Fig. 230.—Austin Dam, Texas. View taken during Flood, a few Minutes after the Break.

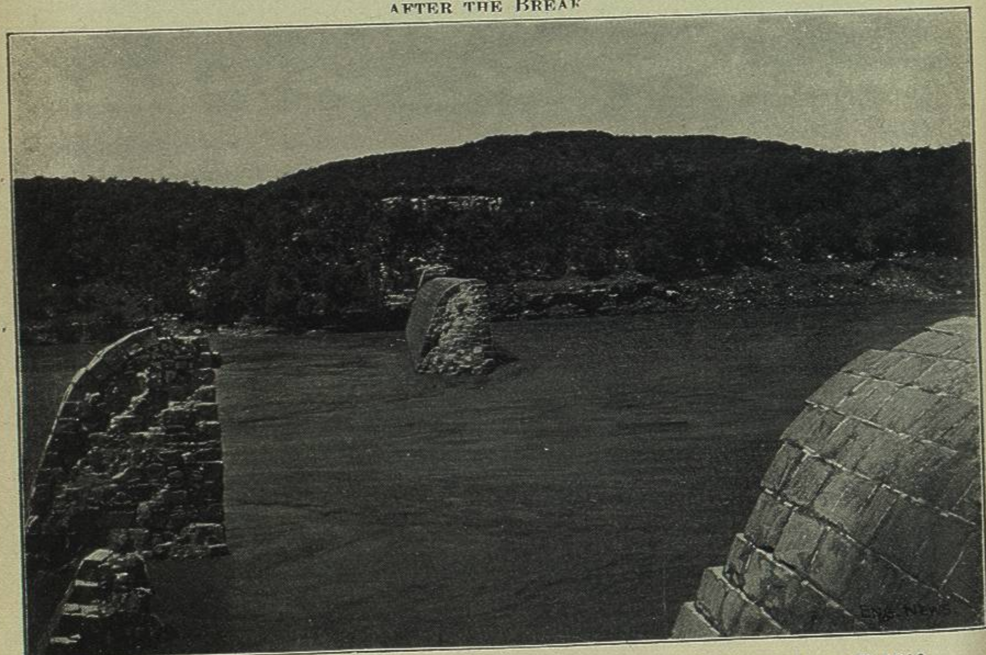

Fig. 231.—Austin Dam, Texas, after Subsidence of Flood of April 7, 1900. Showing section of masonry moved bodily down-stream.

posited. Measured along the crest, the break left about 500 feet of the dam at the west end and 83 feet at the east end still unaffected. About two-thirds of the wall of the power-house below the dam next the river was also destroyed by the flood. The entire property loss must have exceeded $500,000. At the time of the break the lake-level had reached a height of 11.07 feet above the crest. The flood was the result of extraordinary rains throughout a very extensive watershed area. In fifteen hours the rainfall at Austin and vicinity was 5 inches, falling on ground already well soaked by previous rains. The maximum flood prior to the catastrophe occurred June 7, 1899, when the water rose to 9.8 feet above the crest of the dam, without injury to the structure. The dam will probably be rebuilt upon safer plans, and precautions taken to anchor it into bed-rock a sufficient depth to prevent it from sliding on its foundations.

The appearance of the dam immediately before the break is shown in Fig. 229. Figs. 230 and 231 graphically present the break and the bodily movement of a section of the dam down-stream intact, better than any detailed description. The author is indebted to *Engineering News* for thsse three cuts.

Granite Springs Masonry Dam, Wyoming.—There are few dams in Western America more correctly representing the principles of modern science as applied to dam construction, and more generally satisfactory in economy of design and execution than the dam erected in 1903–04 by the City of Cheyenne, Wyoming, for the storage of a domestic water-supply at Granite Springs, on Middle Fork of Crow Creek, 12 miles from the city. The work was designed and built by A. J. Wiley, M. Am. Soc. C. E., to whom the author is indebted for the facts regarding the work, and the accompanying illustrations. (Figs. 232, 233, and 234.)

