SAN JOAQUIN PIPELINES

From Foothill Tunnel, Hetch Hetchy waters are piped under pressure 47.5 miles across California's San Joaquin Valley through three pipelines, built over a period of 37 years.

O'Shaughnessy anticipated the San Francisco Bay Area's growing need for water, and provided a 100-foot right of way for the aqueduct, sufficient space to build four parallel pipelines over time. The fourth bore has yet to be built, but is in the planning stages now, more than 70 years after the first pipeline was completed.

Water supplies enter the San Joaquin Pipelines at Oakdale Portal, where valves control the flow in all three lines, and is discharged into the Coast Range Tunnel at Tesla Portal, seven miles south of Tracy. Dropping below sea level, the pipelines pass 15 feet under the deep San Joaquin River and nearby Elliott Cut, where they are supported by timber piles and encased in reinforced concrete jackets.

Construction of Pipeline No. 1 started in 1931 and was completed the next year. The pipe is welded and riveted steel with a diameter that varies from 56 to 72 inches. Originally coated with asphalt and wrapped with asphaltum felt, in 1953 the interior asphalt lining was removed and replaced with cement mortar. At a construction cost of $5 million, the capacity of Pipeline No. 1 is 70 million gallons per day.

Pipeline No. 2, with a capacity of 80 million gallons a day, was completed in 1953 in response to regional growth during the baby boom. With an inside diameter of 61 inches throughout its length, the line includes 28.5 miles of welded steel pipe, coated and lined with cement mortar, and 18.5 miles of reinforced concrete pipe. The line cost $12.3 million to build.

Pipeline No. 3 is the largest of the three with a capacity of 150 million gallons a day. East of the San Joaquin River it is 78 inches in diameter, lined with coal tar enamel. Completed in 1968 at a cost of $19.5 million, it doubled the aqueduct capacity to a total for all three pipelines of 300 million gallons per day.

Coast Range Tunnel workers outside Mitchell Shaft 1934

At the San Joaquin River crossing, automatic pressure relief valves on all three lines discharge into the river in case of excess pressure.

COAST RANGE TUNNEL AND CONSTRUCTION DELAYS

One of the largest and most dramatic of the Hetch Hetchy undertakings, the Coast Range Tunnel is the final leg of the journey for Sierra Nevada waters before reaching the San Francisco Bay Area. This 28.5-mile-long tunnel through the Coast Range Mountains is in two sections - a 25-mile-long continuous tunnel from Tesla Portal to Alameda Creek, which was the longest in the world upon completion, and a 3.5-mile segment from Alameda Creek to Irvington Portal near Mission San Jose. At Alameda Creek, the two tunnel segments are connected by a multiple-pipe, inverted siphon, one-half mile long across the creek and Sunol Valley. The short section of tunnel through the Coast Range between the Alameda Siphons and Irvington Portal is now called Irvington Tunnel.

At the Alameda Siphons, interconnecting pipelines were built to transport local water supplies from San Francisco's reservoirs in the East Bay to the Sunol Valley Water Treatment Plant, and back to the Hetch Hetchy Aqueduct for transmission through the Bay Division pipelines.

O'Shaughnessy's master plan for Hetch Hetchy scheduled tunnel construction to start in the winter of 1925, but the work was delayed awaiting approval of the budget by the city's Board of Supervisors. When the budget was finally adopted in 1927, tunnel drilling started without delay.

Part of the two-year delay was caused by an increasing number of critics who viewed with alarm the hazardous working conditions, including flammable gases, groundwater, quicksand and swelling ground. Some engineers and political groups wanted the Hetch Hetchy water pumped over the Coast Range to save time and the expense of tunneling. O'Shaughnessy proved that a pipeline providing 60 million gallons per day, plus the pumping costs, would cost almost as much as a 200-million-gallon-per-day gravity-flow tunnel. Also, the pipeline would require a supplementary line in 12 years, while the pumping costs would go on forever!

Possible earthquakes were also forecast by tunnel critics. This threat was well known to the engineers; fracture areas of two earthquake fault lines were identified. The tunnel was designed to withstand earth tremors - some sections of the concrete-lined tunnel were even given flexible joints, innovative at the time.

Swelling ground was also a problem. Under Crane Ridge, at a depth of 2,500 feet, the 18-foot-in-diameter tunnel bore, supported and braced by timbers 18 inches square, was squeezed by ground swelling. In 24 hours the tunnel bore was reduced to three feet all around, turning the heavy timbers to kindling. In a few days the tunnel became so narrow that workers crawled through with difficulty.

To solve this problem, Hetch Hetchy engineers excavated the tunnel bore to an oversize diameter and sprayed thick rings of gunite, a slurry of cement mortar and water, on the tunnel walls, to stabilize them, leaving a one-foot gap for the swelling ground. As the ground-supporting gunite lining set up, it developed sufficient strength to hold before the swelling ground filled the gap. The problems have not recurred after a half century of constant use. Regular inspections confirm the tunnel to be virtually as sound as the first day water passed through it.

Lined entirely with concrete, three feet thick in some places, the 10.5-foot-diameter tunnel follows the general line recommended in the 1912 Freeman Plan. O'Shaughnessy's engineers moved the final route a little to the south to avoid, as much as possible, areas to the north suspected of producing noxious and flammable gases, especially hydrogen sulphide and methane, which were anticipated in the marshier areas.

DISASTROUS EXPLOSION - 12 LIVES LOST

With the start of construction, the 25-mile-long Coast Range tunnel was divided into seven work sections or headings by the two portals at Tesla and Alameda East, and five shafts: Thomas, Mitchell, Mocho, Valley and Indian Creek. Methane gas was first detected in Mocho Shaft and more stringent precautionary safety measures were imposed.

