contemplation for some years as a storage for irrigation and domestic supply in and around Denver, from which city it is some sixty miles distant.

ACKNOWLEDGMENTS.

Throughout the text of this work the author has endeavored to make due acknowledgment for information furnished and courtesies extended, in connection with each of the subjects treated. If any omissions have been made, their subsequent discovery will cause him sincere regret and mortification. To cover any such omissions in the first edition he begs to make a broad and general expression of gratitude for all aid extended in making the work more complete.

Special acknowledgments are due the Director of the U. S. Geological Survey, for the use of many of the cuts and illustrations which embellish the foregoing pages, and are indispensable to the proper understanding of the text.

CHAPTER VIII.

MISCELLANEOUS.

After completing the proof-reading of the revised edition presented in the foregoing chapters, a number of photographs were received which had been intended to be incorporated in the body of the work had they been available. As these illustrations, mostly of new or little known types, are particularly valuable and instructive, adding much to the illumination of the subject, they have been assembled in a concluding chapter of miscellany.

The author takes pleasure in acknowledging his indebtedness for these photographs and notes descriptive of them, as follows:

To Mr. Samuel Storrow, M. Am. Soc. C. E., for thirteen recent photographs of the Bowman Lake, the English, the Weaver Lake, and the Eureka Lake rock-fill dams in the mining regions of Northern California, referred to in the text; also a view of the Faucherie timber frame, triangular dam—a very old structure still in service—and a late picture of the Lake Frances hydraulic-fill dam, as it appears after completion. Many of these dams are remotely situated in the Sierra Nevada mountains and not readily visited or photographed. The views supplied by Mr. Storrow have been taken in the course of his professional work, and his notes upon the construction of these curious old dams of the mining-day type of temporary structure, have been kindly placed at the author's disposal. The obligation is still further increased by the fourteen pictures of four Mexican masonry dams, most of which are quite new to the world at large, but one of them having been illustrated in the first edition. These fourteen pictures were taken by Mr. Storrow on a tour of Mexico with a party of mining engineers in November, 1901.

The author is under obligations to Messrs. Wiley & Lewis, contractors, for the interesting pictures of the hydraulic-sluicing operations which are transforming the topography of the city of Seattle, Washington, by deep excavations and high embankments.