The dam has an extreme height from foundation to parapet of 96 feet, and is constructed in arch form, with a radius of 300 feet. It is but 10 feet long on the base, and 410 feet in length on top, where its thickness is 10 feet. The base is 56 feet in width, up and down stream. Although curved in plan it is of gravity section and the resultant lines of pressure and weight are within the limits of the middle third, assuming the masonry to have a specific gravity of 2.5, when the reservoir is filled. The dam is built throughout of uncoursed rubble masonry laid in Portland cement mortar, and its cubic contents are 14,422 cubic yards, including a parapet wall 2 feet thick, 3 feet high.

The rock was found to weigh 177 pounds per cubic foot and the mortar was estimated at 138 pounds per cubic foot. The proportions of each entering into the composition of the wall gave the estimated weight of the masonry at 165 pounds per cubic foot, corresponding to a specific gravity of 2.64.

The spillway is located apart from the dam in a saddle or gap, 200 feet away, the height of the saddle being 85 feet above the creek bed. Here a masonry spillway structure was erected with its crest 90 feet above the bed of the stream. The discharge from the spillway returns to the stream 500 feet below the dam. The spillway wall is 180 feet long over all, with an overflow crest 52 feet long, 3 feet lower than the top of the parapet. Its discharge capacity is approximately 900 second-feet or 12 times the maximum observed discharge of the stream. The spillway structure is also curved, on a radius of 200 feet.

The watershed area of the stream above the dam is 27.5 square miles, from 7000 to 10,000 feet in elevation, reaching to the Continental

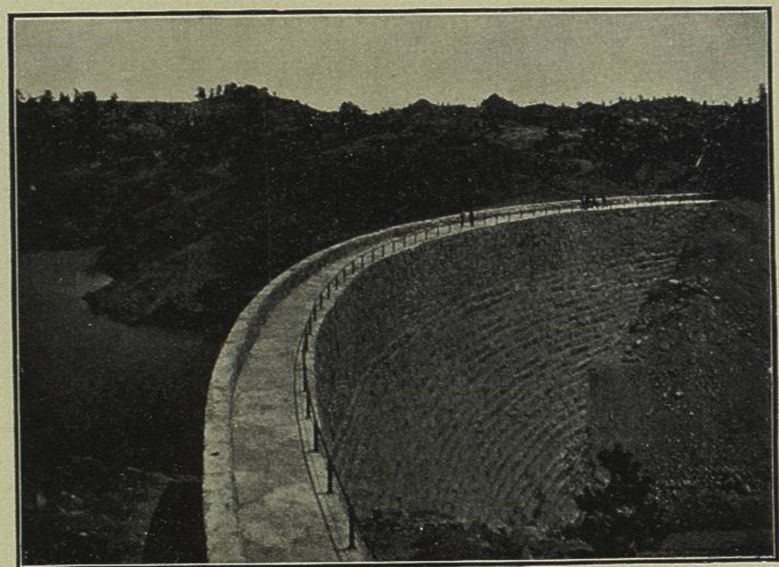

FIG. 232.—GRANITE SPRINGS DAM, CHEYENNE, WYOMING.

Divide. The measured run-off from this watershed, as determined by the U. S. Geological Survey for the year 1903, aggregated 7344 acre-feet, or 41% of the precipitation of 12.25 inches of that year in the City of Cheyenne. The mean of thirty-four years' record in that city is 13.23 inches. Two thirds of the total annual run-off occurred in the months of April and May.

The capacity of the reservoir is 5321 acre-feet, covering a surface of 185 acres, to a mean depth of 28.76 feet.

