RUSH CREEK HYDROELECTRIC SYSTEM, GEM LAKE DAM

HAER CA-166-G

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June Lake vicinity
Mono County
California

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, DC 20240-0001

HISTORIC AMERICAN ENGINEERING RECORD

Rush Creek Hydroelectric System, Gem Lake Dam
HAER No. CA-166-G

Location: The Gem Lake Dam is located approximately 4.0 air miles southeast of the approximate center of the town of June Lake in Mono County, California, and approximately 1.5 air miles southeast of the Rush Creek Powerhouse, which is situated on the west side of California State Route 158 (the June Lake Loop). The dam is located on the boundary of the Ansel Adams Wilderness in the Inyo National Forest. From the Rush Creek Powerhouse, the dam site is accessible by a series of two incline railroads, the Agnew Tram and the Gem Tram, and by boat across Agnew Lake, controlled by the Southern California Edison Company. Public access to the dam site from the highway is provided by a foot/equestrian trail. There is no automobile access to the site.

The approximate center of the crest of the Gem Lake Dam is located at UTM Zone 11S, easting 311332.00m, northing 4180387.00m. Distances and coordinates were obtained on November 6, 2012, by plotting location using Google Earth. The coordinate datum is World Geodetic System 1984.

Present Owner: Southern California Edison Company
P.O. Box 800
Rosemead, California 91770

Present Use: The Gem Lake Dam is a reinforced concrete multiple-arch dam that is a component of the Rush Creek Hydroelectric System. The dam impounds a natural glacial lake, the Gem Lake reservoir, which supplies water to the Rush Creek Powerhouse via pressure pipelines, or penstocks. The Gem Lake Dam is one of three dams in the Rush Creek Hydroelectric System.

Significance: The Gem Lake Dam, constructed in 1915-1916 and 1924, is a contributing element of the Rush Creek Hydroelectric System historic district. It is significant for its position in the development of hydroelectric generation on the eastern slope of the Sierra Nevada and its nationally distinctive engineering characteristics. The district is significant under National Register of Historic Places Criterion A (broad patterns of history) and Criterion C (distinctive characteristics of period and type of engineering and construction that represent the work of a master). The Period of Significance for the district is 1915-1925.

Historian:

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Project Information:

The Historic American Engineering Record (HAER) is a long-range program that documents and interprets historically significant engineering sites and structures throughout the United States. HAER is part of Heritage Documentation Programs (Richard O'Connor, Manager), a division of the National Park Service (NPS), United States Department of the Interior. The Gem Lake Dam recording project was undertaken by Galvin Preservation Associates Inc. (GPA) for the Southern California Edison Company (SCE) in cooperation with Justine Christianson, HAER Historian (NPS). SCE initiated the project with the intention of making a donation to NPS. Archaeologist Crystal West (SCE) oversaw the project and provided access to the site. Architectural Historian Andrea Galvin (GPA) served as project leader. Preservation Planner Matthew Weintraub (GPA) served as the project historian. James Sanderson (GPA) produced the large format photographs. The field team consisted of Andrea Galvin (GPA), James Sanderson (GPA), and Crystal West (SCE).

Researchers may also refer to:

- HAER No. CA-166-A, Rush Creek Hydroelectric System, Powerhouse Exciters (January 15, 1995)
- HAER No. CA-166-B, C, D, E, Rush Creek Hydroelectric Worker Cottages (Buildings 103, 104, 105, 108) (September 30, 1997)
- HAER No. CA-166-F, Rush Creek Hydroelectric System, Agnew Lake Dam (January 14, 2013)
- HAER No. CA-166-H, Rush Creek Hydroelectric System, Rush Meadow Dam (January 14, 2013)

Part I. Historical Information

A. Physical History:

1. **Date of Construction:**
Construction of the Gem Lake Dam occurred in 1915-1916.[1] Addition of gravity sections occurred from June to November 15, 1924.[2]

2. **Engineer:**
Lars R. Jorgensen, engineer, of San Francisco, designed the Gem Lake Dam and supervised its construction. E. J. Waugh served as resident engineer, and L. B. Curtis served as field engineer. Charles Oscar Poole of the Nevada-California Power Company served as the chief engineer for the entire development.[3]

3. **Builder/Contractor/Supplier:**
The Duncan-Harrelson Company of San Francisco, contractors, originally constructed the Gem Lake Dam, with F. O. Dolson serving as superintendent of construction.[4] Bear brand Portland cement was delivered to the site and mixed with local sand and rock to make concrete; lumber for forms was procured at the dam site.[5] The Dwight P. Robinson and Company, Inc. built the additional gravity sections, with E. C. Macy in personal charge. Again, cement was hauled to the site, and local sand and rock were used.[6]

4. **Original Plans:**
Original construction plans for the Gem Lake Dam are not found in the records of the Southern California Edison Company (SCE), which currently owns the dam. However, a pair of papers published in the *Transactions of the American Society of Civil Engineers* during the early twentieth century describes the original design and construction of the Gem Lake Dam. The first paper, "Multiple-Arch Dams on Rush Creek, California," by Lars R. Jorgensen, the engineer who designed the Gem Lake Dam, was published in 1917, shortly after the major work of building the dam was completed. The second paper, "Multiple-Arch Dam at Gem Lake on Rush Creek, California," by Fred O. Dolson, an assistant general manager for the Southern Sierras Power Co., which owned the dam at the time of publication, and Walter L. Huber, engineer, of San Francisco, was published in 1926, shortly after gravity sections were added to the dam. Both papers include narrative descriptions, photographs, and drawings of the dam's design and construction.

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[1] L. R. Jorgensen, "Multiple-Arch Dams on Rush Creek, California," Transactions of the American Society of Civil Engineers 81 (1917): 850.
[2] Fred O. Dolson and Walter L. Huber, "Multiple-Arch Dam at Gem Lake on Rush Creek, California," Transactions of the American Society of Civil Engineers 89 (1926): 729, 735.
[3] Jorgensen, "Multiple-Arch Dams," 881.
[4] Jorgensen, "Multiple-Arch Dams," 881.
[5] Jorgensen, "Multiple-Arch Dams," 879.
[6] Dolson and Huber, "Multiple-Arch Dam," 729.

