	Orange County's first PFAS treatment plant comes online in Fullerton
2022	GWRS makes over 1,000,000 acre-feet of water since coming online in 2008
2023	OCWD celebrates 90th anniversary and 15th anniversary of GWRS
2023	OCWD increases the BPP up to 85 percent
2023	Final expansion of GWRS is completed

Locations of District Headquarters

1933–1935	Garden Grove Chamber of Commerce office
1935–1941	Medical Building, 622 N. Main St., Santa Ana
1941–1947	Ramona Building, 118 W. 5th St., Santa Ana
1947–1957	1104 W. 8th St., Santa Ana
1957–1960	941 E. 1st St., Santa Ana
1960–1974	1629 W. 17th St., Santa Ana
March 1974	10500 Ellis Ave., Fountain Valley
1988–present	Field Headquarters, 4060 E. La Palma Ave., Anaheim
August 1991	New Administration Building completed
2007–present	18700 Ward St., Fountain Valley

Fountain Valley headquarters

Current Board of Directors

Division No.	Director	Since	Current Term Expires
1	Dina L. Nguyen, Esq.	12/14	12/26
2	Denis R. Bilodeau, P.E. 1st Vice President	12/00	12/24
3	Roger C. Yoh, P.E.	12/04	12/24
4	Van Tran, Esq. 2nd Vice President	12/22	12/24
5	Stephen R. Sheldon	05/05	12/26
6	Cathy Green President	12/10	12/24
7	Kelly E. Rowe, CFM, P.G., C.E.G., C.H.	12/18	12/26
8	Valerie Amezcua	12/22	12/26
9	Natalie Meeks	12/22	12/26
10	Bruce Whitaker	01/21	12/24

ORANGE COUNTY WATER DISTRICT
SECRETARY MANAGER/GENERAL MANAGER

C. A. Palmer	Director/Secretary	1933–1939
Wm. C. Mauerhan	Director/Secretary	1939–1942
W. W. Hoy	Secretary *(part-time)*	1942–1945
Dion R. Gardner	Secretary–Engineer *(part-time)*	1945–1949
W. D. Miller	Secretary *(part-time)*	1949–1953
Howard W. Crooke	Secretary Manager	1953–1968
Langdon W. Owen	Secretary Manager	1968–1973
Neil M. Cline	Secretary Manager	1973–1987
William R. Mills Jr.	Secretary Manager General Manager	1987–1988 1988–2002
Virginia Grebbien	General Manager	2002–2007
Michael R. Markus	General Manager	2007–present

DISTRICT SECRETARY

Mary E. Johnson	1988–1995
Barbara White	1995–1999
Janice Durant	1999–2023
Christina Fuller	2023–present

ASSISTANT DISTRICT SECRETARY

Thelma G. Willoughby	1952–1972
Mary E. Johnson	1972–1988
Barbara A. White	1988–1995
Janice Durant	1995–1999
Judy–Rae Karlsen	2000–2017
Christina Fuller	2017–2023
Leticia Villarreal	2023–present

History of Board of Directors

DIRECTORS
ORANGE COUNTY WATER DISTRICT
DIVISION 1

NAME	OFFICE HELD	DATES	TERM OF OFFICE
William C. Mauerhan			1933–1937
			1937–1941
Resigned 11/44			1941–1945
John W. Crill	President	1951–1955	1944–1945
	Vice President	1945–1951	1945–1949
Appointed 11/44			1949–1953
Died 5/55			1953–1957
Walter R. Schmid			1955–1957
Appointed 6/55			1957–1961
H. Louis Lake	1st Vice President	1973–1974	1961–1965
	2nd Vice President	1965–1973	1965–1969
			1969–1973
Died 4/74			1973–1977

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Thomas T. Lacy			1974–1977
Appointed 6/74			1977–1981
Resigned 6/79			
Kathryn L. Barr	President	1995, 2010	1979–1981
Appointed 8/79	1st Vice President	1988–1995	1981–1985
		2000–2002	1985–1990
	2nd Vice President	1985–1988	1990–1994
		2005–2007	1994–1998
			1998–2002
			2002–2006
			2006–2010
Retired 12/14			2010–2014
Dina L. Nguyen			2014–2018
			2018–2022
			2022–2026

DIRECTORS
ORANGE COUNTY WATER DISTRICT
DIVISION 2

NAME	OFFICE HELD	DATES	TERM OF OFFICE
C.A. Palmer	Secretary	1933–1939	1933–1935 1935–1939
Dion R. Gardner	President	1939–1943	1939–1943
Errol Trafford (E.T.) Watson *Resigned 11/75*	President Vice President	1955–1961 1951–1955	1943–1947 1947–1951 1951–1955 1955–1959 1959–1963 1963–1967 1967–1971 1971–1975