Despite the precautions and safety measures, however, the gang working on the east tunnel of the Mitchell Shaft encountered methane gas on July 17, 1931. In the resultant explosion twelve lives were lost. Several investigations following the tragedy concluded that Hetch Hetchy had conducted tunneling operations under the most strict safety methods used in California and the nation. The Alameda County Coroner's Jury found San Francisco and its agent Hetch Hetchy blameless. Although impossible to isolate the cause conclusively, the investigations established that neither electric wires nor locomotives had ignited the gas. Both Wolf Safety Lamps used for the detection of flammable gases were broken. In violation of safety rules, matches and smoking materials were also found in two of the victims' pockets.

These and other problems delayed construction progress. At times during the depression years, investment money was in short supply and several work headings were shut down for various periods pending the sale of bonds to finance the work.

O'SHAUGHNESSY BLAMED FOR DELAYS

By 1932, O'Shaughnessy had been City Engineer and Chief of the Hetch Hetchy Project for two decades. Delivery of Sierra Nevada water to San Francisco was still two years away from realization. Construction delays due to lack of financing, troublesome geological conditions and the loss of twelve lives, fueled the concerns of critics and officials who blamed O'Shaughnessy. The arrival of Hetch Hetchy water to a thirsty city was postponed because of the extra time it took to tunnel through the Coast Range. O'Shaughnessy's fiery temperament and abrasive manner over the years was starting to bear bitter fruit. Long-held grievances of important people who had been publicly challenged and rebuffed, resurfaced when Mayor Rolph, who had championed O'Shaughnessy in tough times, left San Francisco for Sacramento, having been elected Governor of California in 1931.

The new City Charter of 1932 went into effect following the purchase of the Spring Valley Water Company, forming the San Francisco Public Utilities Commission to control the Hetch Hetchy Project, San Francisco Municipal Railway, Water Department and Airport. A new management team was appointed to run the utility, and O'Shaughnessy was removed from his post as Chief Engineer. Edward G. Cahill was appointed the first General Manager of Utilities and Lloyd T. McAfee, an Assistant Chief Engineer under O'Shaughnessy, replaced his former superior as Manager and Chief Engineer of the Hetch Hetchy Project. The former Chief O'Shaughnessy was given an office in the Water Department and the title "Consulting Engineer," but he was effectively sidelined from an active role in construction and, according to accounts at the time, consulting with him was discouraged.

Construction workers in Coast Range Tunnel 1930

Construction of submarine sections of Bay Crossing Pipeline No. 1 1925

The new Charter required a competitive bidding process to complete the Coast Range Tunnel construction. Hetch Hetchy also had the right to bid and came in at $5,257,665, over half a million dollars less than the next lowest bid. When city forces finished the project, they still had some $1.5 million left over. In addition to the twelve men, the tunnel cost $28 million to build.

The final holing through of the Coast Range Tunnel came on January 5, 1934, between the Mitchell and Mocho access shafts, in the presence of, among others, Mayor Angelo Rossi, SFPUC Commissioners Lewis Byington and Erwin Eddy, and Utilities General Manager Edward Cahill. The Coast Range Tunnel was the last of facilities to be built in the aqueduct that stretched more than 160 miles across California to bring the mountain waters of Hetch Hetchy to the San Francisco Bay Peninsula. To honor the system's engineer, the ceremony of drilling through the last 12 inches of tunnel was briefly halted until O'Shaughnessy could arrive to take the first handshake from foreman Pete Peterson.

BAY CROSSING PIPELINE NO. 1 - SPRING VALLEY FINANCES START OF CONSTRUCTION

From Irvington Portal, the Hetch Hetchy waters only had to travel another 25 miles to reach the Peninsula. Spring Valley's Alameda Pipeline, built in 1888, consisted of 20 miles of riveted steel pipe 36 inches in diameter, followed by a 6,400-foot section of two submerged 16 inch pipelines on the floor of San Francisco Bay, too small to carry planned Hetch Hetchy water supplies. Spring Valley's deliveries were also constrained by the submarine pipes, and they became interested in San Francisco's proposals for a new Bay Crossing Pipeline.

By the time San Francisco was ready to build the first Bay Crossing Pipeline, it appeared that all of the $45 million originally authorized in 1910 to construct Hetch Hetchy had been expended. The city planned to request authority from San Francisco voters in October 1924 to issue $10 million in revenue bonds to complete the project, but that would result in an unacceptable construction shut down of nearly two years, laying off some 500 trained men with no guarantee of their return when work resumed. An alternative, to hold an early, special election for an interim $1 million bond issue was also rejected, due to its high $35,000 cost, a work stoppage of six months or more, and accompanying worker layoffs.

Rather than go for the $1 million bond issue and its associated costs and delays, Hetch Hetchy approached the Spring Valley Water Company for financing to begin construction of the transbay line. Under the terms of the 1911 State Railroad Commission order, the water arbiter at the time, and the 1922 agreement between Spring Valley and San Francisco, the city acquired an option to buy the Spring Valley Water Company and its assets to integrate with the Hetch Hetchy system once completed. Spring Valley agreed to cooperate with the city's request, and advanced four annual payments of $250,000 each, as pre-paid rent for its use of the Pipeline No. 1.

The private company did not make any money on this deal. It used its own good credit to borrow the money at the lowest available rates. San Francisco compensated Spring Valley for the interest costs so that the water company neither made nor lost money on the transaction. But, at the same time, Spring Valley was required to borrow money to finance its own construction work.

In an *Oakland Tribune* editorial on December 12, 1924, referring to "controversies which have hindered and threatened to halt the work...," the *Tribune* opined, "In the light of history, it seems a little incongruous that at the most critical period in the Hetch Hetchy war, and when the money was not available, the much-maligned Spring Valley Water Company came to the front to furnish the funds to complete the job. Volumes might be written on the subject, but suffice to say the company is to be commended... regardless of the fact that those who berated it and made it a target are some of those who are most prominent in Hetch Hetchy circles..."