Jorgensen reported that the crest of the Gem Lake Dam was 700' long and located at an elevation of 9,053'.[7] Jorgensen's drawings show that the dam was built as a contiguous, linear series of reinforced concrete arches, inclined at 50 degrees to horizontal on the upstream side. The span included 16 full arches (which became designated as Arches No. 1 to No. 16, from north to south), a nearly complete arch at the south abutment (Arch No. 17), and a narrow fractional arch at the north abutment (not numbered). Each full arch segment was 40' wide between the centers of the adjoining buttresses. The vertical distance between the crest and the toe of the dam varied along the span according to the uneven terrain within the incised stream channel. The greatest vertical distance from crest to toe was 84', and the greatest vertical distance between the crest and the lowest point of the foundation was 112', at Arch No. 2. The thickness of the arches increased consistently from 1.0' at the crest, to 3.60' at a point 80' below the crest, to 3.95' at the deepest point of the foundation.[8] At the downstream faces of the arches, the intrados transitioned from circular at the bases to elliptical at the tops.[9]

Concrete buttresses adjoined the arches, extending approximately 14' back from the springing line of the arches to the downstream side at the crest of the dam. The tapered buttresses varied in thickness from 1.85' at the crest to 4.25' at the deepest point. Beginning at a point 15' below the crest of the dam, the buttresses were strengthened by concrete counterforts that were 4.5' thick at their tops and 11.0' thick at the deepest point.[10] The triangular construction of steel reinforcing rods embedded in the buttresses and counterforts "ties the adjacent arches into the buttresses... Should one arch fail, this triangular girder would immediately take up the unbalanced thrust and prevent adjacent arches from collapsing, and this is its principal duty."[11] In addition, at Arches No. 1 through No. 15, pairs of double, horizontal braced steel struts were tied to the internal vertical reinforcements between the buttresses at points 15' below and 45' below the crest of the dam.[12] The upper horizontal struts "are designed so that, besides their main purpose of holding the upper portion of the buttress in place, they are capable of supporting a light roadway"; the lower horizontal struts were "placed near the up-stream face, mainly in order to support the triangular girder, should the latter ever be required to support any unbalanced arch pressure."[13]

The southernmost arches, No. 16 and No. 17, were constructed with spillways. These arches, each of which was less than 30' in height, were not outfitted with the horizontal steel struts that were installed at Arches No. 1 through No. 15. Each

[7] Jorgensen, "Multiple-Arch Dams," 868.
[8] Jorgensen, "Multiple-Arch Dams," 860 (Fig. 4), 861 (Fig. 5), 867 (Fig. 7).
[9] Jorgensen, "Multiple-Arch Dams," 857.
[10] Jorgensen, "Multiple-Arch Dams," 860 (Fig. 4), 861 (Fig. 5).
[11] Jorgensen, "Multiple-Arch Dams," 866.
[12] Jorgensen, "Multiple-Arch Dams," 860 (Fig. 4), 861 (Fig. 5), 867 (Fig. 7).
[13] Jorgensen, "Multiple-Arch Dams," 867.

spillway consisted of a row of rectangular openings arranged symmetrically across the top of the arch. Arch No. 16 contained eight openings, while Arch No. 17 contained five openings. The overflow openings were approximately 24" tall and 64" wide, with 8" wide column separations between the openings. The openings could be closed with loose flash-boards. In Arch No. 17, the tops of the overflow openings were located 1' below the crest of the dam, such that the bottom of the spillway was at an elevation of 9,050'. The overflow openings in Arch No. 16 were located 2' lower, with the bottom of the spillway at an elevation of 9,048'.[14] Running beneath the foundation of Arch No. 3, a tunnel with a 48" diameter steel pipeline, approximately 300' long, served the outlet works.[15]

5. **Alterations and Additions:**
As described in 1924 in "Multiple-Arch Dam at Gem Lake on Rush Creek, California," by Dolson and Huber, the most substantial change to the Gem Lake Dam occurred in 1924 as a result of repairs. Within a few years of its original construction, deterioration on the face of the dam became evident. The deterioration occurred as a result of water penetrating the concrete and freezing during the severe winters. Efforts to arrest the deterioration by applying a waterproof coating to the face of the dam were not successful.[16] Ultimately, a structural solution was sought in order to protect the thin concrete sections of the arches from extremely low temperatures. "It was finally decided that the best method of repair would be to pour a concrete gravity section on the back of each of the arches, extending it up to within 30 ft. of their tops."[17]

According to plan drawings by the Southern Sierras Power Co., the gravity sections were poured against the downstream faces of the arches, partially filling in the intrados but retaining the arched plan profile. Vertical channels, 4" deep and 2'6" wide, were cut in the adjacent buttresses, and refilled with concrete when the sections were poured, thus creating an interlocking structure. The gravity sections were sloped and carried back to form bonds against the counterforts. At a point 30' below the crest, the tops of the sections were 2' thick. They increased in depth to 25.31' thick at a point 55' below the crest, and 56.49' thick at a point 80' below the crest. Pouring of the sections resulted in the encasing in concrete of the majority of the lower horizontal struts that extended between the buttresses. The work also included installation of ¾" diameter galvanized steel steps set into the faces of the gravity sections, and elliptical runways at the tops of the gravity sections, comprised of galvanized pipe supports and 2" by 12" wood planks. Precast porous blocks, 12" square with 4" cores, were placed at the base of the gravity sections, and 4" diameter tile pipes were embedded to provide drainage. A 36" diameter draw-off pipe, covered by a screen

[14] Jorgensen, "Multiple-Arch Dams," 867 (Fig. 7), 870 (Fig. 10).
[15] Jorgensen, "Multiple-Arch Dams," 867-868.
[16] Dolson and Huber, "Multiple-Arch Dam," 723-724.
[17] Dolson and Huber, "Multiple-Arch Dam," 727.

on the upstream face of the dam, was installed horizontally though the gravity section of a single arch, shown as No. 7 in plans.[18]

Since the addition of the gravity sections in 1924, minimal alterations to the Gem Lake Dam have occurred as a result of maintenance and improvement projects. A notation added in 1965 to a plan that was originally drawn up in 1924 reads "Moved outlet to Arch 8." This appears to clarify the location of the draw-off pipe installed in 1924, which may have been incorrectly shown on earlier plans as being located in Arch No. 7. (It is not likely that the draw-off pipe was physically moved from Arch No. 7 to Arch No. 8.) In 1947, under the ownership of the California Electric Power Company (Calectric), a 40' long, 36" diameter discharge pipe and a 36" gate valve were installed at the downstream end of the draw-off pipe, in conjunction with the construction of a galvanized iron valve house, 8' by 9', on a 4' high concrete basement, on the downstream side of Arch No. 8.[19]

Also, according to plan drawings by SCE, a gunite coating was applied to the upstream face of the dam in 1966. The thickness of the gunite coating was variously specified as either 2" or 3" for different arches. The work involved chipping out of the original concave profile of the crest line to allow for a gunite cap over the lip of the crest. At each arch, gunite was applied in a single continuous operation over a layer of welded wire fabric that was tied into the upstream face of the dam. The gunite coating was troweled smooth and Thiokol or equal waterproofing material was applied. Also during this work, existing drain holes in gravity sections were reamed out or replaced, and new drain pipes, spanning the full width of each arch, were connected to existing drain channels.[20] In addition, a drawing from 1988, which was prepared for a plan compendium, indicates that a 3" thick coating of gunite was applied uniformly in 1967-1968.[21] It is not known if this later drawing is an as-built drawing that corrects the thickness of gunite that was applied in approximately 1966, or if it refers to a separate coating of gunite that was applied afterward.

