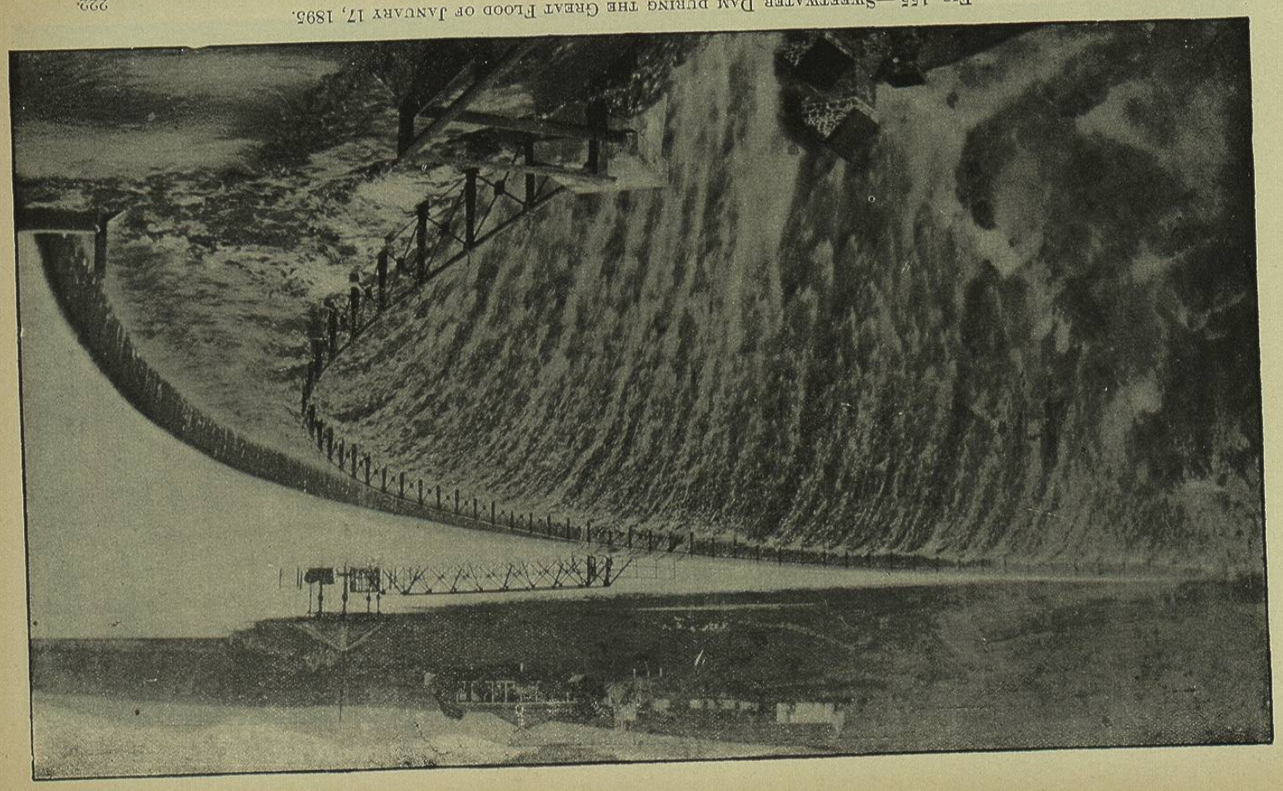

FIG. 155.—SWEETWATER DAM DURING THE GREAT FLOOD OF JANUARY 17, 1895.

