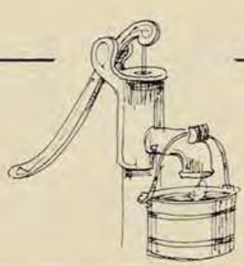
A Water Supply for San Francisco



Dedicated as a California Historic Civil Engineering Landmark by the San Francisco Section, ASCE

The city and county of San Francisco sits on the end of a 50-mile-long, semi-arid peninsula. Surrounded on three sides by salt water and constructed on sandy ground with little retentive capacity, very early in its history San Francisco had to solve its water supply problem.

With the great influx of gold seekers in 1849, San Francisco became the premier city of the Pacific Coast. Very quickly the few brackish streams and wells became inadequate for the thousands who settled in the shanties along the marshes and sandhills of the bay front. Enterprising peddlers ferried barges over from Marin, loaded with barrels of the precious liquid. In those pioneer days, "water routes," similar to modern milk-and-paper routes, crisscrossed the city, where water was delivered from stout barrels. During periods of scarcity, water sold for as much as one dollar in gold per five-gallon bucket.

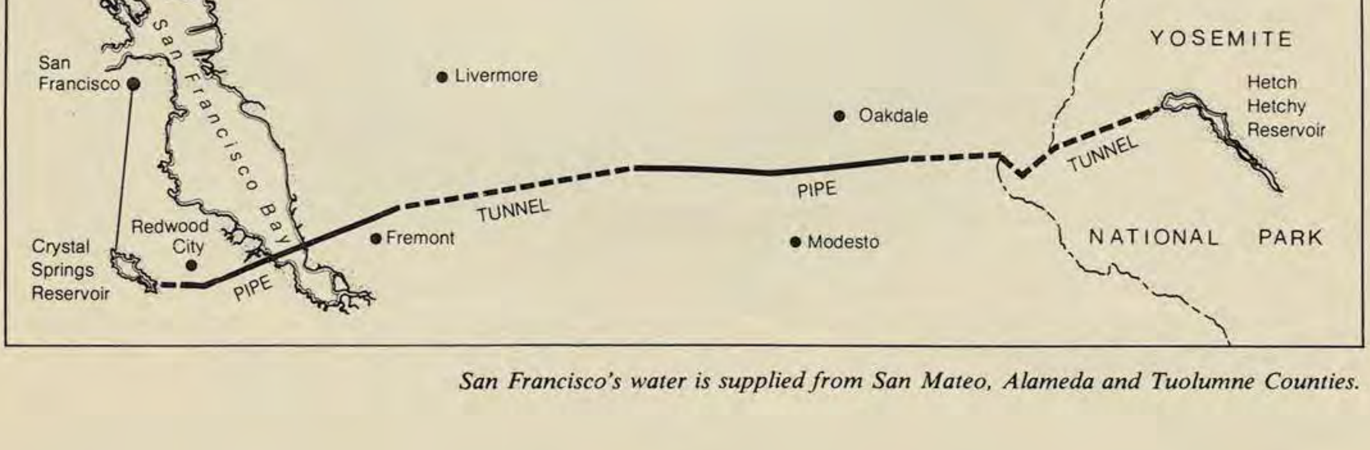
In 1857, the San Francisco Water Works was organized by a group of citizens who realized that the provision of an adequate water supply was standing in the way of San Francisco's continued growth. Tapping Lobos Creek, which then ran through the present Richmond District in western San Francisco, the company was able to supply two million gallons of water daily through five miles of flume and tunnel clinging precariously to the Golden Gate shoreline to a pumping plant at Black Point, near the present Aquatic Park. From this primitive steam-operated pumping plant, the first on the Pacific Coast, water was lifted to the Lombard and Francisco Reservoirs on Russian Hill, reservoirs still in use today.

In 1860, the Spring Valley Water Works was organized to develop water sources in San Mateo County. A reservoir was constructed on Pilarcitos Creek, twelve miles south of San Francisco, and carried in pipes and redwood flumes to the Laguna Honda Reservoir on present-day Seventh Avenue. Soon thereafter, the company acquired rights at spring-fed Lake Merced near the ocean.

