HISTORIC CIVIL ENGINEERING LANDMARKS

OF SAN FRANCISCO AND NORTHERN CALIFORNIA

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125th Anniversary
American Society of Civil Engineers
Annual Convention
San Francisco Section, Sponsor

OCTOBER 1977

Sixteen of the historic civil engineering landmarks in this book have been further recognized by the dedication of plaques commemorating their contribution to the profession and to the improved quality of life of the region. Typical of these plaques is that for Pacific Gas and Electric Company's Carquinez Straits transmission crossing, dedicated on September 16, 1976.

HISTORIC CIVIL ENGINEERING LANDMARKS

Prepared by
THE HISTORY AND HERITAGE COMMITTEE
San Francisco Section
American Society of Civil Engineers

William A. Myers, Editor

In recognition of
the outstanding pioneering achievements made by
the civil engineers of San Francisco and Northern California
in their quest for an improved quality of life.

October 1977

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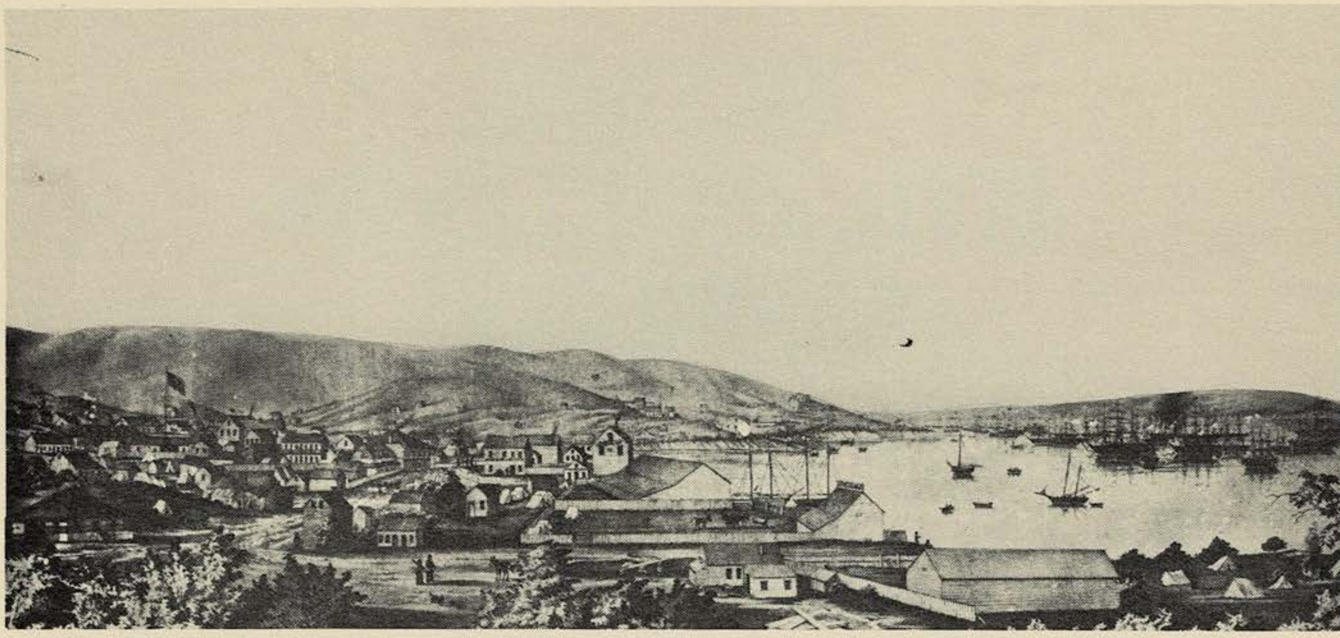
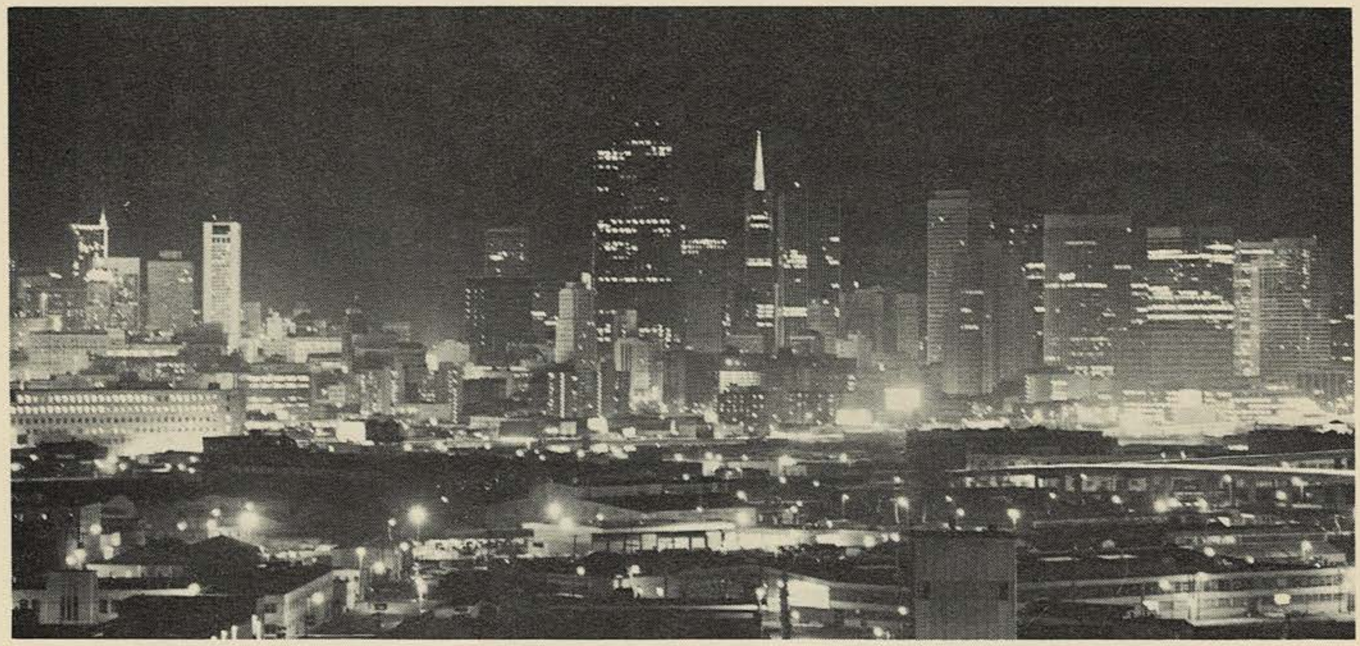
Pacific Gas and Electric Company





San Francisco has changed remarkably in 130 years. Major contributions by the civil engineering profession have enabled the tiny, flammable, disease-ridden Gold Rush boom town of 1849 to become today's thriving metropolis and commercial center.

Preface

The title page to this work contains the phrase "in recognition of the outstanding pioneering achievements made by the civil engineers of San Francisco and Northern California in their quest for an improved quality of life." Throughout its long and dedicated history, this quest has been the goal of the world's senior engineering discipline.

From the arrival of the first civil engineers in California one hundred and twenty-five years ago, the Golden State has presented unique problems which have called for innovative solutions by dedicated engineers. Earthquakes, population pressures with attendant problems of water supply and transportation, rugged geography, and long years of isolation from other centers of civilization are some of the threads weaving through the events on the pages which follow. The reader will encounter Anthony Chabot using herds of horses to compact the clay core of his dam; Joseph Strauss envisioning and building the impossible bridge; John Eastwood wandering alone through the rugged Sierras to design a hydroelectric project; Michael O'Shaughnessy overcoming, through the strength of his character, bitter personal attacks to see through to completion one of the world's major water projects; and Herman Schussler, whose personal attention to detail prevented a dam failure during a major earthquake. In these pages, too, will be found 100-foot waves, giant earthquakes, swift torrents, parched lands, friable "swelling ground," and the brilliant innovations which tamed, modified or conquered these forces of nature.

The San Francisco Section of the American Society of Civil Engineers, on behalf of its constituent branches North Coast, Redwood Empire, Golden Gate, San Jose and Fresno, presents with pride this catalog of noteworthy and historic civil engineering landmarks in San Francisco and Northern California. Some of these landmarks have received national recognition and will be familiar to many, while others are of primarily local significance. Nonetheless, all have contributed significantly to the technology and methodology of the civil engineering profession, and, more importantly, they have improved the quality of life for the people of the Bay Area and Northern California.

James E. McCarty, President

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Committee Co-Chairman, 1975-77

Brigadier General Richard M. Connell,
Committee Co-Chairman, 1976-77

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Committee Co-Chairman, 1975-76

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It is impossible to list all of the individuals and agencies who contributed to the success of the Northern California Historic Civil Engineering Landmark Designation Program. The History and Heritage Committee hereby wishes to thank everyone who made the program and this booklet possible.

The following are members of the History and Heritage Committee who have worked on this program over the last three years: Robert G. Binkley, Roberta Bliss, George D. Burr, Richard G. Carlile, Brigadier General Richard M. Connell, Guy Conversano, Thor J. Corwin, J.W. Desmond, William G. Dunn, Major General T.J. Hayes (USA, Ret.), Franklin T. Matthias, William H. McNeice, Bud McRae, A.J. Orselli, Major General David S. Parker (USA, Ret.), Rear Admiral Ira T. Sanders (NOAA, Ret.), Victor W. Sauer, F. Weston Starrett, Craig L. Sprankle, Arthur G. Strassburger, Leon Winters and Mark U. Viesselman.

The Editor

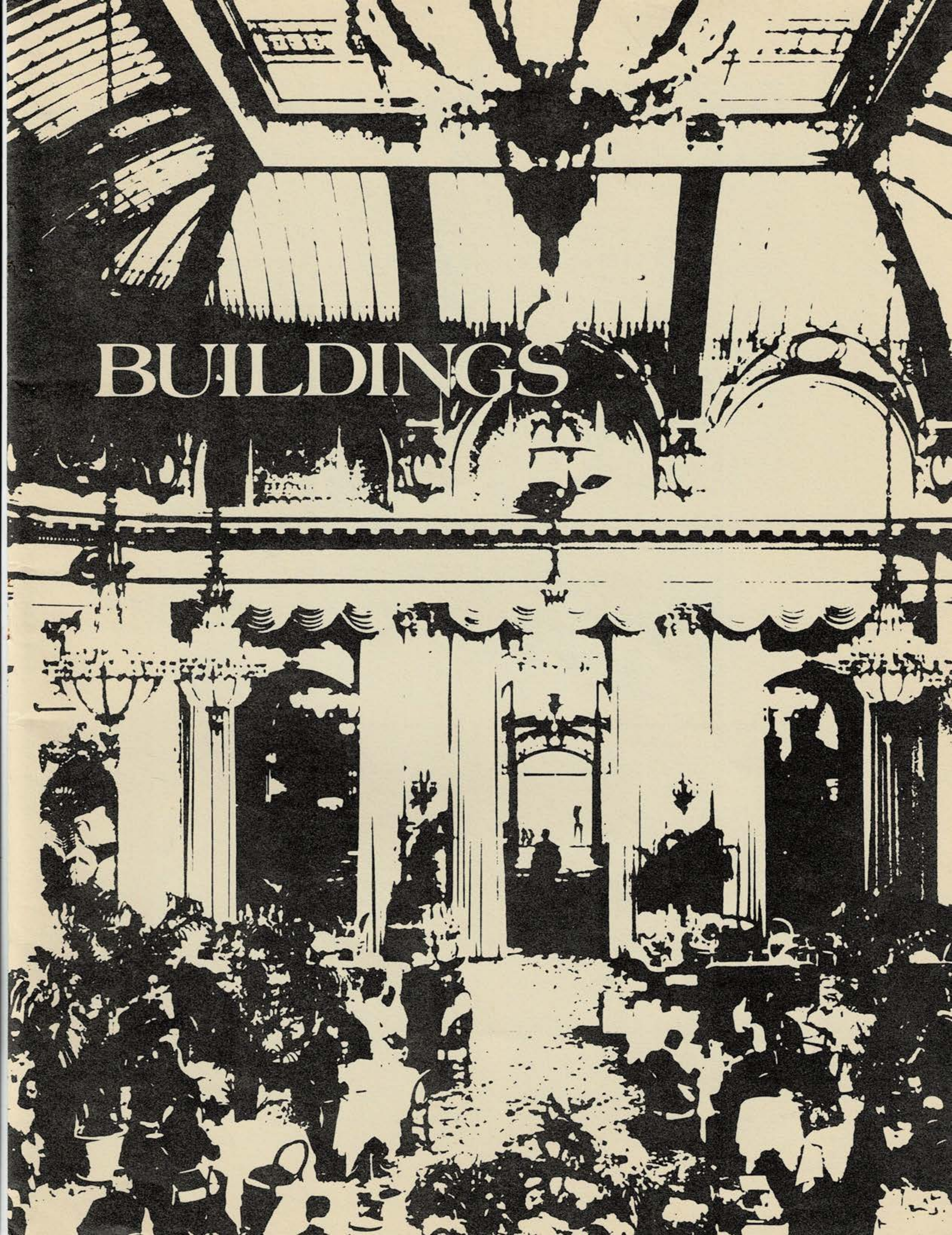
A sixth generation native of California, William A. Myers was born in San Francisco in 1947. He attended Menlo School in Menlo Park, California, and California State University at Los Angeles, majoring in history.

Mr. Myers has worked for the Southern California Edison Company since June 1971, working first in the Engineering and Construction Department, and presently in the Corporate Communications Department.

In addition to two books of poetry and articles for business and railway hobby periodicals, Mr. Myers has written for the American Society of Civil Engineers an earlier book in their historical series. This book describes the historic civil engineering landmarks of Southern California. His most recent publication, entitled "Trolleys to the Surf," is a history of West Los Angeles' Los Angeles Pacific Railway, a predecessor of the southland's famed "Big Red Cars." He is presently researching for additional books on electric railways. Mr. Myers has also produced a number of documentary films on railroad subjects. His hobbies include photography and model and prototype railroading.

Mr. Myers is an associate member of the American Society of Civil Engineers, a life member of the Railway and Locomotive Historical Society and a member of the California Historical Society.

BUILDINGS



The Ferry Building (1898)

Over 100,000 commuters a day once passed beneath the Ferry Buiding's famed clock tower.

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

Constructed at a time when the use of reinforced concrete as a building material was not entirely accepted by most engineers, San Francisco's famed Ferry Building was inspired by the pioneering work of Ernest L. Ransome, the San Francisco engineer who did much to make reinforced concrete a common structural material. By the mid-eighteen-nineties, West Coast civil engineers, led by Ransome, were willing to attempt complex concrete forms, and the design for San Francisco's new ferry terminal provided the opportunity, calling for the use of a series of groined vaults cast as a continuous structure.

Architect Arthur Page Brown supervised the initial construction of the Ferry Building in 1896 but was fatally injured in an accident, and work was carried on by Edward R. Swain. Although the contiguous state offices were not completed until 1903, the building was dedicated on July 11, 1898, when ferry service officially began from the new slips. Intended as both a ferryboat terminal and a state office building, the new structure replaced the old Central Terminal Building, whose three wooden sheds had been in operation since 1877.

Until the completion of the Golden Gate and Bay Bridges in the late 1930's, the Ferry Building served over 100,000 commuters a day, being surpassed only by London's Charing Cross Station as the world's busiest passenger terminal. Although an estimated 30 million people passing through the site proved a source of difficulty during construction, ferryboat service, amounting to 170 daily crossings, suffered no delay, nor were there any accidents or injuries to the traveling public.

The 1906 earthquake left the Ferry Building, already an important San Francisco landmark, shaken but scarcely damaged, although for an entire year afterward, the tower's clock hands pointed eloquently to 5:17 a.m. Fortunately, an order to demolish the building as unsafe was ignored. Ultimately, a committee of engineers inspected the building and found it structurally sound, vindicating the pioneering construction methods used.

After World War II, the famed ferries began to disappear from the bay, the last boat leaving the Ferry Building in 1958. Reflecting the changing role of the structure, the north wing was rebuilt in 1957 as the World Trade Center, with the addition of an inner third floor of office space. In 1962, the south wing was similarly rebuilt, so that today the Ferry Building has office space for over 1,000 people. The Embarcadero Freeway virtually became a part of the building's facade in the 1960's, eliminating the famous vista up Market Street before appalled San Franciscans halted further freeway construction. The Bay Area Rapid Transit District's transbay tube runs under the south wing. The Ferry Building became city property in 1969 when the State of California transferred port operations to the City and County of San Francisco.

The shoeshine stands, flower stalls, newsstands and Grand Central Station atmosphere of the building's heyday are gone now, but businessmen still congregate at the popular restaurant at the World Trade Club for lunch. And, in recent years, something new has been added to the Ferry Building: a ferryboat pier adjacent to the north wing.

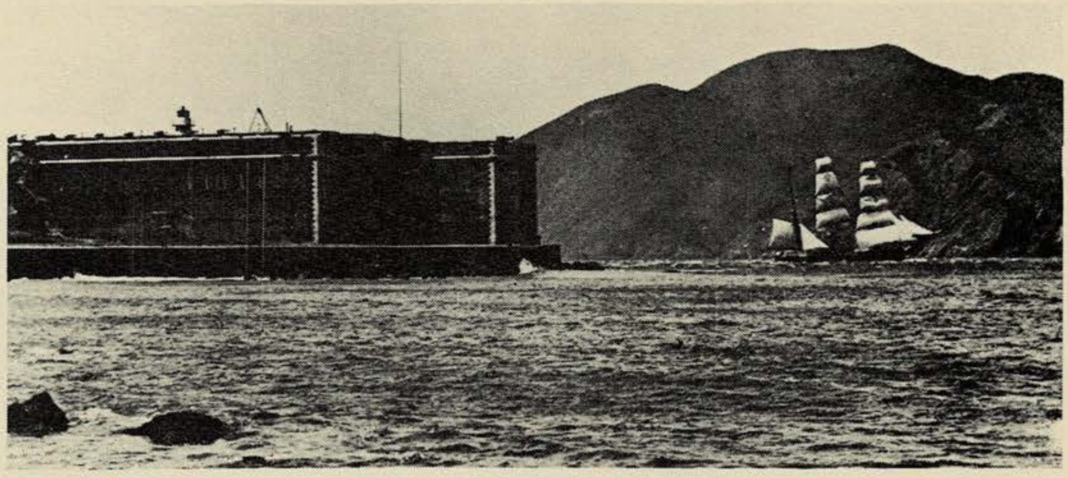
TECHNICAL DATA:

Location:	Foot of Market Street, San Francisco
Dates	Constructed 1896-1903 Dedicated July 11, 1898
Cost	$3.5 million (to 1903)
Architects	Arthur Page Brown Edward R. Swain
Engineer	Howard C. Holmes, chief engineer for the Board of Harbor Commissioners
Dimensions	Main building and wings: 659 feet long, 159 feet wide Wings: 58 feet high Clock tower: 32 feet square, 235 feet high

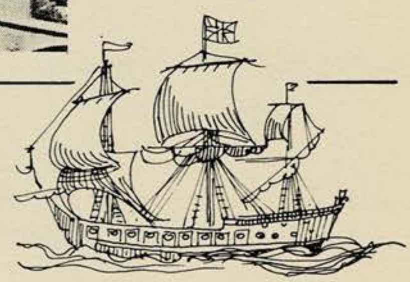
SPECIAL NOTES

1. The Ferry Building's foundation, completed in 1896, consists of 11 concrete piers, 16′ x 28′ at the base and 8′6″ x 28″ at the top, with a depth of 20′ below city base. These piers are joined together by a series of groined concrete arches 2′ thick at the soffitts to form a floor dimension of 160′ x 670′. Supported by 5,000 piles, this type of construction was the first of its kind ever used on the West Coast.
2. During construction, a test arch of expanded metal and concrete was built and tested, and it was found able to support a load of 744 pounds per square inch (psi), ten times the actual requirement.

The Ferry Building once was one of the world's busiest intermodal transportation facilities, with over 170 ferryboats connecting with streetcar lines radiating throughout San Francisco.

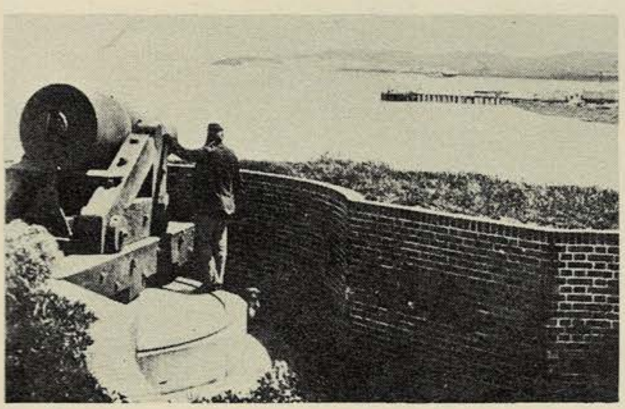


Old Fort Point, bristling with cannon, was for years known as "The Gibraltar of the Pacific."



Fort Point (1861)

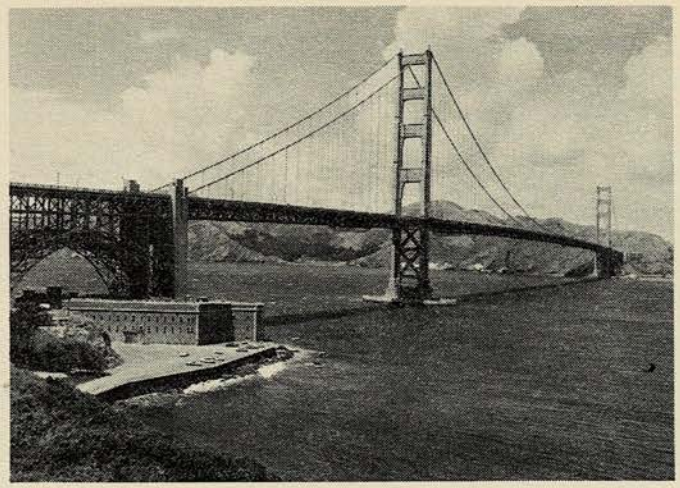
Dedicated as a California Historic Civil Engineering Landmark by the San Francisco Section, ASCE



The fortress's Civil War-era muzzle-loading cannon commanded a broad expanse of the bay and the Golden Gate.