Pipeline No. 1 was constructed 60 inches in diameter in a trench 25 feet deep in the mud and 75 feet below the water surface at Newark Slough and Dumbarton Strait. Completed in 1925 at a total cost of $6 million, the 21-mile-long line was put to use immediately per the agreement with Spring Valley Water Company to augment their own small line carrying Alameda waters to the Peninsula. When Pipeline No. 1 entered service, Spring Valley's Peninsula storage contained only 70 days water supply for the city.

Construction on the 1.7-mile long Pulgas Tunnel, the western terminus of the Hetch Hetchy Aqueduct in San Mateo County, was started June 23, 1922. By 1924 it carried Spring Valley water under a lease agreement six years before the city was to purchase the private water system in 1930.

Crystal Springs Pipeline No. 1 after earthquake 1906

BAY DIVISION PIPELINE NOS. 2, 3 & 4

In October 1924, San Francisco voters approved an additional $10 million to complete the Coast Range Tunnel and Bay Crossing, but this new money was not to be available until after January 1, 1925.

To increase water delivery capacity on the Hetch Hetchy Aqueduct, construction started on Bay Crossing Pipeline No. 2 in the summer of 1934, a few months after completion of the Coast Range Tunnel. Running parallel to Pipeline No. 1 in the same right-of-way across San Francisco Bay, Pipeline No. 2 is slightly larger at 62 to 66 inches in diameter. It was completed in 1936 at a cost of $4 million.

Pipeline Nos. 3 and 4 are each 34 miles long and rather than cross the Bay, they follow an underground right-of-way around its south end. The Bay Crossing Pipelines were renamed Bay Division Pipelines, which together with the two new transmission lines, were numbered 1 through 4 by date of construction. Separating the four pipelines into two pairs along very different alignments created operational advantages for delivery reliability, providing insurance against the loss of water supplies in a major earthquake or other natural disaster.

The Bay Division Pipelines differ in composition along their alignments, depending on their underlying ground or submarine conditions, consisting in portions of riveted steel, welded steel, reinforced steel cylinder and pre-stressed concrete. Completed in 1956, No. 3 is 72 to 78 inches in diameter and cost $10 million to build. Pipeline No. 4 is the largest, with a diameter ranging from 84 to 96 inches. Its final eight-mile link was completed on June 14, 1973 at a cost of $5.6 million, bringing the total transbay transmission capacity to 307 million gallons per day.

Bay Division Pipeline No. 1 on Trestle Bridge 1925

CRYSTAL SPRINGS BYPASS TUNNEL

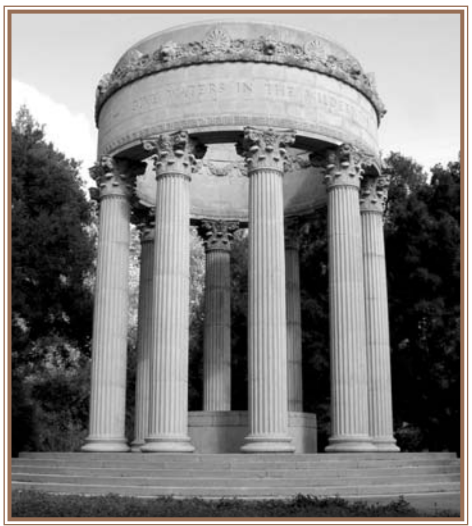
The Crystal Springs Bypass Tunnel was the realization of a Water Department plan to bring water directly from the Hetch Hetchy Aqueduct and the Sunol Filtration Plant into San Francisco and northern San Mateo County, bypassing Lower Crystal Springs Reservoir to streamline water deliveries and avoid the additional costs of surface water treatment on the Peninsula.

The tunnel was designed as a 3.25-mile-long bypass, nine feet in diameter and lined with concrete. Along with its connecting pipeline to the existing Crystal Springs Pipelines, the tunnel was completed in 1968 at a total cost of $8.6 million.

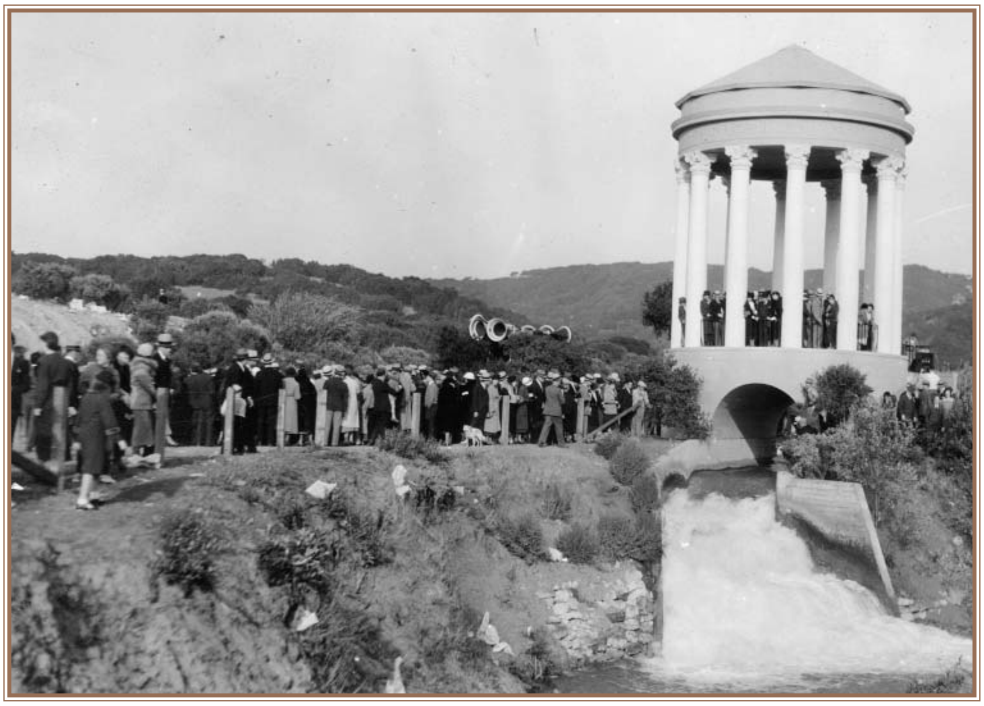
In 1975, a new $4.6 million, 60-million-gallon covered balancing reservoir, was built with its attendant pumping station near the Pulgas Water Temple, to coordinate the flows through Pulgas Tunnel into Crystal Springs Reservoir.

