BIG CREEK HYDROELECTRIC SYSTEM,
BEAR CREEK DIVERSION DAM
Sierra National Forest
Big Creek vicinity
Fresno County
California

HAER CA-167-M

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

FIELD RECORDS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, D.C. 20240

HISTORIC AMERICAN ENGINEERING RECORD

BIG CREEK HYDROELECTRIC SYSTEM, BEAR CREEK DIVERSION DAM

HAER CA-167-M

Location: Sierra National Forest, Big Creek Vicinity, Fresno County, CA
Centerpoint of the dam crest at latitude 37.3357, longitude -118.9752 (location data derived from Google Earth)
Section 12, T7S R27E, MDBM

Present Owner: Southern California Edison Company

Present Use: Diversion Dam

Significance: Constructed in 1926-1927, the Bear Creek Diversion Dam is part of the Mono-Bear Diversion, an integral element of Southern California Edison's Big Creek hydroelectric system. The Big Creek system was the premiere example of integrated water storage and hydroelectric generation in the American West during the period 1911-1929. Big Creek set records in hydroelectric generation, dam construction, and tunnel excavation in rugged terrain with harsh climactic conditions. It also pioneered high-voltage transmission, allowing power to be generated in remote locations for distant markets. The Big Creek system is also significant in the history of the Los Angeles region. Conceived as a means of powering both residential development and electric railways, power from Southern California Edison's Big Creek plants was instrumental in the rise of suburban development in the region. The system is closely associated with railroad, energy, and development magnate Henry Huntington; with Edison executives and power pioneers A.C. Balch, William Kerckhoff, and George C. Ward; visionary California hydroelectric engineer John Eastwood; and Big Creek Resident Engineer David Redinger.

Historian(s): Daniel David Shoup, PhD
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Project Information:

Research for this report was sponsored by Southern California Edison Corporation as part of the HAER documentation of the Big Creek hydroelectric system. The historical narrative was written by Daniel David Shoup of Archaeological/Historical Consultants (Oakland, California). Historical research was conducted between June and October 2012 by Laurence Shoup and Suzanne Baker of Archaeological/ Historical Consultants. HAER photography was produced by David De Vries and Marissa Rocke of Mesa Technical

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HAER reports on the Big Creek hydroelectric system to date include:

- Powerhouse 8, Operator Cottage (HAER CA-167-A)
- Powerhouse 3 penstock standpipes (HAER CA-167-B)
- Big Creek Town, Operator House (HAER CA-167-C)
- Big Creek Town, Operator House Garage (HAER CA-167-D)
- Big Creek Powerhouse 1 (HAER CA-167-E)
- Big Creek Powerhouse 2/2A (HAER CA-167-F)
- Big Creek Powerhouse 8 (HAER CA-167-G)
- Big Creek Powerhouse 3 (HAER CA-167-H)
- Cottage 115 (HAER CA-167-I)
- Cottage 112 (HAER CA-167-J)
- Cottage 113 (HAER CA-167-K)
- Florence Lake Dam (HAER CA-167-L)

For more information on the history of the Big Creek system, see the bibliography to this and other reports in the series.

Historic photographs of the dam are available in the Field Notes appendix to this HAER and online via the Huntington Library website: http://hdl.huntington.org/

Historical Information

Description

The Bear Diversion Dam is a concrete arch dam 293' long at its crest and a maximum of 49' high. Its spillway is located at 7350' elevation. Made of unreinforced concrete, the dam forms a small reservoir on Bear Creek with a capacity of 138 acre-feet. Water can be drained from the reservoir via two 24" pipes at the base of the dam, which are controlled by two sluice gates .[1] Water is diverted into the Bear Tunnel intake, located on the north bank of the creek. After preparatory work in 1926, the dam was constructed between April and November, 1927. Together with the Mono Creek Diversion Dam, the Bear Diversion collected runoff from a 139 square mile area and delivers it via tunnel and siphon to the Ward Tunnel, Huntington Lake, and the powerhouses of the Big Creek system.

Architect/Engineer

John S. Eastwood, the original designer of the Big Creek system, first suggested diverting the waters of Mono and Bear Creeks for hydroelectric use in 1904.[2] The present dam and tunnel were designed at some time between 1924 and 1926 by unknown architects and engineers in the service of the Southern California Edison Construction and Engineering departments. Assistant Engineer Russell Booth was the supervisor of the Mono-Bear Development during 1927, the period of greatest construction activity.[3] As SCE's Resident Engineer, David Redinger was in overall charge of the Big Creek project from 1916 until his retirement in 1949.

Contractors and Suppliers

The Bear Creek Diversion Dam and Bear Tunnel were constructed by Southern California Edison's Construction Department. Much construction material for the dam was derived from tunnel construction byproducts: rock waste from excavation was crushed to provide the aggregate for dam concrete, while rails used to transport tunnel muck were welded into trash racks for the sluice gate and tunnel intakes.

Specialized steel products such as pipe, gates, and hoists were mostly purchased from suppliers in California, including Pacific Iron and Steel, Baker Iron Works, and Llewellyn Iron Works (Los Angeles), Madsen Iron Works (Huntington Park), California Corrugated Culvert (Berkeley), and Harron, Rickard, and McCone (San Francisco). Minor specialized equipment was also procured from the Taylor Instrument Company (Rochester, NY), and the Coffin Valve Company (Boston, MA).