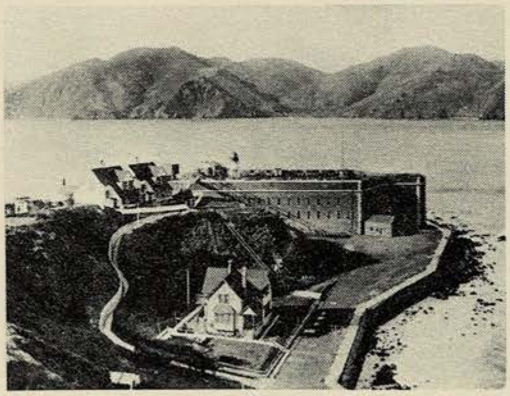
When Captain George Vancouver of the British Royal Navy sailed into San Francisco Bay in November 1792, he was graciously received by the Spanish colonists at Yerba Buena. Shrewdly, the sea captain visited the precipitous white cliffs along the south side of the Golden Gate, noticing the lack of defensive works. After Vancouver sailed away, the Spanish governor of California, angry over the hospitality of the local residents, ordered a fortress built on top of the white cliffs.

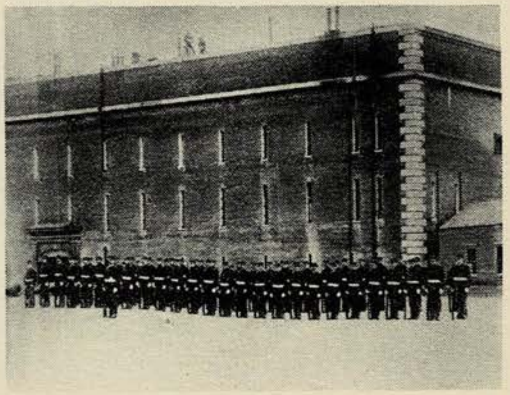
Named **El Castillo de San Joaquin,** the rude adobe structure armed with century-old brass cannons cost the Spanish treasury $6,400. Wind, rain, salt, fog and several earthquakes kept the fort in a constant state of disrepair until, in 1835, the crumbling fort, by then flying the flag of Mexico, was abandoned.



The builders of the Golden Gate Bridge recognized the historical value of Fort Point and modified the south approach design to preserve the structure.

From a home of military pomp and ceremony during the Civil War (far right), *Old Fort Point deteriorated into a lighthouse station by the turn of the century* (near right).





The old **Castillo** stood as an uncertain guardian over the entrance to the Golden Gate until July 1, 1846, when, in anticipation of the forthcoming war with Mexico, the fort's few remaining guns were spiked by irregular American forces led by John C. Fremont.

After the conquest of California, US troops moved into the Presidio of San Francisco and set up a battery of guns in the old fort. Plans for a new permanent fortification were prepared, and in 1853 the **Castillo** was torn down, and the 100-foot-high white cliffs upon which it stood were cut down to within 10 feet of the water, so that the flat-trajectory guns of the new fort would have a better shot at the waterlines of invading ships. The new fort itself was patterned after the French-style brick forts common on the East Coast, like Fort Sumter.

By March 1855, granite slabs were being laid in cement in a deep trench to form the fort's foundation. China clippers sailing through the Golden Gate brought in some of the blocks as ballast but most of the granite was quarried at nearby Folsom. By 1856, the first story was completed using pressed brick supplied by George D. Nagles of San Francisco, each brick bearing his name. In 1857 the second tier of gun arches was finished. In September 1858, engineer Lieutenant G.W.C. Lee, son of Robert E. Lee, was placed in charge of the construction work at the fort and ordered 200,000 bricks from the state prison at San Quentin to finish the fourth floor.

By January 1861, the massive fort was completed. At that time, it appeared in official correspondence as "Fort Point" and began its half century of guard duty at the Golden Gate as the anchor for the nation's entire Pacific Coast defenses.

Ironically, within a year, the shells and rifled cannons used in the Civil War rendered Fort Point's brick construction obsolete. Fortunately, no rifled cannon came into the hands of Southern sympathizers on the Pacific Coast, and the fort remained "impregnable" during the Civil War.

By the 1890's, however, the fort, officially renamed Fort Winfield Scott in 1882, was hopelessly obsolete. Augmented with, then replaced by, more modern "disappearing guns" and heavy coast artillery batteries emplaced on the bluffs behind the fort, the old facility was finally deactivated in 1905, having never fired a shot in anger.

So well built was the old fort that it survived the 1906 earthquake with little damage. In 1917, Fort Point, as it was again called, was used as a temporary billet for AEF trainees. It was also prepared to serve as a military prison for German prisoners of war, although there is no record that any were actually confined there.

The greatest threat to the fort came when work began on the Golden Gate Bridge in 1933. Directly in the path of the southern approaches to the bridge, the fort was saved by bridge engineer Joseph P. Strauss who designed a steel arch to vault the bridge approach over Fort Point. During bridge construction, the fort became a warehouse and construction headquarters.

Reactivated in World War II, the fort was headquarters of Battery B, First Battalion, 6th Coast Artillery, charged with the antisubmarine defense of the Golden Gate. In 1970, the fort was declared a national historic site, and restoration to its Civil-War-era appearance is ongoing. It is now operated by the National Park Service as a part of the Golden Gate National Recreation Area.

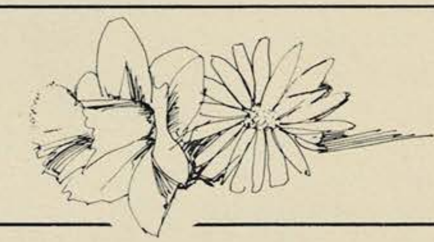
TECHNICAL DATA

Location	Fort Point (Fort Winfield Scott), Presidio of San Francisco
Dates	Original construction: 1853-1861 Activated: January 19, 1861 Deactivated: 1905
Cost	Original construction, including fort and seawall: $3.2 million
Engineers	(all US Army Corps of Engineers) Lt. Col. James L. Mason Major J.G. Barnard Lt. Col. R.E. DeRussy Major Z.R. Tower LT. G.W.C. Lee
Dimensions	Fort Point has an irregular quadrangular shape, similar in plan to Fort Sumter, South Carolina. The width is 150 feet, the longest side is 250 feet and the height is 45 feet. The walls average seven feet thick and are of brick trimmed with granite quoins, cornices and sills. The four tiers originally mounted 149 cannon.

SPECIAL NOTES

Fort Point was the first and only brick coast artillery fortress built west of the Mississippi River and is the finest surviving example of this classical style of military defensive architecture.

Conservatory of Flowers (1879)



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

The English have always loved flowers and gardening, and during Victoria's reign, a unique type of greenhouse was designed to permit year-round enjoyment of blooming plants. These glass, iron and wood conservatories were the idea of Sir Joseph Paxton who built, in 1840, the first of this type on the estate of the Duke of Devonshire. Paxton later designed the gigantic Crystal Palace for the Great Exhibition of 1851. This vast structure, enclosing 21 acres, was considered the pinnacle of Victorian conservatory design and was used variously as meeting hall and museum until its destruction by fire in 1936.

As would be expected, the glass conservatory was but one of the many aspects of Victorian life adopted by wealthy Americans after the Civil War. James Lick, the noted San Francisco philanthropist, purchased a conservatory for his homestead in San Jose. Fabricated in London, then disassembled and shipped around Cape Horn to San Francisco, the conservatory remained in crates on the grounds of Lick's estate at the time of his death in 1876.

The Society of California Pioneers fell heir to the structure and subsequently sold it for $2,600 to a group of public-spirited citizens who, in turn, offered it to the newly formed Golden Gate Park. The conditions of the offer stipulated that the building was to be assembled within 18 months and maintained thereafter for the use and benefit of the public.

The Board of Park Commissioners acknowledged the offer and assured donors that, if sufficient funds were provided, the conservatory would be erected. However, a considerable sum of money was needed and all expenditures by the park, at that time, required approval by the State Legislature. An act appropriating $40,000 for the improvement of Golden Gate Park, including the erection of the Lick Conservatory, was passed in 1878. In May of that year, the London firm of Lord and Burnham was engaged by the park commissioners to put up the building at a cost of $2,050. F.A. Lord, head of the firm, came to San Francisco to supervise construction.

Strangely, no metal parts had been provided, so Lord was authorized to purchase additional materials. Part of the iron structure, shipped from England on the steamer **Georgia,** was believed lost when she became shipwrecked, although, subsequently, some of the cargo was recovered. Despite these difficulties, construction of the glass, wood and iron conservatory was a fairly simple task and was completed in 1879.

On January 5, 1883, the structure caught fire and the dome was largely destroyed. Since funds for restoring the conservatory were not available, Charles Crocker, one of the "Big Four" of Central Pacific Railroad fame, donated $10,000 for the restoration. Over the years, a number of minor changes have been made to the building, but it retains its original appearance.

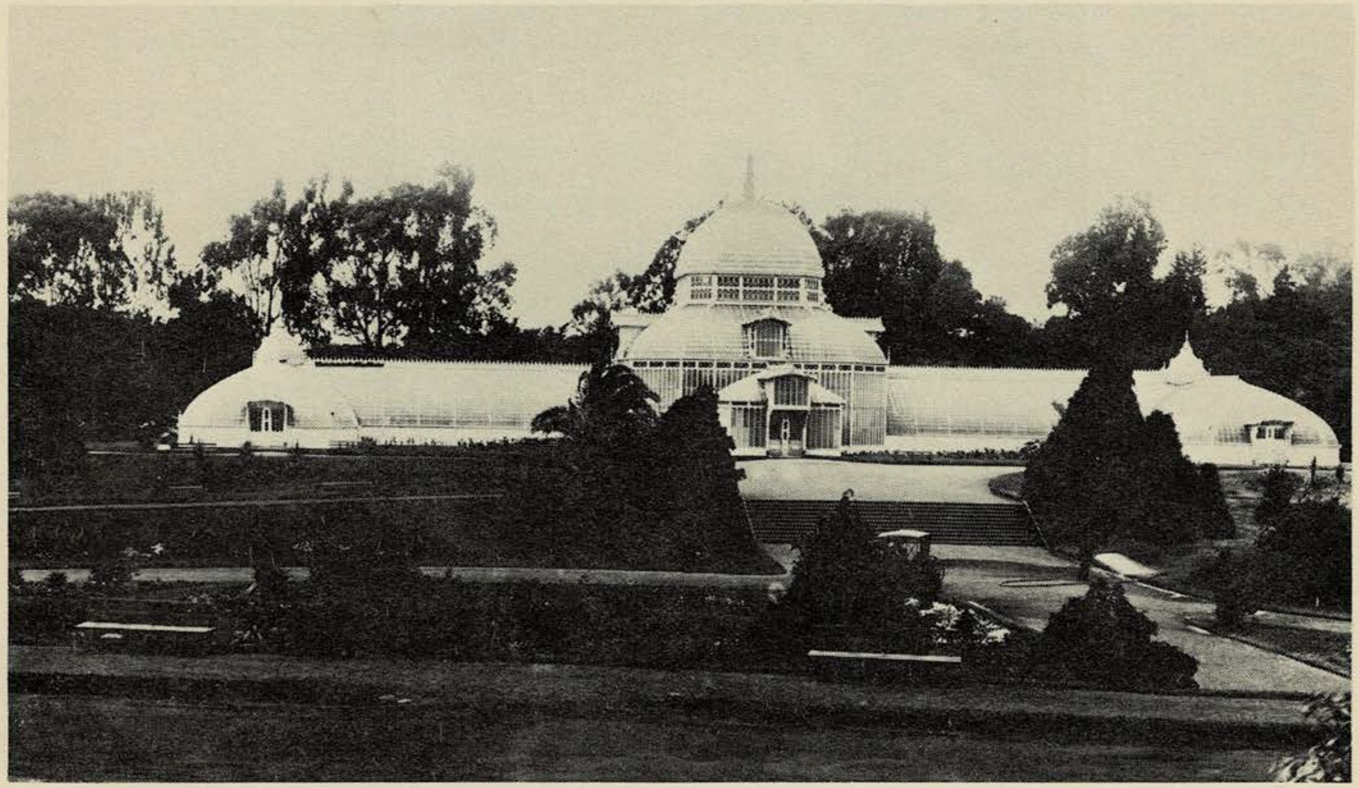
Still providing a dazzling display of tropical and foliage plants, the conservatory is the oldest existing building in Golden Gate Park and is probably the most outstanding example of Victorian architecture in the Bay Area. In addition to being a civil engineering landmark, it is California Historical Landmark #841 and is listed on the National Register of Historic Places.

TECHNICAL DATA

Location	Golden Gate Park, San Francisco
Date	Erected 1879
Architect	F.A. Lord, supervising erection

SPECIAL NOTES

1. The oldest surviving building in Golden Gate Park.
2. The largest surviving glass conservatory structure of the Victorian era in the United States.



During its early years, the Conservatory of Flowers was the focal point of a Sunday visit to Golden Gate Park.

Moffett Field Airship Hangar No. 1 (1933)

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

A unique feature of America's defense program in the late 1920's and early 1930's was the experimentation with lighter-than-air craft. Patterned after the famous German zeppelins of World War I, it was hoped these huge but graceful dirigibles would become battleships of the air, floating high above the reach of guns or airplanes. Unfortunately, America's proud airships were plagued by disaster: the **Los Angeles** (LZ 126), provided as war reparations by the German Zeppelin Company in 1924, and the American-built ships **Shenandoah, Akron** and **Macon** all met violent ends, although, being helium-filled, none of the American ships died as spectacularly as the hydrogen-filled **Hindenberg.**

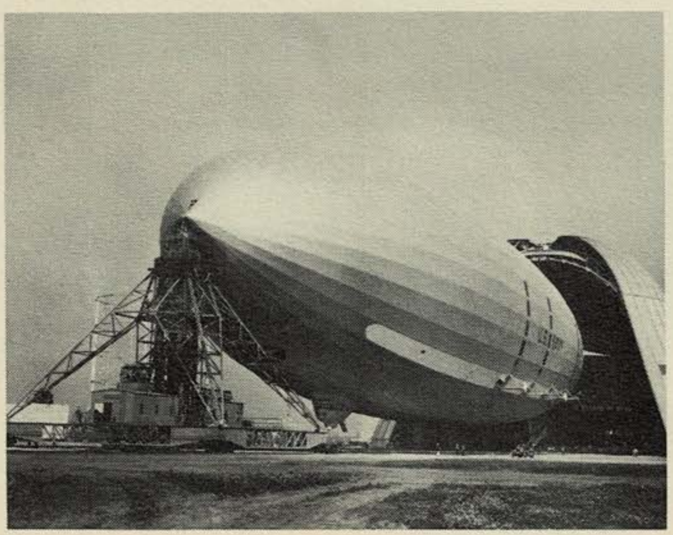
In support of the dirigible program, a chain of airship mooring and docking stations were constructed on the East Coast **(Lakehurst),** in the Midwest **(Akron)** and on the Pacific Coast. The West Coast facility, originally designated the Sunnyvale Naval Air Station, contained a unique feature: a gigantic airship dock (hangar) only a few feet smaller in size than the world's largest hangar at Akron. The design and erection of this hangar was to provide a unique test of civil engineering skill, as the profession responded to the challenge to create a structure of huge proportions and unusual configuration.

Construction of the $1.1 million hangar began in October 1931. Although intended to house the USS **Macon,** an airship of 6.5 million cubic feet,* the hangar's eight acres of clear floor space was designed ultimately to house airships of nearly twice that volume. The inverted "U"-shaped structure, 1,133 feet long, 308 feet wide and 194 feet high, quickly dominated the landscape.

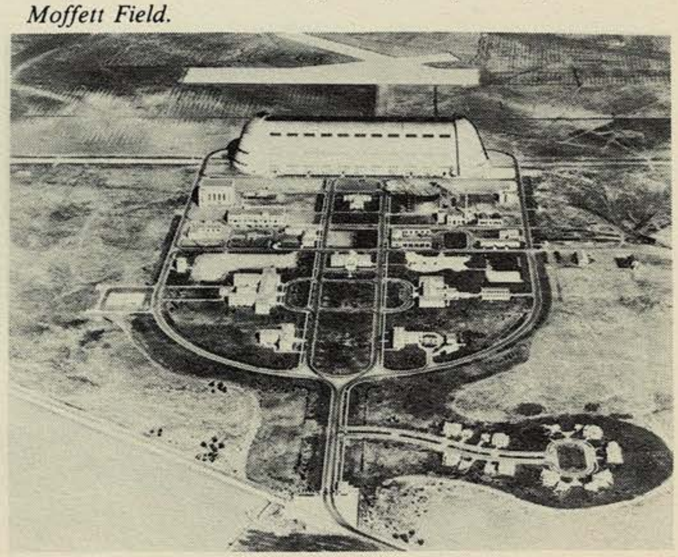
The construction of the steel framework was ingeniously done, using a huge timber traveler mounted on eight 50-ton railroad flatcars running on three parallel railroad tracks. Weighing 500 tons, standing 194 feet high and mounting three stiff-leg derricks, the traveler enabled the installation of a complete 72-foot-long bay assembly, consisting of arch truss, bracing, roof members and catwalks, totaling some 350 tons of steel, in as little as three and one-half days. This use of a traveler represented a distinct departure from methods used in the erection of previous airship docks.

The air station, with its huge airship hangar, landing field for airplanes, and administrative buildings, was commissioned on April 12, 1933. A scant month later, the facility's name was changed to Moffett Field to honor the Chief of Naval Aeronautics who was killed in the crash of the airship **Akron.**

Hangar One was built to house the gigantic airship USS Macon.



Early aerial view shows original layout of airship facilities at Moffett Field.



*Dimensions of the USS **Macon,** the largest airship built for the US dirigible program, were: 785 feet long, 136 feet maximum diameter, 6.5 million cubic feet of volume, 70-man complement. Launched in 1933, the **Macon** crashed and was destroyed in 1935.

Two years later, in 1935, the tragic loss of the **Macon,** Moffett Field's "own" airship, put an end to the Navy's airship program. During World War II, the vast hangar, now known as "Hangar Number One," was used to house the blimps (nonrigid airships) and observation balloons that played an important part in coastal anti-submarine work. The hangar remains in use today as an airplane repair and storage facility, an ironic use of the greatest surviving monument to a brief, tragic but colorful chapter in man's exploration of the air.

TECHNICAL DATA

Location	Sunnyvale, California
Dates	First contract let: October 1, 1931 Commissioned: April 12, 1933 Name changed to Moffett Field: May 18, 1933
Cost	Hangar: $1.1 million Total facility: $5 million
Engineers	Rear Admiral A.L. Parsons (CEC) USN, Chief of the Bureau of Docks and Yards, designer; Lieut. Cdr. E.L. Marshall (CEC) USN, officer-in-charge of construction. J.H. Pomeroy personally designed and supervised the operation of the timber traveler.
Dimensions	(Hangar No. One) Length: 1,133 feet Width: 308 feet Height (overall): 194 feet Height (interior clear space): 180 feet

SPECIAL NOTES

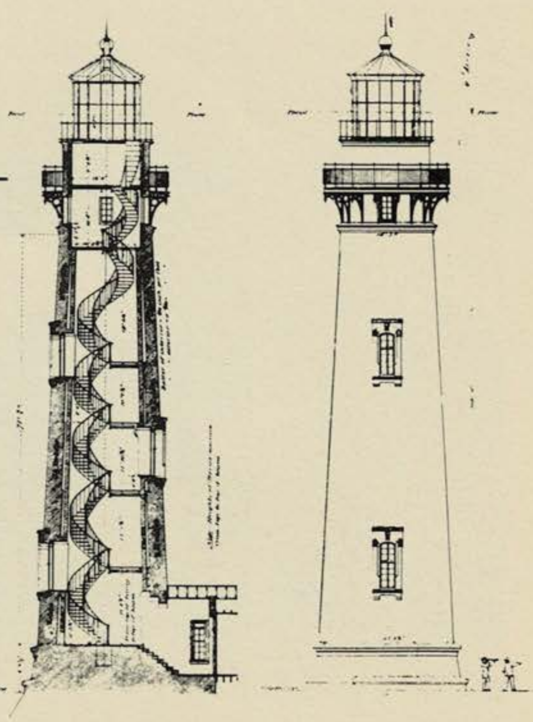
1. The hangar frame consists of a series of equal-depth arch trusses on 72-foot centers. There are eleven of these 72-foot centers. The trusses are made up of three-hinged arches resting on rigid A-frames 55 feet high. Temperature expansion is provided for by use of two transverse expansion joints that divide the structure into three units, with the end doors anchored to reduce end thrust on the door framing and opening mechanisms. The upper 70 feet of hangar cover consists of two-inch redwood sheathing and built-up asphalt felt roofing, with the rest of the sides covered with asbestos-protected metal sheets and V-beam sheathing.
2. At each end of the structure there are huge doorways made of two spherical orange-peel leaves that provide almost unobstructed openings. Each door leaf weighs 550 tons and operates on a circular rail track.

Pigeon Point Lighthouse (1872)

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

On the foggy night of Monday, June 6, 1853, the clipper ship **Carrier Pigeon,** 130 days out of Boston with a cargo of general merchandise destined for California's gold fields, drifted aground on a headland then known as Whale Point, about 30 miles north of Santa Cruz. Although the ship itself was a total loss, Captain Doane and his crew labored to save what they could of the cargo, and there ensued a drama typical of the pioneering days of coastwise shipping in California.