PULGAS WATER TEMPLE

The Pulgas Water Temple, bordering the Crystal Springs Reservoir, marks the terminus of the Hetch Hetchy aqueduct that conveys Tuolumne River water more than 160 miles from the Sierra Nevada to the San Francisco Bay Area. On October 28, 1934, the rush of Hetch Hetchy mountain water greeted a festive crowd of dignitaries gathered at the temple to celebrate its arrival.



Pulgas Water Temple 1940



Dedication ceremony for completion of Hetch Hetchy System, Pulgas Water Temple 1934

With vivid memories of the fire that had raged unchecked for lack of water following the 1906 earthquake, San Francisco rejoiced in its new secure, plentiful supply of high quality drinking water.

A new temple was designed in the Beaux Arts style by William Merchant, a San Francisco architect trained by Bernard Maybeck, completed in 1938. Merchant's design featured fluted columns and Corinthian capitals to reflect the architecture of ancient Greeks and Romans, whose engineering methods were used to build the new water system. Artist and master stone carver Albert Bernasconi brought Merchant's drawings to life. The frieze above the columns expresses the city's joyful relief at its new source: "I give waters in the wilderness and rivers in the desert, to give drink to my people."

O'SHAUGHNESSY TRAGICALLY MISSES HISTORIC DAY

By October 1934, San Francisco voters had authorized seven bond issues for a total of nearly $102 million to finance the Hetch Hetchy work: $600,000 in 1910, $45 million in 1910, $10 million in 1924, $24 million in 1928, $6.5 million in 1932, $3.5 million and $12.1 million in 1933. The terrible cost in human life to bring a secure, high quality water supply from the Sierra to San Francisco was 89 workers, including 12 workers lost in the Coast Range Tunnel disaster.

The first flow of mountain water into the San Francisco distribution system was an historical event, celebrated nationally on the occasion via radio on October 24, 1934. Accompanied by the Municipal Band, San Francisco Public Utilities Commission President Lewis Byington introduced the builders of Hetch Hetchy. Interior Secretary Harold Ickes, Mayor Angelo Rossi and Supervisor Jesse Coleman addressed the assembly and the nation over the Columbia Broadcasting System (CBS) coast-to-coast network, paying tribute to Chief O'Shaughnessy, but he was not there to hear it. Tragically, in the early morning hours of Friday, October 12, the 72-year-old O'Shaughnessy passed away at his home, after complaining of a pain over his heart.

CHERRY VALLEY SYSTEM

After raising O'Shaughnessy Dam in 1938, Hetch Hetchy engineers moved on to Cherry Creek Canyon, about 17 miles northwest. The Raker Act had authorized a third impounding reservoir in this valley to provide additional supply reliability and develop new energy resources.

San Francisco and the Modesto and Turlock Irrigation Districts had mutual interests in a new storage reservoir on Cherry Creek. San Francisco wanted to assure the reliability of its supply, while the two Irrigation Districts faced increasing demands for irrigation supplies from expanding agricultural development in the Central Valley.

Developing storage on the Cherry River, a tributary of the Tuolumne, would enable San Francisco to satisfy its obligations for daily releases to the two Irrigation Districts as required under the Raker Act, while preserving the high quality Hetch Hetchy supply for San Francisco's domestic water use.

The Army Corps of Engineers also became interested in the city's discussions about water storage facilities in the Cherry Valley, to address their concerns about ongoing damage from flooding on the lower reaches of the Tuolumne and San Joaquin Rivers.

Starting exploratory work in the Cherry Valley in 1941, San Francisco spent $200,000 over the next eight years to protect its rights and program the way until the four interested agencies entered into a cooperative agreement in 1949.

The agreement provided and required that:

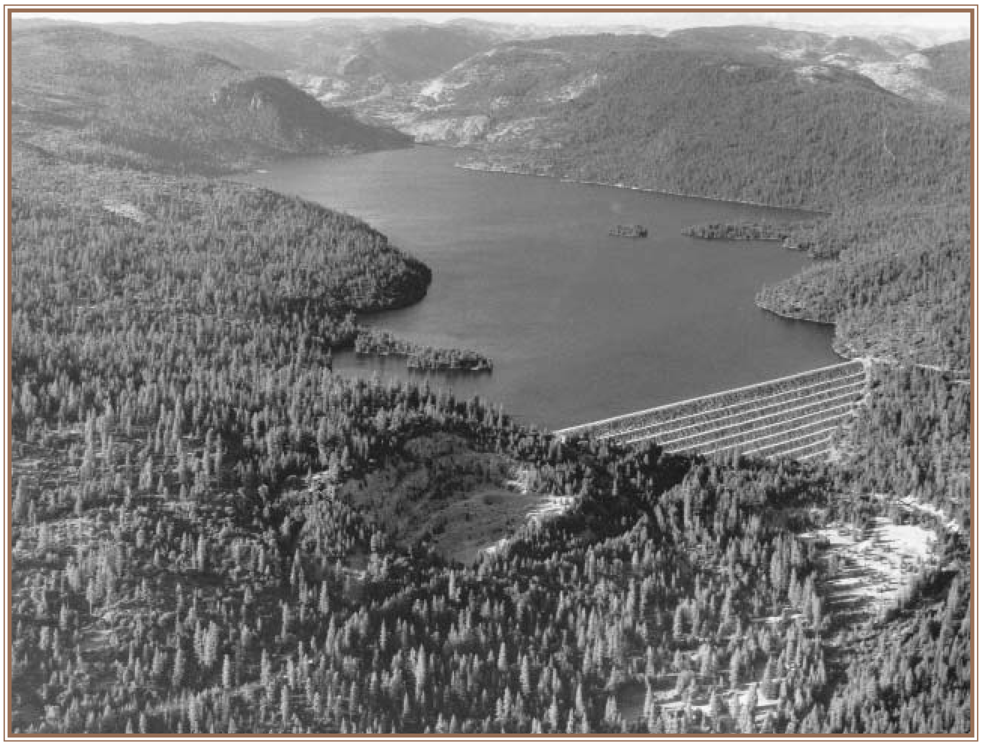
- San Francisco and the Modesto and Turlock Irrigation Districts would modify their existing facilities, construct new facilities, and operate them to reserve reservoir space for protection against Tuolumne River floods, in accordance with regulations established by the Corps of Engineers.
- San Francisco would construct a reservoir in Cherry Valley immediately.
- The Irrigation Districts would develop a new, larger reservoir on the lower Tuolumne at a later date, below the old Don Pedro Dam, inundating it.
- Upon completion of this larger New Don Pedro Reservoir, all flood control operations on the Tuolumne would be transferred to it.
- For flood control benefits, the Federal Government would pay $9 million toward construction of the $13 million Cherry Valley Reservoir and a subsequent amount (about $5.4 million) toward building the New Don Pedro Reservoir.
- For the right to use a stipulated amount of storage space in New Don Pedro, San Francisco would pay $45 million toward its construction.

The Cherry Valley project started in 1950. Heavy equipment had to be carried to the work site, so 26 miles of roads were built through rugged canyons and over mountain ridges. Power was supplied by a 10-mile-long power line on wooden poles from the venerable Early Intake Powerhouse. A diversion tunnel, 17 feet in diameter and a quarter-mile long, was drifted around the dam site.

Six years later, in 1956, the huge Cherry Dam was complete - 330 feet high above bedrock, 2,600 feet long, and 1,320 feet thick at the base. A composite earth and rock embankment dam, the central impervious core is of compacted, decomposed granite. The diversion tunnel was made a permanent outlet.

The reservoir formed by Cherry Dam, informally called Cherry Lake, was named Lake Lloyd in honor of Harry E. Lloyd, who was General Manager and Chief Engineer for Hetch Hetchy from 1952 to 1961.

Freeman's Plan contemplated a much smaller Cherry Lake, diverting to a much larger Lake Eleanor, which in turn would divert via a tunnel to Hetch Hetchy Reservoir for delivery to San Francisco. The Raker Act provisions granting Modesto and Turlock significantly increased water diversions during the spring runoff necessitated a change in the system's design. The Cherry system was reconsidered, and a new design developed principally to generate hydroelectric power for San Francisco, and divert the system's water supplies downstream to New Don Pedro Reservoir to satisfy the City's obligations to the Irrigation Districts.



Cherry Dam and Lake Lloyd (Cherry Lake) 1960

A six-mile-long, horseshoe-shaped pressure tunnel, 12 feet wide and 12.5 feet high, was bored through granite from Cherry Dam to Dion R. Holm Powerhouse to generate hydroelectric power before the water was returned to the river for delivery to the Irrigation Districts. The tunnel has a 400-foot-tall surge shaft and a rock trap near the downstream portal.

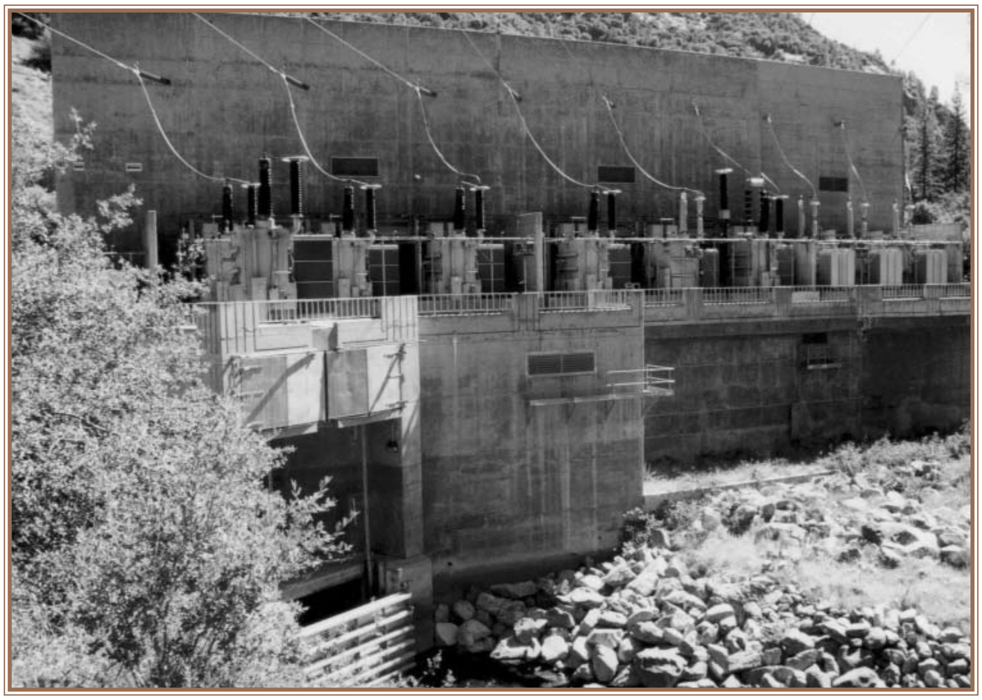
The Lake Eleanor watershed, which has a higher yield than the small lake can hold, supplements storage in the Cherry system via the Cherry-Eleanor Aqueduct and Pump Station, a mile-long tunnel drifted through the ridge between the two lakes which drains Eleanor water into Lake Lloyd.