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[1] The term 'Low Level Outlet Valve' (LLOV) has replaced 'sluice gate' in the industry. This report follows the historical sources on the dam's construction and retains the term 'sluice gate'. Readers should, however, be aware of the new terminology in mind when examining more recent sources on dam construction.
[2] Eastwood, "Comparative Estimate of Cost of Water-Power Transmission Plant vs. Steam Plant."
[3] Redinger, *The Story of Big Creek,* 149.

Construction Narrative

The Mono-Bear project was the last phase of the 'great expansion' of the Big Creek system between 1920 and 1929. The project aimed to increase water supplies for hydroelectric generation by diverting runoff from the Bear and Mono Creek watersheds into the Ward Tunnel via a siphon. Completed in 1925, the Ward Tunnel was a key element of Big Creek infrastructure, connecting the Florence Lake storage reservoir to the Huntington Lake reservoir and the Big Creek powerhouses via 13 miles of hard rock tunnel.

Initially, SCE's interest focused on a possible reservoir site at Vermilion Valley, upstream on Mono Creek. Test holes drllled in August 1924, however, found that the lower end of the valley is crossed by deep glacial moraines that made dam construction impractical.[4] SCE decided instead to build two diversion dams on Bear and Mono Creeks. Water rights to divert 81,000 acre-feet annually from Bear Creek and 146,000 acre-feet from Mono Creek were secured from State of California under Permit 808.[5] An initial plan to connect the dams to Florence Lake via an 8-mile long hard rock tunnel was abandoned as too expensive; instead, SCE chose to connect the two diversion dams directly to the Ward Tunnel via a siphon. Ward Tunnel was accordingly redesigned to accommodate a 96" pipe attachment near Adit 1. The Mono-Bear Development as built included two small diversion dams that fed water to an outlet pipe (Mono) and tunnel (Bear) that met at a riveted steel Y-joint to form the Mono-Bear Siphon. The siphon is 2.6 miles long and made of 92" riveted steel pipe. The overall cost of the project was $4 million.[6]

Mono and Bear Creeks are located in extremely rugged terrain that presents serious logistical challenges to construction. Snow closes the area up to five months per year, requiring careful planning to maximize construction speed. Construction on the project began in late Spring 1926 with the construction of a road to the area. As David Redinger reflected,

> Between six and seven miles of road had to be built through the worst terrain imaginable. Boulders the size of houses, and huge ledges of the hardest granite, were encountered. Steep grades and sharp turns resulted from dodging such obstacles. The routes appeared to be almost impossible, since many large trucks would have to be used for the delivery of material... The "C. and N." – Cheap and Nasty – road was completed, camps made ready, and work on the conduit got underway in July, 1926.[7]

Completion of the road allowed other infrastructure to be established in the area. Construction Camps on the Mono-Bear Development were given the '80' series of numbers and served as home to up to 1,500 men during the period of construction.[8] Camp

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[4] Redinger, *Story of Big Creek,* 145. In 1954 SCE finally constructed a dam in Vermilion valley, which forms Lake Thomas A. Edison.
[5] Southern California Edison, *Unit Cost Report, Mono-Bear Development as of December 31, 1928*, 18.
[6] Ibid., 3-4.
[7] Redinger, *Story of Big Creek,* 147.
[8] *Western Machinery World,* "Pipe Made in Southern Plant for Mono-Bear Creek Siphon", 74.

86 was the base for Bear Dam operations. Due to rugged conditions, "each camp had to be self-sufficient in practically all respects."[9] Power and telephone lines were strung up to the mountain, allowing communication between construction managers at Big Creek and workers in the field. Though little information about Camp 86 is available, Big Creek camps usually consisted of bunk houses, a cook house and mess hall, tool shops, and often a hospital. Construction supplies were brought up from Fresno on the San Joaquin and Eastern Railroad to Big Creek, then from Big Creek by truck over Kaiser Pass.

Excavation of the Bear Tunnel, which was 1.5 miles long, was the largest job in the Bear section of the development. Tunnel excavation began in July 1926, using a combination of drilling and blasting. Excavated material, or 'muck', was removed on a tramway pulled by electric locomotives. Redinger notes that the size of the tunnel – 7' x 7' over most of its length – made removal of excavated material a challenge:

> [the tunnels] were too small for the use of our regular mucking equipment. To facilitate the loading of the cars, Tunnel Foreman Ed McCabe, who had been on the Florence Lake Tunnel, improvised the "McCabe Mucker". This contraption elevated the muck and dumped it into the cars. The men had to shovel it onto the endless belt, but this method was easier and faster than hand-shoveling into the cars, as they would have had to raise the muck four or five feet.[10]

Initially portable compressors were used to provide compressed air for tunnel drills but these were later replaced by a permanent supply from stationary compressor plant at Camp 85.