As soon as the wreck was known in San Francisco, the coastal steamship (actually a sailing ship with auxiliary steam engines) **Sea Bird** was dispatched to the wrecked **Carrier Pigeon** with instructions to attempt salvage. Later the same day, the USS **Active,** enroute to the Farallon Islands with material for the lighthouse under construction there, put in near Whale Point and



The original drawings of the Pigeon Point Lighthouse reveal both sturdiness and a graceful beauty.

learned that the **Carrier Pigeon's** crew was safe, temporarily staying at the whaling colony that gave the place its name.

When the **Sea Bird** arrived on the ninth, it began salvage of the wrecked ship's cargo but soon succumbed itself to the raging seas for which that coast is famous. Holed and leaking badly, the rescue ship put itself aground at nearby Año Nuevo to prevent its sinking. Over the next two weeks, ships from all over the central coast converged upon the two helpless vessels, scavenging for what they could, before heavy seas finally destroyed the **Carrier Pigeon.**

Exactly a month later, on July 8, 1853, the incident of the wreck of the **Carrier Pigeon** was footnoted by an auction notice in the San Francisco **Daily Herald** announcing an underwriters' auction of the recovered cargo of the lost ship.

So notorious did this maritime incident become that, in a measure of poetic justice, Whale Point, where the hapless clipper went down, became renamed Pigeon Point. Over the next twenty years, there was a growing agitation to the federal government to construct a warning light on Pigeon Point to reduce its toll of unwary ships. At the same time, even as the small whaling industry declined, the cove to the south of Pigeon Point became the shipping point for products from the Pescadero region, including lumber and produce. Unable to use standard docks because of the heavy and hazardous surf, shippers loaded and unloaded cargos from ships anchored in the cove by means of an aerial cableway.

Pigeon Point Lighthouse is probably the most photographed light on the Pacific Coast, thanks to the beauty of its setting.

After a rash of wrecks in the late 1860's, in 1869 Congress finally appropriated money to construct a lighthouse at Pigeon Point. By September 1871, the first navigation aid was installed, a steam-operated fog signal with a 12-inch whistle. In 1872, the lighthouse was completed. It had not been an easy task, for the bricks to erect the tower had been made in Norfolk, Virginia, and, shipped around Cape Horn, were then laboriously unloaded on the rickety cableway in the rocky cove at the point.

The nine-foot-diameter fresnel lens for the light has a mysterious past. Built by Henri Le Paute of Paris in the 1850's, the first twenty years of its history are in doubt. It probably was installed at Cape Hatteras on the East Coast but was removed during the Civil War to prevent its destruction by Confederate forces. Buried in the sand for protection, it was rescued in 1868 and eventually sent to Pigeon Point. There, the 1,008 pieces of glass were reassembled, and the durable fresnel lens began its hundred-year tour of duty in California.

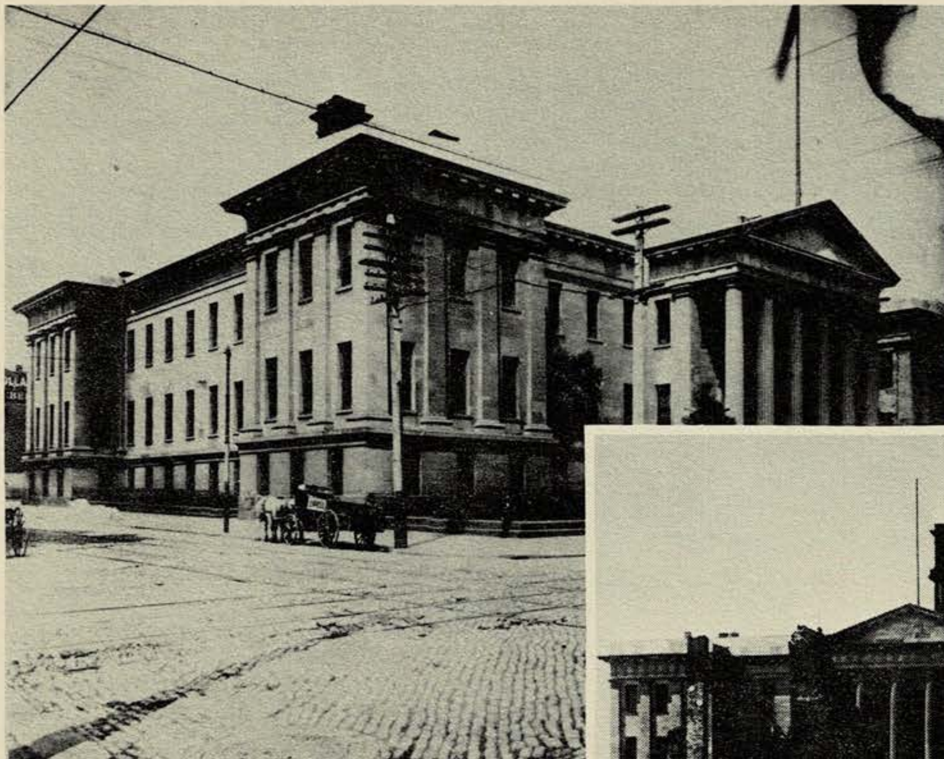
Illumination for the light originally came from burning lard. Later kerosene, and now electricity, provide the light which the old fresnel lens magnifies to 800,000 candlepower, a beam that can be seen 18 miles to sea. Originally rotated by a clockwork mechanism, the light now rotates electrically. Long one of the most photographed landmarks on the central California coast because of its picturesque rural setting, the Pigeon Point lighthouse, despite internal modernization, retains its pleasant Victorian outward appearance.

Since the light was installed, only one wreck has occurred on Pigeon Point. In 1897, the **Columbia** went ashore with a cargo of white lead. Since that time, says one local historian, most houses in the area have been painted white.

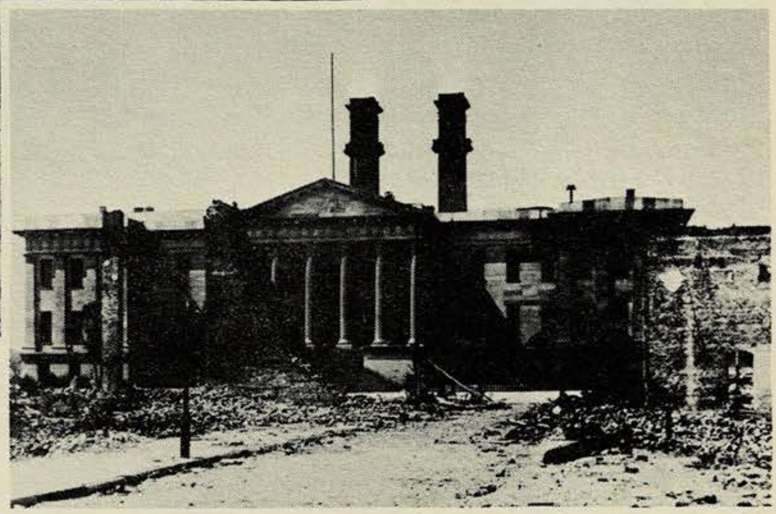
TECHNICAL DATA

Location	Pigeon Point, San Mateo County, California (about 37 miles south of San Francisco on State Highway One)
Date	Light first operated: November 1, 1872
Cost	$140,000 for land and construction
Dimensions	Tower: 115 feet high Light: 148 feet above mean high tide line tower tapers from 28 feet in diameter at the base to 16′3″ at the top. Tower walls taper from 6 feet thick to 3 feet thick.

The Old United States Mint, 1874



(Left) *The Old Mint in the 1890's. At that time still the major source of coinage for the West, millions in gold bullion reposed in its vaults.*



(Right) *Standing virtually unscathed amidst the ruins of the Financial District, the survival of the Mint was a key factor in the rapid revitalization of San Francisco after the 1906 earthquake and fire.*

Some Historic Buildings in San Francisco

Mission Dolores, 1776 (1791)

In the 1860's, Mission Dolores remained a cultural focal point for the surviving hispanic "Californios."

While historic civil engineering landmarks are not chosen primarily for their architectural significance, there are several structures in downtown San Francisco which are representative of contemporary methods of construction and decoration, buildings which are, in some cases, the only survivors from their era remaining in the city today. In the interest of completeness, mention is made of five of these historic buildings.

Mission Dolores, 1776 (1791)

The original colonizing expedition to the Bay Area, led by the redoubtable Juan Bautista De Anza and Father Junipero Serra, arrived in the area of present day San Francisco, camped and held Mass beside a small lake

The Palace Hotel, 1875 (1909)

The courtyard of the original Palace Hotel saw the fine carriages of the great and near great who came to stay at the West's most luxurious hotel.

After 1906, the court was transformed into a sumptuous dining room, the Garden Court.

and stream in the spring of 1776. The watercourse, named Arroyo de Nuestra Senora de los Dolores, was located approximately at modern 18th and Dolores Streets. At this salubrious site, a mission, the sixth established in California, was dedicated. The first chapel, with walls of wooden poles plastered with mud and a roof of tule reeds, lasted but a short time.

In 1782, Father Palou, the pastor, decided to move the chapel to a new location, and laid the cornerstone of the present structure at what is now 16th and Dolores Streets. Completed in 1791, the chapel of Mission Dolores has changed very little since. The four-foot-thick adobe walls have been preserved by clapboard sheathing. The roof has the original rough-hewn redwood timbers and tiles. Pegs of manzanita wood and rawhide lashings hold the structure together. Other original items remaining in the chapel include the altar, statues, an Indian-made paschal candle, a revolving tabernacle and original confessional doors. The ceiling still shows decorations painted by the mission Indians, using vegetable colors and cinnabar from Almaden near San Jose. Surprisingly, this frail, ancient structure survived the 1906 earthquake undamaged.

Although originally dedicated to Saint Francis, the mission popularly became known as Dolores after its proximity to the watercourse that was for many years the community's principal domestic source. Since 1791, the mission complex and the community have grown up around the chapel, leaving it an island of Hispanic culture unaffected by the bustling city surrounding it.

The Old Mint, 1874

In the four-year period from 1848 to 1852, California transformed from a sleepy Hispanic outpost to a bustling American state, primarily as a result of the discovery of gold. Among the many problems faced by the fledgling but isolated state was that of sufficient coinage. To alleviate the problem, a branch mint was authorized for San Francisco in 1852, intended to turn the Mother Lode's gold into coins. Over the next two decades, San Francisco became the premier city of the West, and the tiny mint became inadequate to meet the growing coinage demands of the region.

In the summer of 1874, a new mint was erected at 5th and Mission Streets. One of the best appointed mints in the world, it had ample capacity to provide for the output of the West's great mineral districts.

Just three weeks before the disastrous earthquake and fire of 1906, a private water system was completed within the mint, providing a reliable water supply for fire fighting from wells located in the mint's courtyard. On the day of the calamity, employees and soldiers fought a seven-hour battle against flames which towered over the roof of the mint. Intense heat melted glass in the iron-shuttered windows and cracked the massive sandstone blocks of the mint's walls, but the structure survived.

Left standing virtually alone amid the rubble of the disaster, and with two hundred million dollars of gold in its vaults, the mint was the only financial institution remaining undamaged after the holocaust and, as such,

The Post Office was the only building downtown other than the Mint to survive undamaged the 1906 earthquake and subsequent four-day holocaust.

played a key role in the relief efforts which revitalized the city.

Construction of the new mint in 1937 rendered the historic structure downtown surplus, and deterioration gradually increased. Fortunately, in 1972, The Old Mint was the first federal building restored under Public Law 92-362 providing for preservation of historic structures. In its restored state as a public museum, The Old Mint displays and operates the machinery which minted the gold coins that were a foundation of the Old West.

The Palace Hotel, 1875 (1909)

Born as the dream of two flamboyant westerners, mine owner E.J. "Lucky" Baldwin and Bank of California cashier W.C. Ralston, the Palace Hotel has survived to become one of San Francisco's enduring monuments. Opened in October 1875, six weeks after Ralston's death following the failure of the bank, dedication ceremonies were relatively subdued.

Quite soon, however, the Palace earned a deserved reputation for hospitality and sumptuousness. Its like had never been seen in a West accustomed to poor hostelries. Towering seven stories high above Market Street, the white-painted building, a quarter mile in circumference, had 800 rooms. It boasted the West's largest and costliest dining room, a $5 million extravaganza 150 feet long, containing rugs specially woven in France, able to muster 9,000 cuspidors, 9,000 plates, 8,800 side dishes, 8,000 vegetable dishes and 4,000 cups and saucers for fabulous banquets.

The Palace promptly became **the** place to stay in San Francisco, and, over the years, scores of the famous luxuriated within its walls. Enrico Caruso was at the Palace, resting after his gala performance at the Opera House on April 18, 1906, when the earthquake prostrated the city.

Although little damaged by the temblor itself, the world-famed structure was gutted in the ensuing fire when the rooftop reservoirs finally went dry. A new Palace Hotel sprang from the ashes of the old, modernized, but retaining the former's architectural charm and high standards of service. Focal point of the rebuilt hotel was, and remains, the Garden Court, which, with its potted palms and glass conservatory roof, is a trip back in time to the elegance of pre-1906 San Francisco. Today, the Palace Hotel, under Sheraton management since 1954, is not just a hotel, it is a San Francisco institution.

The United States Court of Appeals and Post Office, 1905

Constructed over a twelve-year period from 1893 to 1905, the US Court of Appeals and Post Office Building is one of the splendid surviving examples of the beautiful "Italian Renaissance" style of federal buildings erected at the turn of the century.

Built of white granite, the corridors are finished in Italian and American marbles, with marble mosaic ceilings. Trims of glass mosaics and Tennessee marbles finish the passages. Interior wood finishes utilize red

The United States Custom House, 1911

The imposing Italian Renaissance style of the Custom House made it the architectural centerpiece of San Francisco's post-1906 Financial District.

and white mahoganies, curly redwood and antique oak. Many of the doors and much of the panelling is elaborately carved, reflecting the skill of immigrant Italian wood carvers.

The courtrooms of the US Court of Appeals best reflect the splendor of the Renaissance style and the ingenuity of the architects. Courtroom No. 1 is furnished with walls and carvings of Pavonezza marble, mosaic panels, glass mosaic trimming and assorted marbles. Courtroom No. 2 is decorated with walls and carvings of Italian marble with trimming of Old Convent Sienna marble. This splendid room contains statues of Carrara marble and a bench of Numidian marble from Africa.

On the morning of April 18, 1906, not long after the building was first occupied, it was struck by the great earthquake which rocked and destroyed much of San Francisco. The building was seriously damaged but was one of two (the other was the Mint) which survived the quake and the fires which followed. Bricks fell from pillars and walls, glass in the roof above split and cracked with the walls, and the floors and dislocated furniture were covered with the thick dust which filled the air. Postal employees prepared to protect the building from the fierce fires which completed the destruction of the area. Combustible matter was removed, the inlet from the fuel oil tanks was covered with earth, valuable records were placed in vaults and all windows were closed. The fire swept by, cracking and breaking several windows, and at eleven o'clock, it entered one of the windows on the third floor. The fire was contained in a few rooms by ten postal employees who covered the doors with wet sacks. The building was saved.

The United States Court of Appeals and Post Office Building is operated by the General Services Administration Public Buildings Service and houses various government agencies, although the main occupants remain the Post Office Department and the United States Court of Appeals.

The Custom House, 1911

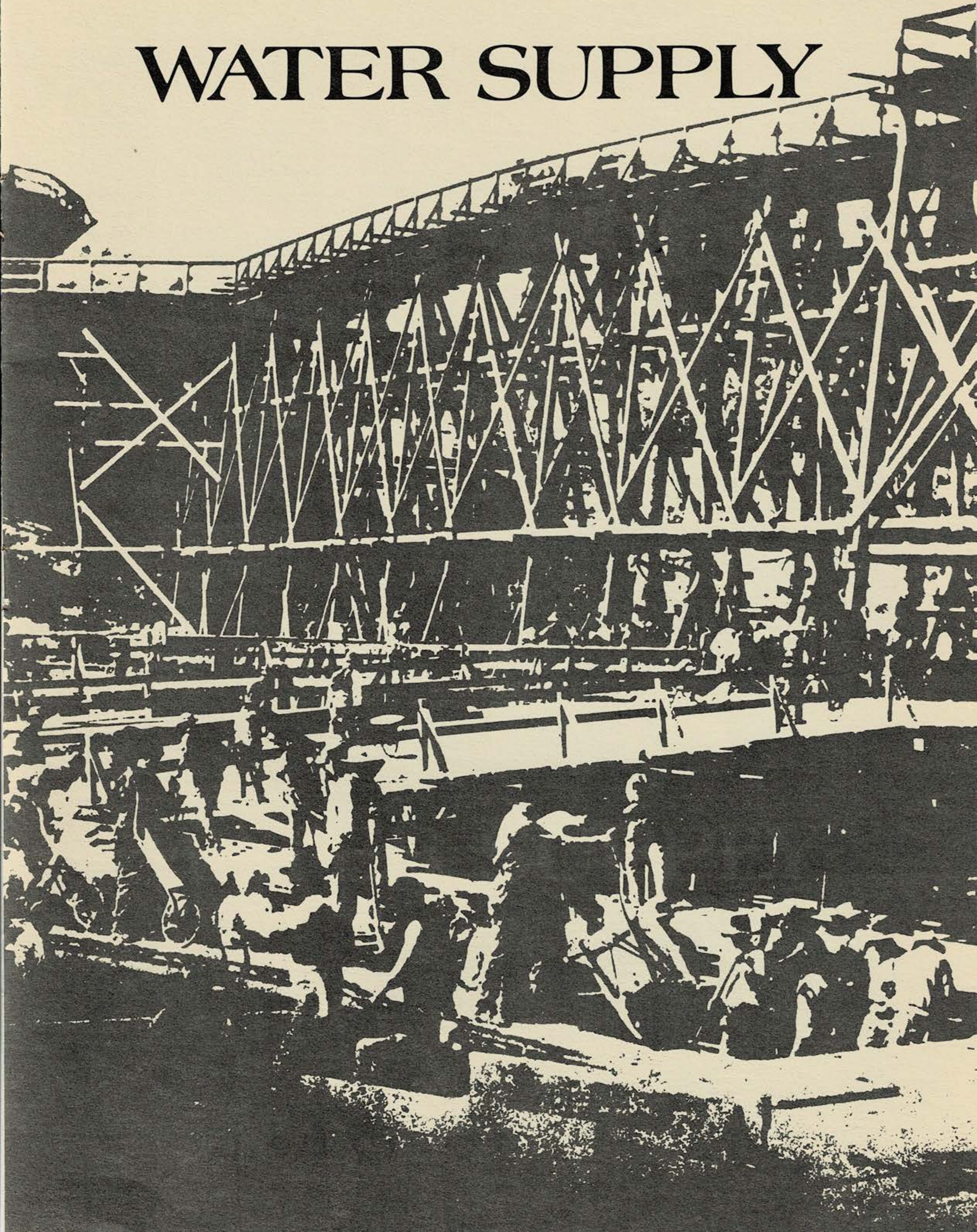
The Custom House at 555 Battery Street is the second to occupy the site, as an earlier customhouse, dating to 1856, was raised in 1905 to make room for the present building. Excavation was completed just days before the earthquake, and the valuable customhouse records were buried in the hole when it became apparent the city would succumb to fire.

After the disaster, work recommenced on the new structure. Interestingly, unlike most government buildings of the time, the Custom House was not designed by a government architect but by a winner of a competition, William R. Eames, then president of the American Institute of Architects.

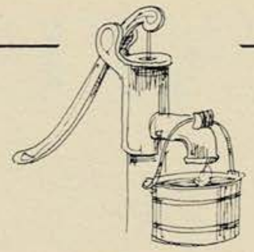
The concrete of the steel-framed building rests on timbers taken from the hull of the steamship **Georgian,** an abandoned vessel from Gold Rush days. The cornerstone was laid in October 1907, but the structure was not completed until 1911, due to the shortage of labor resulting from the reconstruction of San Francisco.

The Custom House, along with the slightly older Post Office, are together the finest surviving examples of the "Italian Renaissance" style of federal architecture, and, additionally, the Custom House contains a number of murals, reliefs and friezes by noted western artist, A. Lincoln Cooper.

WATER SUPPLY



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.

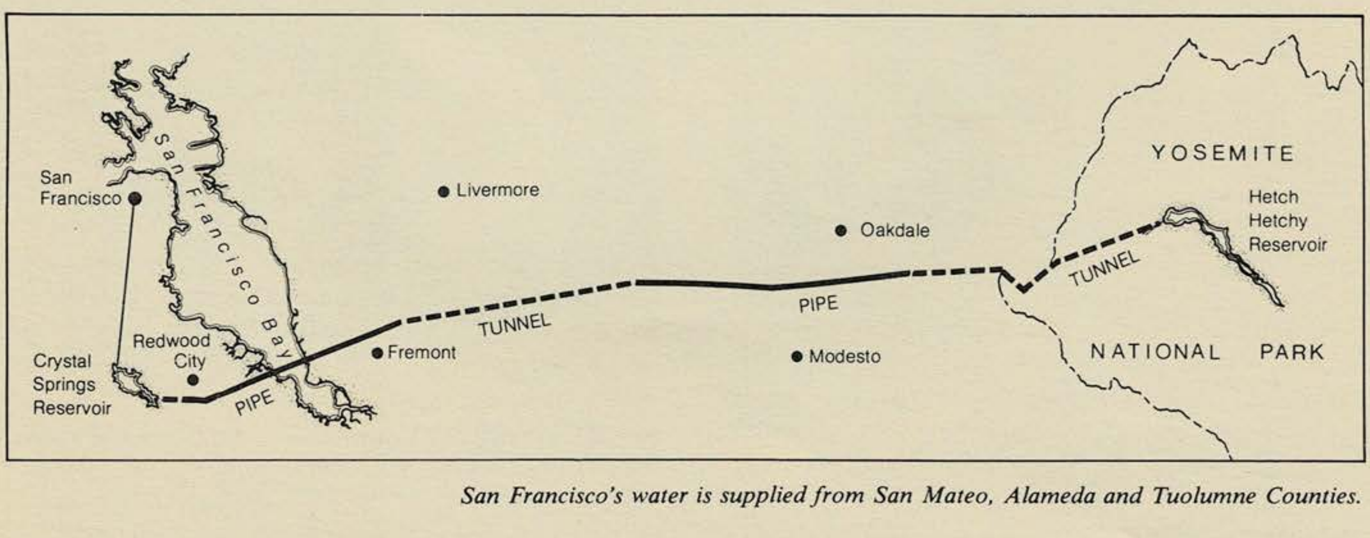
In 1857, the San Francisco Water Works was organized by a group of citizens who realized that the provision of an adequate water supply was standing in the way of San Francisco's continued growth. Tapping Lobos Creek, which then ran through the present Richmond District in western San Francisco, the 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.