DION R. HOLM POWERHOUSE

Development of the two additional hydroelectric power plants in the Hetch Hetchy system was delayed until the early 1960s to consider disposition of the energy created in compliance with Raker Act provisions. Since San Francisco does not own its municipal electric distribution system, Hetch Hetchy energy is delivered at bulk transmission voltages to other agencies for resale, or for wheeling, or transport, to the city's municipal loads and customers under contractual agreements with Pacific Gas and Electric Company (PG&E).

Dion R. Holm Powerhouse on the Cherry River, six miles downstream from the Cherry Valley Dam, came on line in 1960, and is the largest of the three Hetch Hetchy powerhouses. Each of its two vertical-shaft, turbine-driven generators is rated at 82,500 kilovolt amps (kVA). Voltage is stepped up to 230 kilovolts (kV) to transmit the power 1.5 miles to the Early Intake Switchyard.

Water for the powerhouse comes from the Cherry Power Tunnel and enters a 6,800-foot-long steel penstock. Tapering from 7.5 feet in diameter at the top to 5 feet at the powerhouse, the penstock drops the water 2,100 vertical feet. To withstand the high pressure, the penstock pipe is made from steel plate increasing in thickness from less than one inch at the top to 2.5 inches at the bottom.



Robert C. Kirkwood Powerhouse 1968

The Holm Power Plant, Tunnel, Penstock and all equipment except transmission lines represented an investment of $25 million for San Francisco.

The powerhouse was named after Dion R. Holm on August 25, 1967 to memorialize the former City Attorney who served as Hetch Hetchy counsel during the early operating years and who was a devoted advocate of the water and power system.

CANYON POWER TUNNEL

The 11-mile-long Canyon Power Tunnel takes Hetch Hetchy water from the base of O'Shaughnessy Dam through a steel pipe, nine feet in diameter, encased in concrete. Mainly unlined, it is horseshoe-shaped, 14 feet wide and 14.5 feet high. Sloping 10.5 feet to the mile, the pressure tunnel can deliver 970 million gallons per day.

Completed in 1965 at a cost of $11 million, at its greatest depth Canyon Power Tunnel is 2,000 feet below the surface.

ROBERT C. KIRKWOOD POWERHOUSE

Water for Kirkwood Powerhouse comes from the Canyon Power Tunnel and enters a 1,955-foot-long welded steel penstock, bifurcated in the last 65 feet when the third turbine was installed. Portions of the penstock are exposed on the hillside, anchored to their foundation with stressed tendons. The penstock drops the water 1,245 vertical feet.

The powerhouse was dedicated on August 25, 1967 to the memory of Robert C. Kirkwood, the General Manager of Public Utilities from 1959 to 1964, who passed away while in office. Cost of the penstock was $2.3 million and for the powerhouse, $5.6 million.

In 1988, a third generator was installed at Kirkwood Powerhouse at a cost of $47.5 million with a production capacity of 46,665 kVA, nearly one thousand times more powerful than the original turbines. This unit permits the powerhouse to use the full capacity of Canyon Power Tunnel during spill periods and provides sufficient power generation capability during maintenance periods on the other turbines. The original two vertical shaft turbines are rated at 43,125 kVA.

Kirkwood and Holm Powerhouses are normally operated by remote control from Moccasin Powerhouse, some 20 miles to the west. Remote operations start and stop generating units, adjust generator speed and voltage, take readings and perform switching. The Moccasin control room not only operates the three power plants, it also monitors their output into the 115 kV and 230 kV power transmission systems to Early Intake Switchyard.

Hetch Hetchy's power plants generate over 1.8 billion kilowatt hours (kWh) of electricity a year. Roughly 40% of that goes to satisfy San Francisco's municipal needs, including the Municipal Railway and street lighting. The balance is sold to central California irrigation districts and industrial customers.

POWER TRANSMISSION LINES

Two high voltage systems, normally independently operated, deliver Hetch Hetchy power to the Turlock and Modesto Irrigation Districts, and to the Pacific Gas and Electric Company (PG&E). Each delivery system includes its own line, switchyards, substations, circuit breakers, transformers and automatic protective equipment.

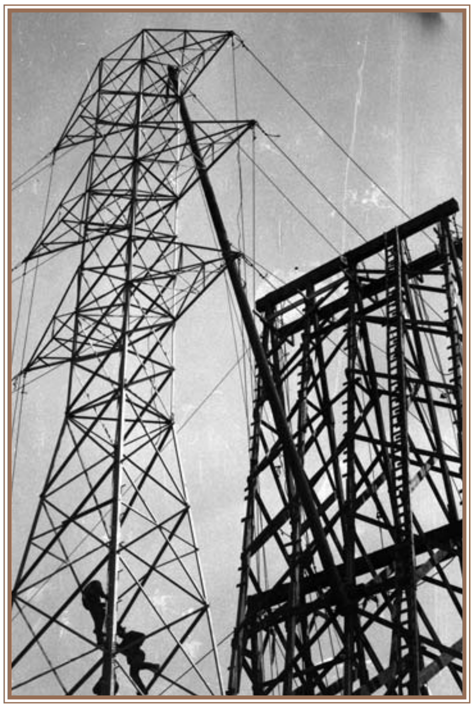
The Moccasin-Newark line operates at 115 kV for its 98.5-mile length. The three phase (six wires) circuits are carried by 506 steel towers, each 97 feet tall, except at the San Joaquin River crossing where they are 208 feet tall. Following the Hetch Hetchy Aqueduct right-of-way as far as Tesla Portal, the line was built during 1923 and 1924, terminating at the PG&E Newark substation.