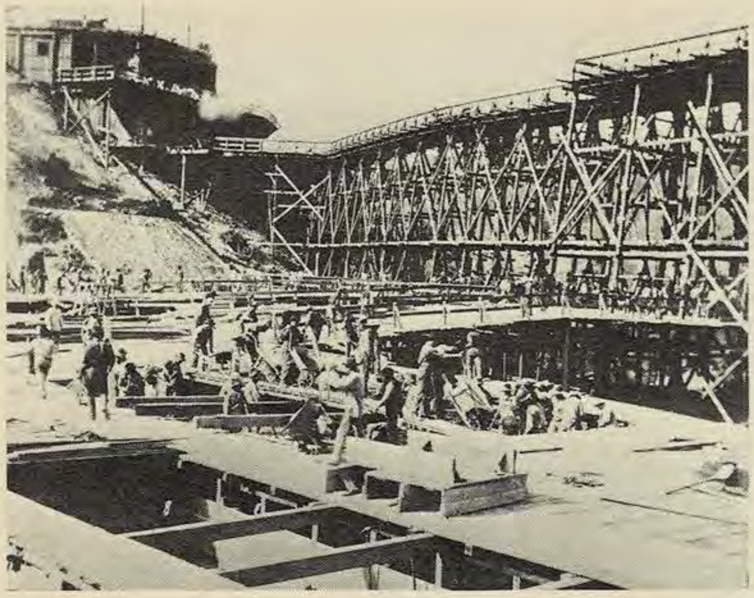
The two pioneer "water works" were consolidated in 1865 into the Spring Valley Water Company which, until municipalization in 1930, operated the city's water distribution system and was its principal source of supply.

Spring Valley first developed its "peninsula system." San Andreas Reservoir was built in 1870. Upper Crystal Springs Reservoir was filled in 1878 and Lower Crystal Springs Dam, completing the system, was finished in 1890. Unfortunately, recurring dry seasons, and the assumed inadequacy of water supply due to the many tragic fires which swept San Francisco, kept the problem of water supply prominent in city politics. Controversy continually arose between the water company and city officials as to rates and adequacy of service.

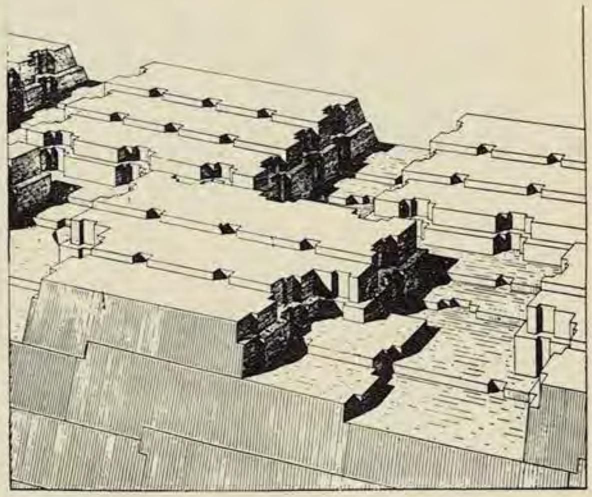
The first attempt by the city to acquire the Spring Valley system came in 1873 but was defeated at the polls. In 1875, the future site of Calaveras Reservoir,

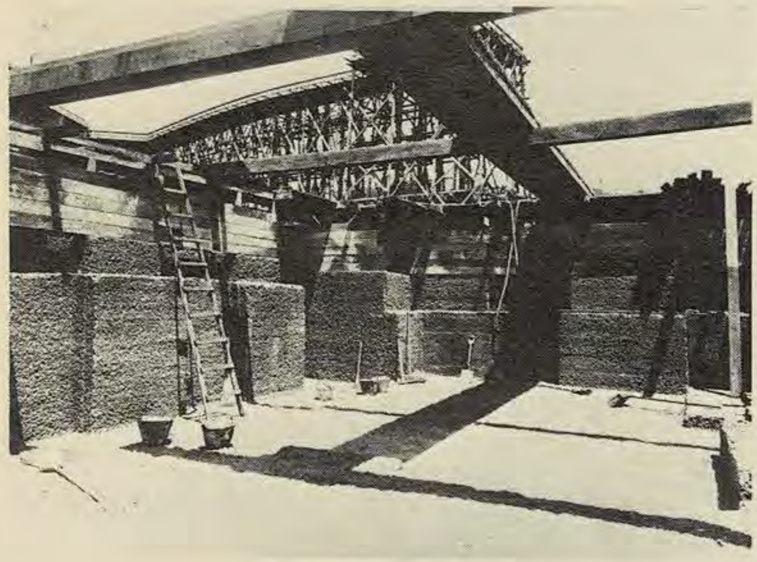


San Francisco's water is supplied from San Mateo, Alameda and Tuolumne Counties.