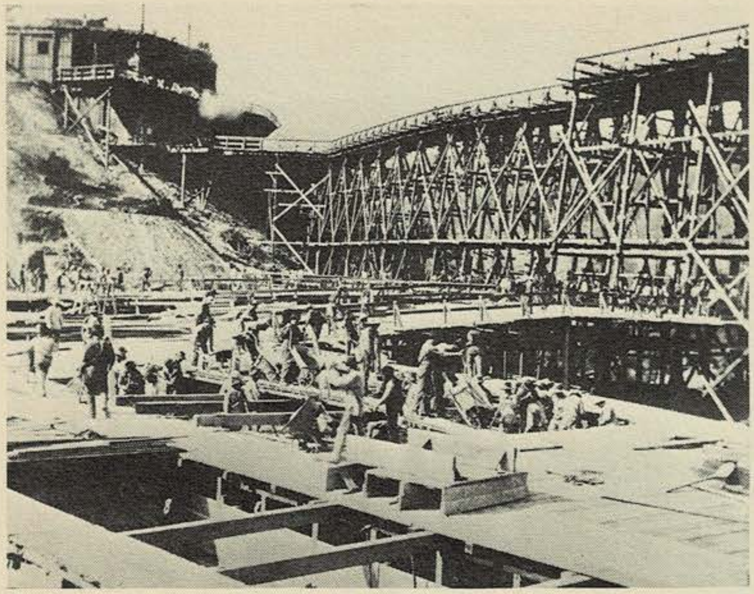
The two pioneer "water works" were consolidated in 1865 into the Spring Valley Water Company which, until municipalization in 1930, operated the city's water distribution system and was its principal source of supply.

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.

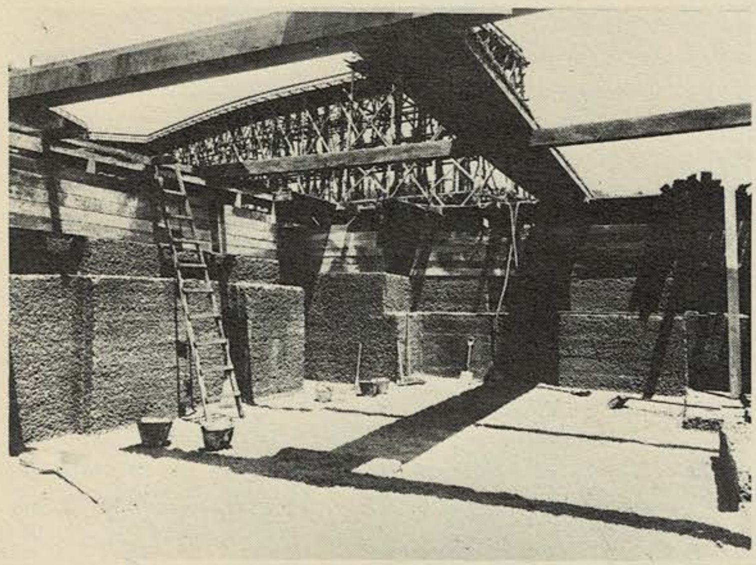
The first attempt by the city to acquire the Spring Valley system came in 1873 but was defeated at the polls. In 1875, the future site of Calaveras Reservoir,

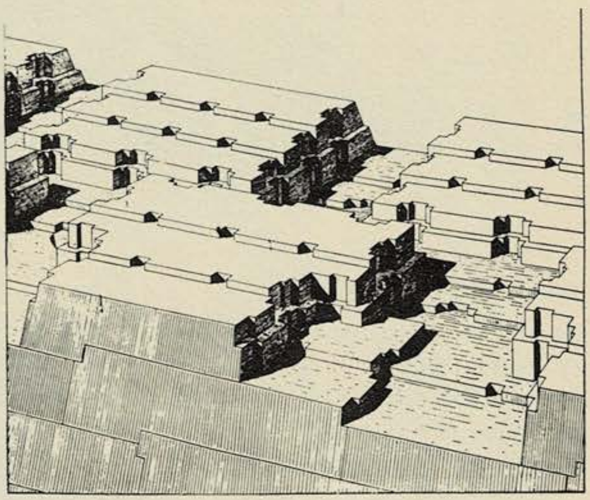


San Francisco's water is supplied from San Mateo, Alameda and Tuolumne Counties.



Crystal Springs Dam, 1890



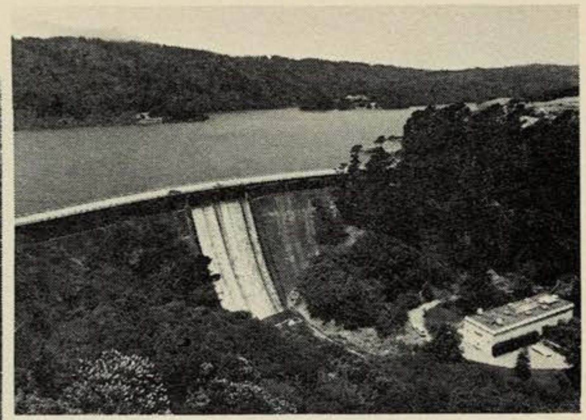


Construction methods used for Crystal Springs Dam were the most advanced of their day. The three illustrations on this page show in detail the method of placing the blocks of concrete. (Upper left) *Workmen are making a pour.* (Lower left) *Block faces have been cleaned and roughened prior to the next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

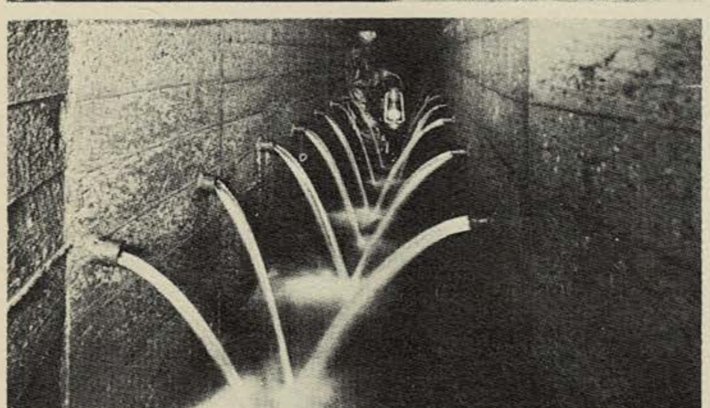
A 28-foot-high concrete structure, Sunol dam, virtually entirely submerged, serves to back up the creek flow and keep the gravels flooded. A system of underground concrete galleries and perforated pipes collects the water percolating through the gravel beds, giving a dependable yield of approximately 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

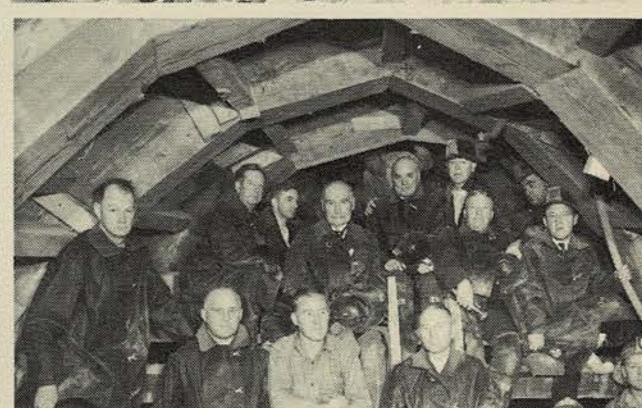
Of all aspects of San Francisco's mammoth Hetch Hetchy water project, the most difficult was the main 25-mile-long Coast Range Tunnel. Never before had such a long tunnel been proposed through such difficult ground. The coast ranges of California are geologically unstable, made of weak sedimentary rocks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

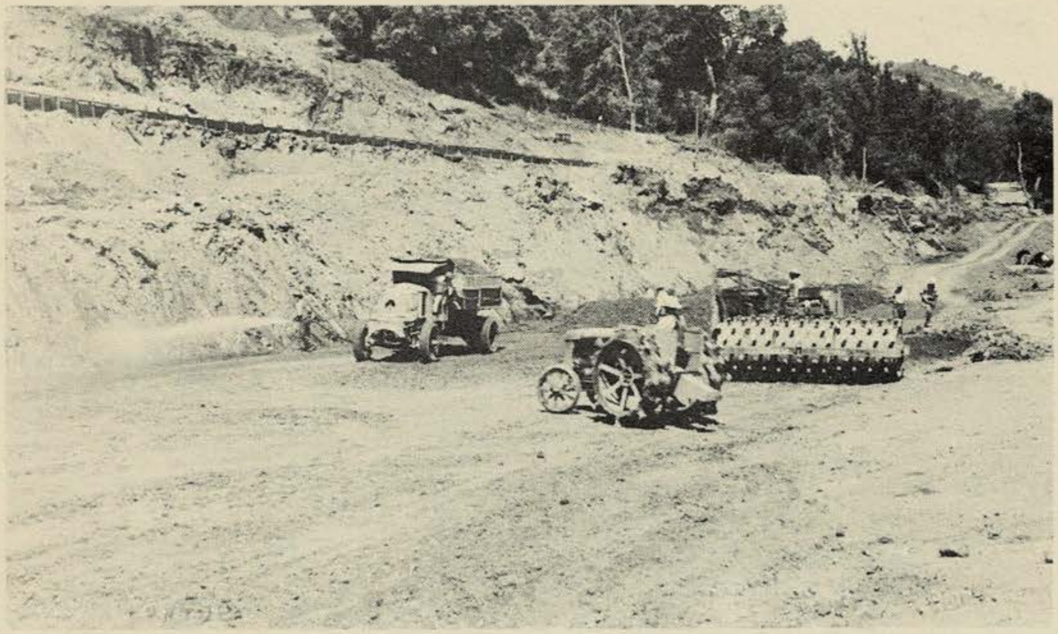
   That this care was important can be seen from the fact that the dam survived the 1906 'quake and remains watertight today, 90 years after construction.

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.

Santa Clara Water Conservation System (1936)

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



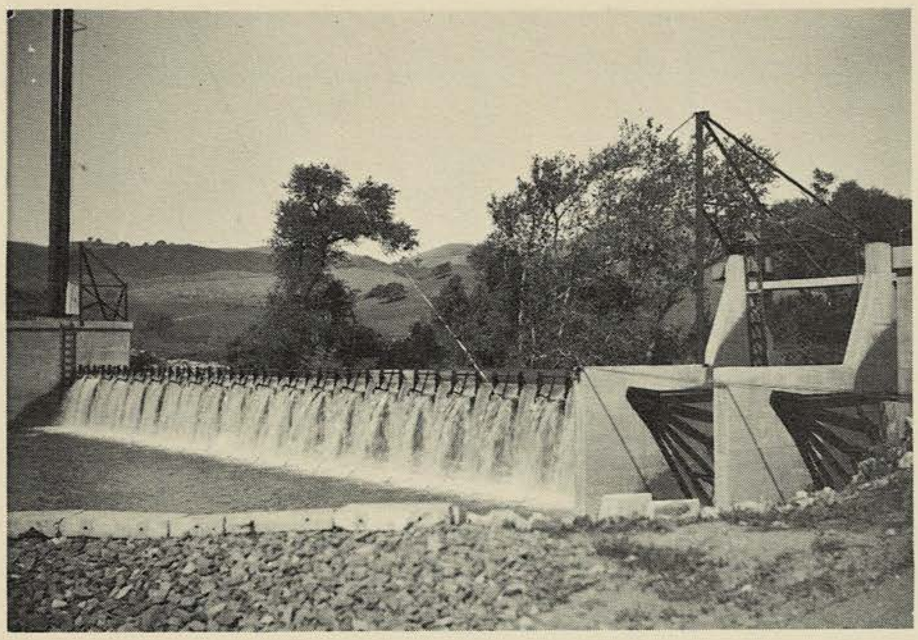
Construction of Coyote Dam and five others for the Water Conservation District provided much needed work for the Santa Clara Valley during the Great Depression.

At the opening of the twentieth century, the Santa Clara Valley, just beginning its change from a cattle-grain-growing economy to a vine and orchard center, enjoyed a surplus of water. The ground water level was so high that, when wells were drilled, water flowed without pumping, and the underground water pressure was great enough to force the water out at the surface, creating an artesian well.

A succession of drought years beginning in 1915 saw the start of widespread pumping as the water table dropped. By 1920, 67 percent of the land in the valley was under irrigation, and the population was steadily increasing in the urban areas. By 1929, a dramatic drop in the water table of 50 feet in four years had caused widespread damage from land subsidence.

Prominent San Francisco engineers Fred H. Tibbetts and Stephen E. Kieffer spent years in the 1920's preparing a report covering every phase of the Santa Clara Valley's water problem, and made recommendations for water conservation. Still used as a guide for action, their report called for the formation of a water conservation district to build flood control dams and channels, percolation beds and other projects.

Led by prominent valley citizens under the leadership of Leroy Anderson, a water conservation committee fought a long and frustrating battle to have the district formed. What made the idea difficult to sell was its very novelty. Nowhere else in the arid West was a water conservation district being proposed. In areas where there were no federal irrigation projects, local projects envisioned either flood control or irrigation, not both. Even in Los Angeles, whose first-in-the-nation flood control district had built spreading grounds (percolation areas) as early as 1917, there were no major year-round reservoirs to augment the percolation grounds. Little wonder, then, that the conservative Santa Clara Valley farmers viewed the proposed district skeptically. At two elections in 1927 and 1928, the proposal was defeated, but



Coyote Percolation Dam. The cable car at right trips each dam section during excessive flows.

in November 1929, as the water table dropped to a frightening 100 feet below ground level, a new water conservation district was approved by Santa Clara Valley residents by the margin of nine to one.

Building on the earlier Tibbetts-Kieffer report, engineers studied the valley's principle watersheds where dams could be built to impound rainy season runoff and release it in the dry season to replenish the groundwater through percolation beds. A $2 million bond issue approved in 1934, augmented by federal WPA money, was used to construct the first six conservation dams, which were completed in 1936.

With the first rains of the winter of 1936-37, the new dams, Vasona, Almaden, Guadalupe, Stevens Creek, Calero and Coyote, began to impound water, and not a moment too soon. The average depth of water had now dropped to 131 feet, when only 20 years earlier it had been only 56!

At first the new conservation system worked beautifully. By 1943, the water table had risen to its early 1920's average of 50 feet, but in 1944, once again it began to drop. Spurred by wartime increases in industry and population, in addition to year-round farming to raise more crops for the war effort, the valley's water use was rising beyond anything the planners had anticipated. Coupled to this was a series of dry years in the late forties.

Plans were completed to construct two additional dams for water storage. Lexington Dam, built after the rail line to Santa Cruz was abandoned, and Anderson Dam on the Coyote River, forming the largest reservoir on the system, were completed in the early 1950's.

In 1952, the conservation district was augmented by the addition of a south district, for which two dams, Chesbro and Uvas, were built in the fifties.

Today, the Santa Clara Water Conservation District system operates more than the flood control dams, reservoirs, percolation areas and irrigation canals of its original charter. It includes a system of sewage treatment and water reclaiming plants, imports water from the Central Valley and conducts cloud seeding, all in an effort to augment the water supply of an area which has become one of the most rapidly growing population centers in the nation.

TECHNICAL DATA

Location	Santa Clara County, California (county seat in San Jose)
Dates	District formed: 1929 Construction of major facilities: 1932-52
Engineers	Frederick H. Tibbetts (1882-1938) and Stephen E. Kieffer did the original design and conceptual work. Walter Hunt was chief engineer in charge of construction of all dams.

Dimensions of dams and reservoirs

Almaden
Built: 1935
Reservoir capacity: 1,780 acre feet
Dam type: rolled earth fill
Fill contains 250,000 cubic yards

Anderson
Built: 1950
Reservoir capacity: 91,280 acre feet
Dam type: rolled earth and rock fill
Fill contains 3,320,000 cubic yards

Calero
Built: 1935
Reservoir capacity: 10,160 acre feet
Dam type: rolled earth fill
Fill contains 550,000 cubic yards

Coyote
Built: 1936
Reservoir capacity: 23,700 acre feet
Dam type: rolled earth and rock fill
Fill contains 1,060,000 cubic yards

Guadalupe
Built: 1935
Reservoir capacity: 3,740 acre feet
Dam type: rolled earth fill
Fill contains 520,000 cubic yards

Lexington
Built: 1952
Reservoir capacity: 20,210 acre feet
Dam type: rolled earth fill
Fill contains 2,124,000 cubic yards

Stevens Creek
Built: 1935
Reservoir capacity: 3,600 acre feet
Dam type: rolled earth fill
Fill contains 530,000 cubic yards

Vasona
Built: 1935
Reservoir capacity: 410 acre feet
Dam type: rolled earth and rock fill
Fill contains 70,000 cubic yards

SPECIAL NOTES

1. This system is the first, and only major, instance of a major water supply being developed in a single groundwater basin involving the control of numerous independent tributaries to obtain virtually optimal conservation of essentially all of the sources of water flowing into the basin.
2. This water supply development facilitated the post-World War II growth of the Santa Clara Valley into one of the major metropolitan areas of the country.

Chabot Dam (1876)

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

When Anthony Chabot organized his Contra Costa Water Company to provide an adequate water supply for Oakland, he was faced with a serious difficulty. The Comstock Rush in Nevada, a building boom in San Francisco, plus a number of railway construction projects throughout the state had drained the East Bay of the laborers needed to build the dam he envisioned on San Leandro Creek. Despite the labor shortage, the demand for a dependable water supply for Oakland was urgent, and Chabot depended upon a number of novel innovations to insure construction of his dam.

Because the majority of his small construction force were newly arrived Chinese immigrants, Chabot prepared construction drawings in which the details were presented as pictographs, rather than with written instructions or numerical dimensions. On the plans, each stone or brick was delineated but measurements were omitted.

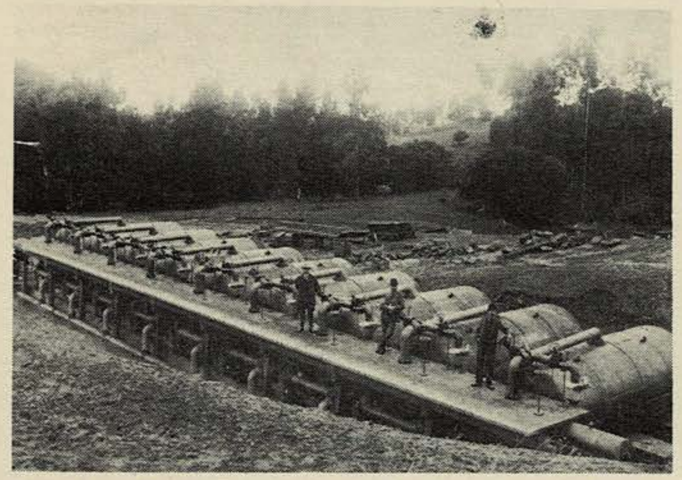
A major labor-conserving method was Chabot's importation of 200 horses from Oregon to tamp the 90-

foot-wide clay core of the dam.

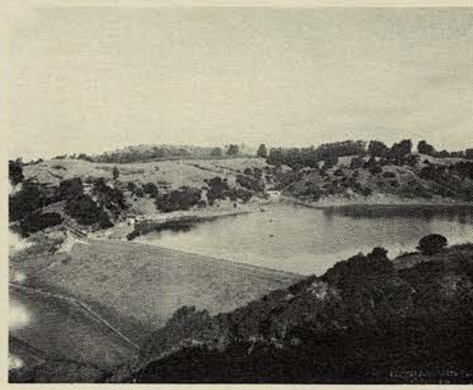
As completed in 1876, Chabot's San Leandro Dam, built on earth with a clay core, became the nucleus of Oakland's first dependable water supply. The dam itself, although modified or enlarged in 1878, 1882, 1892 and 1913, remains seismically sound. In honor of the builder, the dam was renamed Chabot Dam when it was acquired by the East Bay Municipal Utility District in 1928.

TECHNICAL DATA

Location	San Leandro Creek, Alameda County, California
Dates	Original construction: 1874-1876
Engineer	Anthony Chabot
Dimensions	Water surface: 340 acres Crest length: 450 feet Height (above stream bed): 115 feet Volume: 662,000 cubic yards

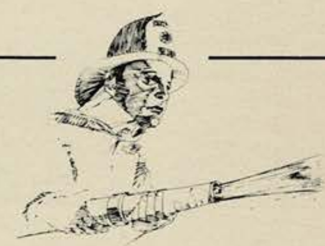


Water from Chabot Dam went through a filtration system, one of the West's first, before going into city mains.



Chabot Dam today, although much enlarged, still retains traces of the original structure.

San Francisco's High Pressure Water System (1908)



Mention should be made of one additional unique feature of San Francisco's water system: the high pressure system. After the tremendous fire losses in the 1906 disaster, caused in part by over 23,000 breaks in the water mains, the city resolved to design an independent water system entirely for fire protection and with sufficiently high pressure to enable its use without pumpers if streets were blocked.