According to a historic resources inventory of the Rush Creek Hydroelectric System completed in 1988, gunite repairs also occurred in 1945, 1950-1951, and 1954-1956; the upstream face was treated with poly-sulfide paint in 1966 (which occurred in conjunction with application of a gunite coating at the same time); and drainage holes were drilled to treat leaking between the arches and gravity sections in 1954-1959. Also, large cavities in the outlet tunnel, which runs

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[18] Southern Sierras Power Company, Reinforcement of Gem Lake Dam (1924, revised 1965), Southern California Edison Company database (SCE Drawing No. 571313).
[19] Southern Sierras Power Company, Reinforcement.
[20] Southern California Edison Company, Gem Lake Dam and Agnew Lake Dam Maintenance (1966), Southern California Edison Company database (SCE Drawing No. 585927-3).
[21] Southern California Edison Company, Gem Lake Dam (1988), Southern California Edison Company database (SCE Drawing No. 5204741-0).

beneath the dam structure, were repaired with new pipe sections and new concrete fill in 1950.[22] In addition, it appears that the steel ladder steps and the metal-and-wood plank runways that were included in the design and construction of the gravity sections in 1924 were replaced with casted, welded metal runways and ladders with safety cages in approximately the mid-twentieth century.[23]

Between June and September 2007, a geomembrane liner was installed on the upstream face of the dam to block current leaks and prevent future leaks. This involved installation of stainless steel batten strips at the spring of the arches vertically, and installation of stainless steel tensioning profiles on the center of each arch vertically to hold the geomembrane to the dam. Then, the geocomposite was installed in 1.05-meter wide sections horizontally on the face of each arch. The geomembrane system covers more than 60,800 square feet.[24]

B. Historical Context:

The Gem Lake Dam and the Rush Creek Hydroelectric System, of which the dam is a part, were constructed during the early twentieth century, which was an era of growth and advancement for the hydroelectric generation industry. Spurred on by great commercial demand for electricity, various parties sought to capitalize on the tremendous potential of Rush Creek, and other watersheds of the Sierra Nevada, for power generation. Ultimately, it was the Pacific Power Corporation that began hydroelectric development of Rush Creek in 1915, led by James Stuart Cain, who initially acquired the rights to develop Rush Creek, and Delos Allen Chappell, president of the Nevada-California Power Company. Development proceeded under the Pacific Power Corporation, and later under the Nevada-California Power and Southern Sierras Power companies, all of which were controlled by the Nevada-California Electric Corporation.[25]

In 1915, the Pacific Power Corporation commissioned the design and construction of two reinforced concrete multiple-arch dams to impound reservoirs on the Rush Creek system.[26] This was an important decision because, at the time, reinforced concrete multiple-arch dams were rare and controversial. "Compared with gravity, arch, and flat-slab buttress dams, the multiple arch concept occupied a minor – almost nonexistent – place in the world of hydraulic engineering at the start of the twentieth century."[27] Nonetheless, reinforced concrete multiple-arch dams generally represented a 30 to 40

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[22] James C. Williams and Roger A. Hicks, Evaluation of the Historic Resources of the Lee Vining (FERC Project Number 1388) and Rush Creek (FERC Project Number 1389) Hydroelectric System, Mono County, California (Fair Oaks, California: Theodoratus Cultural Research, Inc., 1989), A-70.
[23] Visual observation, September 6, 2012.
[24] John C. Stoessel and John A. Wilkes, "Dams and Civil Structures: Geomembrane Installed to Control Leakage at Gem Lake Dam," Hydro Review 29 (2010): not paginated, http://www.hydroworld.com/articles/hr/print/volume-29/issue-5/articles/dams-and-civil-structures.html.
[25] Valerie H. Diamond and Roger A. Hicks, Historic Overview of the Rush Creek and Lee Vining Creek Hydroelectric Projects (Fair Oaks, California: Theodoratus Cultural Research, Inc., 1988), 7-12.
[26] Diamond and Hicks, Historic Overview, 13, 19.
[27] Donald C. Jackson, Building the Ultimate Dam: John S. Eastwood and the Control of Water in the West (Lawrence, Kansas: University Press of Kansas, 1995), 34.

percent savings in material costs over conventional gravity dams because they used far less cement.[28] According to Dolson and Huber in 1926, this was a key consideration in the decision to build reinforced concrete multiple-arch dams on Rush Creek, which was located in a very isolated location that made material costs exorbitant:

> Physical conditions governing the original construction of Gem Dam had much to do with the selection of the multiple-arch type. Materials for an earth dam were not available. A masonry dam was thought, at the time, to have certain advantages over a rock-fill type. Because of the excessive cost of materials, the quantities required for a masonry dam of the gravity type had to be avoided. These considerations led to the selection of the multiple-arch type.[29]

Less than a decade earlier, in 1908-1909, the first reinforced concrete multiple-arch dam in the world was built at Hume Lake, California. This dam was designed by engineer John W. Eastwood, who championed the multiple-arch dam design as "The Ultimate Dam," due to its structural characteristics as well as its savings in construction costs over other types of dams. The multiple-arch dam design made development of water projects feasible that would otherwise have remained economically marginal or prohibitively expensive, such as the Rush Creek Hydroelectric System. Eastwood designed more than 60 hydraulic projects in his career throughout the western United States and Mexico, including multiple-arch dams, none of which ever failed or caused loss of life or substantial property loss.[30]

However, despite their utility and economic advantages, multiple-arch dams were not widely accepted because they departed from traditional dam-building methods and principles. They belonged to the category of carefully engineered "structural dams," whose strengths were not visually obvious. Most engineers and the general public preferred the simpler designs of "massive dams," which conveyed strength and mass through their visual characteristics.[31] According to Donald C. Jackson, who authored a text on Eastwood and the development of multiple-arch dams, this dichotomy between massive dams and structural dams lay at the root of the deep-seated reluctance of the general public and many professionals to accept multiple-arch dams:

> While massive dams are simple to conceptualize, they make profligate use of construction materials. In contrast, structural dams require relatively small amounts of material, but can present more sophisticated problems in design and construction... Historians must appreciate the conflict between the massive and structural traditions in order to come to grips with many

[28] Jackson, Building the Ultimate Dam, 3.
[29] Dolson and Huber, Multiple-Arch Dam, 714-715.
[30] Jackson, Building the Ultimate Dam, 2-3, 12.
[31] Jackson, Building the Ultimate Dam, 18-21.