NAME	OFFICE HELD	DATES	TERM OF OFFICE
John V. Fonley	President 1st Vice President 2nd Vice President	1985–1988 1983–1985 1981–1983 1998–2000	1975–1979 1979–1983 1983–1988 1988–1992 1992–1996 1996–2000
Denis R. Bilodeau	President 1st Vice President 2nd Vice President	2002, 2003 2016–2018 2022– present 2008–2009	2000–2004 2004–2008 2008–2012 2012–2016 2016–2020 2020–2024

DIRECTORS
ORANGE COUNTY WATER DISTRICT
DIVISION 3

NAME	OFFICE HELD	DATES	TERM OF OFFICE
William Wallop			1933–1935
Resigned 12/38			1935–1939
Ralph J. McFadden			1938–1939
Appointed 12/38			1939–1943
			1943–1947
Resigned 12/48			1947–1951
Lewis Lemke			1948–1951
Appointed 12/48			1951–1955
Died 4/51			
Merwin Wagner	President	1961–1967	1951–1955
Appointed 4/51	Vice President	1959–1961	1955–1959
			1959–1963
			1963–1967
			1967–1971
			1971–1975
Resigned 2/78			1975–1979

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Lawrence P.	President	1988–1990	1978–1979
Kraemer Jr.	1st Vice President	1985–1988	1979–1983
Appointed 4/78		1998–2000	1983–1988
	2nd Vice President	1983–1985	1988–1992
		2000–2002	1992–1996
			1996–2000
			2000–2004
Roger C. Yoh	2nd Vice President	2013–2014	2004–2008
			2008–2012
			2012–2016
			2016–2020
			2020–2024

DIRECTORS
ORANGE COUNTY WATER DISTRICT
DIVISION 4

NAME	OFFICE HELD	DATES	TERM OF OFFICE
William Schumacher			1933–1935
			1935–1939
Job J. Denni Sr.			1939–1943
			1943–1947
			1947–1951
			1951–1955
			1955–1959
Resigned 9/62			1959–1963
Jake Van Dyke			1963–1967
Appointed 3/63			
Resigned 2/65			
Preston K. Allen	President	1975–1979	1965–1967
Appointed 4/65	Vice President	1974–1975	1967–1971
	2nd Vice President	1973–1974	1971–1975
			1975–1979
Resigned 12/80			1979–1983

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Philip L. Anthony	President	1992–1995	1981–1983
Appointed 2/81		2005–2007	1983–1988
	1st Vice President	2003	1988–1992
		2010–2012	1992–1996
		2016 –2018	1996–2000
	2nd Vice President	1990–1992	2000–2004
		2004	2004–2008
		2014–2016	2008–2012
			2012–2016
Died 7/18			2016–2020
Tri Ta	2nd Vice President	2020–2022	2018–2020
Appointed 9/18			2020–2024
Resigned 11/22			
Van Tran	2nd Vice President	2022–	2022–2024
Appointed 12/22		present	

DIRECTORS
ORANGE COUNTY WATER DISTRICT
DIVISION 5

NAME	OFFICE HELD	DATES	TERM OF OFFICE
C. Roy Browning			1933–1937
Resigned 3/39			1937–1941
Charles E. Smith			1939–1941
Appointed 3/39			1941–1945
Resigned 4/42			
C. Roy Browning			1942–1945
Appointed 4/42			1945–1949
			1949–1953
Resigned 2/55			1953–1957
Wayne Eaton			1955–1957
Appointed 2/55			
Disqualified by boundary realignment 9/55			
W. F. Mitchell			1956–1957
Appointed 1/56			1957–1961
Resigned 9/64			1961–1965
Minor Warne			1964–1965
Appointed 10/64			1965–1969
Resigned 1/70			1969–1973

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Paul H. Cleary			1970–1973
Appointed 3/70			1973–1977
Resigned 6/74			
E. Ray Quigley Jr.			1974–1977
Appointed 9/74			1977–1981
Resigned 10/80			
Langdon W. Owen	President	1990–1992	1980–1981
Appointed 12/80	2nd Vice President	1988–1990	1981–1985
			1985–1990
			1990–1994
			1994–1998
Jerry A. King	President	2000–2002	1998–2002
Paul Cook	1st Vice President	2004	2002–2006
Resigned 4/05			
Stephen R. Sheldon	President	2008–2009	2005–2006
Appointed 5/05		2020–2022	2006–2010
	2nd Vice President	2018–2020	2010–2014
			2014–2018
			2018–2022
			2022–2026