All work was stopped in November 1926 due to the onset of bad weather. When it resumed in 1927, preparation for dam construction rapidly got underway. The reservoir area, which totaled 8 acres, was cleared of timber and brush. Wood usable for firewood was dragged to trucks using a derrick, while the remaining material was burned in place.[11] A small coffer dam diverted water into a diversion flume during construction of the dam footings. Excavation for the dam footings removed 707 cubic yards of rock and earth with steam and gasoline derricks and hand labor. Very limited amounts of explosive – only one pound of blasting powder – were used.[12]

A rock crushing and screening plant was built just below the dam near Camp 86 to produce aggregate for dam concrete, using waste rock from tunnel construction. Concrete for the dam was mixed by machine and placed by 'derrick and buggies'.[13] The entire Mono-Bear project was completed on November 15, 1927, when diversion of water into the Bear tunnel and Mono-Bear siphon began.[14]

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[9] Redinger, *Story of Big Creek,* 125.
[10] Ibid., 149.
[11] Southern California Edison, *Unit Cost Report*, 36.
[12] Ibid., 37.
[13] Ibid., 38.
[14] Redinger, *Story of Big Creek,* 150.

Soon after completion of the dam, the construction camps were dismantled. In 1929, SCE abandoned the 'Cheap and Nasty' road to Bear and Mono Dams, surrendering it to the US Forest Service.[15]

Alterations and Additions

The Bear Dam retains, by and large, its original appearance and equipment, including sluice gates, intake gate, and gate house. Regular maintenance has been carried out, including repainting the upstream face of the dam and repairs to the gate house as necessary.

Two minor structures have been added in the dam area since the 1980s. The first is a small concrete fish weir in front of the dam approximately 18" thick, which forms a pool on the dam's downstream face (View CA-167-M-10). Installed after 1980, its function is to measure flow into Bear Creek to ensure the release of sufficient water to sustain fish stocks. Water is fed into the weir via a pipe attached to one of the sluice gate outlets (View CA-167-M-2). It is drained by a steel-lined outlet channel about 8" wide that extends back into the weir pool about three feet (Views CA-167-M-3 and CA-167-M-4). The second structure is a corrugated metal shack measuring 8' x 8', which stands behind the Gate House (View CA-167-M-7). Constructed in the 1980s, it contains electronic monitoring devices.

At the time of writing, Southern California Edison intended to remove both the gate house and metal shack, replacing them with a new waterproof structure higher up the granite face on the north bank, in order to facilitate access during periods of heavy snow.

Historical Context

California and the Hydroelectric Development of the West

California holds an important place in the history of hydroelectric power generation. Despite relatively low rainfall, especially in the southern regions, the high heads available in the state's mountainous terrain made waterpower important in California's industrial development. The mining industry pioneered the development of dam, flume, and penstock technologies at an early date, while Lester Pelton's development of the Pelton wheel in the 1880s dramatically increased the efficiency of the waterwheel in high head settings.[16] In California, however, this energy was typically located in remote areas far distant from urban centers, restricting its use to industries located nearby.

The development of Thomas Edison's integrated system of dynamos, lamps, and circuitry after 1880 led to a boom in urban electrification. However, widespread dependence on direct current, which had a high rate of transmission loss, made the usefulness of electricity dependent on proximity to a central station. The introduction of alternating current transmission and voltage transformers by George Westinghouse after 1886, however, opened up the possibility of transmitting electricity over long distances.[17] Much

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[15] Ibid., 151.
[16] Hay, *Hydroelectric Development in the United States, 1880-1940,* 6.
[17] Ibid., 9.

of the world's pioneering work in AC transmission took place in California, with early world records for distance and voltage set by transmission lines in Bodie (Standard Consolidated Mining Company, 1891), San Antonio to Pomona (San Antonio Light and Power, 1892), and Folsom to Sacramento (Horatio Livermore, 1895).[18]

Once the potential for connecting hydraulic and electrical power was demonstrated by Westinghouse's development at Niagara Falls (1895), hydroelectric development began in earnest, and nowhere more intensely than in California. Record-setting developments included the first 33 kilovolt (kV) transmission by Southern California Edison's Santa Ana No. 1 plant (1898); use of a 1,300' head in the Mount Whitney Power Company's plant (1899); and, superlatively, the 140-mile, 60kV Colgate transmission line built by Bay Counties Power Company in 1901.[19] "California," claimed the journal *Electrical West* in 1912, "is the birthplace of real long-distance power transmission on this continent".[20]

Southern California Edison's Big Creek project, begun in 1911, was the apex of early twentieth century hydroelectric development in California and was among the world's largest hydroelectric systems at the time of its construction. The system set successive world records for highest voltage ever used in commercial transmission (150kV in 1913, 220 kV in 1923), and used some of the highest heads in North America. In 1929, at the end of the great expansion of the Big Creek system, the five Big Creek powerhouses (1, 2, 2A, 3, and 8) each held a place among the top ten California hydroelectric plants for kilowatts and horsepower generated. Its three storage reservoirs – Florence, Shaver, and Huntington Lakes – captured runoff from 1,050 square miles, impounded 289,000 acre-feet, and were connected by almost 20 miles of hard-rock tunnel.[21]

Origins of the Big Creek System

The Big Creek system was the brainchild of visionary engineer John Eastwood (1857-1924), who first identified the Big Creek and San Joaquin River systems as an ideal location for a series of storage reservoirs and power plants. Eastwood was born in Minnesota and came to California in 1878 to work on the Pacific extension of the Minneapolis and St. Louis railroad. After establishing a private engineering firm in Fresno in 1883, Eastwood turned his attention to the Sierras. In 1893 he first visited the present location of Big Creek town, and saw its potential as the anchor point of a huge hydroelectric generating system. However, demand, distribution, and transmission networks for such quantities of power did not yet exist in California.[22]

By 1895, Eastwood had shown that high-head hydroelectric plants were feasible in the area by developing a plant further down the San Joaquin River for the San Joaquin

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[18] Ibid., 19, 28.
[19] Ibid., 30; Hughes, *Networks of Power: Electrification in Western Society, 1880-1930,* 277.
[20] Quoted in Hughes, *Networks of Power*, 265.
[21] Downing *et al.,* "Water Development on the Pacific Coast," 594-601; Federal Power Commission, *Directory of Electric Generating Plants,* 14-21; US Department of Energy, *Inventory of Power Plants in the United States,,* 41-54; *Western Construction News*, "Big Creek-San Joaquin Project".
[22] Shoup, *The Hardest Working Water in the World,* 55-59; Whitney, "John Eastwood", 38, 41.