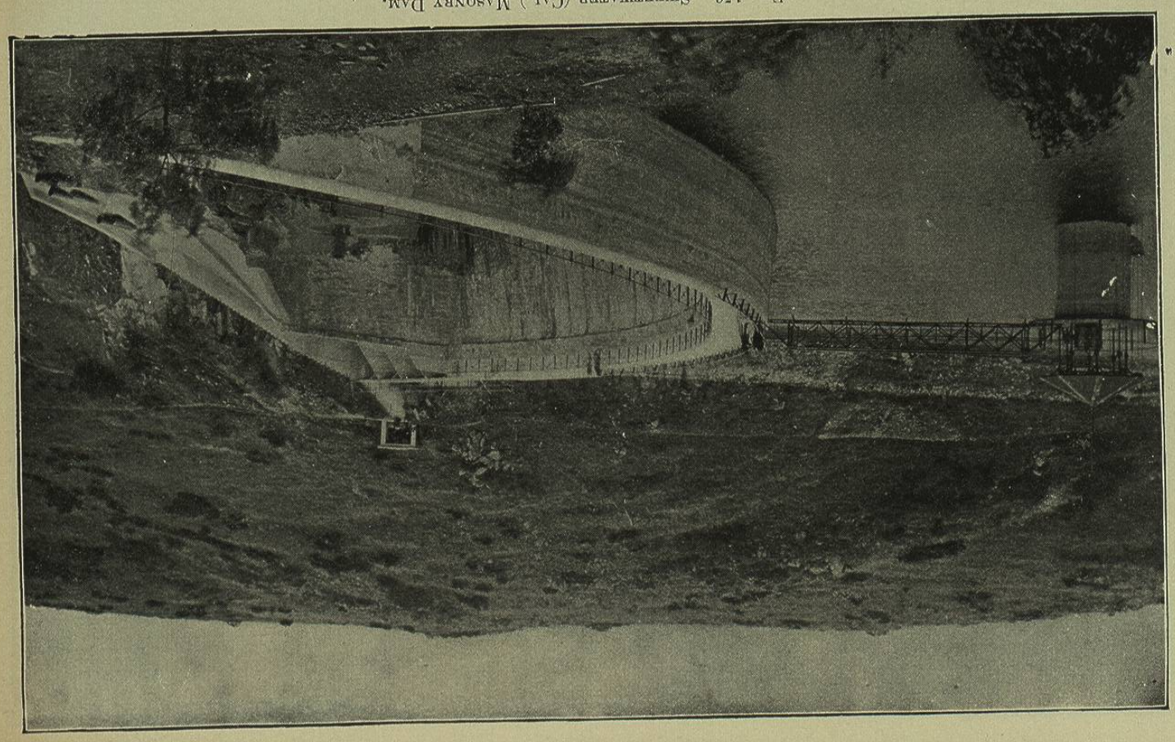

FIG. 156.—SWEETWATER (CAL.) MASONRY DAM.