> of the controversies that attended dam building during the early twentieth century.[32]

Engineer Lars R. Jorgensen of San Francisco, who was commissioned by the Pacific Power Corporation to design the two original dams in the Rush Creek system, was a proponent of reinforced concrete multiple-arch dams. Jorgensen, an established theoretician on arch dams, was aware of Eastwood's work. Jorgensen proceeded to design the Gem Lake Dam and the Agnew Lake Dam as reinforced concrete multiple-arch dams that were similar to Eastwood's dam at Hume Lake. Jorgensen used an identical design for both dams, which originally differed from each other only in span length and in details. Jorgensen introduced elliptical shapes at the tops of the arches for greater strength, and he included hooped steel reinforcement, which allowed him to patent the dam design.[33]

Within a few years of its construction, deterioration occurred on the downstream face of the Gem Lake Dam, apparently caused by water penetrating the concrete and freezing during the extremely cold winters. Although the problem was not structural, ultimately caused minor damage, and was successfully remedied by the addition of gravity sections that insulated the thin concrete arches, it fueled the controversy over the suitability of reinforced concrete multiple-arch dams. The deterioration of Gem Lake Dam was discussed extensively at meetings and in publications of the American Society of Civil Engineers, and it ultimately contributed to the downfall of the multiple-arch dam movement in the United States.[34] According to Jackson, the legacy of multiple-arch dams such as the Gem Lake Dam is mixed:

> Consequently, in terms of performance, they can be considered a success worthy of his [Eastwood's] claims. In another sense, however, multiple arch dams represent a profound failure, since they never achieved great influence in the development of America's water resources. Although approximately fifty multiple arch dams were built in the United States in the first part of the twentieth century, this number pales in comparison to hundreds of earthen and concrete gravity dams built during the same period; by 1945 the technology had almost completely disappeared from the design lexicon of American dam engineers.
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> Thus, the history of Eastwood and the multiple arch dam encompasses both success and failure, depending on the context of analysis. For historians, this dichotomy is significant because it offers insight into important aspects of western water development that might be overlooked in analyses of more traditionally "successful" or prominent technologies. Eastwood's hopes of deploying "The Ultimate Dam" throughout the arid region provided chimerical, but his accomplishments and frustrations

[32] Jackson, Building the Ultimate Dam, 20-21.
[33] Williams and Hicks, Evaluation, A-67-68.
[34] Williams and Hicks, Evaluation, A-69.

survive as touchstones for those seeking to comprehend the modern West's hydraulic infrastructure.[35]

Part II: Structural/Design Information

A. General Description:

The Gem Lake Dam is a linear, reinforced concrete multiple-arch structure. The crest is 688' long and located at 9,057.5' in elevation. The dam is comprised of 16 full arches adjoined by buttresses, designated as Arches No. 1 to No. 16 from north to south, and two partial arches, including the nearly complete Arch No. 17 at the south end and the non-numbered arch fragment at the north end. The arches are tilted at 50 degrees to the horizontal, with the intrados open to the downstream side. In plan view, the multiple-arch dam has a reeded, scalloped profile.[36] The maximum height of the dam above grade is 84', and the maximum height from the crest to the lowest point in the foundation is 112'.[37] Metal pipe handrails are installed along a runway atop the crest. A geomembrane layer covers the upstream face of the dam.

The arches are circular at the bases and transition to elliptical at the tops. Each full arch segment is 40' wide between the centers of the adjoining buttresses. The arches vary in thickness from 1.25' at the crest (which appears to include the thickness of the gunite coating) to 3.75' at a point 80' below the crest. The tapered buttresses are 1.85' wide at the crest and 4.25' wide at a point 80' below the crest. Beginning at a point 15' below the crest, counterforts strengthen the buttresses; they are 4.5' wide at the tops and 11.0' wide at a point 80' below the crest. Along the span from Arches No. 1 through No. 15, the arch segments are reinforced by pairs of horizontal, cross-braced, steel-reinforced concrete struts between the buttresses – one located 15' below the crest and entirely exposed, and one located 45' below the crest and mostly embedded in poured concrete. The intrados are partially filled in up to approximately 30' below the crest with sloping gravity sections, which encase the lower reinforcing struts.[38]

Spillways are located at the south end of the dam. The partial arch segment at the south abutment (No. 17) contains the upper spillway at 9,053.64' in elevation, comprised of five rectangular openings, each approximately 5' wide and 2' high, arranged in a horizontal row just below the crest of the dam. The adjacent arch segment (No. 16) contains the lower spillway, consisting of a row of eight identical openings, set 2' lower than the upper spillway at 9,051.63' in elevation. The outflow of the dam is located near the middle of the span, consisting of a 36" diameter draw-off pipe, centered at 8,985.33' in elevation, which extends through the base of an arch segment (No. 8). A screen covers the upstream end of the draw-off pipe. The downstream end of the pipe passes through a small, galvanized iron valve house and terminates at an anchor block, situated on a

[35] Jackson, Building the Ultimate Dam, 12.
[36] Southern California Edison Company, Gem Lake Dam.
[37] Williams and Hicks, Evaluation, A-64.
[38] Southern California Edison Company, Gem Lake Dam.

concrete footing at the base of the dam. The pressure pipeline from the reservoir to the powerhouse is contained within a tunnel that passes beneath the dam structure.[39]

1. **Character:**
   The Gem Lake Dam exhibits the historic character of an early twentieth century, reinforced concrete multiple-arch dam. It displays the form, scale, materials, and craftsmanship of its original and historic construction. While the addition of gravity sections to the downstream faces of the arches substantially increased the mass of the original structure, the historic repair did not adversely alter the architectural character of the Gem Lake Dam. This is because only the lower, circular portions of the intrados were filled in, while the upper, elliptical portions of the intrados, which are particularly characteristic of the design, remain visible. In addition, while the construction of gravity sections insulated the existing arch sections against the effects of severe winter weather, it did not change the original structural character of the dam as a buttressed, multiple-arch structure. While some minor physical repairs and improvements have occurred over time, they generally augment rather than diminish the historic character of the dam, by allowing it to continue to function according to its original structural design.

2. **Condition of Fabric:**
   The Gem Lake Dam is in good condition. The rapid deterioration that afflicted the downstream faces of the arches during its first decade of existence was remedied by the addition of the gravity sections. Since that time, and with the benefit of frequent maintenance and repair, the original structure and the historic additions have remained sound and generally intact. Over time, alterations to fabric have generally been limited to the repair and replacement of deteriorated concrete on the surface of the downstream face, and several cycles of removal and replacement of sprayed concrete and/or gunite coatings on the upstream face. Other minor alterations to the fabric include the drilling of drain holes in the gravity sections, the replacement of steps and runways on the faces of the gravity sections, and the application of a geomembrane that covers the upstream face of the dam. None of these alterations negatively affects the soundness or intactness of the historic structure and its design.

B. Construction:

Between May and December 1915, workers established a supply chain to the remote Rush Creek area and cleared construction sites. In May 1916, workers began actual construction of the Gem Lake Dam and other facilities.[40] The shipping of materials from their points of origin, across the difficult terrain of the eastern Sierras, to the construction site of the Gem Lake Dam at approximately 9,000’ in elevation, presented great challenges.[41] In 1926, Dolson and Huber described how these transportation challenges were overcome:

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[39] Southern California Edison Company, Gem Lake Dam.
[40] Diamond and Hicks, Historic Overview, 13-19.
[41] Williams and Hicks, Evaluation, A-68.