DIRECTORS
ORANGE COUNTY WATER DISTRICT
DIVISION 6

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Willis H. Warner	President	1933–1938	1933–1935
Resigned 12/38			1935–1939
Vernon C. Heil			1938–1939
Appointed 12/38			1939–1943
			1943–1947
Died 1/51			1947–1951
Gerald E. Price			
Appointed to fill term, never qualified because of election			
Roy Seabridge	President	1959–1961	1951–1955
	Vice President	1955–1959	1955–1959
			1959–1963
			1963–1967
Resigned 4/70			1967–1971
Noble J. Waite	President	1981–1983	1970–1971
Appointed 7/70	1st Vice President	1979–1981	1971–1975
	2nd Vice President	1975–1979	1975–1979
			1979–1983
			1983–1988
Resigned 11/91			1988–1992

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Wesley M. Bannister	President	1996–1997	1991–1992
Appointed 12/91	1st Vice President	1995–1996	1992–1996
		2008–2009	1996–2000
	2nd Vice President	1995	2000–2004
			2004–2008
Died 12/09			2008–2012
Noble J. Waite			2010–2010
Appointed 2/10			
Cathy Green	President	2014–2016	2010–2012
		2022–present	2012–2016
			2016–2020
	1st Vice President	2013–2014	2020–2024
		2018–2022	

DIRECTORS
ORANGE COUNTY WATER DISTRICT
DIVISION 7

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Frank B. Champion	President	1942–1943	1933–1937
	Vice President	1935–1945	1937–1941
			1941–1945
Resigned 3/45			1945–1949
Donald J. Dodge			1945–1949
Appointed 3/45			
Disqualified by boundary survey 7/49			
Stephen Griset			1949–1953
Appointed 7/49			1953–1957
Henry T. Segerstrom	President	1967–1983	1957–1961
	1st Vice President	1962–1967	1961–1965
			1965–1969
			1969–1973
			1973–1977
			1977–1981
Resigned 3/84			1981–1985
Donn Hall	2nd Vice President	1993–1994	1984–1985
Appointed 5/84			1985–1990
			1990–1994
Arnt G. "Bud" Quist	1st Vice President	1997–1998	1994–1998
	2nd Vice President	1996–1997	
Kelly E. Rowe			1998–2002
Resigned 12/00			
Jan Debay	President	2006–2007	2001–2002
Appointed 2/01	1st Vice President	2005	2002–2006
	2nd Vice President	2010	2006–2010
Shawn Dewane	President	2013–2014	2010–2014
	2nd Vice President	2016–2018	2014–2018
Kelly E. Rowe			2018–2022
			2022–2026

DIRECTORS
ORANGE COUNTY WATER DISTRICT
DIVISION 8, CITY OF SANTA ANA

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Courtney R. Chandler			1953–1977
John Garthe	President 1st Vice President 2nd Vice President	1983–1985 1981–1983 1979–1981	1977–1992
Daniel E. Griset	President 1st Vice President 2nd Vice President	1997–1998 1996–1997 1995–1996	1992–1998
Miguel A. Pulido			1998–1999
Thomas A. Lutz			1999–2000
Brett Franklin	2nd Vice President	2003	2000–2005
Jose Solorio			2005–2006

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Claudia Alvarez	President	2010–2012	2007–2013
Vincent Sarmiento	1st Vice President	2015	2013–2015
Roman Reyna			2015–2016
Vicente Sarmiento	President	2018–2020	2017–2020
Nelida Mendoza			2021–2022
Valerie Amezecua			2022–present

DIRECTORS
ORANGE COUNTY WATER DISTRICT
DIVISION 9, CITY OF ANAHEIM

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Charles H. Pearson			1953–1972
August F. Lenain			1972–1991
William D. Ehrle			1991–1992
Irv Pickler			1992–1995
Bob Zemel			1995–1996
Irv Pickler	President 2nd Vice President	1998–2000 1997–1998	1996–2002
Richard Chavez			2002–2007
Irv Pickler			2007–2012

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Harry S. Sidhu			2012–2015
Jordan Brandman			2015–2017
James Vanderbilt			2017–2018
Jordan Brandman			2018–2021
Harry S. Sidhu			2021–2022
Gloria Ma'ae			2022–2022
Natalie Meeks			2022–present

DIRECTORS
ORANGE COUNTY WATER DISTRICT
DIVISION 10, CITY OF FULLERTON

NAME	OFFICE HELD	DATES	TERM OF OFFICE
Cecil Crew			1953–1961
Howard M. Cornwall			1961–1968
Robert L. Clark	President 1st Vice President 2nd Vice President	1979–1981 1975–1979 1974–1975	1968–1988
George Osborne	President 1st Vice President 2nd Vice President	1995–1996 1995–1995 1994–1995	1988–1999
Jan M. Flory			1999–2002
Shawn Nelson			2002–2009
Don Bankhead	2nd Vice President	2011–2012	2009–2012
Bruce Whitaker			2012–2014
Jan M. Flory			2014–2017
Bruce Whitaker			2017–2019
Ahmad Zahra			2019–2021
Bruce Whitaker			2021–present

Glossary

"A"

Accumulated overdraft. The amount of water necessary to be replaced into the groundwater basin to prevent the landward movement of ocean water into the fresh groundwater body.