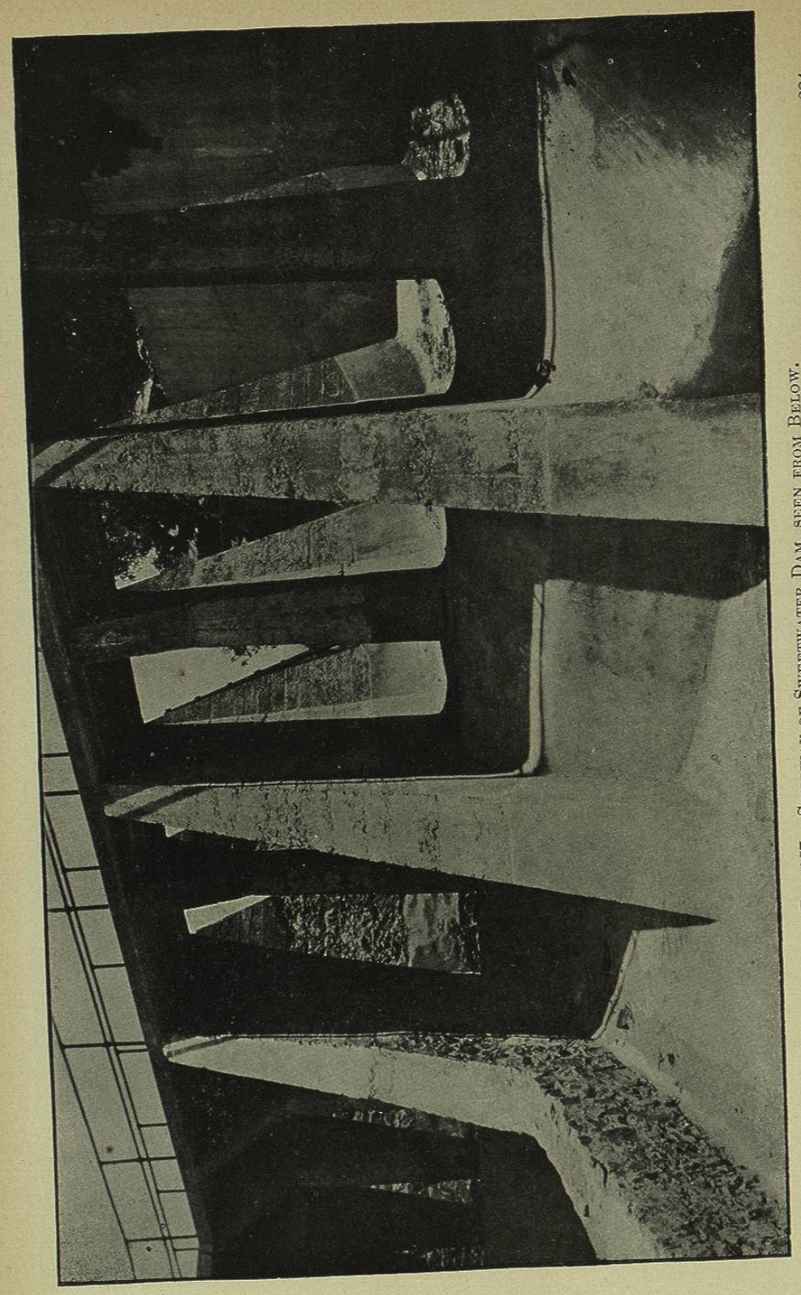

FIG. 157.—SPILLWAY OF SWEETWATER DAM, SEEN FROM BELOW.

cement, an average of 1.17 cubic yards per barrel. The total cost was $234,074.11, divided as follows:

Plant	$6,236.76
Materials	87,431.70
Labor	140,405.65
Total	$234,074.11

The reservoir capacity formed by the dam was 5,882,278,000 gallons or 18,053 acre-feet, of which 80% is within the upper 30 feet, and 40% in the last 10 feet. The area covered at high-water mark was 722 acres, of which 300 acres was cleared and grubbed at a cost of $10,808.46, or about $36 per acre. The average depth of the reservoir is 25 feet.

Enlargement.—On the 17th and 18th of January, 1895, the Sweetwater dam successfully withstood a test far more severe than is usually imposed on reservoir walls of such comparatively slender dimensions (thanks to the painstaking care exercised in its original construction), and beyond any previous calculation or expectation. On those dates the reservoir was filled to overflowing by a flood resulting from a rainfall of more than 6 inches in 24 hours, and for forty hours the dam was submerged to a maximum depth of 22 inches over the parapet wall, with the wasteway and blow-off gate wide open. This was 5.5 feet higher than the water had been expected to rise in extreme floods, as it had not been considered possible for the crest of the parapet to be reached.

A gap in the ridge to the south of the reservoir, the crest of which was about level with the parapet, carried off quite a large additional volume at the extreme of the flood. The maximum rate of discharge during the flood was carefully computed by Mr. H. N. Savage from weir measurement, and found to be 18,150 second-feet, a rate of discharge which was maintained for one hour.

This extraordinary freshet, which within a week produced a run-off of nearly three times the capacity of the reservoir, was gratifying in one respect, in that it demonstrated the ability of the dam to cope with such emergencies, as not a stone of the masonry was disturbed or moved from place, although so much damage was done to the pipes and surroundings of the dam as to necessitate a large expenditure in repairs. The water-supply was cut off from consumers for more than a month before a partial restoration could be made.

Advantage was taken of the opportunity afforded by the general repairs to make a material enlargement of the reservoir capacity by virtually raising the permanent high-water level to the point it had assumed during the flood, and at the same time preparing the dam for receiving a repetition of such an experience by enlarging the wasteway and fortifying the weak points developed by the flood.

The freshet caused a tremendous erosion of the bed-rock on either side of the dam, particularly in front of the spillway discharge, where the strata were inclined at about the proper angle to enable the water to strip off layer after layer with surprising rapidity. It was estimated that no less than 10,000 cubic yards of the solid rock on that side were torn away and washed down-stream, and some 2000 yards from the opposite wall of the canyon. The approach of a disused tunnel below the spillway, which was some 25 feet long, and about 30 feet of the tunnel itself, in solid rock, were cut off and the surrounding rock washed away. This tunnel had been opened some years before to draw down the reservoir, in compliance with the order of the United States Circuit Court, in the famous litigation over the condemnation of lands in the reservoir-basin, and terminated directly in front of the spillway channel. The bombard ment of the stones rolled down the canyon during the flood uopn the pipe-line resting on one side and covered with masonry, destroyed it for a considerable distance down-stream, as well as the railway track leading to the dam.