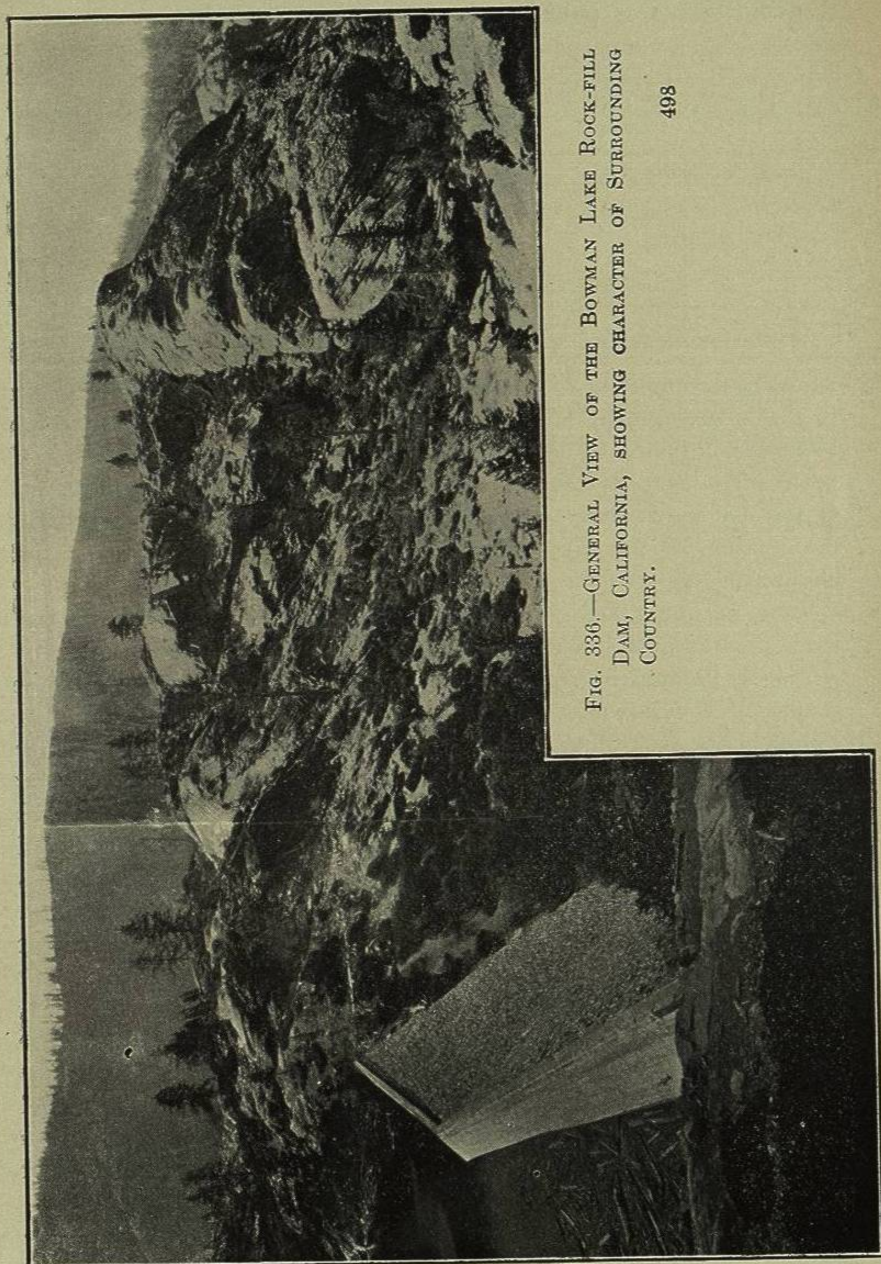

Fig. 336.—General View of the Bowman Lake Rock-fill Dam, California, showing Character of Surrounding Country.

To the kindness of Mr. P. S. A. Bickel, civil engineer, of Twin Falls, Idaho, the author is indebted for the panoramic picture of the three dams at Milner, Idaho, and to Mr. James W. Martin for the photograph taken just after the completion of the Granite Reef dam, Arizona.

Mr. C. E. Curtis, M. Am. Soc. C. E., has contributed the photographs

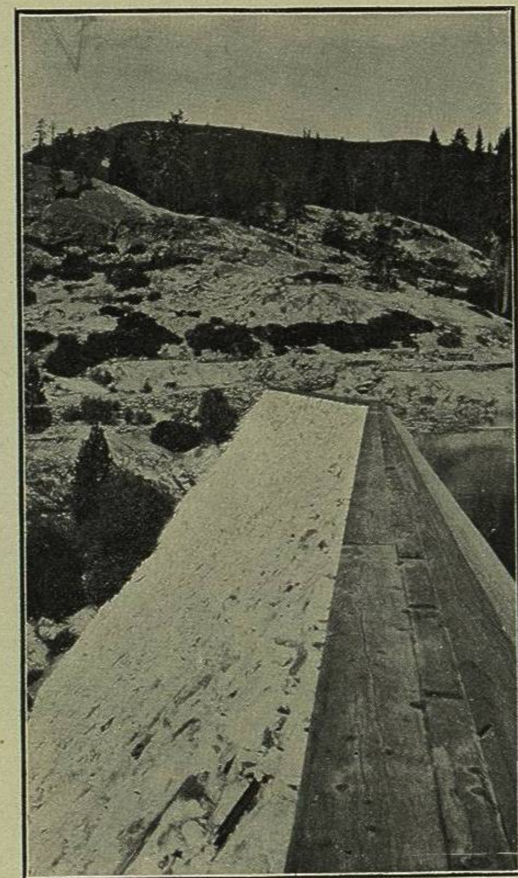

Fig. 337.—Near View of Crest of Bowman Lake Dam, showing Angle in Dam.

and drawing illustrating the cinder-fill dam built on Hinckston Run by the Cambria Steel Works of Johnstown, Penn.

The pictures of the Santo Amaro dam, Brazil, are kindly supplied by Mr. Thomas Berry, chief engineer, while the latest view of the Necaxa dam is contributed by Mr. R. F. Hayward, M. Am. Soc. C. E., general manager of the Mexican Light and Power Company. The plan and sections of the high hydraulic-fill dam projected in Japan are from the office of J. M. Howells, M. Am. Soc. C. E., chief engineer.