> All materials necessary for its construction except lumber, which could be cut locally, and rock, must be moved long distances and under difficult conditions. Cement had to be shipped from the place of manufacture by broad-gauge railroad 336 miles, transhipped [sic] to a narrow-gauge railroad, and hauled 84 miles farther; then hauled over a sandy desert road, using engines or motor trucks of the caterpillar type, for 70 miles, to the power-house below the dam. Here, it was reloaded on tram cars and raised more than 1250 ft. vertically on a 4826-ft. tramway to Agnew Lake, where it was rehandled, loaded on barges, and towed across the lake to be again rehandled and raised an additional height of 550 ft. by another tramway, being finally placed on the dam site at a total cost, even under 1915 conditions, of $7.50 per bbl.[42]

Due to the high costs and difficulty of transporting building materials to the isolated construction site, local materials were used in the construction of the Gem Lake Dam, except for the steel used for reinforcement and the Bear brand Portland cement used for mixing concrete, which were shipped. According to Jorgensen, local building materials were found, prepared, conveyed, and used in the following ways:

> The building material for the dam was found near-by. The sand was taken from the shore of the natural lake. The rock had to be hauled a short distance on a tramway, from the outlet tunnel dump (limestone), and later from a large rockslide (granite) about 2500 ft. away. All available materials in the neighborhood, especially the different sand deposits, were tested before any particular material was selected for construction. As the sand deposit along the shore of the Gem Lake Dam was good, it was used. This sand was first pumped, and later shoveled, from the lake, and transported to a storage pile near the mixing plant. This lake sand, which contained 3½% of clay and 1% of dirt, was mixed with the sand from the rock crusher (all particles being less than ¼ in. in diameter) in the proportion of about three-fourths of lake sand to one-fourth of crushed rock sand. This gave a very good combination, both as to strength and water tightness.
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> A 1:2:4 mix [of cement to sand to rock] was adopted for the arches and struts, and a 1:2½:5 mix for the buttresses. The actual proportions, however, were sometimes changed, but 1½ bbl. of cement for the arches, and 1¼ bbl. for the buttresses were used always. The rock was crushed in a gyratory crusher, and separated into three sizes through a revolving screen having 1½, ¾, and ¼-in. meshes. The rejects from the screen went into a jaw crusher, the jaws of which were set to give a maximum size of 2 in.

[42] Dolson and Huber, "Multiple-Arch Dam," 714.

> The distribution of the concrete to the different arches and buttresses was done with two-wheeled push carts and short chutes.
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> The reinforcement placed in the dam consisted of high-carbon steel bars, either corrugated or twisted.
>
> The trees standing on the reservoir site were cut down, sawed into lumber in a mill and erected on the ground by the contractors, and used for the forms.
>
> A 1:2 plaster coat of cement mortar ¼ in. thick at the crest, and increasing to ¾ in. thick 80 ft. below, was put on the up-stream face with a cement gun.
>
> The Gem Lake Dam contains 8537 cu. yd. of concrete and 82 tons of reinforcing steel. The contract price was $22 per cu. yd., including cement, forms, plastering the up-stream face, and all tools and materials except the reinforcing steel, which was paid for as an extra at the rate of $110 per ton in place. The excavation, of which there was only a limited quantity, was also paid for as an extra.[43]

Most of the Gem Lake Dam structure was built during the construction season of 1916, which ended in December. The last of the concrete was poured and concrete coating was applied by mid-June 1917. On June 28, 1917, the Gem Lake reservoir was filled.[44]

Soon after construction, leakage occurred at the concrete faces of the arches. Initially, the leaks were not believed to be serious, as indicated by Jorgensen in 1917: "Some of the arches on the Gem Lake Dam are absolutely tight, some of them sweat in places, and a few drip in places. A few small springs have formed behind the dam, and a trickle of water comes under one arch; but, all told, the total leakage is very small."[45] However, by the early 1920s, the downstream faces of many arches began to show serious deterioration. Attempts to remedy the situation by applying waterproofing compounds to the dam face failed. The Southern Sierras Power Company, which owned the Rush Creek Hydroelectric System at that time, sought a structural solution in order to protect the disintegrating arches. They insulated the thin arch sections by partially filling in the intrados with curved concrete gravity sections.[46] According to Dolson and Huber, this construction project was comparable in effort to the original construction of the Gem Lake Dam – its scale necessitated the use of local building materials again – and it

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[43] Jorgensen, "Multiple-Arch Dams," 868, 879-880.
[44] Diamond and Hicks, Historic Overview, 19-20.
[45] F. O. Blackwell et al., Discussion of "Multiple-Arch Dam on Rush Creek, California," by L. R. Jorgensen, Transactions of the American Society of Civil Engineers 81 (1917): 906.
[46] Dolson and Huber, "Multiple-Arch Dam," 723, 727-729.

increased the total quantity of concrete used in the Gem Lake Dam by nearly two-and-half times the original amount:

> The work was begun in June, 1924, and approximately two months of the short available field season was required for installation of plant and equipment, consisting of rock crusher, serial cableway, inclined tramway, bunkers, decking, etc.
>
> The tramway from the power-house at Silver Lake to a boat landing at Agnew Lake, constructed in 1915, and previously mentioned, was again utilized after extensive repairs... All construction equipment, tools, camp supplies, lumber, and cement, was hauled up this incline; in fact; all material used except sand and rock. The usual trip load was 5 tons... In handling regular loads, such as cement, a round trip was ordinarily made in 50 min., including time for loading and unloading.
>
> Material delivered at the boat landing on Agnew Lake was loaded on a barge (18 by 24 ft. by 3 ft. deep; capacity, 400 sacks of cement, or approximately 20 tons) and towed across Agnew Lake by a launch driven by an 8-h.p. motor.
>
> From the upper end of Agnew Lake, a double-track, 36-in. gauge, incline railway was constructed to the concreting plant situated above the south end of Gem Dam. Because of the precipitous rock slopes, it was necessary to support this tramway on a trestle throughout its length of 1715 lin. ft... This tram not only carried the loads from the lower tramway, but also all the rock and sand for concrete... Sand and rock were hauled in a steel trip car of 4 cu. yd. capacity, which, when loaded, weighed approximately 7 tons... The rock car was able to make approximately 4 round trips per hour. It is estimated that 26428 tons of materials were hauled by this double incline during the short field season.
>
> It was hoped that suitable rock could be found near and above the elevation of the top of Gem Lake Dam, but final examinations showed the most suitable rock available for both the crushed rock aggregate and for making sand, to be a deposit of broken granite located below the dam and across Agnew Lake. Laboratory tests of samples of this rock showed it to be entirely satisfactory. To transport this rock across Agnew Lake, a cableway was constructed from the rock pit to the crushing plant which was at the foot of the upper incline.
>
> A total quantity of 12004 cu. yd. of concrete was added to the dam and 16425 bbl. of cement, or 1.368 bbl. per cu. yd. of concrete, were used. The approximate proportions of the mix were 1 part cement, 3 parts sand, 3 parts crushed stone (¼ in. to 1½ in.) and 1.84 parts cobbles.