Construction.—The entire base of the dam, except that part of the east end which lies more than 50 feet above the creek-bed, is a dense hard variety of granite, classified as gabbro, and entirely free from seams or cracks, and almost devoid of defined cleavage planes. Above elevation

50 at the north end the gabbro is overlaid, by a different variety of granite, with regular cleavage planes, soft at the surface but increasing in hardness with depth. At the contact with the underlying gabbro there was no apparent seam, although a marked difference in hardness and texture distinguished the two varieties of rock. Excavation was made into the softer rock as deep as 30 feet in places before a satisfactory

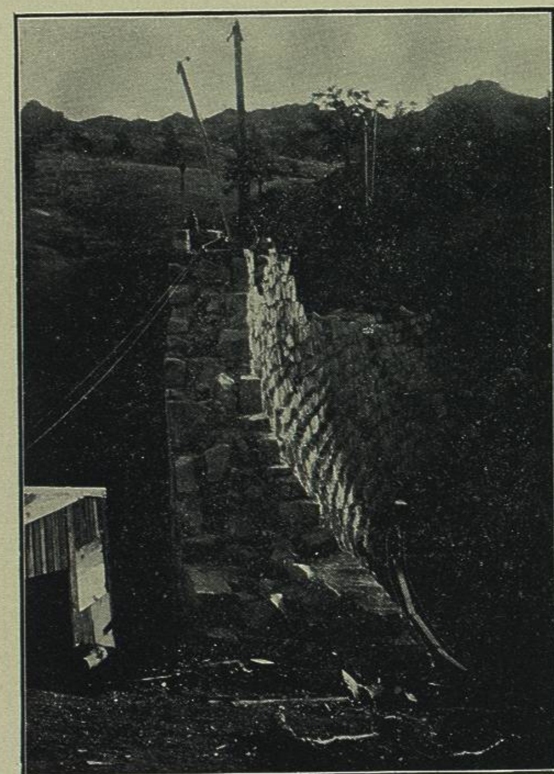

FIG. 233.—GRANITE SPRINGS DAM, WYOMING, SHOWING GENERAL CHARACTER OF RUBBLE MASONRY.

foundation was secured. The gabbro, where exposed, had been worn to a smooth glassy surface, which was roughened by shallow blasts previous to laying masonry upon it.

The rock used for the masonry was taken from a granite quarry 100 feet below the dam, and as taken out by blasting ranged in size from spawls to irregular shaped blocks of 4 cubic yards, averaging about 2 cubic yards. The largest rock placed in the wall contained 5 cubic yards and weighed nearly 12 tons, but rock over 3 cubic yards in size were unprofitable to use on account of extra care required in handling. All drilling was done by hand. The rock was taken from the quarry by a guyed derrick with 40-foot boom, and loaded upon platform cars, on a track laid with a grade on which loaded cars ran by gravity to the dam, and the empties were pushed back by hand.