Power generated by Holm and Kirkwood Powerhouses starts from the Early Intake Switchyard on a separate steel tower transmission line operating at 230 kV, double circuit. Via Moccasin, the line carries the power 48 miles to Warnerville substation near Oakdale, where the voltage is reduced to 115 kV for delivery to Turlock's Oakdale Substation and Modesto's Station J, 12.5 miles further down the line.

The circuits of the two lines are interconnected to the extent that the Moccasin-Newark line is tapped by irrigation district substations, while Warnerville is the terminal connection point with the PG&E 230-kV transmission system.

NEW DON PEDRO DAM AND RESERVOIR

As specified in the 1949 cooperative agreements with San Francisco and the Army Corps of Engineers, Modesto and Turlock Irrigation Districts proceeded



Hetch Hetchy power transmission towers 1924

with their construction of a massive new dam, about 1.5 miles downstream from the Don Pedro Dam they had built on the Tuolumne in 1923. At its completion, the old Don Pedro Dam had been the highest dam in the world. Now, less than half a century later, it was to lie 200 feet beneath the surface of a tremendously expanded reservoir, with a 165-mile-long shoreline, extending 24 miles into Moccasin Creek to the doorstep of Moccasin Powerhouse.

The San Francisco Public Utilities Commission invested $45 million of the 1961 voter-approved $115 million water system bond issue in the project, in return for a Hetch Hetchy credit of 740,000 acre feet of exchange water storage space in the new reservoir. The exchange storage created a water banking account for flows in excess of San Francisco's required water releases to Modesto and Turlock Irrigation Districts. San Francisco banks water in New Don Pedro during periods when daily runoff exceeds the Districts' flow entitlements under the Raker Act. This allows the City to later divert at its upstream facilities more water than it would be otherwise entitled to in exchange for a debit in the water bank. Along with San Francisco's investment in New Don Pedro Reservoir, the Army Corps of Engineers contributed $5.4 million for flood control.

Construction on New Don Pedro Dam started in 1967. A massive rock-fill dam rising 585 feet, it creates New Don Pedro Lake, inundating the old dam upstream under 250 feet of water. The new reservoir stores more than two million acre feet of water. Total cost of the project was $100 million.

On May 22, 1971, nearly 3,000 persons gathered for the dedication ceremonies and an address by San Francisco Mayor Joseph L. Alioto, followed by a beef barbecue hosted by the Turlock Irrigation District.

In 1996 during its reauthorization review of New Don Pedro Dam, the Federal Energy Regulatory Commission (FERC) required additional environmental releases from the dam to increase downstream flows for fish habitat in the San Joaquin River. San Francisco agreed to pay $3.5 million to the Irrigation Districts in lieu of releasing stored supplies from its water bank.

LOMA PRIETA EARTHQUAKE TESTS WATER SYSTEM

The great unknown about the magnificent system engineered to bring water from the mountains to San Francisco was how it would fare in a major earthquake. The Hetch Hetchy Project tunnels and pipelines had been constructed more than a decade after the Great Earthquake and Fire of 1906. Many original Spring Valley transmission mains that survived the 1906 temblor were still in place, and San Francisco reservoirs, built on bare hills in the late 19th century, now overlooked densely populated neighborhoods.

In preparation for the real thing, the San Francisco Public Utilities Commission had been conducting regular earthquake drills, testing radio transmission from various sites in the city, preparing priority response scenarios, and assigning field representatives to assess potential damage sites, including mains, reservoirs and pump stations. After every small earthquake, engineers checked the dams, tunnel portals and above-ground pipe supports for cracks or signs of strain.

On October 17, 1989, the Loma Prieta Earthquake struck shortly after 5:00 p.m., just prior to the scheduled start of the first game of the Bay Bridge World Series in San Francisco's Candlestick Park. Centered in Santa Cruz about 60 miles south-southeast of San Francisco on the San Andreas Fault, the magnitude 6.9 earthquake gave the city a major jolt, and its first field test of the water system's structural integrity and reliability under severe seismic strain.

Although the water mains in the Marina District failed, and there were pockets of low pressure in certain areas of the city caused by power failure, ninety-seven percent of customers in San Francisco had no loss of water supply. On the Peninsula, the dams and transmission lines were unaffected. The careful design of San Francisco's water system infrastructure withstood the attenuated force of the earthquake, enabling the system to meet most firefighting needs, except in the Marina, and supply the 2.4 million people in the Bay Area who depended on it.

Bay Division Pipelines on trestle bridge

Reliable delivery systems and earthquake preparedness continue to be very high priorities for San Francisco. Experts predict the very high probability of a major earthquake, magnitude 6.7 or greater, in the Bay Area within the next 30 years. Such an earthquake would impact San Francisco's infrastructure to a much greater extent than Loma Prieta, severely damaging transmission and distribution pipelines throughout the region, and potentially leaving customers in the city and its suburbs without safe drinking water for thirty days or longer. To improve system reliability in seismic events, San Francisco is taking steps to upgrade its water infrastructure, build new facilities with operational flexibility to provide alternate routes for water supplies when the main transmission system fails, and create interconnections with neighboring water systems to provide needed water supplies in an emergency.