Electrical Company (today the site of Pacific Gas & Electric Company's Wishon powerhouse). The San Joaquin Electrical Company soon went bankrupt, however, and in 1900 Eastwood turned in earnest to planning and surveying the Big Creek system, securing water rights and identifying locations for tunnels, dams, and power plants.[23] These plans, however, only came to fruition when Eastwood's engineering vision was combined with Southern California capital, in the person of Henry Huntington.

Huntington was born in 1850 in Oneonta, New York. His uncle Collis P. Huntington was the force behind the consolidation of the Southern Pacific Railroad. After the death of his uncle, and determined to make his own mark on the industry, Henry Huntington sold his Southern Pacific stock in 1901 and moved to Los Angeles. He became a major figure in the development of the Los Angeles region through his consolidation of street railroads, public utilities, and large real estate holdings. By acquiring land and then connecting it to the metropolis by electric railroad, Huntington was able to sell suburban parcels at hefty profits.[24]

Huntington's expanding network of street railroads depended on a reliable and inexpensive source of electrical power. In 1902, he joined with Allan C. Balch and William G. Kerckhoff to found Pacific Light and Power Company for this purpose. Kerckhoff was born in 1856 and moved to Los Angeles with his family in 1878. Through his father's lumber company he acquired an interest in the San Gabriel Valley Rapid Transit Railway, which was later absorbed by the Southern Pacific. Balch, born in New York in 1864, was trained as an electrical engineer and managed a steam-electric plant in Portland before moving to Los Angeles in 1896. Together, Balch and Kerckhoff founded the San Gabriel Electric Company, which brought them into contact with Henry Huntington.[25]

Huntington was looking for sources of electrical power, while Balch and Kerckhoff had successfully developed a hydroelectric plant on the San Gabriel River, and were proceeding with plans for another on the Kern River, 100 miles to the north. In 1901 and 1902 the three men founded Pacific Light and Power Company with the short-term aim of supplying cheap power to the street railroads, with the eventual aim of consolidating the electric utilities of the greater Los Angeles area into a monopoly.[26] Initially, 51% of the company was owned by the Los Angeles Railroad, in which Henry Huntington held a 55% interest, with the remainder owned by the Southern Pacific. Balch and Kerckhoff owned 40% of Pacific Light and Power, and appointed three of the seven directors, while Huntington named the rest. The intimate relationship between power and railroads at this early date is evidenced by the fact that the power company was formed as a subsidiary of the railroad, and not the other way around.

Kerckhoff and Balch acquired Fresno's San Joaquin Electric Light and Power in late 1902 as a large source of low cost power that could meet the projected demands of the

[23] Shoup, *Hardest Working Water,* 60-62; Redinger, *Story of Big Creek,* 6.
[24] Shoup, *Hardest Working Water,* 66.
[25] Ibid., 67-69.
[26] Ibid., 74.

fast-growing metropolis of Los Angeles.[27] At the time, John Eastwood was Vice President and Chief Engineer of San Joaquin Electric Light and Power. Balch and Kerckhoff were receptive to Eastwood's plans for Big Creek, and hired him in July 1902 to fully plan the system. Eastwood immediately began filing water rights claims and by late 1903 had claimed over 410,000 miner's inches of water in the basin.[28] By 1905, Eastwood had prepared plans for a system of powerhouses and transmission lines that by his estimate would offer considerable savings over similarly sized steam plants.[29] Pacific Light and Power's directors, however, were uncertain whether existing demand could absorb the huge quantities of power that Eastwood's proposed plants would generate, and decided in 1903 to prioritize steam development over hydroelectric. As a result, the period up to 1910 saw little progress on the Big Creek project.

Despite this delay, Eastwood continued to file water claims and began securing permits from the U.S. Department of the Interior to develop the hydroelectric plants, which are located on Federal land on the Sierra National Forest. Road permits were granted in 1903-1904 and comprehensive permits for the initial Big Creek development issued in 1909.[30] In 1906 Pacific Light and Power reached an agreement with Miller and Lux, a land and livestock company holding much of the downstream water rights on the San Joaquin River, and in late 1905 construction of a road from Shaver (then a timber camp) to the Big Creek basin was begun. Another route, from Auberry to Camp 1 (the site of today's Big Creek town), was begun in 1908.[31]

By 1905, Eastwood had outlined his vision for the initial development of the Big Creek system. He identified the later locations of Powerhouses 1 and 2 as the sites for two powerhouses with 2050 and 1861 feet of head, respectively. He also identified locations for Powerhouse 3 and the enlargement of larger Shaver Dam (then owned by the Fresno Flume and Lumber Company), and anticipated the use of water from Mono and Bear Creeks and Mammoth Lakes. All of these facilities were eventually constructed in the locations proposed by Eastwood – although the power eventually supplied by the system was considerably more than even he anticipated.[32]