The repairs to the dam, and the general improvements designed, were completed in the summer following at a cost of $30,000, under the capable direction of H. N. Savage, chief engineer, the author acting as consulting engineer during its progress. The alterations made were the following:

1. The parapet of the dam was raised 2 feet and strengthened, so as to permit of permanently holding the water in the reservoir as high as its crest, leaving 200 feet in the center as a weir, 2 feet deep. This weir was arranged with cast-iron frames carrying flashboards, to be removed in extreme floods, as shown in Fig. 157.

2. The spillway was extended in length by adding four more bays, each 5 feet wide, and carrying all the bays up to the level of the new crest of the dam, giving it a maximum depth of 11.2 feet and a discharging capacity of 5500 second feet.

3. The unused tunnel, 8 by 12 feet in size, the bottom of which at the head is 50 feet below high-water mark, was adapted for use as an additional spillway discharge, by laying four pipes through it on a 4% grade, two of which are 36 inches and two 30 inches in diameter, all arranged with valve covers over elbows at their upper ends, where a shaft, reaching to the surface on the line of the dam, gives means of control (see Figs. 159, 160, and 161). Further control is had by gate-valves set in the pipes directly below the masonry bulkhead built across the tunnel at the shaft, all the pipes passing through this bulkhead. In the summer of 1899, when the reservoir was empty, the head of this tunnel was protected by a concrete portal with an inclined grillage of iron rails to keep out drift, as shown in Fig. 161.

4. The eroded rock slope below the wasteway after being made uniform was covered with a grillage of iron rails embedded in concrete, which has a