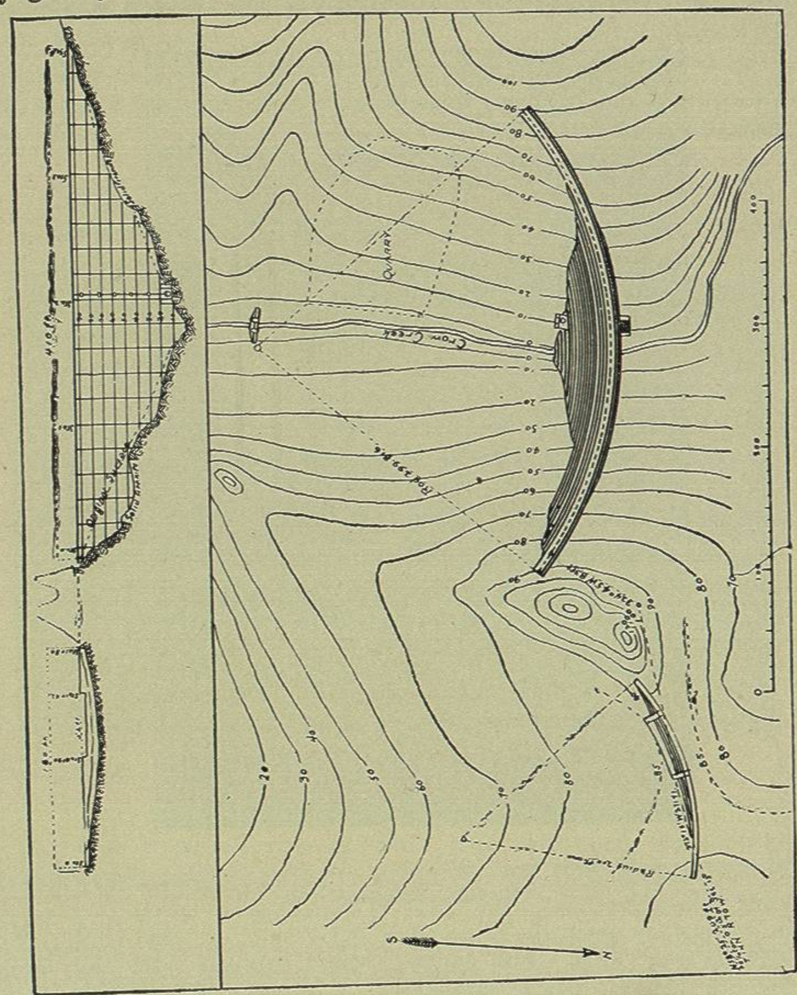

FIG. 234.—PLAN AND PROFILE OF GRANITE SPRINGS DAM, WYOMING.

A trestle carrying the track along the curved down-stream face of the dam was supported on one side by the steps in the masonry. Upon the top of the dam were located two derricks with 40-foot booms similar to the quarry derrick. Each derrick was operated by a 10-ton hoisting-engine, located in an engine-house near the south end of the dam. The derricks on top of the dam took the rock from the cars on the lower

side of the wall and set them in the position desired in the masonry. They also hoisted the mortar buckets from cars on the up-stream side of the dam and dumped them where the mortar was needed on top. The mortar was mixed with a Smith mechanical mixer in half yard batches, and distributed by long-handled shovels. To insure the filling of the voids the mortar was mixed very wet, even sloppy, requiring but little tamping.

The face stones and those laid in contact with the bed-rock were laid in mortar in the proportion of 1 of cement to 3 of sand. All the interior of the dam was laid in 1 to 4 mortar.

In setting the large rock a bed was prepared with spawls and mortar, and then a considerable excess of mortar was placed on the bed. The rock was then slowly lowered and settled in place by working it with bars. The excess mortar would ooze from under the rock which would then float upon an even layer of mortar, filling all the irregular spaces beneath. The large rocks were set as closely as possible to each other without being in contact, the intervening spaces being filled with mortar and small stones, which were crowded down into the wet mortar until submerged.

The proportions of rock and mortar were determined to be 64.8% and 35.2% of the entire mass respectively. The total quantity of cement used was 8843.75 barrels, an average of 0.613 barrels of cement to the cubic yard of masonry. The average rate of progress was 60 cubic yards of masonry per day of ten hours or 240 working days for the entire work.

Alpha cement of American manufacture was used exclusively on the work. It was shipped in sacks and test samples taken from every twentieth sack. The average time of initial set was 45 minutes, varying from 30 to 60 minutes. The final set invariably occurred within ten hours. The average fineness was 93% passing through a sieve of 10,000 meshes per square inch. Neat cement tests showed a tensile strength of 654, 792, and 806 pounds respectively in 7 days, 28 days, and 90 days. For 1 to 3 hand-mixed mortar the results were respectively 233, 312, and 345 pounds in the same period. The 1 to 4 mixture gave tests of 226, 306, and 361 pounds respectively.

The sand was obtained from the adjacent dry stream-beds, and hauled in wagons an average distance of half a mile. It was passed through screens with $\frac{3}{8}$-inch openings and used without washing. The voids in the sand were determined by depositing it slowly in a measured depth of water in a cylindrical vessel. After compacting the sand by light blows on the side of the vessel the depth of the sand and the depth of the water above the sand was measured. The difference between this latter and the original depth of the water was taken to represent the voids, and divided by the depth of the sand to determine the percentage of voids. The result of twenty-five tests gave an average of 23.4% of voids.