The Bowman Rock-fill Dam.—Renewed interest is being taken in the old rock-fill dams of the Sierra Nevada Mountains, in Northern California, built originally to store water for hydraulic mining, because they are becoming valuable for the double uses of generating power and affording domestic and irrigation supply to the valley below. The Bowman dam, described on page 65, and outlined by cross-sections, Fig. 44, is more clearly illustrated in its situation and construction by Figs. 336, 337, 338, 339, and 340.

The dam was first built as a timber structure, prior to 1869, as shown by the cross-section, Fig. 44. In that year work began by which it was raised to a total height of 63 feet, and when finished it contained

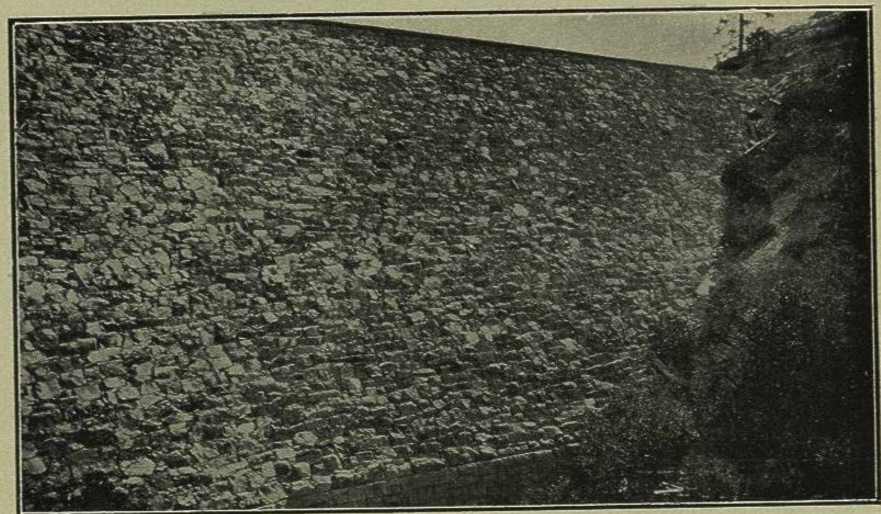

Fig. 338.—Down-stream Face of Bowman Lake Dam, California, illustrating the Quality of the dry Masonry.

17,000 cubic yards of stone filling, 33,000 lineal feet of heavy timber, and 63,000 feet, B. M., of three-inch plank. It was actually designed to carry flood water over its crest to a depth of 3 feet for a length of 300 feet in emergency. The main spill-way, however, is an entirely separate structure, as described later. Before this work was finally completed it was destroyed by fire, October 12, 1871, and again damaged, or practically destroyed, by flood at the end of the same year. In 1872 it was rebuilt to a height of 65 feet, after the same plan as before, with flash-boards on the crest, raising its height to a total of 72 feet. The final increase in height was made, and the dam completed as it now stands, December 10, 1876. Its height has always been called 100 feet in round numbers, but its actual measure is 96 feet at the highest point.

The present dam contains a great deal of the old timber structure at the bottom unburned in the fire. The upper part of the timber facing differs from the old design in that the inclined posts on which the plank skin is spiked are not parts of timber bents, but are merely embedded into the face of the rock-fill and anchored back into the rock, so that