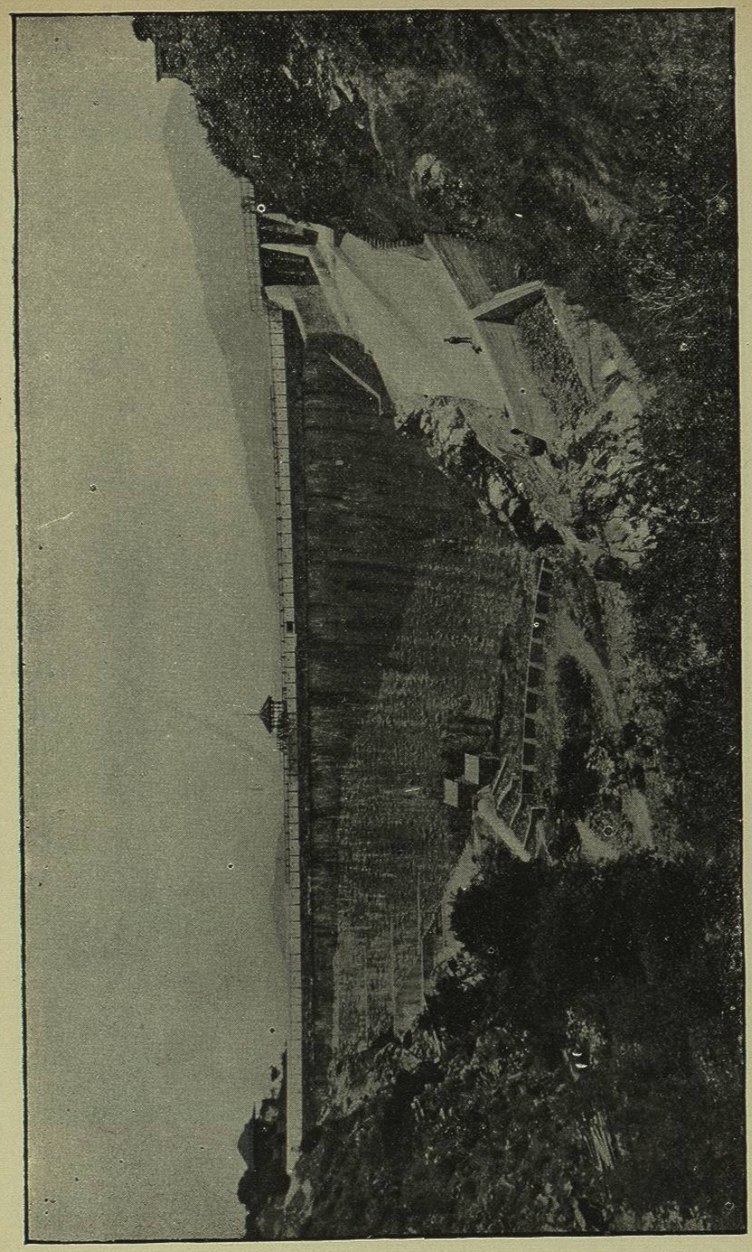

FIG. 158.—SWEETWATER DAM, SHOWING NEW APRON OF SPILLWAY AND PROTECTING SPUR-WALLS ON PIPE-LINE.

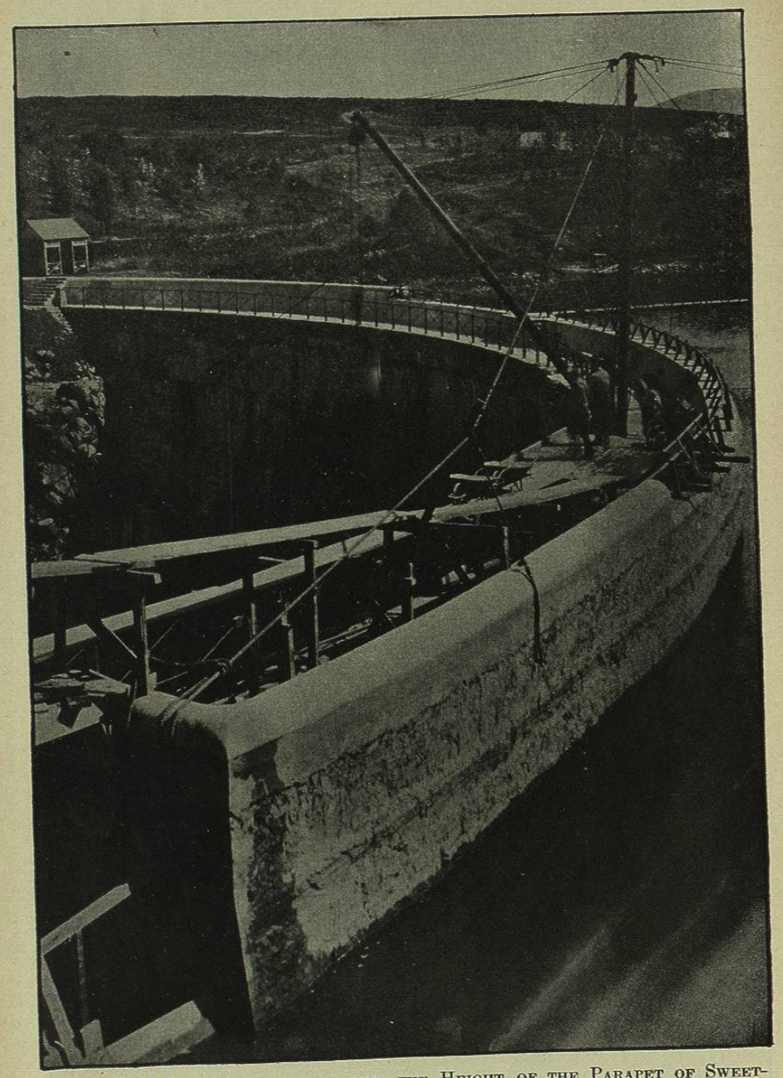

FIG. 159.—REPAIRING AND INCREASING THE HEIGHT OF THE PARAPET OF SWEETWATER DAM.

thickness of 3 feet, and is designed to prevent all future erosion of the bed-rock (Figs. 158 and 162).