> Weather conditions permitted continuance of the work somewhat longer than usual, and the last concrete was poured on November 15, 1924.[47]

The construction of the concrete gravity sections, which included a system of drains, successfully remedied the rapid deterioration that had afflicted the downstream face of the Gem Lake Dam.[48] However, in the wake of the repairs, many engineers criticized the quality of the sand used in the original concrete, which was obtained from the shores of natural Gem Lake.[49] In 1926, Jorgensen responded to criticism by defending the quality of the sand, and by blaming a combination of faulty cement and extremely cold weather on the deterioration:

> The cement had passed the usual test. It might, however, have been slightly underburned without being noticed, causing it to be at the point of unstability when exposed to the severe cold. Under ordinary conditions the concrete undoubtedly would have kept its strength, but under the severe climatic conditions imposed on it in the middle zone, it deteriorated and lost its entire strength.
>
> If the sand had been the cause of the poor showing of the concrete, it could be expected that there would have been good and bad spots of the material, as three kinds of sand were used, sometimes washed and sometimes unwashed.
>
> Inasmuch as the deposit continued to accumulate, it was due, in the writer's opinion, to the cement breaking down gradually and the lime in the cement being leached out continually. The time of actual breaking down was during the coldest weather.[50]

C. Operation:

The Gem Lake Dam captures a watershed area of 22.12 square miles.[51] It impounds a reservoir, Gem Lake at 9,052' in elevation, with a storage capacity of 17,228 acre-feet.[52] The reservoir is used as a water supply to produce power in the Rush Creek Hydroelectric System. Via pressure pipeline, or penstock, water is conveyed from the reservoir a total linear distance of 8,864' to the powerhouse. The upper portion of the pipeline is a 48" diameter, riveted steel conduit that runs downhill from the reservoir for a linear distance of 4,584', to the Agnew Junction. From the Agnew Junction, two parallel, 30" diameter

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[47] Dolson and Huber, "Multiple-Arch Dam," 729-730, 735.
[48] Williams and Hicks, Evaluation, A-69.
[49] Dolson and Huber, "Multiple-Arch Dam," 724.
[50] J. Y. Jewett et al., Discussion of "Multiple-Arch Dam at Gem Lake on Rush Creek, California," by Fred O. Dolson and Walter L. Huber, Transactions of the American Society of Civil Engineers 89 (1926): 741.
[51] Diamond and Hicks, Historic Overview, 19.
[52] Southern California Edison Company, Southern California Edison Hydro Generation Division (Draft) (Rosemead, California: Southern California Edison Company, 1994), 15.

welded steel penstocks convey water an additional linear distance of 3,552' to another pair of parallel pipes, 28" in diameter, which run the final linear distance of 728' to the powerhouse. The decrease in elevation from the head of the penstock (8,963' in elevation as measured from the bottom of the pipe at Gem Lake) to the nozzle of the powerhouse (7,244.63' in elevation) is approximately 1,718'.[53] Water delivered from the reservoir to the powerhouse through the penstock causes impulse-driven water wheels to spin, which in turn move the direct-connected revolving generators that produce electricity for long-distance transmission to customers.

Water in the Gem Lake reservoir that is not conveyed through the penstock to the powerhouse can be passed downstream through the outflow of the Gem Lake Dam. The outflow consists of a 36" diameter draw-off pipe, which is screened on the upstream face of the dam, and which passes through a valve house on the downstream side and terminates at the natural streambed.[54] Water released into the streambed flows downhill into Agnew Lake reservoir, which is located approximately one-quarter mile away and 500' lower in elevation. In addition, spillways are located at the south end of the dam to provide emergency water release in the event that it becomes necessary.

D. Site Information:

The Gem Lake Dam spans Rush Creek canyon and abuts its granitic walls. The dam is aligned along a north-south axis. Immediately to the west lies Gem Lake reservoir at the former site of three natural glacial lakes. At the south abutment of the Gem Lake Dam, a dock consists of a concrete pad with metal stairs and walkways. The dock area contains a number of small, corrugated-metal-clad buildings, including a tram hoist house. Directly to the east of the dam on the downstream side, a loose grouping of buildings occupies a rocky terrace below the toe of the dam. From north to south, they include a residential cottage, a bunkhouse, and a warehouse. These buildings are wood-framed with gable roofs, clad in a combination of corrugated metal and wood, and set on concrete foundations. Additional structures such as a weather station and storage tanks are located on the terrace.

Agnew Lake lies approximately one-quarter mile downstream to the northeast of the Gem Lake Dam. The Gem Tram, an incline railroad, crosses the canyon floor between the Gem Lake dock and Agnew Lake dock on a northeast-southwest route. Access to the dam site is also provided by trails that run along the sides of the canyon and around the shorelines of its reservoirs. The Rush Meadow Dam and Waugh Lake reservoir are found approximately two-and-a-quarter miles further upstream to the west.

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[53] Southern California Edison Company, Gem Lake and Dam, Project 1389 (1980), Southern California Edison Company database (SCE Drawing No. 5161820).
[54] Southern California Edison Company, Gem Lake Dam.