AF. Acre–foot. The amount of water needed to cover an acre (approximately a football field) one foot deep, or approximately 326,000 gallons. One acre–foot can support the annual indoor and outdoor needs of between one and two households per year.

AFY. Acre–foot per year.

Alamitos Barrier. Joint project between OCWD, Los Angeles County Dept. of Public Works, and the Water Replenishment District (WRD) for injection of imported water into a geologic gap at the Orange County–Los Angeles County boundaries subject to seawater intrusion.

Alluvium. A stratified bed of sand, gravel, silt, and clay deposited by flowing water.

AMP. Allen McColloch pipeline. A pipeline operated by the Metropolitan Water District to transport imported water within Orange County.

Annexation. The inclusion of land within a government agency's jurisdiction.

Annual overdraft. The quantity by which the production of water from the groundwater supplies during the water year exceeds the natural replenishment of such groundwater supplies from the same water year.

Aqueduct. A structure for transporting water from one place to another by means of a pipeline, canal, conduit, tunnel, or a combination of these features.

Aquifer. A geologic formation of sand, rock, and gravel through which water can pass and which can store, transmit, and yield significant quantities of water to wells and springs.

Artesian. An aquifer in which the water is under sufficient pressure to cause it to rise above the bottom of the overlying confining bed.

Artificial recharge. The addition of surface water to a groundwater reservoir by human activity, such as putting surface water into recharge basins. (See also: groundwater recharge and recharge basin.)

"B"

Base flow. River surface flow, not counting storm flow and/or purchased imported water.

BCD. Basin cleaning device. Patented by OCWD, a continuous clean–out system for removing the clogging layer that accumulates on the bottoms and sides of deep recharge basins and inhibits percolation.

BEA. Basin equity assessment. The additional fee charged by OCWD on water pumped that exceeds the basin production percentage, which makes the cost of that water equal to the cost of imported water.

Biofouling. The formation of bacterial film (biofilm) on fragile reverse osmosis membrane surfaces.

BMP. Best management practice. An urban water conservation measure that the California Urban Practice Water Conservation Coalition agrees to implement among member agencies.

BPP. Basin production percentage. The percentage of an OCWD member agency's total potable water demand that can be produced from the basin without subjecting that member agency to the BEA.

Brackish water. Water containing dissolved minerals in amounts that exceed normally acceptable standards for municipal, domestic, and irrigation uses. Brackish water is considerably less saline than seawater.

Brown Act. Ralph M. Brown Act. Enacted by the State legislature, a protocol that governs all meetings of legislative bodies. Also known as the Open Meeting requirements.

"C"

CEQA. California Environmental Quality Act. A California statute passed in 1970 that requires public agencies and local governments to evaluate and disclose the environmental impacts of development or other major land use decisions.

cfs. Cubic feet per second. The rate of flow or discharge equivalent to one cubic foot of water per second.

Chloramines. A mixture of ammonia and chlorine used to disinfect water.

Closed basin. A groundwater basin whose topography and geology prevent a subsurface outflow of water.

Colored water. Groundwater that is unsuitable for domestic use without treatment due to high color and odor that exceeds drinking water standards.

Confined aquifer. A water–bearing subsurface stratum that is bounded above and below by formations of impermeable, or relatively impermeable soil or rock.

Conjunctive use. The planned use of groundwater in conjunction with surface water in overall management to optimize total water resources.

"D"

Deep percolation. The percolation of surface water through the ground beyond the lower limit of the root zone of plants into a groundwater aquifer.

Degraded water. Water within the groundwater basin that, in one characteristic or another, does not meet primary drinking water standards.

Denitrification. The physical process of removing nitrate from water through reverse osmosis or other means.

Desalting (or desalination). Specific treatment processes, such as reverse osmosis or multi–stage flash distillation, that demineralize seawater or brackish (saline) waters for reuse. Also sometimes used in wastewater treatment to remove salts and other pollutants.

Desilting. The physical process of removing suspended particles from water.

Direct Potable Reuse. The injection of recycled water directly into the potable water supply distribution system downstream of a water treatment plant, or into the raw water supply immediately upstream of a water treatment plant. Unlike indirect potable reuse, there is no temporal or spatial separation between the recycled water introduction and its distribution to consumers.

Disinfection. Water treatment which destroys potentially harmful bacteria.

Drainage basin. Also called catchment area, watershed, or river basin, the area of land from which water drains into a particular river.