By 1909-1910, Huntington, Kerckhoff, and Balch began seriously considering the fulfillment of Eastwood's hydroelectric plans and began to raise new capital. Pacific Light and Power Company was recapitalized in late 1909 with the help of eastern bankers and sold new bonds to raise money for the Big Creek project. At the same time, Huntington eliminated the Southern Pacific Company from the project by trading one of his interurban electric lines in Los Angeles for the Southern Pacific's 45 percent stake in the Los Angeles Railroad, Pacific Light and Power's holding company. In 1910, Balch exercised his option to buy the plans, water rights, and permits for Big Creek, all of which were held in Eastwood's name. Eastwood received 10 percent of the stock of the

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[27] Ibid., 71.
[28] Ibid., 75.
[29] Eastwood, "Comparative Estimate of Cost of Water-Power Transmission Plant vs. Steam Plant."
[30] Shoup, *Hardest Working Water,* 82.
[31] Shoup, *Hardest Working Water,* 83.
[32] Eastwood, "Comparative Estimate".

new Pacific Light and Power Corporation.[33] Huntington, however, used special assessments on shareholders to force Eastwood to sell his stock cheaply, depriving him of his hoped-for wealth. Despite his visionary role in designing the Big Creek project, Eastwood was excluded from involvement in its construction and ultimately received no financial reward for his work. Balch and Kerckhoff also sold their interests to Huntington about this time, leaving him with full control of the company. About the same time, in October-November 1911, Huntington secured financial backing from a syndicate of New York bankers that allowed construction to proceed.[34]

Initial Construction, 1910-1913

Once the financial resources to construct the project had been secured, construction was ready to begin. Pacific Light and Power, hired the Boston-based Stone and Webster Construction Company to design and manage the construction. The contract with Stone and Webster covered the construction of the 56-mile San Joaquin and Eastern Railroad, three dams to create Huntington Lake, Powerhouses 1 and 2, the 240-mile transmission line to Los Angeles, and the necessary forebays, tunnels, and penstocks.[35]

The development as executed generally followed Eastwood's plans, although Stone and Webster's engineers favored different architectural and engineering solutions: their engineers built Cyclopean masonry dams with gravity sections rather than his proposed earth dams, and combined the generation and transmission facilities in a single structure rather than separating them in detached buildings as Eastwood had proposed.[36]

Blasting for the dam sites and tunnels began in Spring 1912. Over the following summer, 3,500 men were at work in 12 camps scattered across the construction area. At the end of 1912 excavation for the foundations of Powerhouse 1 were well underway.[37] A bitter strike in on January 1913 led to construction delays, with Powerhouses 1 and 2 completed two months behind schedule in November and December, 1913.[38]

When the initial phase of Big Creek was complete, the two powerhouses had four generating units producing 80,000 horsepower and using some of the highest heads in the country. At 240 miles long, the power lines connecting Big Creek with Los Angeles were among the world's longest, and set a new record for using 150kV in commercial transmission. The difficult mountain terrain, high heads, and huge turbines gave the Big Creek plant an essentially experimental character. *Electrical World* recognized the feats achieved in the initial construction of the system as "one of the most advanced contributions of the engineer to the welfare of civilization".[39]

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[33] Ibid., 85.
[34] Ibid., 85, 92.
[35] Redinger, *Story of Big Creek,* 11.
[36] Eastwood, "Progress Report for 1903-1904 of Right of Way Surveys and Outline Plan for Power Plant No. 1."
[37] Stone and Webster, "Progress of the Big Creek Initial Development: Report to Pacific Light and Power Corporation, January 1, 1913," 3.
[38] Ibid., 3.
[39] *Electrical World,* "The 150,000-Volt Big Creek Development – I," 33.

Intermission, 1914-1919

The onset of the European war in late 1914 affected both the American credit markets and power consumption. It became difficult for companies such as Pacific Light and Power to raise money for capital projects, while electrical demand in Los Angeles was not growing fast enough to require immediate construction of additional power plants or generating units.[40] Some tunnel and dam work continued at Big Creek, including raising the three dams at Huntington Lake in summer 1917 to increase its storage capacity.[41]

More significant for the future development of the Big Creek system was the 1917 merger between Pacific Light and Power and Southern California Edison (SCE). The merger combined the extensive street railroad interests of PLP – and excess electric generation capacity – with Edison's rapidly expanding residential electricity business.