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Appendix A: Images

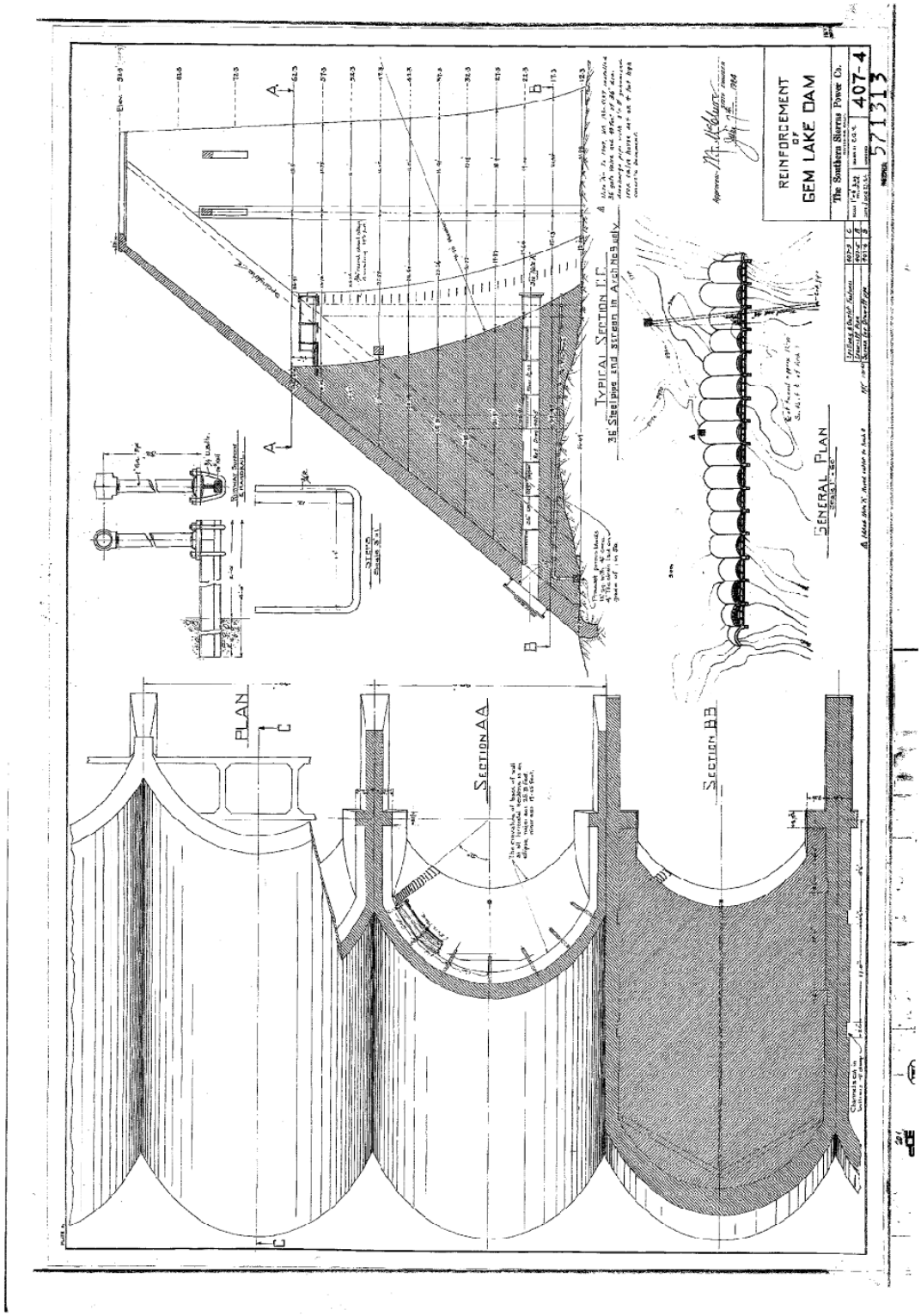

Figure 1: Southern Sierras Power Company, Reinforcement of Gem Lake Dam (1924, revised 1965), Southern California Edison Company database (SCE Drawing No. 571313).

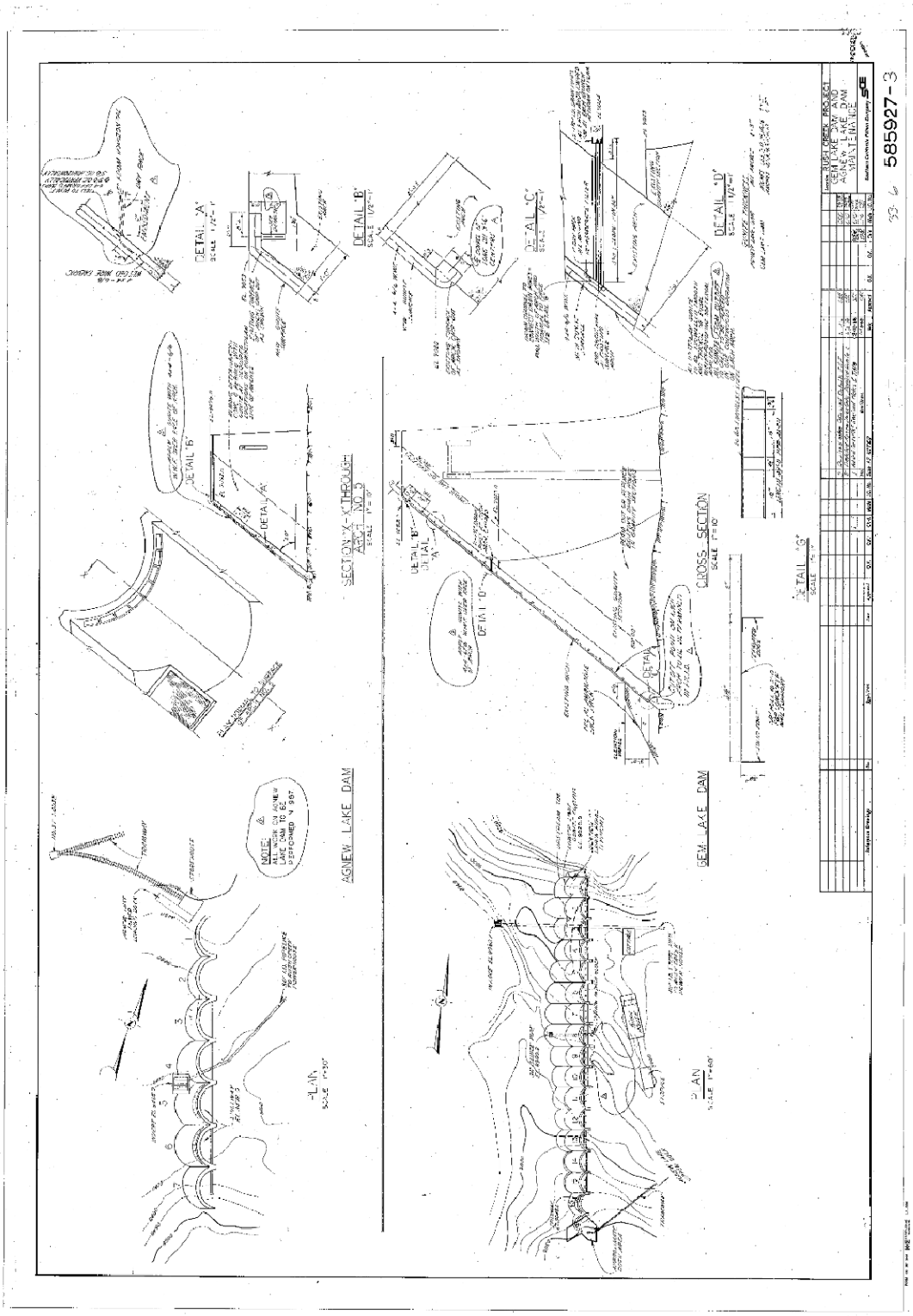

Figure 2: Southern California Edison Company, Gem Lake Dam and Agnew Lake Dam Maintenance (1966), Southern California Edison Company database (SCE Drawing No. 585927-3).