"E"

East Side Reservoir Project. A Metropolitan Water District project in Riverside County for the storage of imported water.

Effluent. Wastewater or other liquid, partially or completely treated or in its natural state, flowing from a treatment plant.

Evapotransporation. The quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and the surrounding soil surface. Quantitatively, it is expressed in terms of depth of water per unit area during a specified period of time.

"F"

Flocculation. A chemical process involving the addition of a coagulant to assist in the removal of turbidity in water.

Forebay. A portion of a groundwater basin where large quantities of surface water can recharge the basin through infiltration; also a reservoir or pond situated at the intake of a pumping plant or power plant that is used to stabilize the water level.

"G"

GAP. Green Acres Project. A 7.5 million gallons per day (mgd) water reclamation project that serves tertiary treated recycled water to irrigation and industrial users in Costa Mesa, Fountain Valley, Huntington Beach, Newport Beach, and Santa Ana.

gpm. Gallons per minute. Also known as flow rate, gpm is a measure of the gallons of water or other fluid that move per minute.

Gray water reuse. Reuse, generally without treatment, of domestic–type wastewater for toilet flushing, garden irrigation, and other nonpotable uses. This excludes water from toilets, kitchen sinks, dishwashers, and basins used for washing diapers.

Groundwater. Water that occurs beneath the land surface and fills partially or wholly pore spaces of the alluvium, soil, or rock formation in which it is situated. It does not include water which is being produced with oil in the production of oil and gas or in a bona fide mining operation.

Groundwater basin. A groundwater reservoir defined by all the overlying land surface and the underlying aquifers that contain water stored in the reservoir. Boundaries of successively deeper aquifers may differ and make it difficult to define the limits of the basin.

Groundwater mining. The withdrawal of water from an aquifer in excess of recharge over a period of time. If continued, the underground supply eventually becomes exhausted or the water table drops below economically feasible pumping lifts.

Groundwater overdraft. The condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average.

Groundwater recharge. The action of increasing groundwater storage by natural conditions or by human activity. See also: Artificial recharge.

Groundwater table. The upper surface of the zone of saturation (all pores of subsoil filled with water), except where the surface is formed by an impermeable body.

GWRS. Groundwater Replenishment System. An OCWD/OC San joint project that can produce up to 130 million gallons of high–quality water each day for groundwater replenishment.

"H"

Hydrologic balance. An accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit over a specified period.

Hydrologic cycle. The process by which water constantly circulates from the ocean to the atmosphere, falling to the earth in some form of precipitation, and finally returning to the ocean.

"I"

Imported water. Water that originates from one hydrologic region and is transferred to another hydrologic region. For example, Metropolitan Water District imports water from the Colorado River and northern California.

Indirect Potable Reuse. The planned use of recycled water for replenishment of a groundwater basin or an aquifer that has been designated as a source of water supply for a public water system.

Indirect Potable Reuse (Unplanned). The entry of wastewater into a natural water system (creek, river, lake, or aquifer) which is eventually extracted from that system for drinking water.

Inflatable rubber dams. A tube–shaped fabric that, when inflated, acts as a dam that raises the upstream water level. OCWD's rubber dams are designed to replace temporary sand levees on the Santa Ana River that wash out during heavy storm flow. They hold back high–volume river flows and divert the water into the off–river system for percolation.

In–lieu program. A program offered by OCWD in conjunction with the MWD seasonal storage program that financially encourages groundwater producers to turn off their pumping facilities and use MWD imported water to meet their demands, thereby indirectly replenishing the groundwater basin.

Interruptible water. Water from MWD that is subject to being shut off at any time, thus available at a discounted rate.

"L"

LIMS. Laboratory Information Management System. A software program that allows water samples to be logged into a computer and the analytical results to be automatically posted to the Water Resources Management System database.

"M"

maf. Million acre–feet. A unit of measurement typically applied to very large bodies of water. See acre–foot.

MCL. Maximum contaminant level. A drinking water standard set by EPA for a regulated substance in drinking water.

mgd. Million gallons per day. A flow rate expressed in millions of gallons per day.

mg/L. Milligrams per liter. A flow rate expressed in milligrams per liter.

Microfiltration. A physical separation process the involves the use of tiny, hollow straw–like membranes that separate particles from water. It is used very effectively as a pre–treatment for reverse osmosis.

"N"

Natural flows. Flows, such as those in the Santa Ana River, that are not placed into the system by human activities.

Non–interruptible. Water from MWD that is not subject to any interruption.

Non–point source pollution. Contamination of water that comes from diffuse sources rather than a single discrete source. See also: point source pollution.

NPDES. National Pollutant Discharge Elimination System. A federal permit authorized by the Clean Water Act, Title IV that is required for the discharge of pollutants to navigable waters of the United States. These waters include lakes, streams, rivers, bays, wetlands, storm sewers, tributaries to any surface water body, and the ocean.