5. A concrete wall 15 feet high, 18 inches thick, with counterforts of

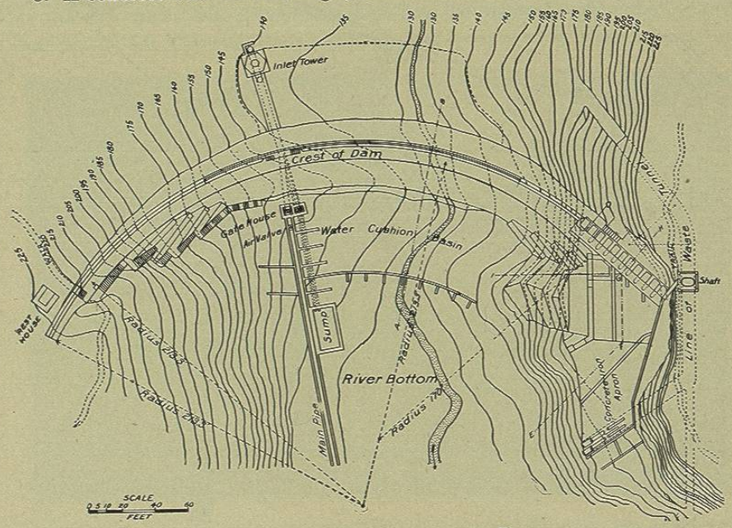

FIG. 160.—PLAN OF SWEETWATER DAM.

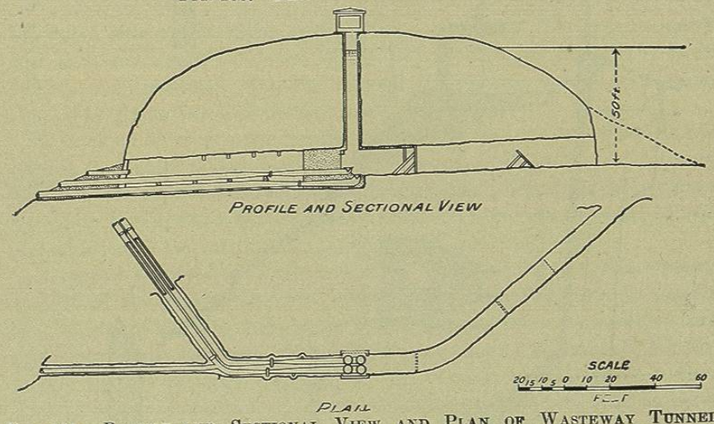

FIG. 161.—PROFILE AND SECTIONAL VIEW AND PLAN OF WASTEWAY TUNNEL, SWEETWATER DAM

15 feet base, was built from bed-rock 50 feet below the dam on a curve concentric with it, to form a water-cushion or pool in case of a future overflow. This is shown in plan in Fig. 160.