Proceeds from a bond issue in 1908 went to construct the independent system, including water mains, fire hydrants, reservoirs, pumping stations, fire boats and underground cisterns, and major extensions to the system continued through the 1930's.

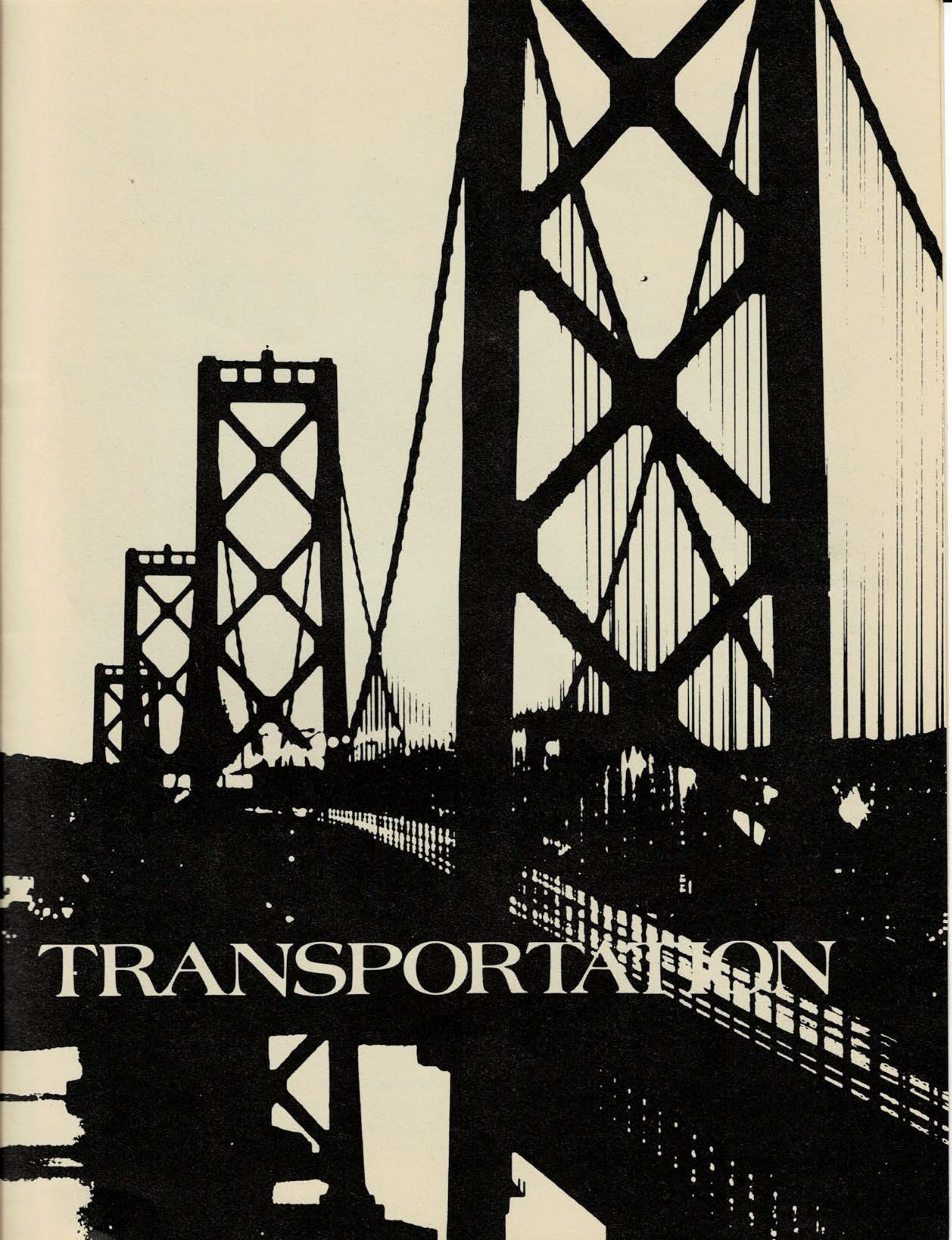
The high pressure system is normally fed with fresh water from tanks and the 10.5-million-gallon Twin Peaks Reservoir, highest in the city. In case of disaster, special valves sectionalize the system to maintain pressure, and two pumping stations activate, pumping saltwater from the bay into the system.

In the event of the failure of both the normal and high pressure systems, over 150 cisterns, each of 75,000-gallon capacity, are located at strategic intersections and along the north-south firebreak formed by Dolores Street and Van Ness Avenue.

Intended primarily for disaster protection, the high pressure system is used many times a year in day-to-day fire fighting. It enables quick response in congested traffic areas of the city.

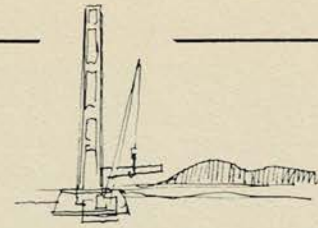
TECHNICAL DATA (1971)

The high pressure water system contains 1,400 hydrants, two pump stations, 115 miles of mains and 150 cisterns.



TRANSPORTATION

The Golden Gate Bridge (1937)



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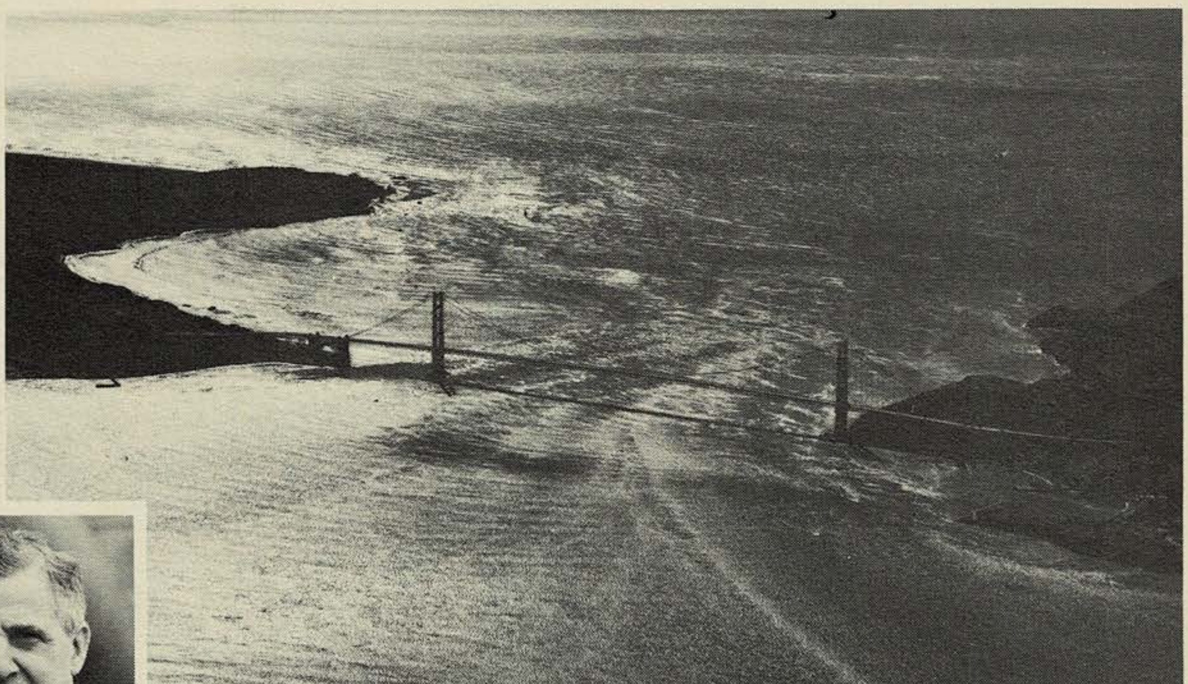


The Golden Gate Bridge, San Francisco's most famous landmark, and (left) *Chief Engineer Joseph B. Strauss.*

Late in 1918, consulting engineer Joseph B. Strauss stood on a windswept cliff overlooking the Golden Gate and pictured in his mind's eye a bridge to span the wide strait. The entrance to a major harbor had never been bridged. The minimum permissible vertical clearance would be greater than that of any other bridge over navigable water. Few believed that the Golden Gate, with its high winds, heavy Pacific swells and fast tidal currents could be bridged at all, but Strauss believed it economically feasible and sketched a daring plan that included a main suspension span of 4,000 feet, far longer than had yet been attempted.

At the request of local officials, Strauss presented a preliminary design costing $27 million in 1921. There followed a period of often bitter discussion over the feasibility of the bridge, a time during which it was not unusual for those of narrow vision to laugh at engineer Strauss.

Finally, in August 1929, after the Golden Gate Bridge District was formed, the first Board of Engineers' meeting was held, during which Joseph B. Strauss was elected chief engineer. This first meeting resulted in the adoption of a simple suspension design over the cantilever-suspension designs that had earlier been proposed.

The second meeting of the engineering board approved the foundation test data and approved Strauss' recommendations for a 4,200-foot main span and approach designs based upon noninterference with Old Fort Point, a landmark, in Strauss' opinion, worthy of preservation. Unfortunately, at this same meeting, it was decided not to include rapid transit tracks in the deck design, it being felt "that the era of surface (rail) cars (for) rapid mass transportation had passed." This latter decision caused the subsequent abandonment of the extensive electrified commuter rail system in Marin

County and has a direct bearing on the bridge's present traffic flow problems.

After voter approval of a $35 million bond issue, construction officially began January 5, 1933. No special problems had to be met in the construction of the Marin pier, the location of which was well sheltered by Lime Point. The building of the San Francisco pier was, however, another story. That pier, located 1,125 feet offshore, lies virtually in the open sea, wholly unprotected from the elements. The trestle built from Fort Point to the pier site was rammed by an offshore vessel and partially carried away in a storm before anchored adequately. The caisson for the south pier was itself nearly lost in a storm before being successfully installed.

While work was proceeding on the piers and towers, construction of the bridge approaches was begun. Especially in the Presidio of San Francisco, this entailed expensive relocation of a number of military installations, in addition to the highway viaducts into San Francisco and Marin County.

The completion of the south pier and its tower was followed by the installation of cable catwalks, the spinning of the cables, the placing of the suspended deck and the paving of the bridge approaches and deck. In most cases, the contractors for each construction phase established new records for speed.

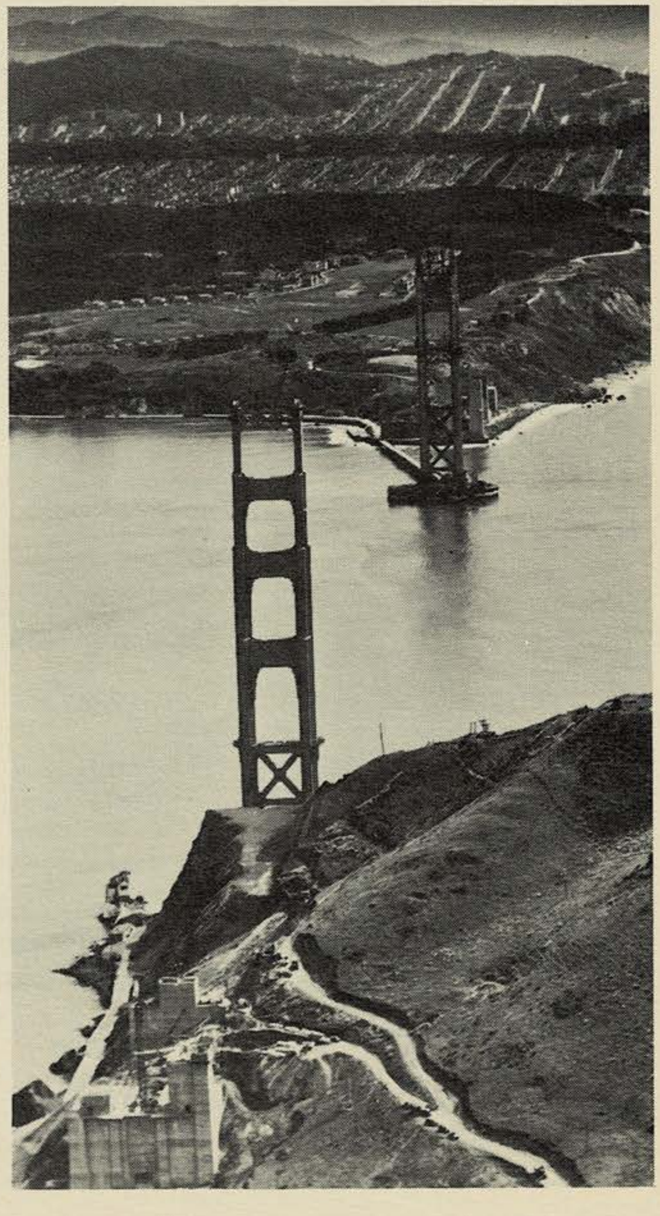
On projects of this nature, it had previously been estimated that one life would be lost for each $1 million of cost. To lessen such a toll, chief engineer Strauss ordered a safety net to be installed beneath the floor system from end to end, which was responsible for the saving of nineteen lives altogether. Unfortunately, the collapse of a scaffold during the paving of the deck swept away the net and killed ten men, but the total of eleven fatalities during the entire bridge construction is unusually low.

The Golden Gate Bridge was completed and ready for traffic on May 28, 1937, but the preceding day the bridge was opened to pedestrians only. During that day, from sunrise to sunset, over 200,000 walked across the mighty span.

Today perhaps the most famous landmark in San Francisco, the Golden Gate Bridge stands as a monument to the engineering skill of Joseph Strauss, whose foresight, skill and patience wrought the bridge in the face of innumerable natural and human obstacles.

TECHNICAL DATA

Location	Across the Golden Gate entrance to San Francisco Bay. The north pier rests off Lime Point, Marin County. The south pier rests off Old Fort Point, San Francisco.
Dates	First Board of Engineers' meeting: August 1929 Construction began: January 5, 1933 Bridge opened to vehicular traffic: May 28, 1937
Engineers	Joseph B. Strauss, chief engineer L.S. Moisseiff C. Derleth A.C. Lawson A.E. Sedgewick, consulting board



The northern tower of the Golden Gate Bridge rises from the Marin headlands.

Dimensions

Length of suspended structure: 6,450 feet
Length of main span: 4,200 feet
Width of bridge: 90 feet
Width of roadway: 60 feet
Height of towers: 746 feet
Clearance above mean lower low water: 220 feet
Live load capacity per lineal foot: 4,000 pounds
Deepest foundation below mean lower low water: 100 feet
Maximum deflections, center span:
- Transverse: 27.7 feet
- Downward: 10.8 feet
- Upward: 5.8 feet

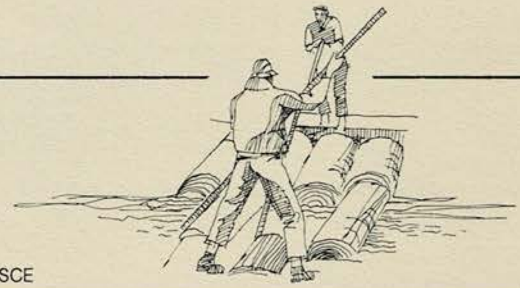
Tower deflection:
- Transverse: 12.5 inches
- Shoreward: 22 inches
- Channelward: 18 inches

Diameter of cables: 36-38 inches
Length of cable: 7,650 feet
Total length of #6 wire used: 80,000 miles

SPECIAL NOTES

1. The entrance to a major harbor had never before been bridged. The permissible vertical clearance was greater than ever before attempted.
2. The main suspension span of 4,200 feet was by far the longest in the world. The total bridge length of 6,450 feet made it the longest suspension bridge in the world. The construction of the south pier was without precedent for depth and difficulty of construction.
3. Use of high-silica cement in the San Francisco pier, producing a concrete with superior sea water exposure, was the first such use in any important engineering work.

Humboldt Harbor and Jetties (1889, 1972)



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Along the stormy, rockbound coast of Northern California, few harbors provide haven for the coastal shipping which plays such a vital role in the economic life of the north coast. Very early in the American period, Humboldt Bay became the focus of a thriving lumber industry, which was, however, hampered by lack of a safe harbor entrance for shipping.

In the mid-nineteenth century, masters of vessels off Humboldt Bay reported waves breaking in ten fathoms (60 feet) of water and claimed that only the stormy Cape Horn rivalled Humboldt's heavy seas. An 1877 report by the Army Corps of Engineers expressed doubt that permanent jetties could withstand the forces of such seas. The improvement of Humboldt Bay for shipping became the greatest challenge faced by the Corps of Engineers on the Pacific Coast.

The Army engineers began construction of the south jetty in 1889. Authorization for the north jetty came in 1891. The jetties were built from a timber trestle constructed with an overhanging pile driver revolving on a turntable. The trestle, consisting of four-pile bents sixteen feet apart supporting a standard gauge railroad track, was designed to last only long enough to complete the jetty beneath it. Carried on in times of quiet seas, jetty construction proceeded slowly because each grillage, brush mattress and stone had to be carefully placed.

When the original jetties were completed in 1899, a channel 25 feet deep and 700 feet wide was formed, and for a few years the dreaded entrance to Humboldt Harbor was safe for the four-masted barks used in the lumber trade.

Although the south jetty was 8,000 feet long and the north jetty 7,400 feet, the entrance channel quickly began to silt up as the outer ends began to sink into the sandy bottom. By 1907, the channel was badly shoaled and the outer ends of the jetties were completely buried in sand. Periodically, heavy seas pounded the weakened structures, rendering the situation worse.

Complete reconstruction of the south jetty took place between 1911 and 1915 and the north jetty between 1915 and 1925. Built on and over the original structures, the new jetties improved upon the old design by the addition, at the vulnerable outer end of each jetty, of a steel-reinforced concrete monolith intended to protect the new structures from the violent assaults of the sea.

Again during 1930 and 1957, emergency repairs were made necessary by severe winter storms. Periodic maintenance utilized concrete to fill the eroded areas in the crest and armor stone on the side slopes to replace what had been washed out. In 1932, concrete blocks weighing over 100 tons each were placed along the outer ends of the jetties for protection but actually disappeared during that winter's storms. In the 1930's and 1940's, 12-ton tetrahedrons, although smaller than those considered stable today, were used for repairs.

During the winter of 1957-58, severe storms caused extensive deterioration of both jetties. Additional storms in 1964-65 washed away much of the outer ends of each jetty. By 1970, the heads of the jetties were totally destroyed and another major rehabilitation work was authorized to thwart the attacks of the sea.

For two generations, the Pacific Ocean demonstrated that a stonewall defense offered no long-term security for the entrance to Humboldt Bay. Several years of extensive testing by the Corps of Engineers took place to determine alternate methods of solving the problem.

One very promising method was the use of the dolos (plural: dolosse), invented in South Africa but never used in the United States, and never produced to a design as large as needed at Humboldt Bay. Interlocking dolosse present no surface large enough to give a giant wave something to smash against, instead permitting the wave's dissolution in a maze of spaces.

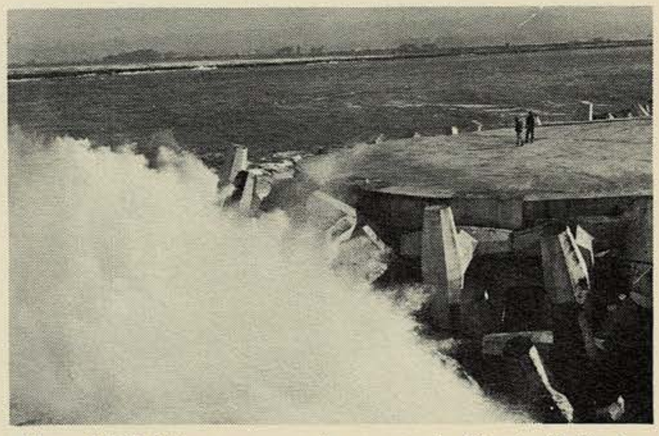
As produced for the jetty restoration at Humboldt, each dolos measured 15x15x15 feet and weighed 42 tons. Special trucks moved them from the laydown area to the jetties, where a 100-ton-capacity crane with a 200-feet reach positioned each in its charted place. Nearly five thousand of these ingenious adaptions of a child's primitive toy have successfully protected the Humboldt entrance since 1972.

TECHNICAL DATA

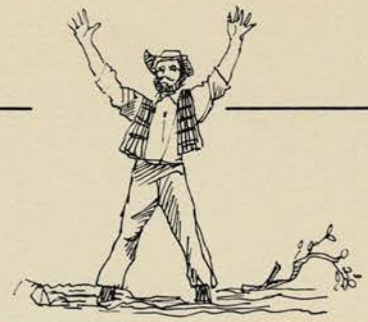
Location	Eureka, Humboldt County, California
Dates	Original jetties begun 1889, completed 1899. Dolosse jetties constructed 1971-72.
Engineers	US Army Corps of Engineers
Dimensions	South jetty (1972): 5,000 feet long North jetty (1972): 4,500 feet long

SPECIAL NOTES

1. Humboldt Harbor was the first on the Pacific Coast to be stabilized by jetties.
2. The use of dolosse is the first in the United States, and the dolosse were by far the largest in use in the world at that time. This was the first time that dolosse were designed to withstand waves of as high as 40 feet.
3. Dolosse data:
   Size: 15x15x15 feet
   Weight: 42 tons
   Concrete: 160 pounds per cubic foot
4. The term "dolos" is the Afrikaans word for the ankle bone of a goat, which were used as toys by Voortrekker (Dutch settlers) children. Eric Merrifield, harbor engineer of the Port of East London, developed the dolos as an interlocking-type alternative to the French tetrapod design of man-made armor stone for harbor protection.



About 2,500 dolosse armor units protect the Humboldt Harbor jetties. This shows the dolosse on the south jetty dissipating the force of a 30-foot wave.