"O"

OCCP. Orange County Coastal Project. The original name of the seawater barrier project at the Fountain Valley site, eventually renamed Water Factory 21.

OCWD Annual Engineer's Report. An annual report on the groundwater conditions, water supply, and basin utilization that is delivered in writing to the Secretary of OCWD on the second Wednesday in February of each year.

Operator or owner. Any person or group to whom a water–producing facility (well) is assessed by the county assessor or the person who owns the land on which the water–producing facility is located.

Overdraft. See: groundwater overdraft.

"P"

Perched groundwater. Groundwater located above an area of low permeability below which an unconnected groundwater basin exists.

Percolation. The downward movement of water through the soil or alluvium to the groundwater table.

Permeability. The capability of soil or other geologic formations to transmit water.

Point source pollution. Contamination of water that comes from a single discrete source. See also: non–point source pollution.

Potable water. Water that is suitable and safe for drinking.

ppb. Parts per billion. A unit of measurement used interchangeably with ug/L (micrograms per liter).

ppm. Parts per million. A unit of measurement used interchangeably with mg/L (milligrams per liter).

ppt. Parts per trillion. A unit of measurement used interchangeably with ng/L (nanograms per liter).

Primary treated water. Wastewater that has undergone the first major treatment in a wastewater treatment facility, usually sedimentation but not biological oxidation.

Prior appropriation doctrine. A policy that allocates water rights to the first party who diverts water from its natural source and applies the water to beneficial use. If at some point the first appropriator fails to use the water beneficially, another person may appropriate the water and gain rights to the water. The central principle is beneficial use, not land ownership.

Production, producing. The act of extracting groundwater by pumping or otherwise.

psi. Pounds per square inch. A measurement of the pound–force of a gas or liquid applied to an area of one square inch.

Purveyor. Another name for groundwater producer or pumper.

"R"

RA. Replenishment assessment. A fee to pump groundwater based on a charge on each acre–foot of groundwater extracted from the basin. Income from the RA finances the replenishment of the basin and projects for water recycling and water quality improvements.

Recharge. The physical process by which water naturally percolates or sinks into a groundwater basin.

Recharge basin. A surface facility, often a large pond, used to increase the infiltration of surface water into a groundwater basin.

Reclaimed wastewater. Wastewater that becomes suitable for a specific beneficial use as a result of treatment. See also: wastewater reclamation.

Reclamation project. A project involving water obtained from a sanitary district or system that undergoes additional treatment for a variety of uses, including landscape irrigation, industrial applications, and groundwater recharge.

Recycling. A type of reuse, usually involving running a supply of water through a closed system again and again. Legislation in 1991 legally equates the term “recycled water” to reclaimed water.

Riparian. Pertaining to the banks of a stream, river, or other body of water.

RO. Reverse osmosis. A method of removing salts or other ions from water by forcing water through a semi–permeable membrane.

“S”

Safe yield. The maximum quantity of water that can be withdrawn from a groundwater basin over a long period of time without developing a condition of overdraft. Sometimes referred to as sustained yield.

Salinity. Generally, the concentration of mineral salts dissolved in water. Salinity may be measured by weight (total dissolved solids – TDS), electrical conductivity, or osmotic pressure. Where seawater is known to be the major source of salt, salinity is often used to refer to the concentration of chlorides in the water.

SARI. Santa Ana Regional Interceptor. A used water discharge line that runs from the Inland Empire to OC San.

SARWQHS. Santa Ana River Water Quality and Health Study. An OCWD study to verify the safety of existing recharge operations using Santa Ana River water and to satisfy regulatory concerns with the Groundwater Replenishment System.

SB 1201. Senate Bill 1201. An Act that passed in June 1933, authorizing the formation of the Orange County Water District as a political sub–division of the State of California.

Seasonal storage. A three–part program offered by MWD.

Seawater barrier. A physical facility or method of operation designed to prevent the intrusion of salt water into a body of freshwater, such as OCWD’s Talbert Barrier or Alamitos Barrier.

Seawater intrusion. The movement of salt water into a body of fresh water. It can occur in either surface water or groundwater basins.

Secondary treatment. A level of treatment that produces 85 percent removal efficiencies for biological oxygen demand and suspended solids. Usually carried out through the use of trickling filters or by the activated sludge process.

Spreading basin; spreading grounds. See: recharge basin.

Storm flow. Surface flow originating from precipitation and run–off which has not percolated to an underground basin.

Subsidence. Sinking of the land surface due to a number of factors, including groundwater extraction.

Supplemental sources. Sources of water outside the watershed of the Santa Ana River purchased for the replenishment of the groundwater basin or used by an OCWD member agency to meet water demands.