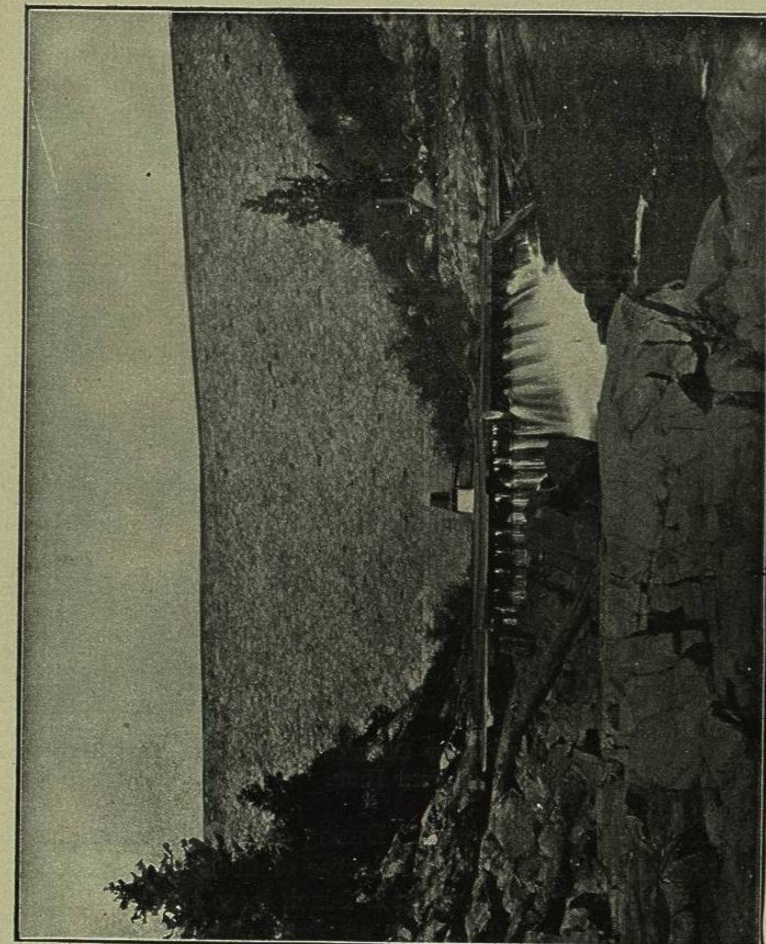

Fig. 339.—Front View of Bowman Lake Dam, from below Measuring Weir.

the first layer of plank is placed horizontally and not vertically as before. At the base the 3-inch plank are in three layers; at the top is but one layer. The plank facing of the lower half of the dam, laid in 1876, is still serviceable after thirty-two years of wear. The upper half of the planking has been replaced once. Since the dam was built, in 1876, there has been a sag in its center amounting to about 12 inches, due to the decay of the timber in the cribs and the settlement of the rock.

The engineer of the company now owning this dam proposes to increase its height to 150 feet by the addition of a structure of reinforced concrete.

Spillway.—While the main dam was intended to act as an emergency overflow, or spillway, the principal spillway is a separate structure (Fig. 340), 52 feet high, built of round logs fastened together by 1-inch drift bolts, forming a crib, filled with small stone. This structure is also covered with a skin of 3-inch plank on the water side, and has a slight angle pointing up stream. The crest is 12 feet lower than the crest of the main dam. It is arranged with A-frame bents so that flash-boards may be added to raise the water 8 feet. There are thirty-one openings

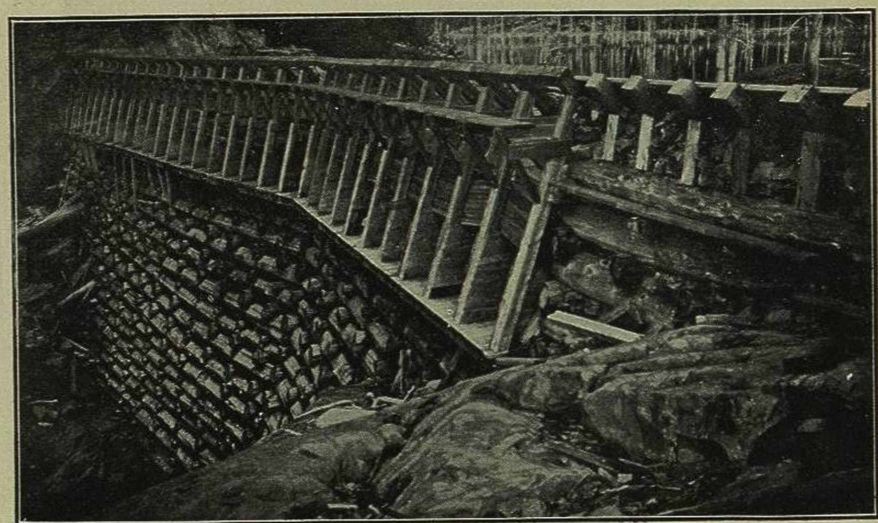

Fig. 340.—Timber Crib Spillway of Bowman Lake Dam. This Structure is 52 Feet High.