Fernbridge (1911)

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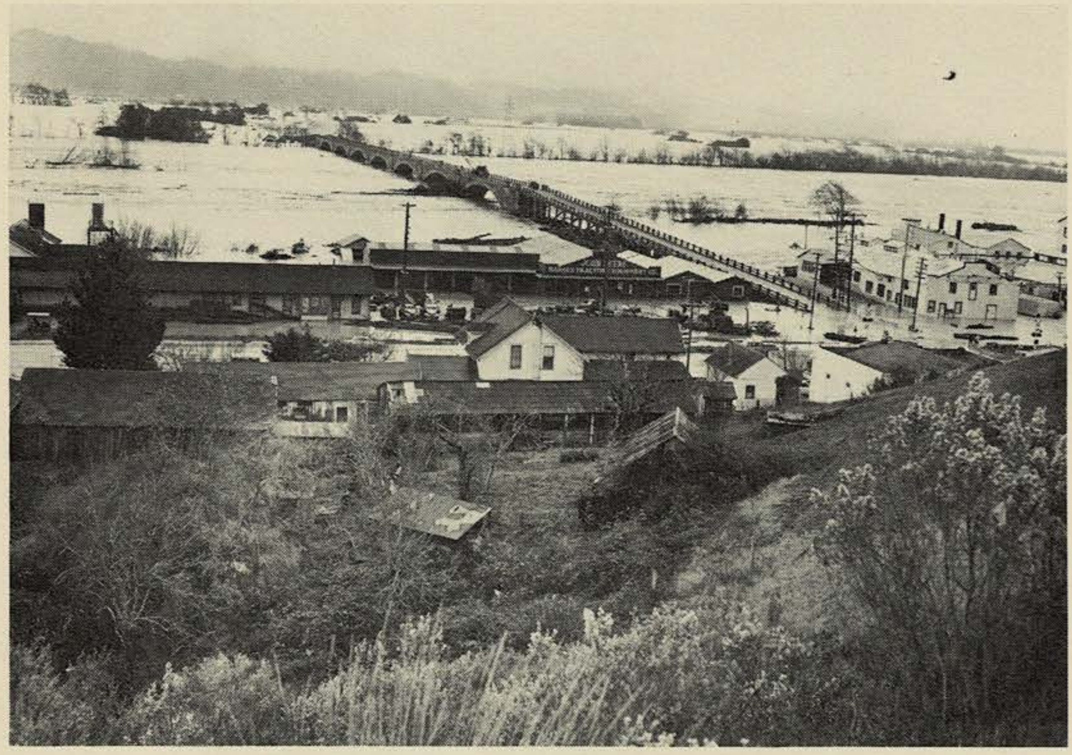
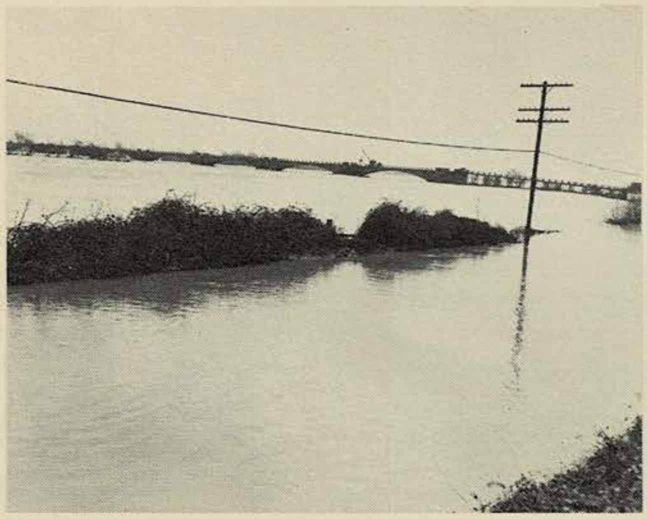




Greatest threat to Fernbridge came in the flood of 1964, which destroyed several more modern bridges. Herculean efforts at debris removal saved the "Queen of Bridges."

During the first decade of the twentieth century, the residents of Humboldt County began agitating for a bridge across the Eel River's lower reaches. At that time, during periods of heavy stream flow, the only access between northern and southern Humboldt County was by often dangerous boat crossing or very circuitous land routes.

As part of the construction of State Route One (now US 101), an innovative bridge design was prepared by J.B. Leonard, envisioning seven reinforced concrete arch spandrels filled with earth, a structure able to support vehicular traffic and an electric interurban railway line. Pacific Construction Company completed the Eel River Bridge in 1911 at a cost of about $246,000. Soon dubbed "Fernbridge, the Queen of Bridges" by grateful residents, the bridge has withstood all of the abuse the unpredictable Eel River could muster in its periodic floods, the greatest of which, in 1964, destroyed a number of modern bridges upstream.

Bridge designers throughout the West recognized Fernbridge as an outstanding engineering feat. When opened in 1911, it was one of the world's largest reinforced concrete structures, and the length of its individual spans was the greatest in the world. Fernbridge provided the precedent for the construction, in 1913, of Pasadena's famous Colorado Street Bridge ("Suicide Bridge") over the Arroyo Seco and, in 1914, of San Diego's Cabrillo Bridge.

The doughty bridge's battle with the Eel River has been prolonged and dramatic. In 1918, the weakened wooden trestle approaches to the bridge were replaced with new reinforced concrete girder and slab spans on concrete piles. In 1924, the foundation under Arch Pier Six was badly damaged by water. It was restored by constructing a cofferdam around it, pumping out the water, removing the earth around the piles, chipping out defective and spalling concrete and pouring a new concrete footing below the original one, thereby restoring bearing of the pier on the original piles. A flood in December 1955 washed out the south abutment and the approach span. The end span was eliminated, and the first bent from the end became the southerly abutment, shortening the bridge 20 feet. An earthen embankment was built to replace the old span. In 1963, a deep scour hole under Arch Pier Seven was filled with gravel and two-ton class rock riprap.

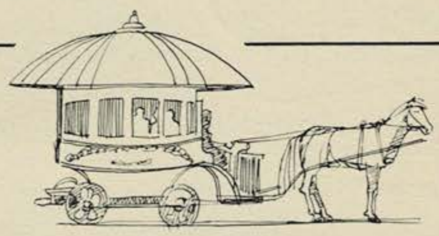
The big flood of 1964 had the "Queen of Bridges" trembling as debris piled up against her, but, with the aid of dynamite and a crane, the debris was cleared and she survived. The next year saw the northerly arch span abutment's base reinforced with sheet metal piling and reinforced concrete.

Except for the width of the roadway, generous in 1911 due to the never built trolley line, the bridge is fully adequate today, serving all kinds of traffic including wide-span potato harvesters and heavily laden logging trucks which sometimes knock corners off the bridge's balustrades.

TECHNICAL DATA

Location	Old State Sign Route One (US 101) between Eureka and Fortuna, Humboldt County, California
Dates	Completed 1911
Cost	\$246,000 (original cost)
Engineers	J.B. Leonard, designer George W. Conners, county surveyor Philetus Bell, resident engineer for Humboldt County
Dimensions	(Since repairs of 1956) Southerly approach: 21 spans of 20.3′ = 426.3 feet Main spans: 7 spans of 180′ clear = 1,260 feet Main span length including piers and abutments: 1,454 feet Northerly approach: 26 spans of 20.3′ = 527.8 feet Total bridge length including approaches: 2,408 feet Roadway width between balustrades: 22.5 feet

The Cable Cars (1873)



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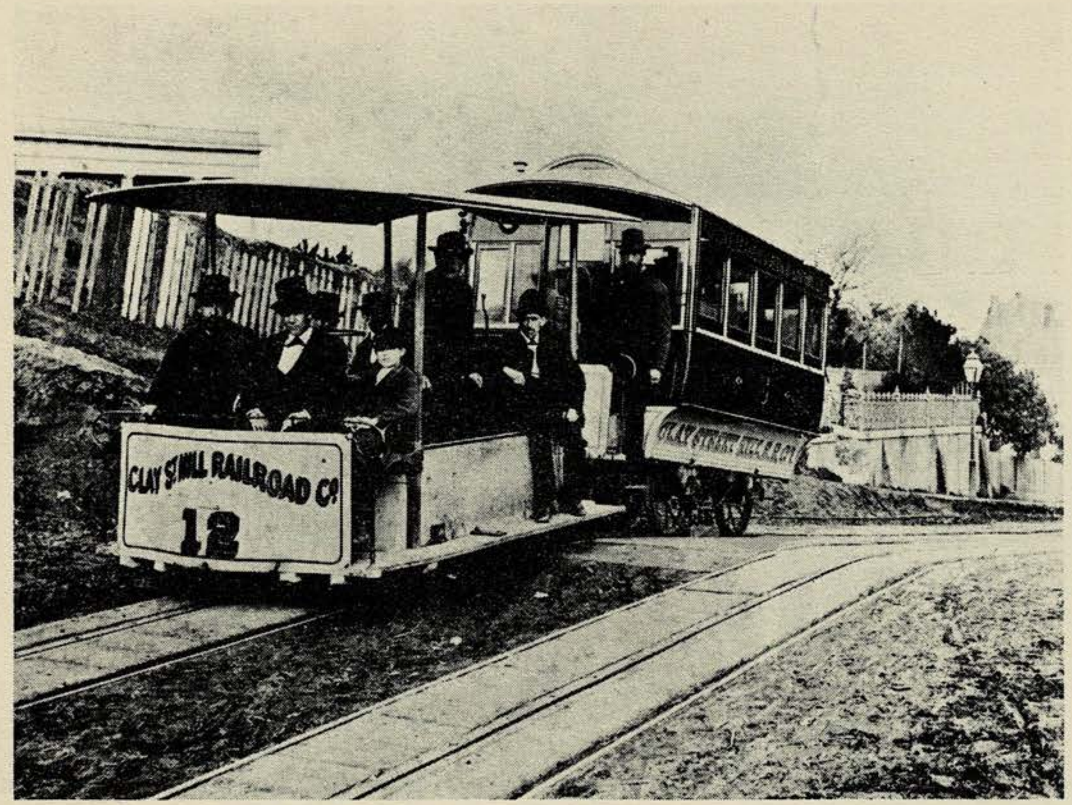
Legend has it that a tragic but not uncommon accident spurred the invention of a system of public transportation which has since become a San Francisco landmark—the cable car.

One rainy winter evening in 1869, Andrew S. Hallidie, an immigrant Scot known in San Francisco for the manufacture of fine quality wire rope, paused to watch an overloaded horse-drawn streetcar struggle up one of San Francisco's proverbial hills. With extreme effort, the four horses moved the car. Partway up the hill, one of the horses slipped on the slick cobblestones. The driver applied the car brakes with such force that the chain mechanism snapped. At once the car began to slide down the hill, dragging the unfortunate horses over the pavement. When the car came to rest at the bottom of the hill, it was found that, while the terrified passengers were unharmed, the four horses were dead.

Hallidie, shocked by the gruesome spectacle and angered by the cruel treatment generally given to the horses which powered the public transport of that era, was inspired to invent a new system to replace the horse-drawn streetcars.



Very early photo of the Clay Street line shows original equipment: a gripcar (left) *hauling a trailer ("dummy"). A.S. Hallidie himself is sitting second from left in the front of the grip car.*

By 1871, Hallidie had designed a system of underground moving endless cables to which could be gripped and released at will streetcars running along railroad tracks in the street. Due to the radical innovation in public transportation represented by this "cable-drawn car," coupled with the conservatism of the horsecar owners of San Francisco, it took Hallidie over a year to raise enough money to construct a demonstration line. In 1872, Hallidie and three partners incorporated the Clay Street Hill Railroad Company to install and operate a cable car line along the steep (one foot of rise in six horizontal feet) suburban street. A franchise was secured from the city, and construction of the underground cable conduit, the tracks and the cable winding powerhouse was begun.

Despite a chronic shortage of money, Hallidie managed to get the complex system installed by the last week of July 1873. Faced with a deadline of August 1, 1873 to have the new cable cars running or lose his franchise, Hallidie ordered the boilers fired up at the powerhouse on the corner of Leavenworth and Clay Streets in the evening of July 31. At five o'clock on the foggy morning of August 1, the engines were started and the cables began buzzing and humming through the underground conduits, a noise that has not been stilled from that day to this.

The first grip car was poised on the brow of the steep Clay Street grade at Jones Street, but the gripman, unable to see through the fog to the bottom of the hill at Kearny Street, refused to budge. Undaunted, Andrew Hallidie himself stepped aboard the car, confidently tightened the grip and descended at a gentle eight miles an hour to the bottom.

During the ensuing decade, cable car lines spread throughout San Francisco, operating not just on hilly streets but on flat as well. Even as Hallidie had predicted, the cable car largely replaced the horsecar on the major thoroughfares of San Francisco. Nevertheless, until 1882, when a major system, ultimately the nation's largest cable railway network, began operation in Chicago, the cable car was considered appropriate only to San Francisco. But the Chicago installation altered that attitude, and in a frenzied period of construction lasting from 1882 until 1890, cable systems were installed in 35 cities in the United States and overseas.

Unfortunately, the rapid perfection of electric streetcar technology during 1886-88 quickly ended the reign of the cable car as a viable method of public transportation, and between 1890 and 1902, most cable systems were replaced with electric trolley cars—except in San Francisco.

The steep hills of San Francisco (many too steep for trolley cars) and a ban on erecting "unsightly" trolley wires downtown meant that San Francisco's cable cars remained in operation far longer than elsewhere.

The earthquake and fire of 1906 destroyed virtually all the cable equipment in the city, and hastened the conversion of all but a few lines to electric operation. Of the eight cable lines restored afterwards, most were abandoned and replaced by bus by World War II. When the pioneer Sacramento-Clay cable was "busified" in 1944, the people of San Francisco became indignant over the wanton destruction of a priceless heritage and began an often bitter ten-year campaign to save the cables.

Today the three remaining San Francisco cable lines are secure. Operated as a division of the Municipal Railway, the cables were declared a National Historic Landmark in 1964 and a National Civil Engineering Landmark in 1973. Of all the unusual features of this unique system, one of the most unique remains the fare: it still costs just a quarter to ride anywhere on the cable system!

TECHNICAL DATA

Location

San Francisco, California

California Street line operates on California Street between Market and Van Ness

Powell-Mason line operates between Powell and Market and Bay and Taylor Streets, via Powell, Jackson, Mason, Columbus, Taylor

Powell-Hyde line operates between Powell and Market and Hyde and North Beach Street, via Powell, Jackson (return via Washington), Hyde

The cable power house and car barn, with a museum of historic cable cars, is located at Washington and Mason Streets

Dates

First operation (Clay St. line): August 1, 1873

First operation (Powell-Mason): March 28, 1888
Jackson): Ferries and Cliff House Point, April 5, 1888

First operation (California St. line): April 10, 1878

First operation (Hyde St. line): February 9, 1891

Date of maximum cable mileage in San Francisco: 52.8 miles in 1893

Clay Street line abandoned: February 15, 1942

Powell-Mason, Washington-Jackson lines bought by city: 1944

California-Hyde lines bought by city: January 13, 1952

Present system of operation inaugurated: April 7, 1957

Cost

Original Clay St. line (between Kearny and Jones Streets): $85,150

The 1954-56 "streamlining": $20 million
(The cost of constructing a cable line was estimated to range [in the gold dollars of 1880] between $100,000 per mile in flat lands to $250,000 per mile in hilly lands.)

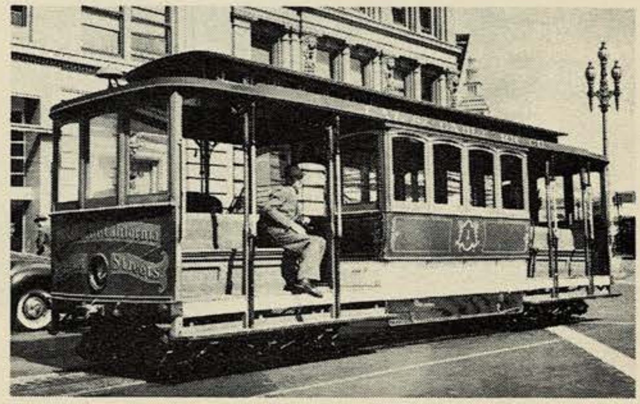
Engineers

Andrew Smith Hallidie invented the original system

William Eppelsheimer invented the bottom grip presently used in San Francisco

Dimensions

(Present system)
Maximum gradient: 24% on Hyde St. between Lombard and Bay



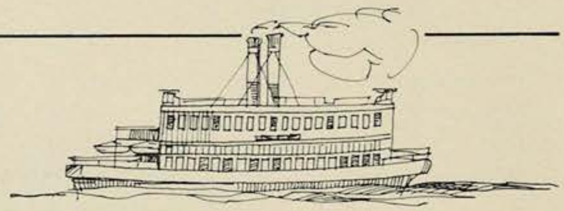
During World War II, the red and gold California Cable Railroad Car No. 1 awaits passengers at California and Drumm Streets. Returning servicemen spread the fame of the cable cars, aiding in their preservation.

SPECIAL NOTES

1. The present cable system was consolidated in a reconstruction program from 1954 to 1956. Originally, the Hyde Street line operated as a branch of the California Street line, and the Washington-Jackson lines operated as far west as Presidio. During the reconstruction, the Cal Cable lines on O'Farrell and Jones were abandoned, the California line was cut back to Van Ness, and the Washington-Jackson lines were cut back to and routed over Hyde Street.
2. The technology of the present cable systems is clearly and simply explained in a brochure available from the Municipal Railway of San Francisco. The brochure can be purchased at the cable car barn. Serious students of cable technology are invited to read Professor George Hilton's **The Cable Car in America**, available from Howell-North in Oakland.
3. Other West Coast cable systems included:

Oakland (2 companies)	1886-1896
Los Angeles (3 companies)	1885-1902
Seattle (5 companies)	1888-1940
San Diego (1 company)	1890-1892

The San Francisco-Oakland Bay Bridge (1936)

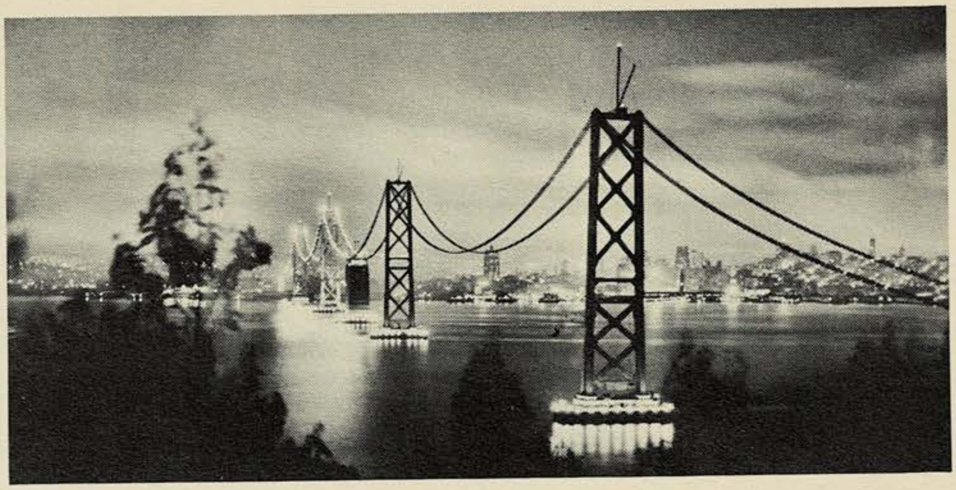


Even while Joseph Strauss was building support for the construction of the Golden Gate Bridge, interest was growing in a companion project, a bridge to replace the picturesque, but slow, ferry trip between Oakland and San Francisco. The physical spanning of San Francisco Bay was not in itself difficult, several low level structures having been proposed prior to the turn of the century, but the danger to navigation, especially in the frequent fogs, required a high-level design.

When construction began in 1933, the Bay Bridge's design called for two structures aggregating 8½ miles long, separated by a tunnel through Yerba Buena Island. The western portion is a double suspension bridge joined by a common center pier, while the eastern is a combination of through and deck trusses, with a cantilever channel span of 1,400 feet, which remained a record for over twenty years. The outstanding engineering feature of the bridge is the center pier of the two 2,310-foot suspension spans. The pier, extending 220 feet below the water surface to bedrock, utilized a special caisson of steel cylinders balanced by compressed air ballast to be emplaced into its record depth.

As originally planned and as opened in November 1936, the double-decked structure carried six lanes of auto traffic on the top level and four lanes of trucks and a double-track rapid transit line on the lower deck. This

The Bay Bridge's ribbon cutting ceremony on November 12, 1936, was held on the San Francisco approach.



Spinning of the Bay Bridge's cables went on around the clock. Here, the work lights along the catwalks add a new dimension to one of San Francisco's famous sunsets.

fortuitous and farsighted inclusion of a rail line on the Bay Bridge, a failing on the Golden Gate structure, enabled through electric railway service to enter downtown San Francisco from East Bay points and destinations as distant as Sacramento and Chico.

Since 1958, the principle modification to the Bay Bridge has been the expansion of the roadways for mixed trucks and auto traffic: six lanes westbound above and six eastbound below, as a result of the abandonment of rail service in 1958. Although now carrying rush hour traffic far in excess of designated capacity, the Bay Bridge remains a key part of the Bay Area's transportation network.

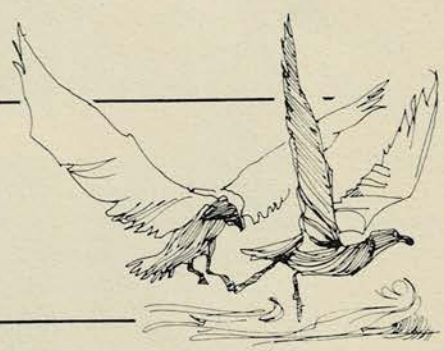
TECHNICAL DATA

Location	San Francisco and Alameda Counties, California Western pier on Rincon Hill, San Francisco, eastern (toll plaza) end in Port of Oakland
Dates	June 1932: Congress approved a $73 million RFC loan to begin construction July 1933: Construction began November 12, 1936: Opened for traffic
Cost	$70 million
Engineers	Charles H. Purcell, chief engineer Charles E. Andrew, bridge engineer Glenn B. Woodruff, design engineer

SPECIAL NOTES

1. The pier between the two suspension spans on the western portion was the highest and deepest sunk suspension bridge pier at time of construction.
2. The Yerba Buena Island Tunnel between the east and west portions of the bridge was the first double-deck highway tunnel in the US.