Cost.—The entire work was done by contract at a total cost to the city of $109,194.50, including water-rights, land, clearing, building, excavation, outlet-pipes, and valves, spillway, measuring weirs, engineering, superintendence and general expense. For the body of the dam the average cost to the city was $6.04 per cubic yard exclusive of engineering, etc., while the contractor's profit was 85 cents per cubic yard, or 14%. The cost to the contractor was as follows, per cubic yard of masonry in the dam:

				Per Cu. Yd. Masonry.
Rock	9,414 cubic yards delivered,	at $1.96	$18,452.60	$1.28
Mortar..........	5,008 " " "	" 1.93	9,676.08	0.67
Laying	14,422 " " "	" 1.11	16,017.90	1.11
Total		....	....	$3.06
8844 barrels cement, delivered,		at 3.58	31,665.38	2.13
Total		....	....	$5.19

The contractor's plant was estimated to have cost $10,700, and to have depreciated 50% in two years of use, which depreciation is included in the above estimate of cost.

The outlet of the reservoir is a 24-inch cast-iron pipe laid through the masonry on bed-rock at a height of 12 feet above the stream-bed. The pipe is $1\frac{1}{4}$ inch thick, with bolted flanged joints, and provided with a 24-inch high-pressure Rensselaer standard gate-valve at each end, operated by hand-wheels. The up-stream valve is protected by a timber screen, and operated by a hand-wheel with an indicating stand mounted on the crest of the dam, and connecting with the valve by a vertical non-rising stem supported at intervals of 14 feet by brass boxes set in stones projecting from the face of the dam. This valve is usually kept wide open, the regulation being done by the down-stream valve, which is more accessible.

The conditions under which this dam has been built appear to have been extremely favorable for economy and safety of construction, with first-class materials immediately available, excellent foundations, and an entire absence of complications of an unusual or embarrassing nature in the preparation of foundations or the conduct of the work.

The excellent character of the construction and the skill and care with which it was executed, are shown by the absence of leakage further than the usual unimportant sweating which is observed at times on the

down-stream face, when the water-level rises in the reservoir. This sweating stops when the water-level ceases to rise for about thirty days, and on a hot day is offset by evaporation, when it practically disappears.

Lake Cheesman Dam, Colorado.—A storage reservoir for the domestic water supply of the City of Denver, Colorado, was formed in the heart of the Rocky Mountains, 48 miles southwest from Denver, on the south fork of the Platte river, by the building of a masonry dam of notable height and dimensions, called Lake Cheesman, after the President of the Denver Union Water Co. The dam was begun immediately after the destruction by flood of the rock-filled dam begun on this site (page 62) in May, 1900, and completed in July, 1904.

The dam has an extreme height of 234 feet, and carries a maximum depth of water of 224 feet, which exceeds that of any dam ever constructed. Its thickness at the base is 176 feet, and for the upper 30 feet it is 18 feet thick. It is built on a semi-circular arch, with radius of 400 feet at the up-stream face. The length on the crest is 710 feet. The gorge is exceedingly narrow, being only 30 feet wide at the base of dam, 40 feet wide at 40 feet above base, and 130 feet wide at 100 feet height. The width of the canyon is equal to the thickness of the masonry at the height of 70 feet above the base. The volume of masonry in the dam is 103,000 cubic yards. The work was done under contract by the Geddes & Seerie Stone Co., of Denver, at a total cost of about $1,000,000. The excavation of foundations required the removal of about 26,000 cubic yards of rock, sand and gravel. The spillway is located 200 feet north of the dam, in a natural gap of the ridge of granite forming the abutment on that side, and is about 300 feet in length. Its capacity is greatly in excess of the maximum recorded discharge of the stream, 1945 second-feet. Its crest is 6856 feet above sea level, or about 1600 feet higher than the Denver City Post-office.

The quality of the masonry is of unusual excellence, and the dam is said to be entirely free from leakage or the appearance of seepage on the down-stream face.