The economic boom after the end of the World War I led to rapid urban and industrial growth in Los Angeles that rapidly increased electrical demand. As a result, the previously modest expansion plans for Big Creek were accelerated, beginning a construction boom that lasted until 1929.[42]

The Great Expansion: Electrical Plants

In January 1921 the California Railroad Commission approved expansion of Powerhouse 1 and construction of Powerhouse 3 and Powerhouse 8.[43] Big Creek town soon saw the addition of thousands of new construction workers. Powerhouse 8 was built between January and August 1921.[44] A pioneer facility in several respects, it was the first commercial powerhouse ever designed for 220kV transmission and set records for construction speed, which earned the plant the monicker of the 'Ninety-day wonder'.[45] Soon after the completion of Powerhouse 8, construction began on the tunnels, forebays, and penstocks for Powerhouse 3. The three initial units of "the electrical giant of the West", were placed online on September 30, October 2, and October 5, 1923.[46] The three units of Big Creek No. 3 made up the largest hydroelectric plant in the west at the time of their construction, with an aggregate capacity of 75,000 kW. At the same time, existing plants were expanded: third and fourth generating units were added to Big Creek Nos. 1 and 2 between 1921 and 1925.[47]

After the construction of Florence Lake and Shaver Lake, two additional generating units were built next to Powerhouse 2. Powerhouse 2A's generators were among the largest in the world at the time of their installation and harnessed a 2,418' head, the highest in the Big Creek system.[48] When the second unit of Powerhouse 8 went on line in June 1929,

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[40] Shoup, *Hardest Working Water,* 153.
[41] Redinger, "Progress on the Big Creek Hydro-Electric Project, Part I", 722.
[42] Shoup, *Hardest Working Water,* 162.
[43] Untitled memorandum, Folder 6, Box 302, Southern California Edison Collection, Huntington Library, San Marino, CA.
[44] *Journal of Electricity and Western Industry,* "Big Creek No. 8 Hydro-Electric Unit Completed," 160.
[45] Shoup, *Hardest Working Water,* 190; *Electrical World,* "First 220,000-Volt Station Completed," 117.
[46] Redinger, "Progress on the Big Creek Hydro-Electric Project, Part V," 991.
[47] *Journal of Electricity,* "Big Creek No. 2 Power House Being Extended 56 ft," 297.
[48] *Electrical West,* "Southern California Edison's Advance," 829.

fifteen generating units were in service, with an aggregate capacity of 344,500kW. The system went from generating 213 million kilowatt-hours in 1914 (its first full year of service) to 1.6 billion in 1928.[49]

The Great Expansion: Dams and Tunnels

All of this generation, however, was dependent on the infrastructure that brought water to the powerhouse turbines. Southern California has a semi-arid climate with seasonal winter rainfall, making water storage a necessity in the summers to ensure a predictable supply of water to the powerhouse turbines. Storage reservoirs and tunnels were thus the most crucial parts of the system, and as such absorbed most of Southern California Edison's investment at Big Creek.

In 1917 Southern California Edison purchased Shaver Lake, originally built by the Fresno Flume and Lumber Company as part of their logging and sawmill operation. The Shaver Tunnel, which connected Shaver Lake to Powerhouse 2, was begun in February 1920 and completed in May 1921.

The lynchpin of the great expansion was the Florence Lake development, which included the construction of Florence Lake Dam high up on the South Fork of the San Joaquin River at 7327' elevation and a hard rock tunnel 13 miles long connecting it to Huntington Lake. The tunnel, later named the Ward Tunnel after SCE President George C. Ward, was the longest water tunnel in the world. Beginning in 1920, thousands of workmen labored around the clock at six working faces to cut through solid granite, finishing the tunnel in April 1925. Florence Lake Dam was constructed in 1925-1926 and was the longest multiple-arch dam in the world at the time of its construction.[50]

As soon as Florence Lake was completed the Edison construction force moved to Mono and Bear Creeks, tributaries of the South Fork San Joaquin River. Two small diversion dams directed water through tunnels and aboveground piping into a steel siphon three miles long that delivered water into the Ward Tunnel. Construction began in Spring 1926 and began delivering water in November 1927.[51]

Simultaneous with the Mono-Bear Diversion was the expansion of Shaver Lake to form the largest reservoir in the Big Creek system. The new Shaver Lake Dam, begun in April 1926 and completed in October 1927, was the longest and largest gravity dam in California, forming a reservoir of 2,200 acres with a capacity of more than 135,000 acre-feet. The new Shaver Lake stored excess water from Florence and Huntington Lakes and also made possible the new high-head generating units at Powerhouse 2A.[52]

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[49] Southern California Edison, *Annual Report 1928*, 21.
[50] Redinger, *Story of Big Creek,* 136, 150.
[51] Redinger, *Story of Big Creek,* 149; Shoup, *Hardest Working Water,* 136.
[52] Ibid., 153.

Powerhouse	Units	Capacity (kW)
1	4	66,000
2	4	56,000
8	2	56,400
3	3	75,000
2A	2	93,000
Total	**15**	**344,800**
Reservoir		**Capacity (acre-ft)**
Shaver		135,283
Huntington		89,166
Florence		64,406
Total		**288,855**

Table 1. Electrical and Storage Capacity in the Big Creek System, 1929

At the end of the great expansion, the number of electric generating units in the Big Creek system had grown from four to 15 and generating capacity from 56 to 345 megawatts. Construction of its complex system of dams and tunnels set records for speed, size, and technical innovation; when finished, this expansion of the system gave SCE control of almost all of the flow over the 1,050 square mile watershed of the upper San Joaquin River, adding an industrial function to a wilderness landscape and providing the initial infrastructure for tourism on the western slope of the high Sierra.[53]

The Great Expansion: Life in Big Creek's Construction Camps

In 1920, the town of Big Creek (then called Cascada), had only 525 inhabitants, overwhelmingly males of European descent[54] Five years later, however, the population of the area had grown by over 5,000, making Big Creek a boom town. By 1925,