The Big Sur Highway and Bixby Creek Bridge (1932)



Although authorized as early as 1918, the Ocean Highway, now known as State Highway One, was not completed until some fifteen years later due to difficulties of construction and opposition by powerful landowners, including William Randolph Hearst. Intended as an alternate to US Route 101 running inland in the Salinas Valley, the Ocean Highway provides access to the spectacular coastline of Central California. To achieve this access, however, the highway was, of necessity, located along the steep slopes facing the sea, often running at considerable height above the beach to avoid the sheer wave-formed cliffs and to take advantage of occasional bench lands. The route required the crossing of numerous intersecting ravines and canyons, which resulted in the construction of four beautiful reinforced concrete arch bridges.

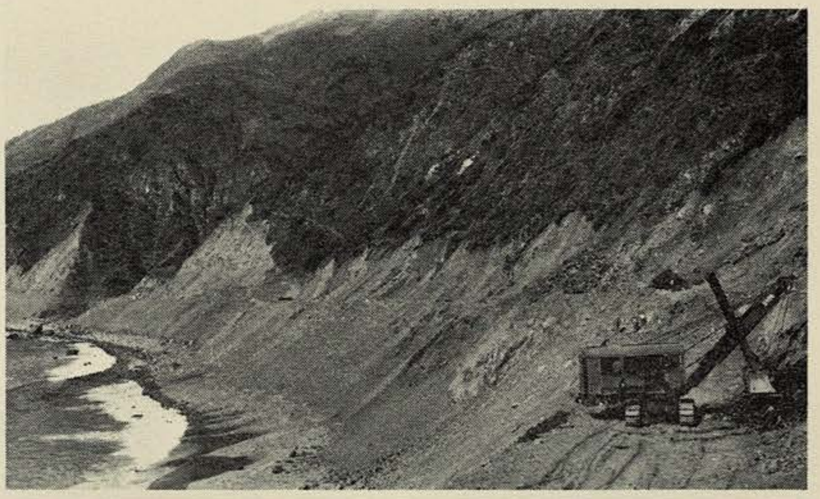
Of the four structures, the most notable is that spanning Bixby Creek, due to the length of span, height above streambed and construction difficulties. The highway bridge builders found at the proposed site that the canyon slopes were badly faulted and decomposing and the high tide line so close as to expose permanent footings and construction falsework to wave damage during storms.

After considerable investigation, including an alternative highway routing to avoid the location as well as other bridge designs, it was decided to erect a concrete open-spandrel arch instead of a steel structure, as concrete would better resist the wind and salt spray.

The Bixby Creek Bridge, as designed and built, has an arch of 330-foot span with three 40-foot girder approach spans at the south and six similar spans at the north. Construction of the approaches began in November 1931, but due to the danger from winter storms, work on the center arch did not begin until the following April. The nearest railhead was 21 miles to the north, and all lumber and cement was trucked to the site over a one-way road with numerous hairpin turns. The bridge was completed in November 1932, and has become famous for its beauty along a highway noted for scenic grandeur.

TECHNICAL DATA

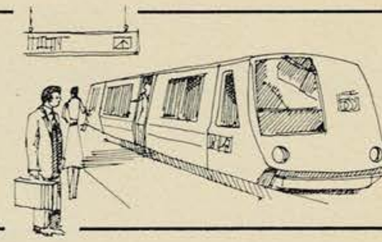
Location	18 miles south of Carmel on Highway One
Dates	Dedicated November 27, 1932
Cost	$202,000
Engineers	F.W. Panhorst, Stewart Mitchell, I.O. Jahlstrom, from the State Division of Highways E.C. Panton, superintendent of construction for the contractor, Ward Engineering Company
Dimensions	Total bridge length: 714 feet Arch diameter: 330 feet Height of roadway above stream: 265 feet Footing pressure on arch abutments: 11 tons p.s.f.



Construction of the Big Sur Highway was made more difficult by often treacherous shifting shale on the steep coastal cliffs.

The graceful arch of Bixby Creek Bridge complements the grandeur of the coastal scenery.

BART's Transbay Tube, 1969 (1974)



BART, the Bay Area Rapid Transit System, came into existence as a result of the precipitate abandonment of existing interurban electric rail systems during the post-World War II automania. In 1958, mere months after the abandonment of train service across the Bay Bridge, the newly constituted "BART" first met to plan a new mass transit system.

Key to the new BART system would be a tunnel across the floor of San Francisco Bay, a tunnel enabling high-speed trains to reach downtown San Francisco from Oakland in under five minutes. The resulting transbay tube has become recognized as one of the nation's outstanding civil engineering achievements.

Studies begun in 1959 led to the design of a virtually earthquake-proof structure, cushioned on bay floor and flexible at terminal points. Stretching 3.6 miles in a trench along the bay floor between Oakland and San Francisco, the tube is both the longest and, at its maximum of 135 feet below the surface, the deepest vehicular tube in the world.

The tube's fabrication and placement pioneered methods now being used on several transit system projects around the world. Fifty-seven tube sections, averaging 330 feet long, were built of steel plate and beams at a South San Francisco shipyard, launched, towed to the trench site and sunk into proper position. The tube sections, resembling huge binoculars in cross-section, contained separate trackways for trains running in each direction. The first section was launched in February 1967. Gradually, all of the 10,000-ton sections were emplaced and welded together beneath the bay.

The last tube section was placed just east of Yerba Buena Island in April 1969. Track laying, electrification and installation of train control and ventilation equipment was completed in 1973. Following a year of testing of safety devices and train controls, the first revenue train ran through the tube on September 16, 1974. The three-and-one-half-minute travel time under the bay is the envy of old-time railroaders and traffic-bound auto commuters alike.

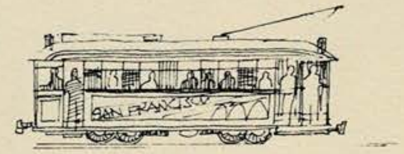
TECHNICAL DATA

Location	San Francisco Bay, California; western terminus is Embarcardero Station, San Francisco, eastern terminus is Oakland West Station
Dates	February 1967: First tube emplaced April 1969: Last tube emplaced August 1969: Track laying in tube completed September 16, 1974: First revenue train run through tube
Cost	$176 million (fabrication and placement of tube, tracks, vents and signals)
Engineers	Parsons Brinckerhoff — Tudor — Bechtel
Dimensions	3.6 miles long 24 feet high (each of two tubes) 48 feet wide (two tubes parallel) Varies from 75 feet to 135 feet underwater

SPECIAL NOTES

1. Deepest and longest underwater transit tube in the world.
2. Pioneered underwater placement now being used on several transit systems.

Twin Peaks Tunnel (1917)



When San Francisco adopted a new city charter in 1900, one of the important provisions called for the creation of a municipally owned street railway system for urban transportation. However, it was not until 1908, when the city began operating electric trolleys on Geary Street, that the municipal railway concept achieved reality.

The city's urban transportation system was in chaotic condition after the devastation wrought by the great earthquake, and nationally known mass transit expert, Bion J. Arnold, was called in to prepare a long-range master plan. As finally published in 1912, the "Arnold Report" called for gradual acquisition by the municipal railway (the "Muni") of the properties of the competing private company, the Market Street Railway Company, and urged that the Muni take the lead in extending transit services to the growing western suburbs.

Principal among Arnold's proposals was that calling for a tunnel into the Sunset District from the head of Market Street, this tunnel to carry Muni lines into the new residential area being carved from the sand dunes of the city's far west side. A $3.4 million bond issue, passed late in 1914, earmarked funds for what became known as the Twin Peaks Tunnel.

Construction of the 2.23-mile-long tunnel began in 1914 and proceeded without unusual difficulties. The tunnel was double tracked and had a vent shaft nearly midway along, at the location of the Laguna Honda Station. The sandy soil of the Twin Peaks enabled the use of a wallplate heading, and a major construction innovation was the pneumatic delivery of concrete for the tunnel lining for distances up to 3,700 feet inside the bore, the first use of this technique in the West.

Twin Peaks Tunnel was opened with appropriate ceremony in 1917 when the first gold-striped, gray-painted "iron monster" rumbled through the tunnel and ran to the ocean over what became known as the "L" line. In a city where public transportation has always provided an effective and comprehensive competition to the automobile, the Muni lines radiating westward from the Twin Peaks Tunnel have enabled development of San Francisco's west side by offering the shortest time to downtown.

Pneumatic pumping of concrete first used in the West on this project.

During the last quarter century, while electric railway systems have died in other cities in the nation, the Twin Peaks Tunnel has proven both the linchpin and the salvation of the Muni's rail lines by offering a route free of traffic and still providing the fastest journey from downtown to the west. Of the five remaining Muni rail lines, three, the "K" to City College, the "L" to the zoo and the "M" to Ocean View, still operate through the tunnel.

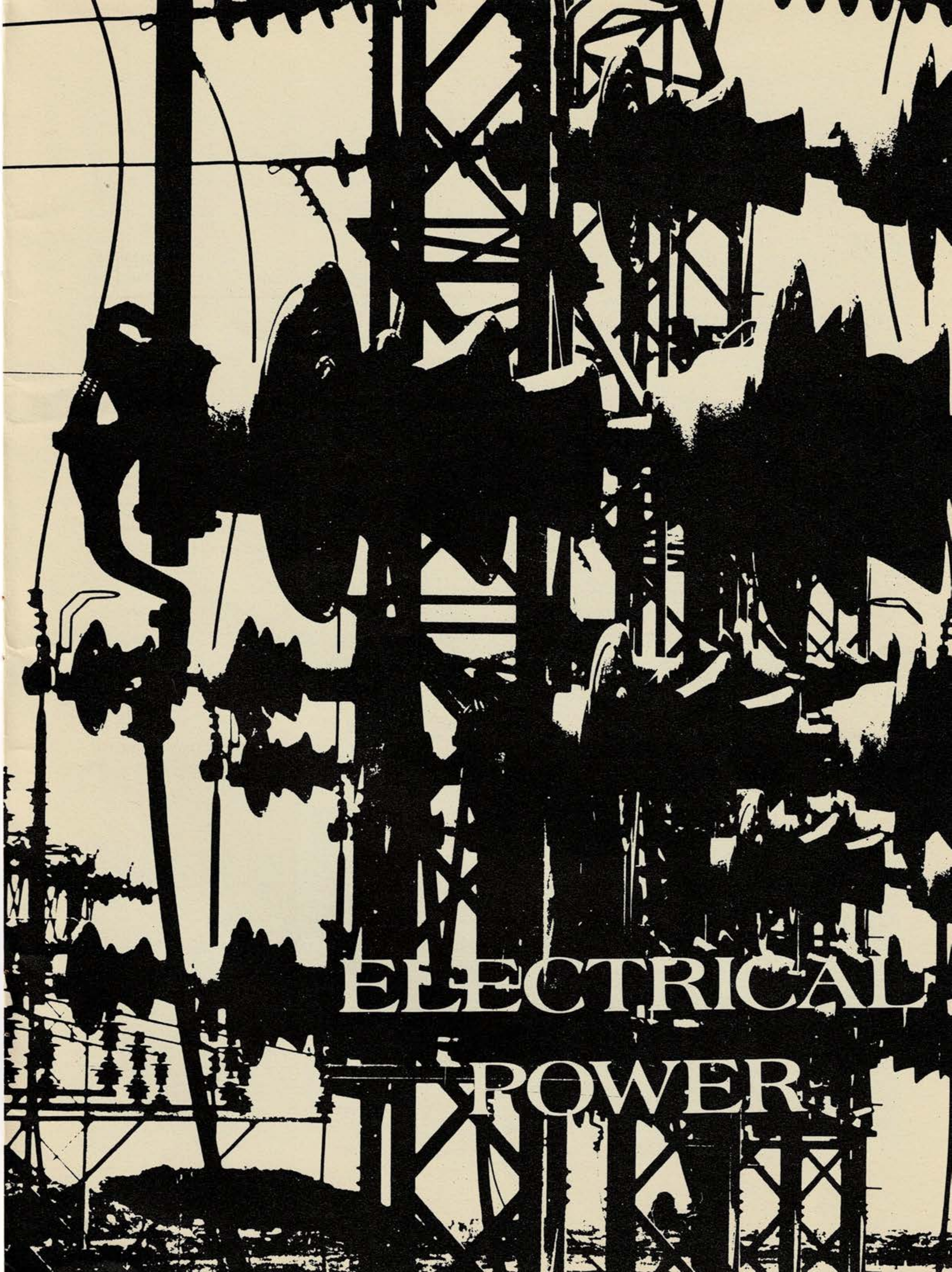
Fortunately, the Twin Peaks Tunnel has not been relegated to the status of an anachronism, but remains today a viable part of San Francisco's mass transit system, thanks to an extension of the tunnel eastward the full length of Market Street to the Embarcadero as part of the Bay Area Rapid Transit project. Presently completed and awaiting only delivery of new cars to be inaugurated, the new Muni Metro and its extension through a revitalized Twin Peaks Tunnel are the ultimate embodiment of the crosstown transit system envisioned sixty years ago by Bion J. Arnold.

TECHNICAL DATA

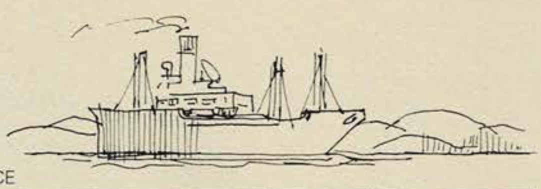
Location	San Francisco, California
	Former east portal (now removed) at Market and Castro Streets; west portal at West Portal Avenue and Ulloa Street
Dates	November 30, 1914 to July 14, 1917
Cost	$3,948,000
Engineers	Bion J. Arnold, preliminary designs M.J. O'Shaughnessy, city engineer
Dimensions	25′ x 18′

SPECIAL NOTES

Pneumatic pumping of concrete first used in the west on this project.


ELECTRICAL
POWER

Carquinez 60 KV Crossing (1902)



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

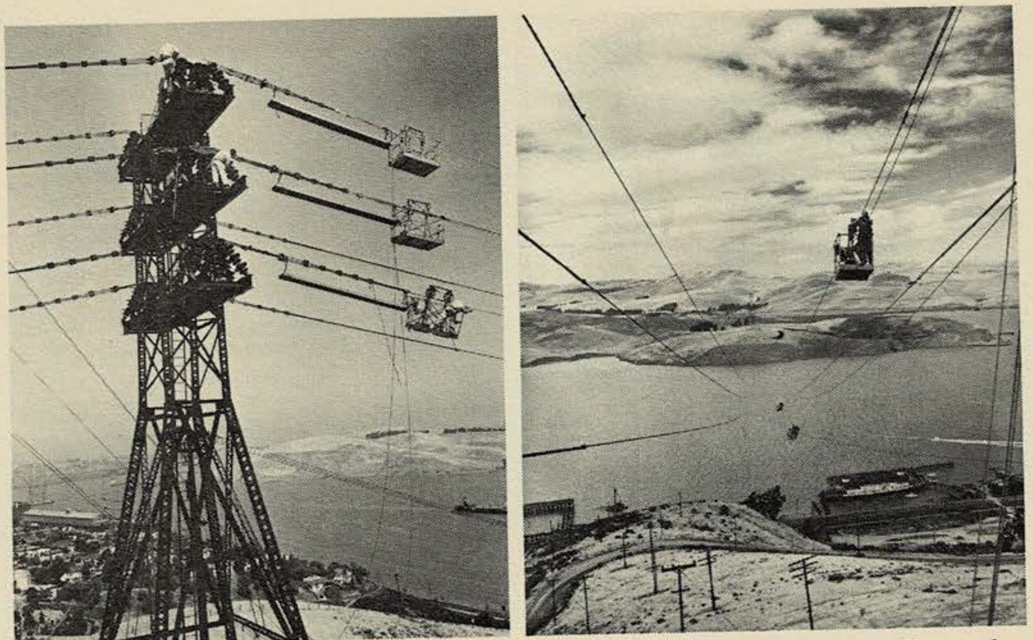
Throughout the long, hot summer of 1900, John Martin tramped through the picturesque ranchlands of Central California, negotiating and "palavering" with farmers for rights to a strip of land to be used for a new electric power transmission line to extend from the Sierras to San Francisco Bay. Only the warmth of Martin's personality persuaded the often reluctant landowners to permit the "newfangled" power line across their property.

Martin's Bay Counties Power Company, a predecessor to the Pacific Gas and Electric Company, was a pioneer in the electrification of Northern California. An inexpensive, plentiful supply of electricity from its Colgate Powerhouse on the Yuba River would be available to San Francisco Bay communities for domestic, industrial and transportation needs if problems connected with a long distance transmission line could be solved. John Martin solved the problem of conservative, reluctant ranchers; the industry developed a 60,000-volt technology, enabling electricity to be sent very long distances. Only one problem remained: how to cross vast San Francisco Bay with the high-tension lines.

Martin and his engineers considered the bay crossing problem carefully. Underwater cables were ruled out due to the high voltage of the line. An aerial crossing, even at the bay's narrowest point, Carquinez Straits, would be over 4,000 feet in length, and would have to be high enough to clear the masts of the sailing vessels which still plied the bay. There was no precedent for a cable crossing of this size, yet Martin and his associates unflinchingly prepared a unique, record-shattering design.

As designed and built, the Carquinez Straits' transmission crossing utilized tall steel towers on the tops of hills flanking the straits to gain enough height to clear the ship channel. The towers and cables, designed to withstand tremendous wind loadings, provided a major breakthrough in the structural design of long-span electric transmission crossings, thereby assisting in the electrification of the nation. Although augmented by additional crossings built subsequently, the original Carquinez transmission crossing, with its picturesque towers, remains in service today.

The north, or leaning, tower and the huge center tower, both recently completed, dominate the landscape in this pastoral scene from 1902.



Painting the power cables is a constant task. Work begins from south tower (left) *and proceeds northwards across the straits* (right).

TECHNICAL DATA

Engineer	John Martin
Dimensions	North (leaning) tower: 96 feet high Center (Dillon's Point) tower: 225 feet high South (Crockett) tower: 64 feet high Span between center and south tower: 4,427 feet Lowest cable is 206 feet above high water.

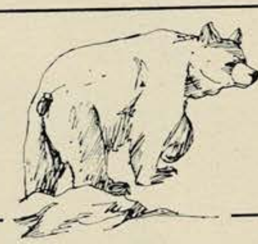
NOTES

1. The design incorporated several new features, including cable design for high voltage and long span, anchorage design to accommodate the heavy pull (12 tons per cable, 4 cables total), and structural design to accommodate wind and cable loading, span and height requirements.

2. The 60,000-volt transmission line from Colgate Powerhouse to Oakland (142 miles), of which the Carquinez crossing is a part, was the longest and highest voltage line in the world when energized on April 27, 1901.

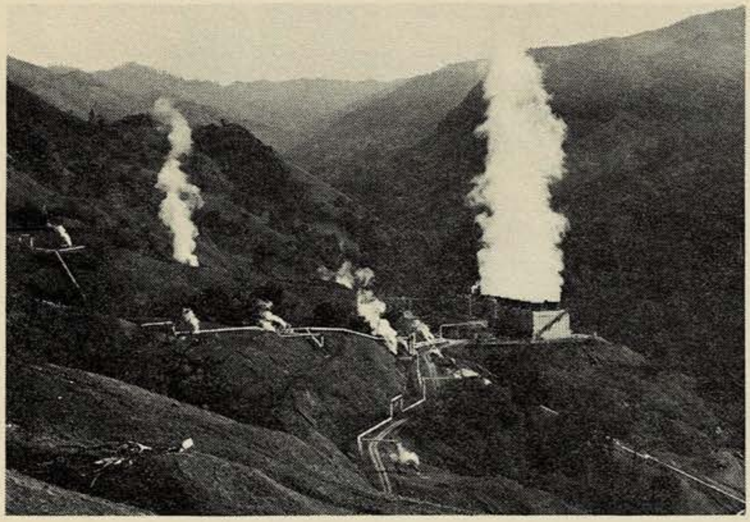
The Geysers Geothermal Power Development (1960)

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



Hiking through the mountains between Cloverdale and Calistoga in search of grizzly bears one day in 1847, explorer-surveyor William Bell Elliott came upon a frightening sight: steam pouring out of a canyon along a quarter mile of its length. He had discovered The Geysers, but the awestruck hunter later told friends that he thought he had come upon the gates of hell itself.

Subsequently, the area became a popular tourist



Cooling towers and escaping steam mark the site of the world's largest geothermal power facility, The Geysers.

attraction, particularly after stagecoach service began in 1863 and a fine resort was built nearby. Although a number of famous people are numbered among the late 19th century visitors to the fumaroles, visitors did not flock in great numbers because of its location in rough and remote countryside.

After the successful generation of electric power from natural steam at Larderello, Italy, in 1904, plans were repeatedly made to use the steam of The Geysers for agricultural and industrial processes. Starting in 1922, eight wells were drilled, tapping the steam, but the piping and turbines of the time simply could not withstand the corrosive and abrasive effects of the impurities contained in the natural steam. Nor, apparently, was the time ripe, for more economical hydroelectric power sites were still available in abundance.

By 1955, however, interest in The Geysers had renewed, due to the vast post-war growth in demand for electricity. Magma Power Company and Thermal Power Company, working jointly, drilled six wells between 1955 and 1957. By this time, great progress had been made in finding stainless steel alloys able to withstand corrosion. After a series of wellhead flow tests, it was proven that geothermal steam could be purchased economically at The Geysers, and Pacific Gas and Electric Company contracted to build a generating station and buy steam from the wells.