The reservoir formed by the dam covers an area of 874 acres, and has a capacity of about 3,500,000,000 cubic feet (80,000 acre-feet) fed by the flow from a catchment basin of 1796 square miles, including almost the whole of South Park.

The dam was designed and built by Charles L. Harrison, M. Am. Soc. C. E., Chief Engineer, Mr. L. E. Cooley, M. Am. Soc. C. E., acting as consulting engineer.

The work is described in detail in a paper prepared by Mr. Harrison for the American Society of Civil Engineers, and published in December, 1904, accompanied by a mathematical analysis of stresses by Silas H. Woodard, Assoc. M. Am. Soc. C. E.

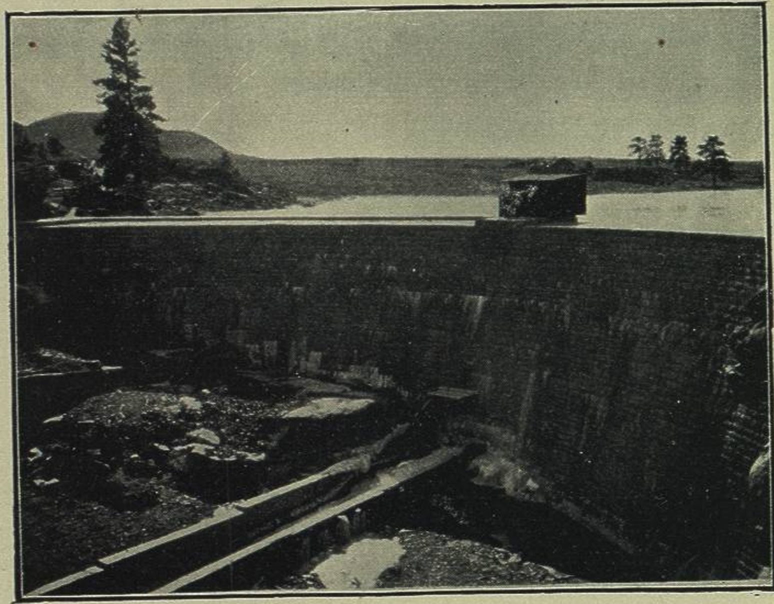

Fig. 235.—De Weese Dam, Colorado

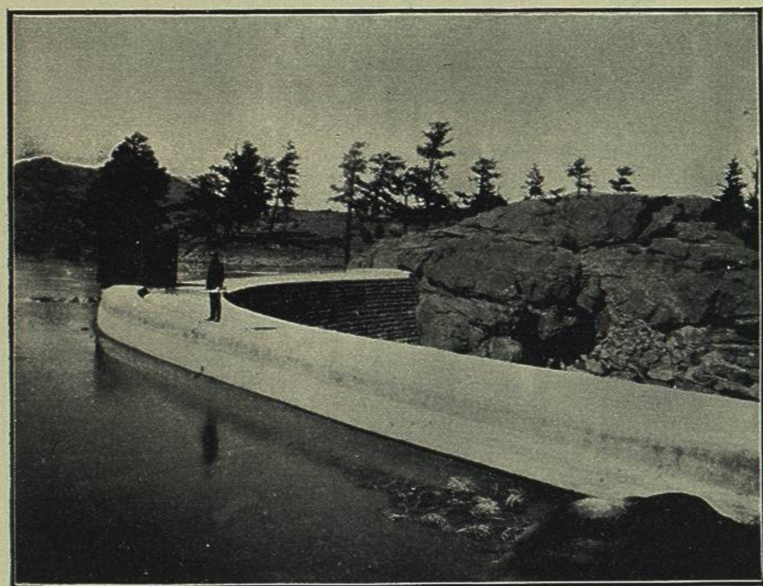

Fig. 236.—De Weese Dam, Wet Mountain Valley, Colorado.