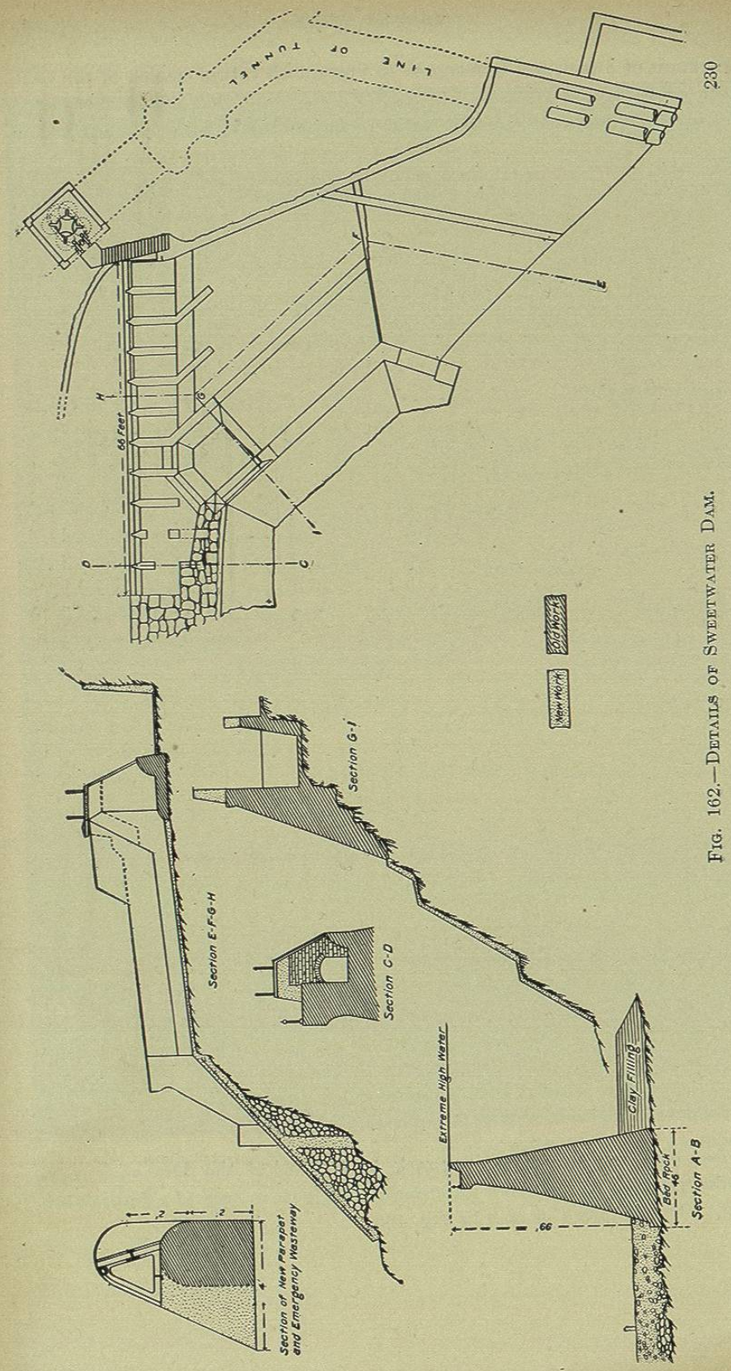

FIG. 162.—DETAILS OF SWEETWATER DAM.

6. The main supply-pipe was replaced through the canyon in a solid rock cut a portion of the way, and protected throughout the canyon by concrete collars and covering and spur walls, all with iron rods incorporated.

At the same time a new steel pipe-line, 24 inches in diameter, which was partly laid when the flood occurred, was completed to National City on

FIG. 163.—SWEETWATER DAM, SHOWING HEAD OF OUTLET TUNNEL AND SPILLWAY.

the north side of the valley, as a high-level conduit. This was connected with and took supply from one of the 30-inch-diameter pipes built in the tunnel, and connected with the original distribution system at National City, thus giving two independent conduits.

The effect of raising the parapet wall in the manner described has been to raise the height of the reservoir 5.5 feet and increase its capacity about 25%, or from 18,053 acre-feet to 22,566 acre-feet. The dam having shown its ability to withstand this increased pressure, it is now proposed to make this addition to the reservoir a permanent feature of the works.

Concrete was used in all the new work, as preferable to rubble masonry, because of the greater ease with which all the materials could be handled and because of the fact that the work could be performed by unskilled labor under intelligent foremen. The concrete was mixed with a rotary Ransome mixer, one of the best machines for the purpose yet devised. A steam hoisting-engine furnished all power required for rock-crushing, actuating the mixer, and hoisting the concrete to the top of the dam, where it was distributed by wheelbarrows. Old rails and scrap bar-iron of all sizes were embedded in the concrete wherever it would add desired reinforcement to the strength, as in the 6-inch floors of concrete forming the foot-bridge

over the wasteway, spanning the 5-foot spaces between piers; in the roof of the gate-house over the shaft in the tunnel from which the heavy gates are suspended, and in the floor of the house; in the curved wall forming the auxiliary water-cushion dam, which is 10 to 15 feet high, and but 18 inches thick, and in the inclined apron of the wasteway. This construction is quite satisfactory, and shows no cracks anywhere. The rates of expansion and contraction of iron and concrete under changes of temperature are practically identical, and no separation of the two elements can occur by such changes.

There are no visible evidences of cracks in any of the masonry of the dam, nor any indications of a tendency towards crushing at the toe of the dam. This may be due to the fact that the stone is extremely hard and strong, and the mortar of prime quality. It may be further owing to the fact that arch action has resisted pressure from the top down to some neutral point where gravity alone suffices. There have never been any spouting leaks to indicate the transmission of an upward pressure upon the masonry of the slightest moment. The leakage through the wall was never of considerable amount, and has steadily diminished, so that when full the wall is practically dry over most of its outer face.