between bents, each 4 feet wide. During the flood season the flash-boards are removed, but when all danger of floods is supposed to be past these wasteways are closed with 2-inch loose planks. This structure, built in 1876, has had little or no repair since that date, and has sagged very perceptibly. The ends of the main timbers are torn from the walls of the canyon, and the header logs have rotted to a soft pulp at their extremities, where exposed to the weather. The water passing through or over this spillway leaps clear of the log face on the down-stream side, otherwise it would not have lasted as long as it has.

The Faucherie Dam.—The Faucherie Dam is a good example of a timber-frame dam, with all rock-filling omitted. Its original height was 35 feet, but after its destruction in the early winter of 1875, it was

rebuilt with a reduced maximum height of 21 feet (see Figs. 341 and 342). The frame supporting the inclined face is triangular in form, leaning

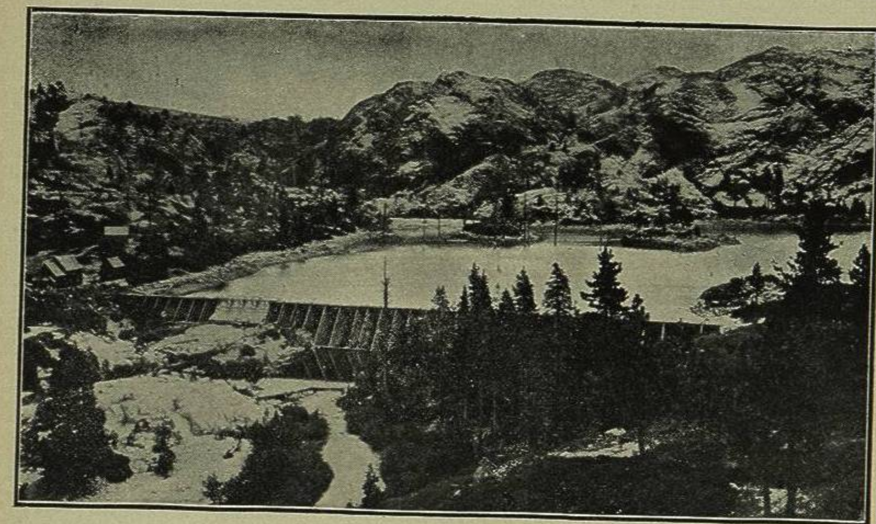

Fig. 341.—The Faucherie Dam, California. A General View of Dam and Reservoir.

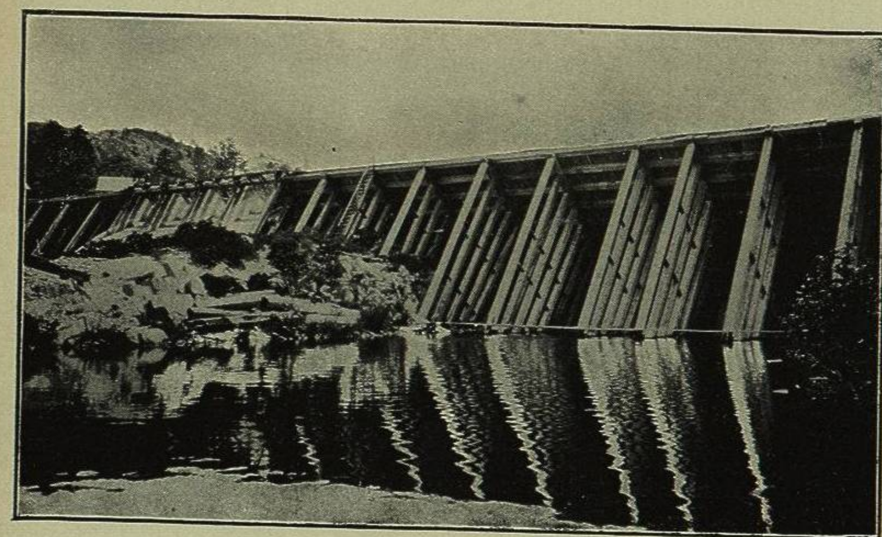

Fig. 342.—The Timber Work of the Faucherie Dam as seen from Below.

down stream at an angle of 55°. The struts supporting the frame have angles varying from 45° to 60° from the horizontal, the latter being the inclination of the longer outer posts.