Sustained yield. See safe yield.

SWP. State Water Project. An aqueduct system that delivers water from northern California to central and southern California.

“T”

Talbert Barrier. A series of multipoint injection wells through which OCWD injects water to maintain a seawater barrier. Water from this project is obtained from GWRS and deep–aquifer wells.

TDS. Total dissolved solids. A quantitative measure of the residual minerals dissolved in water that remain after evaporation of a solution. Usually expressed in milligrams per liter.

Tertiary treatment. The treatment of wastewater beyond the secondary or biological stage. Normally implies the removal of nutrients, such as phosphorous and nitrogen, and a high percentage of suspended solids.

THM. Trihalomethanes. Any of several synthetic organic compounds formed when chlorine or bromine combine with organic materials in water.

Transpiration. A process that occurs when plants take up water in a liquid state from the soil and release water vapor into the atmosphere through their leaves.

Turbidity. Thick or opaque with matter in suspension; muddy water.

"U"

Ultraviolet light disinfection. Often used as an alternative to chlorination, a disinfection method for water that has received either secondary or tertiary treatment.

"V"

VOC. Volatile organic compound. A chemical compound that evaporates readily at room temperature and contains carbon.

"W"

Wastewater. Water that has been previously used by a municipality, industry, or agriculture and has suffered a loss of quality as a result of use.

Wastewater reclamation. Treatment and management of municipal, industrial, or agricultural wastewater to produce water of suitable quality for additional beneficial uses.

Water Factory 21 (WF–21). Orange County Water District's advanced wastewater purification plant (1975–2004).

Water rights. A legally protected right to take possession of water occurring in a natural waterway and to divert that water for beneficial use.

Water year (OCWD). The period between July 1 of one calendar year to June 30 of the following calendar year.

Water year (USGS). The period between October 1 of one calendar year to September 30 of the following calendar year.

Watermaster. A court–appointed person(s) that has specific responsibilities to carry out court decisions pertaining to a river system or watershed.

Watershed. The total land area from which water drains or flows to a particular river, stream, lake, or other body of water.

Weir box. A device to measure and/or control surface water flows in streams or between a series of ponds.

Wellhead treatment. Water quality treatment of water being produced at the well site.

WPF. Water–producing facility. Any device or method, mechanical or otherwise, used for the production of water from the groundwater supplies within the District; a water well.

WRMS. Water Resources Management System. A custom computer application first launched in 1990 to assist District staff with the management and analysis of water resources data. This data includes well information, water quality, water levels, production, and recharge. The system is based on a set of integrated software programs consisting of a relational database (Oracle), computer–aided design (AutoCAD), geographic information system (GIS), and groundwater flow model (MODFLOW).

Bibliographic and Oral History Works Cited

Documents/Publications/Minutes

Anaheim Gazette, 12 March 1931.

Anaheim Gazette, 14 September 1933.

Anaheim Gazette, 19 October 1933.

Bailey, P. *Report to the Board of Supervisors of the Orange County Flood Control District Upon a Plan for The Control of Floods and Conservation of Water,* April 1929.

Baker, R. J. The Progressive Reform of the Santa Ana Watershed. MastersField Report. U of Calif., Riverside, 1983.

Blomquist, W. Dividing the Waters: Governing Groundwater in Southern California. San Francisco: ICS Press, 1992.

Blomquist, W. *Orange County.* Bloomington, IN.: Workshop in Political Theory and Policy Analysis, 1988. Vol. 5 of *The Performance of Institutions for Groundwater Management.* 7 vols.

Brigandi, Phil. Orange: The City Round the Plaza. Encinitas, CA: Heritage Media Corp., 1997.

California Codes. *The Orange County Water District Act,* as amended. Deerings *California Codes,* Uncodified Acts, Act 5683.

California State Senate. *Journal 47th Session, 1927. Report of State Mineralogist.* Sacramento: DNR, 1927.

Crooke, H. Planning and Providing an Adequate Supply of Water for Orange County, California. LTD. Professional Symposium on Salt Water Encroachment of Aquifers. Baton Rouge, Louisiana, May 1967.

Environmental Coalition of Orange County, Inc. Water Quality Report. 1, no. 4 (August 1975).

Gleason, *Present Overdraft.* Statement Regarding the Present Condition of the Underground Water Basin of Orange County. August 1945.

Hall, W. H. Irrigation in California [Southern]: The Second Part of the Report of the State Engineer of California of Irrigation and the Irrigation Question. Sacramento, 1888.

Hundley, N., Jr. The Great Thirst: Californians and Water,1770s–1990s. Berkeley: U of Calif. Press, 1992.

Huntington Beach Independent Review, 25 October 1975.