Crystal Springs Dam, 1890





Construction methods used for Crystal Springs Dam were the most advanced of their day. The three illustrations on this page show in detail the method of placing the blocks of concrete. (Upper left) *Workmen are making a pour.* (Lower left) *Block faces have been cleaned and roughened prior to the next pour.* (Above) *Diagram shows in perspective Engineer Schussler's system of interlocking blocks.*

on a branch of Alameda Creek on the property of General Mariano Vallejo's old mill, was offered for sale. Unable to raise money quickly enough, the city lost the land and water rights to the water company, which then developed the area as its "Alameda Creek System." A pipeline under the southern end of the bay was constructed to carry Alameda Creek water into the company's peninsula system. Development of the Alameda system included sinking wells in the gravel beds near Pleasanton, construction of Sunol Dam with its famous water temple and underground filtration galleries in 1900, and the eventual completion of Calaveras Dam in 1925.

The new city charter of 1900 provided for the eventual municipalization of the water system. With this end in mind, city engineers turned towards the Sierras for an adequate long-term source of high quality domestic water. Confirmed by a congressional grant embodied in the Raker Act of 1913, the city's acquisition of the Hetch Hetchy Valley for a reservoir, along with water rights on the Tuolumne River, were the first firm steps in the municipalization program. At that time, due in part to disruption from the 1906 earthquake and fire seven years earlier, water was selling in San Francisco for more than 25 cents a thousand gallons, and a large

In 1896, members attending the American Society of Civil Engineers convention visited Crystal Springs Dam, a pleasant day's outing by carriage.

Crystal Springs Dam today. The San Andreas fault runs through the middle of the reservoir behind the dam. Despite an eight-foot shift in 1906, the dam survived undamaged.

percentage of the city's residences were without waterlines, being served from water wagons. Somewhat unfairly, the company was blamed for much of the fire damage in the disaster, as the earthquake had ruptured its mains, and water ran freely from broken pipes in thousands of burned buildings.

Construction of the Hetch Hetchy system began in 1915, with a railroad and facilities for the hydroelectric portion of the system. The principal reservoir was impounded behind O'Shaughnessy Dam, completed to its first height in 1923. The transbay portion of the Hetch Hetchy Aqueduct was finished in 1925 to bring additional water from the Spring Valley company's newly finished Calaveras Dam. The city acquired the water company's entire operating properties in 1930, and the first Hetch Hetchy water was delivered in 1934, upon the completion of the Coast Range Tunnel.

Although the phenomenal post-World War II growth of the Bay Area was never imagined by Hetch Hetchy planners, the system has proven adequate in years of average precipitation to supply the needs of San Francisco and San Mateo County populations nearly three times greater than originally predicted.

Crystal Springs Dam, 1890

A key component of the old Spring Valley Water Company's peninsula system, the Crystal Springs Dam, completed in 1890, stands as a monument to the water company's chief engineer, Swiss-born Herman Schussler. Built when knowledge of concrete technology was very meager, it is an outstanding example of a structure free from physical defects after nearly 90 years of service.

By far the largest of the few pre-1900 concrete dams remaining in service today, its excellent quality was no accident but the result of practices even today regarded as excellent. Washed sands and coarse aggregates were used, the first known instance in this country, and, also for the first time, the water-to-cement ratio was carefully specified and monitored. In addition to ensuring a high quality in the materials used, engineer Schussler prepared a careful method of erection. Concrete was put into place within 15 minutes of being mixed. Spread in layers no more than three inches thick and thoroughly hand-rammed to fill all spaces, the placed concrete was water cured until completely hardened. Before each new placement, the exposed surfaces against which new concrete was to be placed were roughed with picks, then broomed and washed clean. Concrete was placed in an intricate system of interlocking blocks, cast alternately to minimize the effects of shrinkage. The blocks were staggered as to depth and height so that neither horizontal or vertical joints would be continuous.

The foregoing description is rather detailed so as to explain why the Crystal Springs Dam survived a disaster of magnitude great enough to destroy an entire city. At the time of the magnitude 8.3 San Francisco earthquake of 1906 along the San Andreas fault, the reservoir behind the dam was virtually full. The dam was located less than a quarter mile east of the fault, which runs through the reservoir. At this point the horizontal movement along the fault was eight feet; yet, although the Crystal Springs Dam was subjected to a torturous series of thrusts and pulls, no failures or cracks appeared, and no water was lost from the reservoir.

Crystal Springs Dam remains in service today, still forming a key segment of San Francisco's water system.

The Sunol Water Temple, 1900

At the upper entrance to Niles Canyon lies the gravel-filled depression of some 1,300 acres known as the Sunol Valley, through which the Alameda Creek drainage flows. To tap the waterflow through the porous gravels of this valley, chief engineer Schussler of the Spring Valley Water Company designed a novel system of subsurface water entrapment which served as a model for a similar system in Los Angeles.