On the up-stream side the facing planks make vertical joints and are supported by and spiked to square timbers lying horizontally and bolted to the frame. There is no diagonal or horizontal bracing. The posts and struts rest upon wood sills that are bolted to the bed-rock. Thus the entire structure depends upon the strength of the timber for its stability, and not in any manner upon its weight. The top length of the dam is 550 feet, forming a reservoir of 90 acres with a capacity of 1344 acre-feet. It is the simplest possible type of dam, a mere fence leaning down stream, supported by a series of props. The face of the fence is composed of several thicknesses of boards which break joints to render the structure more water-tight.

The Eureka Lake Dam.—The two dams just described are located on Canyon creek, a tributary of the South Fork of Yuba river, Bowman dam being the lowest, at an elevation of about 5400 feet, and Faucherie dam at an altitude of 6100 feet. Higher up on the same stream, at an elevation of about 6500 feet, is French lake, or Eureka lake, formed by a rock-fill dam built in 1859.

The dam has an extreme height of 68 feet, is 250 feet long on top, and forms a reservoir of 337 acres, the capacity of which is 15,150 acre-feet.

The offset shown in the photographs (Figs. 343 and 344) was the result of an enforced economy during construction when money became scarce. The dam is built entirely of rock (without timber cribs), rather loosely placed, and with the larger stones in the down-stream face laid up in the form of a dry wall. The up-stream face is made water-tight with two layers of a 3-inch pine planking, laid with broken joints, spiked to inclined posts sunk flush with the stone work, which is also laid up with care as a dry wall, to receive the pressure of the water transmitted through the planks. On the crest is a timber structure about 6 feet high, made by extending the inclined posts and timber facing above the stonework.

The spillway consists of two sluices or wooden flumes, having a combined width of 20 feet and a depth of 30 inches. These are built into the end of the dam on the right bank.

The water is drawn out through an arched sluiceway under the center of the dam, the gates of which are only accessible in winter through the box-like structure, or manway, shown in the photographs, which protects the ladder resting on the face of the dam from the deep snow. The gates are situated near the water face of the dam, at the end of the arched sluiceway.

The Weaver Lake Dam.—A new dam has recently been constructed at Weaver lake, within a mile of Bowman dam, which is typical of the class of rock-fill wood-faced dams. The method of construction is well shown by the photograph, Fig. 345.