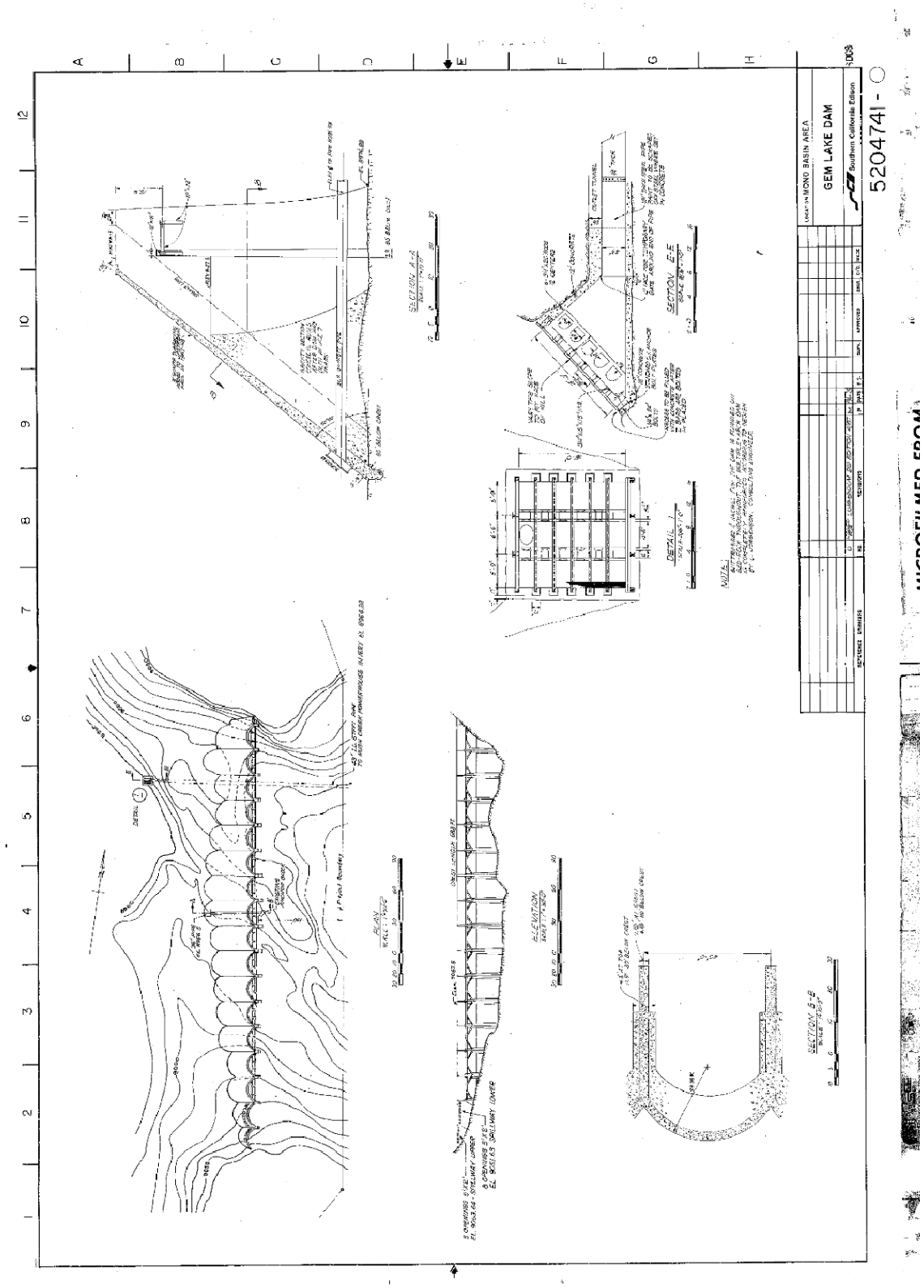

Figure 3: Southern California Edison Company, Gem Lake Dam (1988), Southern California Edison Company database (SCE Drawing No. 5204741-0).

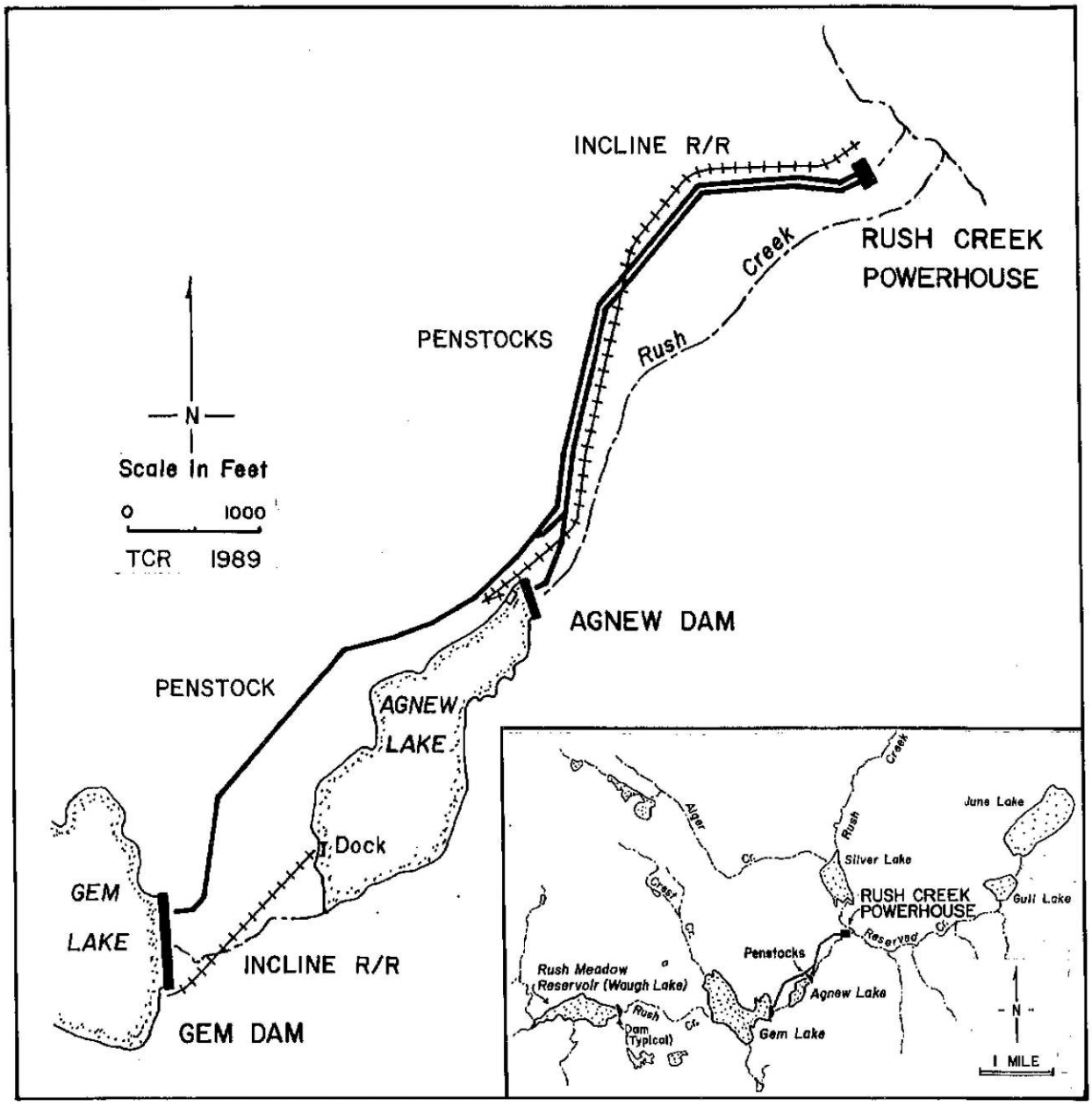

Figure 4: Map of the Rush Creek Hydroelectric System. James C. Williams and Roger A. Hicks, Evaluation of the Historic Resources of the Lee Vining (FERC Project Number 1388) and Rush Creek (FERC Project Number 1389) Hydroelectric System, Mono County, California (Fair Oaks, California: Theodoratus Cultural Research, Inc., 1989), 11.