This leakage was reduced in amount in 1890 by carefully repointing the inside face as far down as the water was lowered in the reservoir, about 60 feet below the top, and applying successive washes of potash-soap and alum-water alternating.

Protracted litigation followed the building of the Sweetwater dam, over the attempted condemnation of a tract of about 300 acres of land at the upper end of the reservoir-basin, submerged by the impounded water. The land was comparatively valueless for agricultural purposes, but a jury gave an exorbitant judgment of its value on testimony erroneously admitted as to its special adaptability for reservoir purposes. This litigation lasted several years and was finally compromised, but the effect of it was quite disastrous to the progress of the country depending upon it for irrigation. During the progress of this litigation a tunnel, heretofore referred to, was opened around the south end of the dam, at the level of 25 feet above the lowest outlet, by means of which the flooding of the land could be avoided. In obedience to an order of the United States Circuit Court the reservoir, which had been filled, was ordered emptied, and an enormous volume of water was thus wasted at a time when it was greatly needed for irrigation.

Including the period of retarded growth during the progress of litigation the dam has been in service for thirteen irrigation seasons, during which time the impounded water has created values aggregating several millions of dollars, reckoning all improvements made in the district directly dependent upon it for water-supply. The area irrigated from it is now 4580 acres, chiefly planted to citrus fruits, of which the greater part is

devoted to lemons. A population of 2500 to 3000 people is dependent upon the reservoir for domestic water. The distribution for irrigation as well as for domestic use is entirely by pressure-pipes, and the agricultural community is as well equipped for fire-pressure and general water-supply as the average American city. All water for irrigation, and practically all domestic water, is measured by standard water-meters. The pipe system has cost in the aggregate some $800,000.

Run-off of Sweetwater River.—The area of watershed above the Sweetwater dam is 186 square miles, ranging in elevation from 220 feet above sea-level, which is the elevation of the top of the dam, to about 5500 feet at the summit of the mountain-range in which it heads. The mean elevation of the basin is probably about 2200 feet. There is practically no diversion of the stream above the reservoir, and no utilization of its water other than that of the dam. Hence the catchment at the reservoir represents the entire run-off of the shed. A careful record of this run-off has been kept since the construction of the dam. Its extremely variable character is shown by the following table:

TABLE OF MEASURED RUN-OFF, SWEETWATER DRAINAGE-BASIN.
Area 186 square miles.

Season.	Rainfall at Sweetwater Dam. Inches.	Run-off as measured at the Dam. Acre-feet.	Average Yearly Run-off in Second-feet per Square Mile.	Average Annual Run-off. Second-feet.
1887–88	.....	7,048	0.0524	9.74
1888–89	13.53	25,253	0.1875	34.88
1889–90	16.52	20,532	0.1525	28.36
1890–91	12.65	21,565.5	0.1602	29.79
1891–92	9.88	6,198.3	0.0460	8.26
1892–93	11.62	16,260.7	0.1210	22.51
1893–94	6.20	1,338.4	0.0099	18.45
1894–95	16.19	73,412.1	0.5452	101.40
1895–96	7.29	1,320.9	0.0098	1.83
1896–97	10.97	6,891.6	0.0512	9.52
1897–98	7.05	4.3	0.00003	0.006
1898–99	5.05	245.5	0.0018	0.34
1899–1900	5.54	0.0	0.0000	0.00
1900–01	7.05	828	0.0061	1.14
1901–02	4.86	0	0.0	0.0
1902–03	5.72	0	0.0	0.0
1903–04	6.39	0	0.0	0.0
1904–05	15.55	13,760	0.1022	19.00
1905–06	15.52	35,000	0.2600	48.35
1906–70	12.88	30,000	0.2228	41.44
Totals	190.46	259,654		
Mean for 20 yrs.	9.52	12,982.7	0.0964	17.93

The average annual run-off for twenty years has been 69.8 acre-feet per square mile of watershed area, while the maximum has been 395 acre-feet per square mile.

Of the entire period of twenty years recorded the run-off has exceeded the capacity of the reservoir in but four seasons. The remaining sixteen seasons have been so far below tthe full-reservoir capacity in yield of stream-