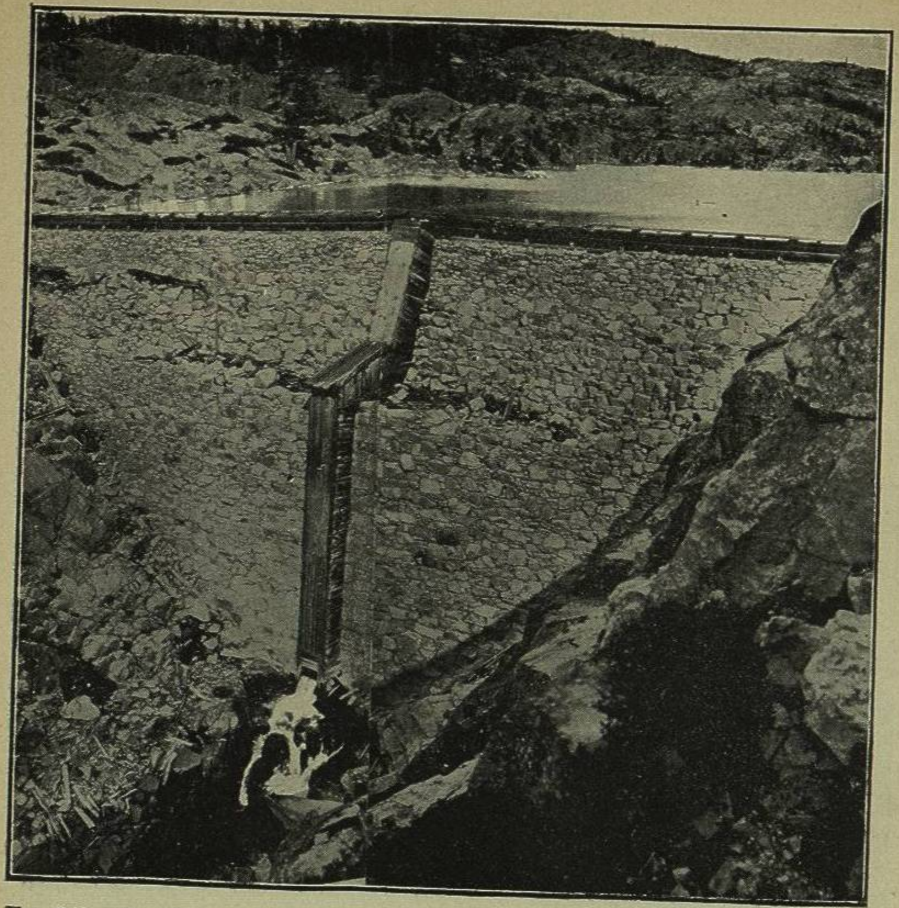

Fig. 343.—The Eureka Lake Rock-fill Dam, California, showing Covered Manway to reach Gates from Crest in Winter.

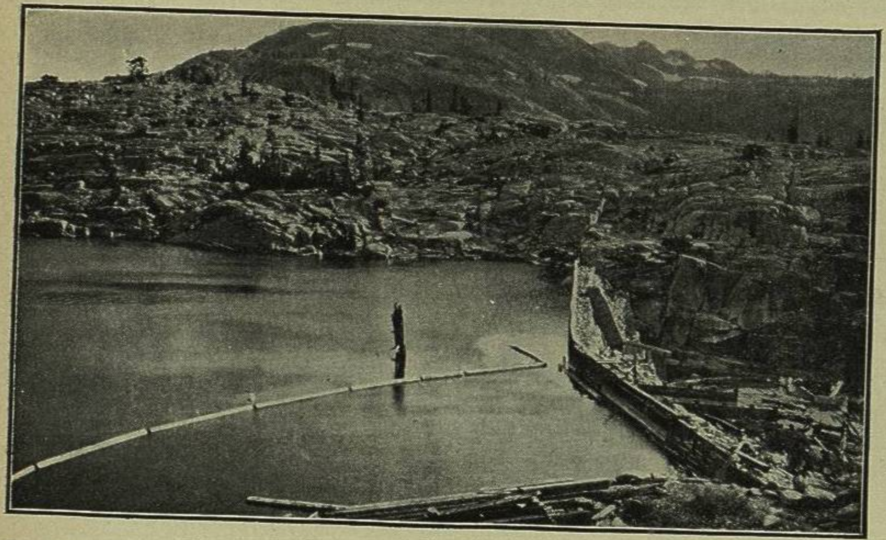

Fig. 344.—Showing the Crest of the Eureka Lake Rock-fill Dam, and a Portion of the Lake.

Inclined posts, placed at an angle of 45°, are first set up and held in position by struts that are subsequently removed. These posts are long enough to reach from bed-rock to the crest of the dam. The rock-fill is carefully laid by hand between the posts, forming a face flush with the exterior face of the posts. They are spaced 4 feet apart, center to center. At intervals of 6 feet, from bottom to top, an iron rod, ¾ of an inch in diameter, passes through each of the posts to an anchorage back in the rock-fill. This anchorage is made by winding the rods around the largest stones that are selected for that purpose. These posts are of varying size, but the smallest are 9 inches across at top.