Lenain, A. The Orange County Water District. Typescript. 1983.

Lenain, A. The Saga of Water into Southern Calif. Typescript. 1983.

Lippincott, J. B. Report of Water Conservation and Flood Control on the Santa Ana River. Orange County, California, 1925.

Los Angeles Times, 1 September 1934.

Los Angeles Times, 23 April 1976.

Orange County Department of Agriculture. *Report of the Agricultural Commissioner,* Orange County, California. Anaheim, CA:, 1911, 1927.

Orange County Water District. *Annual Report* 1991, 1995, 1996. Fountain Valley, CA: OCWD.

Orange County Water District Board of Directors. *Minutes,* 1933–1994.

Orange County Water District. *The Annual Report: 50th Anniversary Edition.* Fountain Valley, CA: OCWD, June 1983.

Orange County Water District. *The District: A Perspective on the Orange County Water District.* 11 January 1994.

Oshio, K. Urban Water Diplomacy: A Policy History of the Metropolitan Water Supply in the Twentieth Century Southern California. Diss., U of Calif., Santa Barbara, 1992.

Poland, J. F. *Summary Statement of Groundwater Conditions and Saline Contamination Along the Coast of Orange County, California.* Orange County, CA: OCWD, September 1947.

Scott, A. J. High Technology Industry and Territorial Development: The Rise of the Orange County Complex, 1955–1984. Urban Geography 7, no. 1 (1986): 3–45.

Scott, M. B. Development of Water Facilities in the Santa Ana River Basin, California, 1810–1968. U. S. Geological Survey Open–File Report #77–398. Menlo Park, CA: U. S. Geological Survey, 1976.

Soja, E. W. Inside Exopolis: Scenes from Orange County. *Variations on a Theme Park.* Ed. Michael Sorkin. New York: Hill and Wang, 1992.

Superior Court of the State of California. *Orange County Water District v. City of Chino, et al.* No. 117628, *Settlement Documents* (1969).

Talbert, T. My Sixty Years in California. Huntington Beach, CA: Ben Franklin, 1982.

Weschler, L. F. Water Resources Management: The Orange County Experience. California Government Series # 14. Davis, CA: U of Calif., Davis, 1968.

Wesner, G. M. Historical Review of Water Factory 21: Orange County Water District Wastewater Reclamation and Groundwater Recharge Program, December 1987.

Wesner, G. M. Water Factory 21: Waste Water Reclamation and Sea Water Barrier Facilities. Santa Ana, CA: OCWD, February 1973.

Works Progress Administration. *A History of Irrigation in Orange County.* Orange County Project WPA #3105. Santa Ana, CA, 1936.

Oral History

Oral histories were conducted by Barbara A. Milkovich, Ph.D. Cassette tapes are on deposit at the Orange County Water District.

Cline, N., Santa Ana Watershed Project Authority General Manager. 17 December 1997. Riverside, California.

Dunivin, W., OCWD Water Production Superintendent. 24 November, 1997. Fountain Valley, California.

Flowers, A., OCWD Forebay Operations Manager. 4 December 1997. Anaheim, California.

Fonley, J., OCWD Director. 5 December 1997. Fountain Valley, California.

Mills, W., OCWD General Manager. 8 December 1997. Fountain Valley, California.

Osborne, G., OCWD Director. 30 October 1997 and 4 December 1997. Fullerton, California.

Owen, L., OCWD Director. 3 November 1997. Fountain Valley, California.

Pearson, C., former OCWD Director. Interview conducted by Richard D. Curtiss on 10, 18, 26 April 1968, and 7 May 1968. Transcript at Anaheim Public Library, Anaheim History Room.

Shen, Y., OCWD Laboratory Director. 5 December 1997. Fountain Valley, California.

Van Haun, J. OCWD Associate General Manager. 19 December 1997. Fountain Valley, California.

Attribution

This history of the Orange County Water District (OCWD) is based in large part on a document prepared for OCWD by Joseph J. Milkovich & Associates of Huntington Beach, California. The document, entitled *A History of the Orange County Water District and the River It Runs*, was primarily the work of Barbara A. Milkovich, Ph.D.

That document was submitted to OCWD in March 1998 and subsequently updated and reorganized to reflect the latest information on water issues and OCWD programs. Renamed *A History of Orange County Water Distric*t, it was published in book form in 2003. In 2013, The Acorn Group prepared the second edition, and in 2023, this third edition which coincides with the 90th anniversary of OCWD. The information stated in this edition is current as of May 2023.

ORANGE COUNTY WATER DISTRICT

SINCE 1933

OCWD's mission is to provide a reliable, high quality water supply in a cost-effective and environmentally responsible manner.

18700 Ward Street | Fountain Valley, CA 92708
714-378-3200
www.ocwd.com