Geothermal power generation became a reality in June 1960 when a 12,500 kilowatt plant began generating electricity from some 250,000 pounds of steam per hour supplied by four wells. From that year onward, The Geysers has been steadily expanded, and since 1973 has been the world's largest geothermal facility, with eleven units producing 504,000 kilowatts of power.

Four additional units are under construction, which will bring the total Geysers' generating capacity up to 908 megawatts with a total project estimated cost of $127 million. Seven more units are in the planning stage.

TECHNICAL DATA

Location	The Geysers, 21 miles northeast of Geyserville, Sonoma County, California
Dates	Geothermal field discovered: 1847 First exploratory well drilled: 1922 First generating unit completed: 1960
Cost	The cost to date of the eleven generating units at The Geysers is $63 million, which does not include the cost of drilling wells.
Engineers	R.V. Bettinger, Chief Civil Engineer, and A.W. Bruce, J.P. Finney, Geysers Project Engineers, PG&E Company Dr. H.J. Ramey, Jr., Stanford University

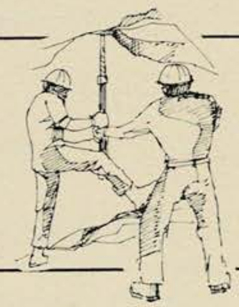
SPECIAL NOTES

How The Geysers power plants work:
Steam supplied to the turbines from the fields is about 350°F in temperature and 100 pounds per square inch pressure. About eleven million pounds of steam per hour will be required for operation of all the units through No. 12. As the steam leaves the wellheads, it is first

cleansed of minute fragments of rock by "whirling" them off. Otherwise they could damage the turbines. The steam is then piped into the power plants to spin the blades in the turbines which, in turn, drive the generators that produce electricity. After the steam has done its job, it is piped to a condenser, which returns the steam to water by combining it with cooling water. The combined waters are pumped to the cooling tower where the water temperature is reduced. One of the unique aspects of the operation is that no make-up water is required for the cooling tower because it is supplied by the condensing geothermal steam.

Haas Underground Powerhouse (1958)

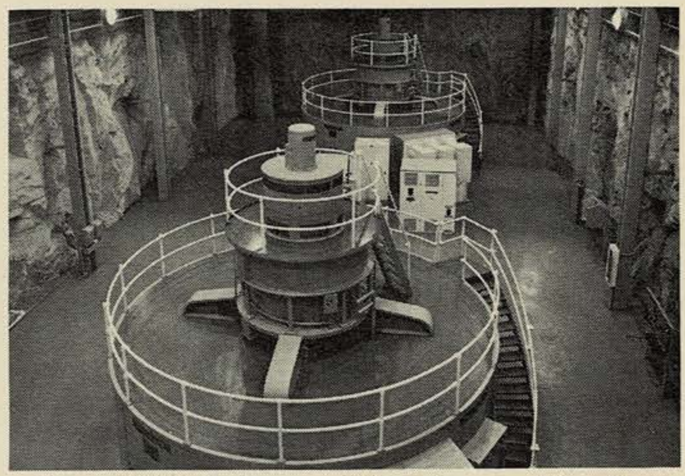
Dedicated as a California Historic Civil Engineering Landmark by the San Francisco Section, ASCE



The High Sierras of Central and Northern California, with their many rivers having small volumes of water but great drops in distance, have been the scene of many of the most important developments in hydraulic engineering. The famous Pelton Wheel, invented in the Sierra foothills, was designed for the particular water supply problems of California to get the maximum power from the minimum water. Most of the region's water utilities, including Pacific Gas and Electric, date their ancestry to the small water companies built by the hardy Forty-niners to provide water to the placer mines of the Mother Lode. By far the greatest impetus to hydraulic technology came with the growing electrification of California, when the Sierran rivers were utilized as a source of plentiful, inexpensive electric power.

The post-World War II Kings River Project of the Pacific Gas and Electric Company introduced a new innovation into the traditional technology of Sierra hydro plants. Haas Powerhouse, a 144-megawatt facility, was located in a vast cavern deep in the granite heart of the mountains. The first large underground power plant built in the United States, Haas' unique location resulted in a large savings in penstock steel, resulting in a lower overall project cost.

The plant is the second highest head (fall of water) plant in the nation, with a vertical drop of 2,444 feet between the forebay reservoir and the turbines. Water from the forebay, Lake Wishon, flows through seven miles of tunnel and penstock to spin the turbo-generators in the powerhouse, which is located nearly 500 feet underground.



Located 500 feet below ground, the vast cavern of Haas Powerhouse contains machines capable of producing 144 megawatts of electricity.

In addition to being the prototype for subsequent underground power plants throughout the world, Haas Powerhouse and the Kings River Project are key elements in the power and water supply systems of Central California.

TECHNICAL DATA

Cost	$80 million for the entire Kings River Project
Engineers	J.B. Cooke, Supv. Civil Engr. Walter Dreyer, Chief Engr. C.W. Appleford, Chief Civil Engr. W.R. Johnson, Chief Elec. Engr. J.E. Schumann, Civil Engr. H.V. Lutge, Chief, Proj. Planning G.B. Thatcher, Project Cons. Engr.

Dimensions

Excavation for turbine room:
173 x 56 x 100
Water conduit:
32,691 feet unlined tunnel
4,563 feet penstock
Plant output (nameplate):
144 megawatts

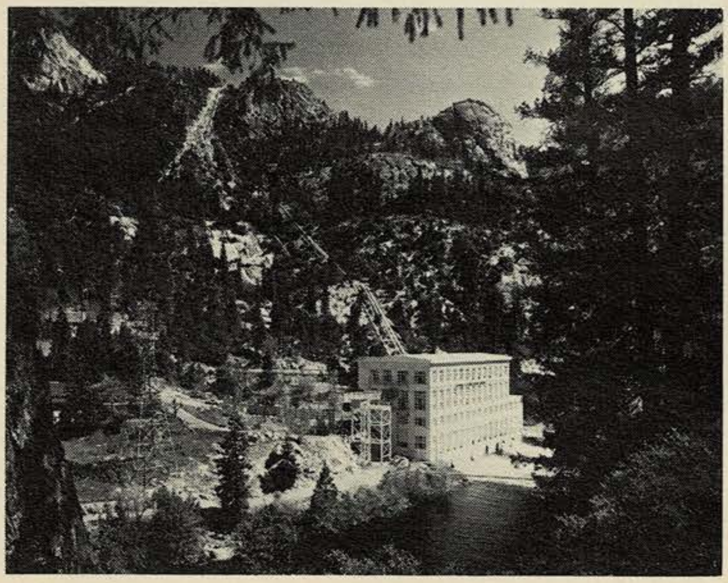
NOTES

1. The Haas design reduces considerably the length of penstock with steel plate from 2 to 3 inches thick. This is replaced by unlined tailrace tunnel that costs only about one-fourth as much as penstock.
2. The adopted scheme provides 28 feet more effective head, which adds to the total saving.
3. The penstock is placed deep in an excellent formation of massive granite. And the profile at the lower end of the high head (2,400 feet) penstock is relatively flat. For much of the underground portion of the penstock, steel thickness is reduced by using higher design stresses in the penstock, which, in this area, will be concrete backfilled and grouted. Thus, the shell need be only 1½ inch thick in this stretch rather than as much as ¾ inch thicker.

   Improved features include the shut-off valves, which are located in the machinery hall excavation rather than in a separate valve chamber excavation as is usually the case.

   Construction of an underground plant, even in excellent granite, was estimated to cost more than a similar surface installation. The scheme was made economic by the saving in penstock construction cost and reduction of head loss.

The Big Creek Project (1913)



Big Creek No. 1, first in the chain of eight powerhouses, which comprise Southern California Edison Company's Big Creek Project.

In the spring of 1902, a civil engineer named John Eastwood got off the train in Fresno, walked through the dusty street of the valley town to a livery stable, and rented a string of horses and mules. A few days later, sufficient supplies packed, Eastwood led his pack train out of town towards the snowcapped Sierras shimmering in the distance.

Thus began a saga unique in the annals of civil engineering, as the indomitable Eastwood, known primarily as the inventor of the multiple-arch thin-shell concrete dam, explored through the rocky gorges and vast timber stands of California's mightiest mountains, from foothills to distant summit, searching for the proper combination of water and geography to locate a chain of hydroelectric plants of unprecedented size. Late that summer, after scores of miles of wanderings all carefully entered into his diary, Eastwood discovered a boulder-strewn gorge which fell thousands of feet into the San Joaquin River. Naming this precipitous watercourse "Big Creek" because of the amount of water it contained even in later summer, the engineer spent more weeks exploring it and its tributaries, and filing water claims.

For the next several years, Eastwood tried unsuccessfully to interest financial backers in his proposed Big Creek Hydroelectric Project but a combination of factors kept investors away. Finally, in 1910, Southern California utility and railway magnate Henry E. Huntington heard of Eastwood's plan to develop huge amounts of electrical energy from the small watercourse of the Sierras. Intrigued, and in desperate need of more energy to operate his huge trolley car system, as well as to supply the burgeoning Southern California marketplace, Huntington met with Eastwood and purchased the rights to Big Creek.

Thus was born the Big Creek Hydroelectric Project, one of the nation's largest projects. From the beginning, it was a project of superlatives, incorporating the biggest and best that technology could produce: the largest Pelton wheels, the biggest generators, the most massive pipes, the longest fall of water from reservoir to turbines, the longest and highest voltage transmission lines to carry the resulting electrical energy to Los Angeles. Even the railroad built to the remote construction site was the nation's steepest, twistiest, most expensive standard gauge adhesion railroad.

Because the water in the reservoirs would fall over an 80% grade over 2,000 feet to the turbines, by far the world's highest "head," special penstock pipe was manufactured by the Krupp Works of Germany, as no American pipemaker would guarantee his product to withstand the massive pressures generated during the long drop.

The first power deliveries from Big Creek's two original powerhouses came in November of 1913. Four years later, the Southern California Edison Company purchased Huntington's power company and undertook to expand Big Creek to the vast size originally envisioned by John Eastwood. A dozen years of construction from 1917 to 1929 saw the completion of three major reservoirs, the world's longest hard-rock water tunnel, four minor reservoirs and eleven generating units, which produced 360,000 kilowatts of electrical energy sent over three 220,000-volt transmission lines, the world's highest voltage, to Southern California. After cascading through the chain of power plants, Big Creek's water was turned into the agricultural irrigation systems of the San Joaquin Valley.

Since World War II, John Eastwood's original master plan envisioning the use and reuse of Big Creek's water has been fulfilled by the addition of three major reservoirs and six generating units, increasing Big Creek's output to 690,000 kilowatts. With very good reason, Big Creek's water, falling thousands of feet from the roof of the Sierras through the chain of powerhouses to the farmlands of the San Joaquin Valley, is known today as "the hardest working water in the world." John Eastwood would be proud!

TECHNICAL DATA

Location	Big Creek and South Fork of the San Joaquin River, Fresno and Madera Counties, California
Dates	Surveys made: 1902 Construction begun: 1910 First delivery of energy: November 13, 1913 Initial development completed: 1929 Postwar development: 1948-1960
Engineers	John S. Eastwood, original locations E.R. Davis, D.H. Redinger, G.C. Ward, engineers for Southern California Edison Company and predecessors, 1912-1949
Dimensions	Eight powerhouses containing 21 units generate 690,000 kilowatts of energy

SPECIAL NOTES

1. John Eastwood is known as the inventor of the thin shell multiple-arch concrete dams used on many power projects in the West. The largest surviving example of this type of dam is Florence Lake Dam on the Big Creek project.
2. The 13.5-mile-long ward tunnel, from Florence to Huntington Lakes, was the world's longest and fastest completed hard-rock tunnel, when finished in 1925.

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125th Anniversary
American Society of Civil Engineers
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A Location Map of

HISTORIC CIVIL ENGINEERING LANDMARKS OF NORTHERN CALIFORNIA

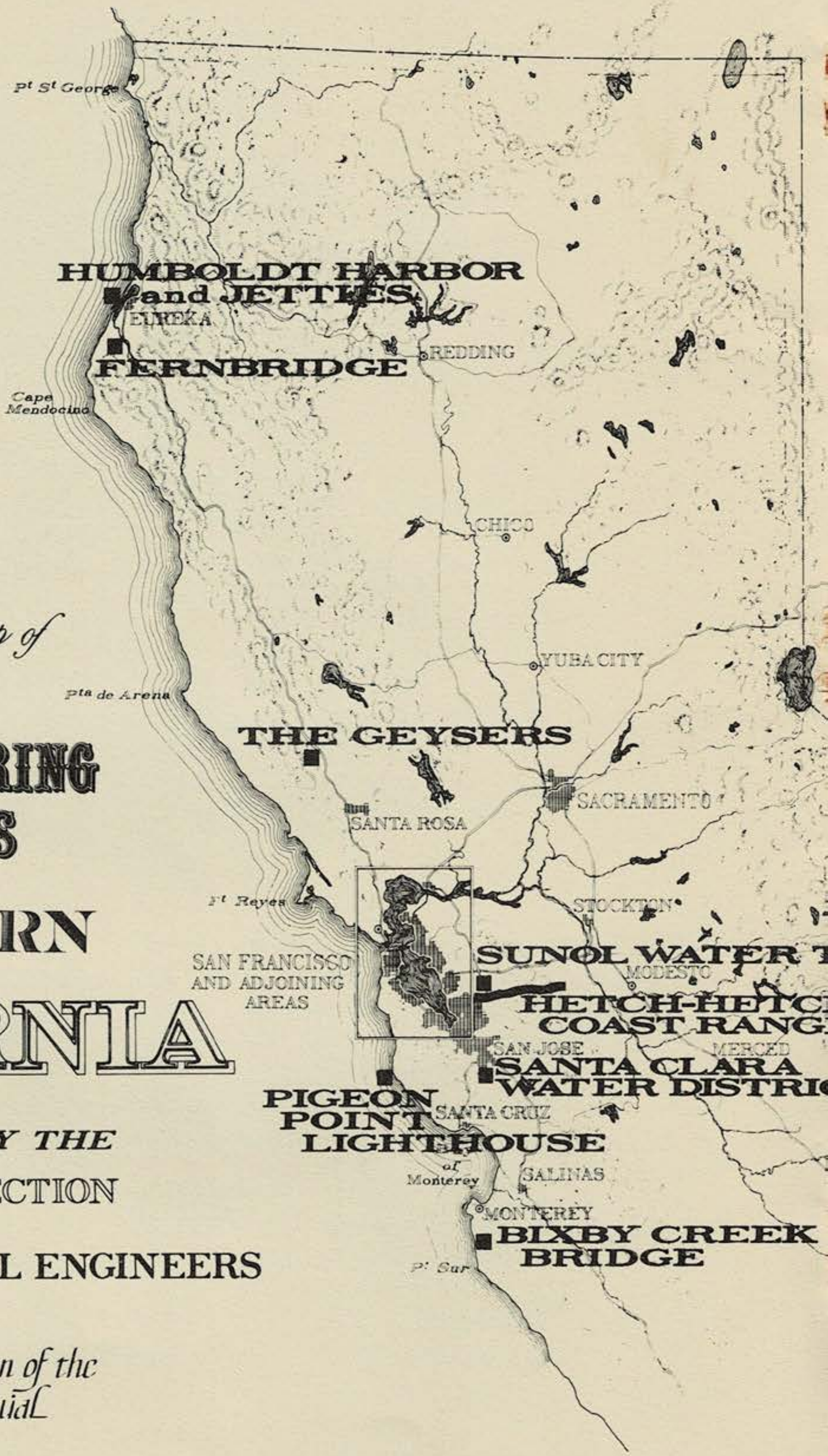
AS DESIGNATED BY THE

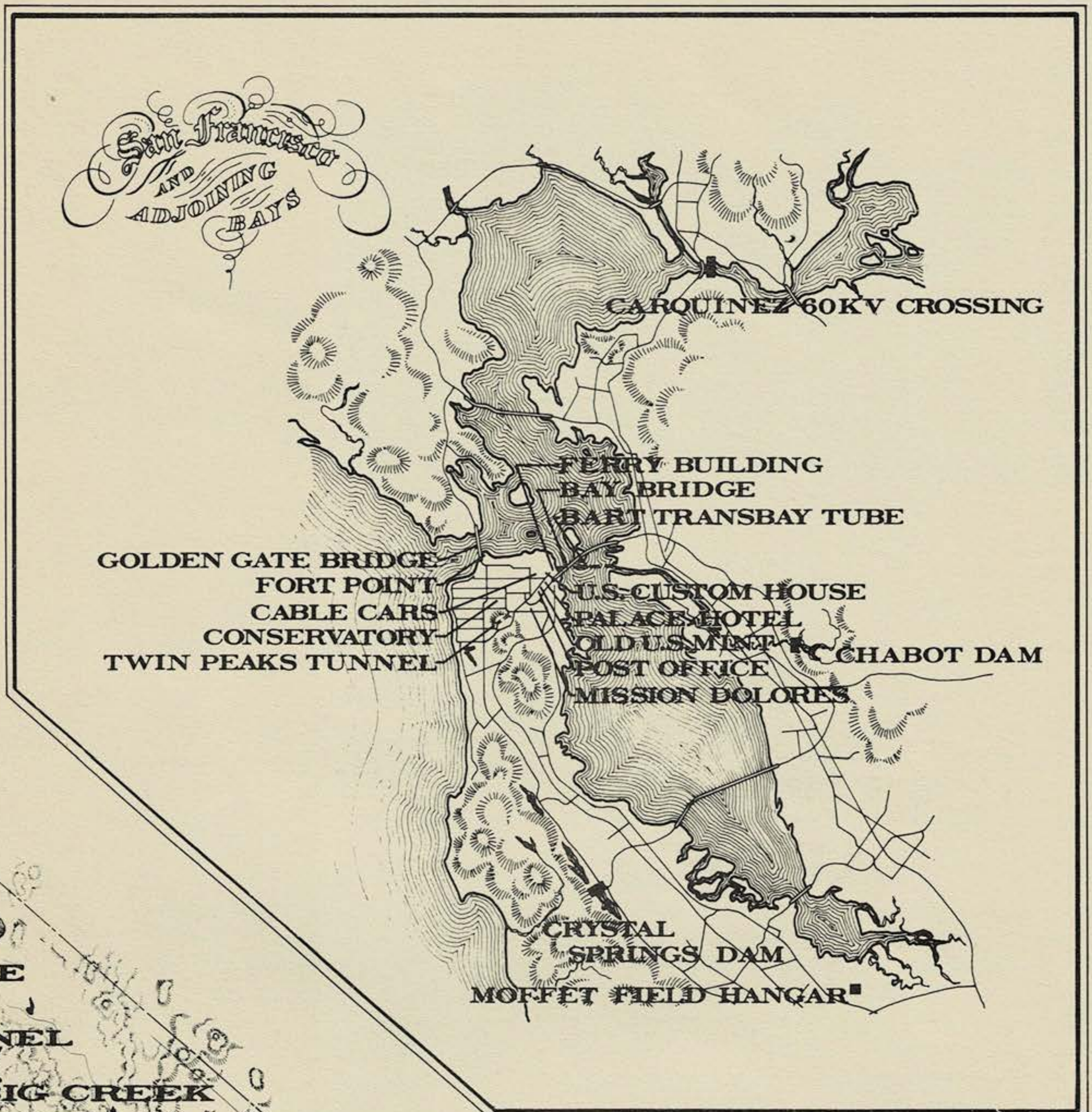
SAN FRANCISCO SECTION

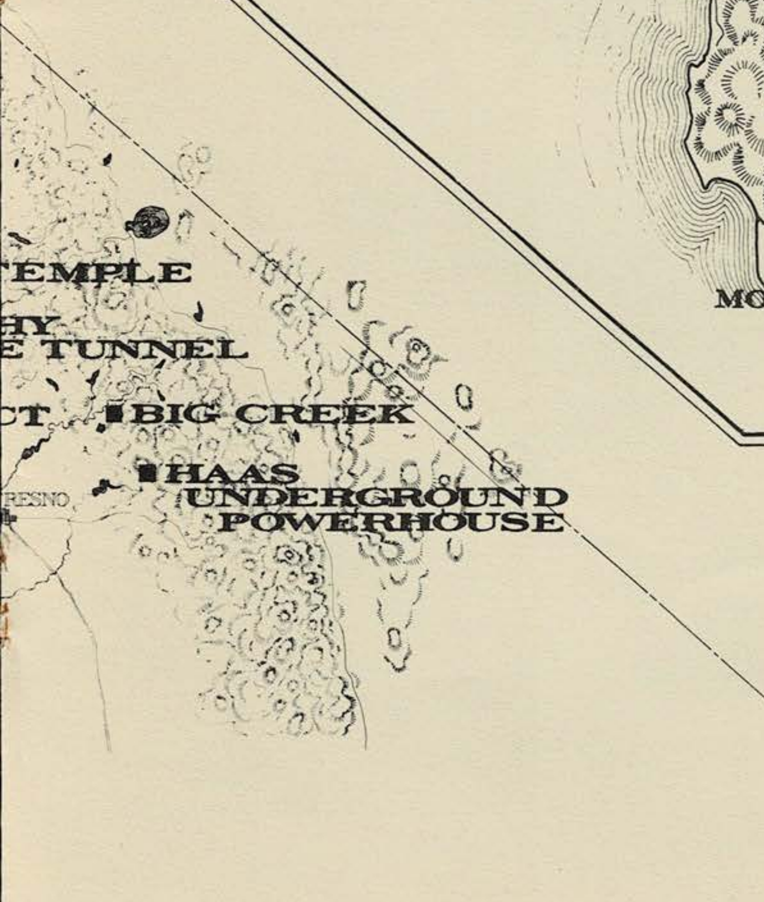
of the

AMERICAN SOCIETY OF CIVIL ENGINEERS

in the year 1976, in recognition of the American Bicentennial







Based on the Official Map of the State of California
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MARCH 25TH 1853

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