The plank face is made with but one layer of well-seasoned 3″×8″ pine plank, laid horizontally, and driven tightly together. The bottom

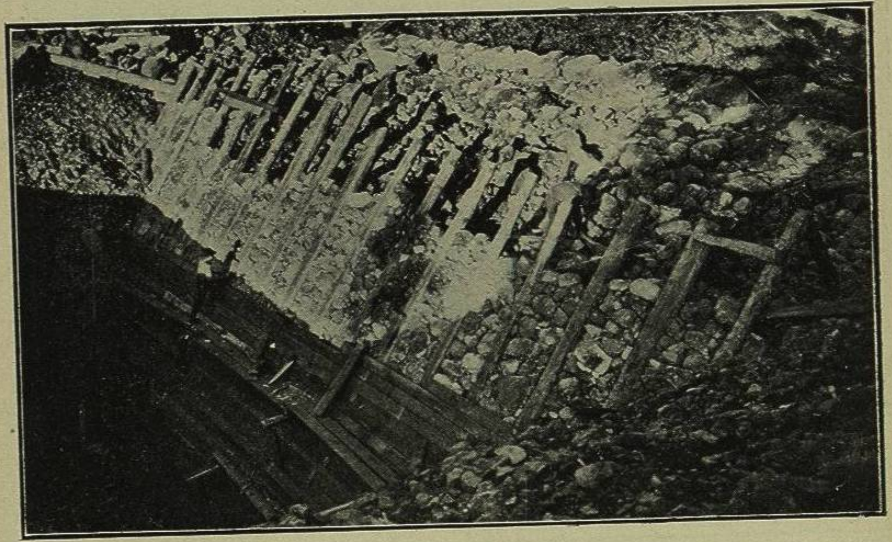

Fig. 345.—The Weaver Lake Dam, California, showing recent Construction.

edge of each plank is cut with a caulking bevel of one-half inch in the thickness of 3 inches, but no caulking is done by hand, reliance being placed upon the sediment and floating organic matter in the water to make the joints tight. The planks are held by two 6-inch spikes at each post.

Especial care has been taken to keep all earth out of the structure. The down-stream face is laid up carefully as a dry wall.

The dam is 22 feet high at present, but is finished off with a crest width of 18 feet, with the intention of making a subsequent addition to the top. The up-stream slope is 45°, but the down-stream slope is unusually steep, being 77°, or but 13° off the vertical. The reservoir formed by the dam is 81.7 acres in area, and it can be drawn off to a

maximum depth of 62.5 feet by a tunnel, at which level the lake is 26.7 acres in area. The capacity is therefore about 3400 acre-feet.

The geological formation at the dam-site is very unusual and interesting. There had been a stream whose bed was filled to a considerable depth with auriferous gravel. A subsequent lava flow crossed the stream forming a natural dam and creating a lake the outlet to which wore down a channel into the lava, but not cutting entirely through it to the gravel. It is in this basaltic formation that the dam is built. The reservoir outlet is through a tunnel, some 500 feet long, excavated chiefly through the gravel beneath the lava flow. This tunnel tapped the lake at a depth of 62.5 feet below the spillway level of the present dam. At its extreme end, before entering the lake, the tunnel reached the granite bed-rock.

The new dam was built to replace an all-timber dam of the same height, the main posts of which inclined at an angle of 29° from the horizontal, and were each supported by five struts, equally spaced against the posts, at angles of 44°, 47°, 52°, 57°, and 60°. The posts have bolted to them six horizontal stringers, each 12″×16″, spaced about 4 feet apart, over which a single layer of 3-inch plank is spiked in a vertical direction.

The English Dam.—On pp. 63–64 the high rock-fill structure known as the English Dam is described, with an account of the bursting and destruction of the main dam, the central one of three which formed the reservoir. Figs. 346, 347, and 348 illustrate the style of construction and present condition of the principal one of the two remaining dams.

These dams were first built for mining purposes in 1856, enlarged in 1876 to their present height, and destroyed by flood in 1883. The reservoir has since been out of service, as the missing dam has not since been rebuilt, although the other two are capable of being restored to usefulness at moderate expense. The middle dam, which failed, was a rock-fill with up-stream slope of 60° and down-stream slope of 40°. In making the addition in 1876 the new work consisted of a dry rock wall on the down-stream side, surfaced on the exterior with large blocks of split granite well laid in a wall of substantial construction. Unfortunately the funds gave out before completion of this work as planned, and the rock work was stopped 16 feet below the proposed crest. The top was then formed by the extension of the plank facing, the inclined posts of the face being supported by struts resting on top of the uncompleted dry-stone embankment. As there was a splice in these inclined posts at the point where the rock-fill stopped a line of weakness was thus made at the toe of the rafter dam. When the dam failed the water was within a foot or two of the top, and the real cause of the failure is now