> the main street of Big Creek was crowded with places of business, including a hardware store, butcher shop, bakery, laundry, dry goods shop, art shop, three barber shops, real estate office, movie theatre, restaurant, six dentists' offices, two garages, a general merchandise shop, beauty shop, and women's apparel store. Every two weeks, three Fresno banks sent representatives to cash checks and receive deposits.[55]

Though Big Creek town was booming, during the great expansion most of SCE's 5000 workers in the area lived in remote camps in the surrounding mountains, near their work sites. The camps above the snow line, such as those for the Ward Tunnel, Florence Lake Dam, and Mono-Bear Diversion, consisted of portable-frame bunkhouses that could be shipped in sections and moved as needed. A 'radical' innovation came in 1923, when

[53] Redinger, *Story of Big Creek,* 150; Shoup, *Hardest Working Water,* 156.
[54] Fourteenth Census of the United States, Cascada Precinct, Fresno County, California.
[55] Fresno Bee, "Pupils Will Play Where Big Creek Landmark Stood."

SCE began to offer bedding to its construction teams – previously, men had furnished their own.[56]

Besides bunkhouses, a typical camp included a dining hall, cook house, warehouse, machine shop for tool repairs, cold storage facility for food, and sometimes garages, hospitals, and recreation halls. Given their remote locations and the high cost of transporting materials, camps had to be mostly self-sufficient and devoted much effort to creative recycling of waste materials.[57] Transporting food alone was a monumental effort, given that 450,000 meals were served to Big Creek workers each month. Though employees paid for food, Edison subsidized commissary and cookhouse costs throughout the period of construction, averaging them into overall construction costs.[58]

Life in the camps was isolated, doubly so for those workers who remained through the winters of 1920-1925 during construction of the Ward Tunnel. With snow 10 feet deep or more blocking Kaiser Pass, a team of Alaskan sled dogs led by one Jerry Dwyer were brought in to transport mail, medicine, and other light supplies. The challenges of weather and terrain also led to the construction of a radio and telephone network enabling instantaneous communication between Big Creek and the outlying camps.[59]

SCE also took measures to enliven the isolation of camp life and build community. A mobile cinema was established:

> Once, and sometimes twice, a week in each of these camps the company provides a free motion picture performance for the workmen. A portable projector and a light automobile made the tours of these camps on regular schedules and gave the men an exhibition almost identical with those seen in motion picture houses in the cities and towns. It consisted of a news reel, a comedy, and a drama… once… the cinematographers' outfit and films were conveyed 30 miles over mountain tops on a big sled drawn by a team of Alaskan sled dogs over a road drifted 20 feet deep with snow and impassable for horses.[60]

SCE organized other entertainments in camp, such as dances, boxing matches and baseball games. Many camps also had a library. Many workers enjoyed fishing in the mountain streams, and Redinger also notes that gambling was common in the camps, as was home-brewing (despite ongoing Prohibition).[61]

Despite these efforts, retention of skilled employees was an ongoing problem. SCE experienced very high employee turnover at Big Creek, especially in the construction workforce. As the shareholder magazine *Edison Partners* magazine reported in 1923:

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[56] Redinger, *Story of Big Creek,* 90.
[57] Shoup *Hardest Working Water,* 155; Redinger, *Story of Big Creek,* 101.
[58] In the unit cost developments and price books for the Big Creek plants, these losses are included in the cost of materials and labor, suggesting that the company saw these subsidies as a routine construction expense.
[59] Redinger, *Story of Big Creek,* 111-113, 155-157.
[60] Lyons, "Camera's Part in Record Industrial Project," 10
[61] Redinger, *Story of Big Creek,* 102.

> Under the plan of permanent organization of the construction forces the labor turnover on the Big Creek-San Joaquin project has been constantly decreasing, until the average for the past year was forty per cent, and the lowest average for any month twenty-six percent. Good living conditions, excellent food, commissary stores which sell everything from clothing to cigarettes at the same prices that obtain in the large cities, amusements, recreation halls, and greatest of all, that intangible thing which can perhaps be termed "camaraderie" and co-operation tend to contentment among the men, and a desire to consider the project in the nature of a life work.[62]

Despite the rosy prose, the writer concedes an average of *40 percent* turnover in the construction workforce, suggesting that many of the workers on the construction jobs at Big Creek during this time found the work too hard, the conditions too isolated, or the pay too low to remain on the job for more than a few months.

Big Creek in Context

Between late 1911, when construction began on Big Creek Powerhouse 1, and 1929, when Powerhouse 2A was completed, the Big Creek region was transformed from inaccessible wilderness to an industrial landscape and company town intimately connected to the economy of greater Los Angeles. Each phase of the great expansion was marked by pioneering technical achievements in transportation, dam building, tunnel driving, powerhouse design, and transmission line construction. In the process, a community developed that was marked by a combination of pioneer spirit and corporate paternalism. For many who worked in Big Creek, such as David Redinger, the experience was one that defined their lives.

[62] *Edison Partners,* "Contented Labor," 6.