A 28-foot-high concrete structure, Sunol dam, virtually entirely submerged, serves to back up the creek flow and keep the gravels flooded. A system of underground concrete galleries and perforated pipes collects the water percolating through the gravel beds, giving a dependable yield of approximately five million gallons daily during years of average precipitation. Over the open gathering basin which collects water from these galleries, engineer Schussler caused to be erected the famous Sunol Water Temple, a structure of classic simplicity. This structure is located in a public park maintained by the San Francisco Water Department.

Hetch Hetchy Project: Coast Range Tunnel, 1934

Of all aspects of San Francisco's mammoth Hetch Hetchy water project, the most difficult was the main 25-mile-long Coast Range Tunnel. Never before had such a long tunnel been proposed through such difficult ground. The coast ranges of California are geologically unstable, made of weak sedimentary rocks and fractured with innumerable faults.

These hazardous conditions prompted many to demand that a costly pipeline and pumping system be built over the range to avoid anticipated construction difficulties, but chief engineer M.M. O'Shaughnessy turned critics aside by pointing out that the tunnel, although the world's longest yet, would cost substantially less than any alternative.

A Water Supply for San Francisco

Graceful Sunol Water Temple (top) *marks the location of the underground percolation galleries* (above) *which are the key to gathering water from the Sunol Valley.*

Tiny Niles Dam (top), *shown under construction in 1897, is the first point of diversion for Alameda Creek water.* (Above) *A tired looking Michael O'Shaughnessy* (second row, fourth from left) *attended the holing through of the Coast Range Tunnel on January 5, 1934.*

Work began in 1927 on the principal 25-mile section, using five shafts to provide for additional working faces. The hazardous working conditions quickly proved to be even worse than predicted, as miners encountered explosive gases, ground water under great pressure, quicksand and swelling ground. The latter, where the rock begins swelling upon contact with air, was particularly severe beneath Crane Ridge, 2,500 feet underground where the squeezing effect was so severe that the timbers supporting the tunnel were crushed to kindling in a matter of hours. Within three days, the tunnel diameter was reduced from eighteen feet to three feet!

Eventually, this, and all other problems, including that of finance in the depths of the Depression, were solved, and the Coast Range Tunnel was "holed through" on January 5, 1934. First delivery of long-awaited Hetch Hetchy water to the city came later that year.

TECHNICAL DATA

Location — The San Francisco water system is made up of four different parts: the city distribution system, the peninsula system, the Alameda Creek system, and the Hetch Hetchy system and aqueduct.

Dates
- Crystal Springs Dam:
  - Built 1888-1890
  - Raised 4 feet 1911
- Sunol Water Temple: Built 1900
- Coast Range Tunnel:
  - Built 1927-1934

Cost
- Crystal Springs Dam: $2,531,000
- Sunol Water Temple: $32,000
- Coast Range Tunnel: $22,332,000

Engineers
- Hermann Schussler (1842-1919), chief engineer, Spring Valley Water Company to 1908
- M.M. O'Shaughnessy, chief engineer, Hetch Hetchy project

Dimensions
- Crystal Springs Dam (original stats.)
  - Built: 1887-1890
- Reservoir capacity: 69,200 feet
- Dam type: concrete gravity
  - Height from foundation to spillway: 154 feet
  - Width of crest at spillway: 40 feet
  - Width of base: 176 feet
  - Length of crest: 600 feet
- Coast Range Tunnel
  - Built: 1927-1934
  - Length: 29 miles from Tesla Portal south of Tracy, to Irvington Portal near Mission San Jose. Comprised of 25 miles of tunnel, a half mile of siphon and an additional 3½ miles of tunnel.
  - Diameter of tunnel as completed: 10.5 feet
  - Grade of tunnel: 2.64 feet per mile
  - Capacity of tunnel: 450 million gallons per day

SPECIAL NOTES

1. The Crystal Springs Dam introduced to US construction practice the following items:

   Required washing of all aggregates;

   Strict control and definite proportions of coarse and fine aggregates, cement and water in the mix;

   A definite water-to-cement ratio;

   Thorough machine-mixing of concrete;

   A short and controlled maximum time from mixing to placing of concrete;

   Thorough roughening, cleaning and washing of all concrete surfaces against which new concrete was to be placed;

   Curing of freshly placed concrete by covering and wetting;

   Controlled construction joints.

   That this care was important can be seen from the fact that the dam survived the 1906 'quake and remains watertight today, 90 years after construction.

2. The Sunol Dam and filtration galleries represent an original method of utilizing California's characteristically gravelly coastal geology and subsurface flowing water courses to develop and filter a municipal water supply. It provided a prototype for later installations in Southern California.

3. The Coast Range Water Tunnel was the longest water tunnel in the world when completed in 1934.