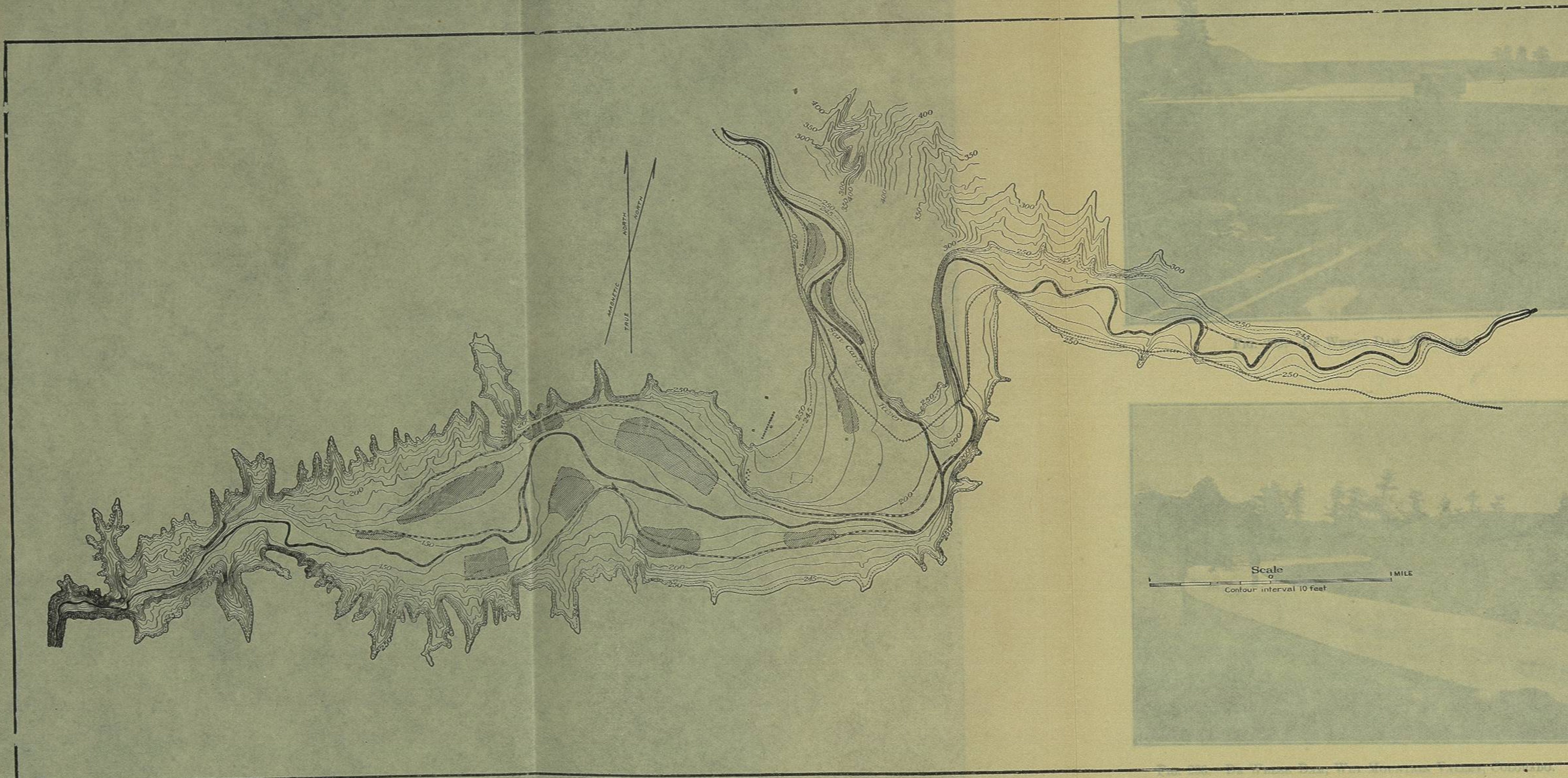

Fig. 146.—Contour Map of San Carlos Reservoir-site, Gila River, Arizona.

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