Part II. Structural and Design Information

The Dam

The Bear Creek Diversion Dam is a concrete arch dam across Bear Creek, a tributary of the South Fork San Joaquin River. It measures 293' long along its crest and has a maximum height of 49'. The radius of the partial circle formed by the upstream face is 102'. The crest is at 7350' elevation for the central 230' of its length, while the sections adjoining the buttresses are at 7356' elevation. This central portion of the dam functions the dam's spillway. The dam is 9'-6" thick at its base, tapering to 4'-0" at its crest. 1,405 cubic yards of concrete were used in dam construction. Reinforcing steel was used only along the crest of the dam. A steel ladder is stubbed into the concrete along the north abutment of the dam. The upstream surface of the dam was originally painted with Inertol waterproofing paint.[63]

Views CA-167-M-1 through CA-167-M-4 show the downstream face of the dam. View CA-167-M-5 shows the dam's southern footing. CA-167-M-6 shows the upstream face of the dam and the reservoir water gauge. Plan, section, and elevation drawings are visible in View CA-167-M-15.

Sluice Gates

Sluice gates are used to drain dam reservoirs close to their bottoms. Two cast iron sluice pipes 4' 8" long and 24" in diameter pass through the base of the Bear Creek Dam at elevation 7330'. The pipes were purchased from Madsen Iron Works, Huntington Park, CA. Water flow through the pipes is controlled by two 24" cast iron sluice gates, plates that can be raised to allow water to pass beneath them. A 26' long stem runs up the upstream face of the dam from each gate and connects to stands on the concrete control platform located atop the dam directly above the sluice gates (view CA-167-M-9). The gates can be hand-operated from the stands. The platform measures 11' x 7' and 6" thick and is connected to the north embankment by a steel walkway 42" wide and 45' long. View CA-167-M-8 shows the walkway and concrete platform.

SCE bought the gates and stems from the Coffin Valve Company, Boston, as the castings on the control stands indicate. The serial number on the stand is 2692. The stems are protected by guards made of ¾" thick plate steel angles with 12" channels, purchased from the Pacific Iron and Steel Company of Los Angeles. The sluice gate intakes are protected by one box-type steel trash rack measuring 5'-6" x 10'-4" x 8'-4" high. The racks were constructed in SCE's Big Creek shop.[64]

Intake Portal and Gate

Water is diverted into Bear Tunnel through an intake portal located on the north bank of Bear Creek, 60' from the dam, with a base elevation is 7327' and a top elevation of 7356'. The intake structure is made of reinforced concrete and measures 21' wide, 24' long at its

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[63] Southern California Edison, *Unit Cost Report,* 21-22, 41, 44.
[64] Ibid., 42-44.

base, and 29’ high with walls 2’ thick. A steel ladder is stubbed into the concrete along its face. Two 10’x11’ high openings allow water to enter the structure. Each of these openings is covered by a 10’ x 11’ trash rack made of ½” x 6” steel bars set on edge, spaced 4” apart, and supported by I-beams. The six tons of structural steel used in the racks was purchased from Baker Iron Works of Los Angeles.[65]

Flow into the tunnel is controlled by a radial gate and a bypass sluice gate. The radial gate is 7’ wide and 15’ high. Its curved front has a 12’6” radius and is made of 5/16” plate steel. The gate is connected by struts to steel seats and bearings set into the tunnel walls at the rear of the intake structure. It was manufactured by Llewellyn Iron Works of Los Angeles. The gate rests in a chain sling, which allows it to be raised 10’. The bypass sluice gate consists of an 18” hand-operated Calco Slide Head Gate, model 101, with a 3’ frame, flanged seat, gate stem, stem guide, and handwheel lift. The bypass gate controls water flow through 8’ of Armco corrugated 18” pipe. The bypass gate was procured from California Corrugated Culvert Company, Berkeley, CA.

Gate House

The operating mechanisms for the intake gate are located in the gate house, a wood frame building 18’-9” x 12’-6” x 8’ high with sides and roof of corrugated iron, and ceilings packed with cork. The gate house was built on top of the intake structure in order to protect the gate and mechanism from snowslides and low temperatures (Unit Cost 70). Inside the gate house, a hand-operated, 5-ton Beebee Bros. chain hoist, serial number D4396, is used to raise and lower the radial gate. The hoist was purchased from Harron, Rickard, and McCone Company of San Francisco. Also inside the gate house is a hand wheel used to operate the bypass gate, and a Tycos Recording Thermometer, No. 8053, serial number 10-J-1-M-151, purchased from Taylor Instrument Company, Rochester, NY.[66]

Views CA-167-M-7 and CA-167-M-11 through CA-167-M-13 show the exterior of the intake tunnel gate house. View CA-167-M-14 shows the original chain hoist and hand wheel. A elevation drawing of the intake and radial gate is shown in View CA-167-M-15.

Bear Tunnel

Bear Tunnel extends from the intake portal through solid granite to form a junction with the Mono Tunnel and the Mono-Bear Siphon. The tunnel is 7’x7’ in section for most of its length, expanding to 8’x9’ near where it joins the Mono-Bear Siphon. Its total length is 7,589’ in two angles. Most excavation was carried out with compressed air-powered drills with some blasting. In places where the ground was blocky or soft, the tunnel was reinforced with timber bracing and lined with unreinforced concrete. Such areas, however, made up only 97’ of the total tunnel length. The tunnel drops from an elevation of 7340’ at the intake to 7203’ at the junction with Mono Tunnel. Both tunnels are connected to

[65] Ibid., 69, 72.
[66] Ibid., 26, 71-72.

expansion joints that feed water into the siphon below.[67] A section drawing of the tunnel is visible in View CA-167-M-15.

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