REBUILDING SAN FRANCISCO'S WATER SYSTEM

San Francisco began to develop its water system improvement program in the late 1990's through a series of studies, reports, and authorizations. In 1998, a water supply planning effort was initiated in partnership with San Francisco's regional wholesale water customers in the Bay Area Water Supply and Conservation Agency (BAWSCA), culminating in the Water Supply Master Plan issued in April 2000. The plan recommended a water resource strategy of demand management, facilities improvements, and development of additional supplies.

Concurrent with water supply planning, the regional partnership cooperated on reliability studies of San Francisco's water system facilities to assess their vulnerability to earthquakes, landslides, fire, flood, and power outages. The studies produced recommendations for capital improvements to strengthen critical facilities against damage from natural events that could interrupt water service to the greater San Francisco Bay Area.

These planning studies led to San Francisco's development in 2002 of an ambitious long-term capital improvement program, along with strategic business and financial plans to accomplish it. The capital improvement program was adopted by the San Francisco Public Utilities Commission (SFPUC) in May 2002. A few months later, San Francisco voters approved the city's $1.6 billion portion of the cost to rebuild the water system and provide for its long-term stewardship.

In response to concerns from BAWSCA members about the risks to their communities if San Francisco's water service should be disrupted in a major seismic event, the California legislature enacted three bills in 2002, including Assembly Bill No. 1823, the Wholesale Regional Water System Security and Reliability Act. The bill requires San Francisco to proceed with due diligence on those capital improvements necessary to secure regional water delivery reliability for the future.

The water system improvement program has since been reconsidered and revised to reflect priorities determined by the service and performance goals established for the water system. The program is designed to:

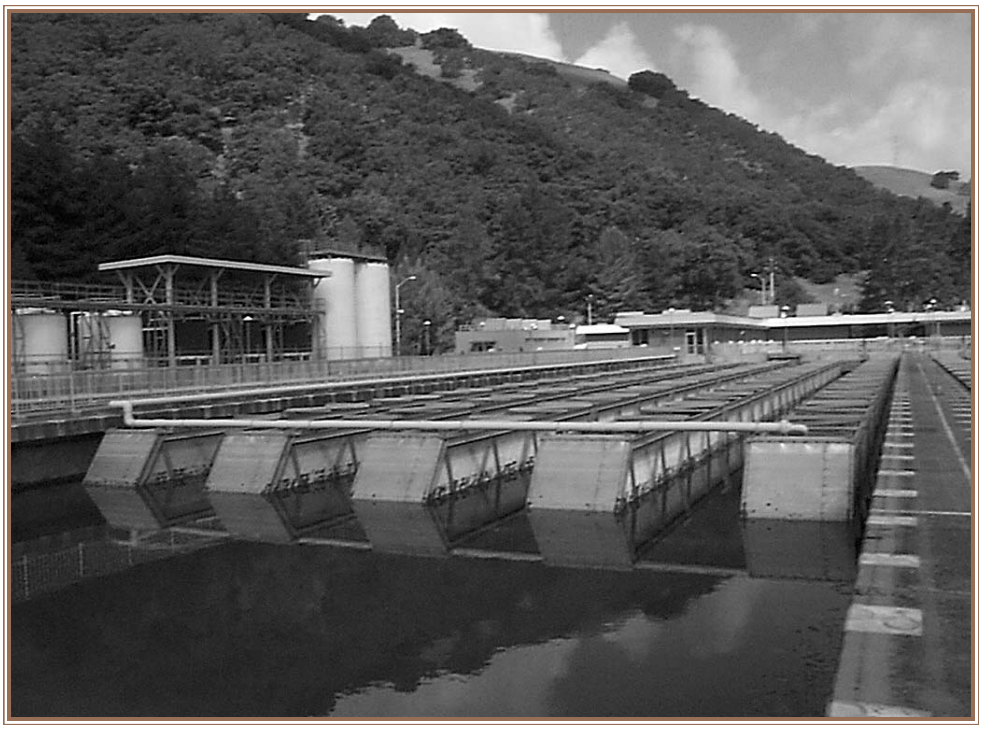
- Provide high quality water to reliably meet current and foreseeable local, state and federal requirements;
- Reduce system vulnerability to damage from earthquakes;
- Increase system reliability by improving redundancy needed to accommodate outages;
- Improve short-term water supply reliability and drought protection;
- Set forth long-term options to address water supply shortages and manage drought;
- Enhance sustainability through improvements that optimize protection of the natural and human environment;
- Provide improvements resulting in a cost effective, fully operational water system.

Achieving a reliable water system requires facility improvements that strengthen the reliability of water storage, treatment and delivery operations, as well as provide sufficient flexibility to operate the system despite facility outages from a catastrophic event, construction shut-down or planned maintenance. System redundancy may be achieved by providing expanded capacity in existing facilities, building a parallel facility, or creating an operational alternative.

Rebuilding the water system includes a variety of capital improvements. New tunnels and pipelines along the Hetch Hetchy aqueduct are planned to improve regional delivery reliability. Reservoirs, tanks and pump stations will be strengthened throughout San Francisco to reliably provide water supplies for public health and firefighting in an emergency. To maintain a healthy water supply, facility upgrades are planned to integrate new technologies and equipment into existing treatment plants. Facilities that are aging, in deteriorated condition or vulnerable to failure will be replaced with new facilities to achieve desired reliability objectives.

SUSTAINABILITY PLANNING

San Francisco is undertaking development of a Sustainability Plan as a strategic management tool to integrate and achieve a continuing balance of social, environmental and economic objectives through its policies and practices. San Francisco and its regional wholesale water customers have made a significant, long-term commitment to the future of their water system. It is critical that the SFPUC appropriately manage the physical and financial risks to its water system on behalf of ratepayers, and to make wise decisions on investments which value the unique natural resources, regional diversity, economic complexity and treasured quality of life of the San Francisco Bay Area today and in years to come.



Sunol Valley Water Treatment Plant improvements