supplies 240,000 acres. On the north side of the river the canal has not yet been constructed, but surveys have determined the feasibility of irrigating about 150,000 acres. Two or more reservoir basins of large capacity will be utilized along the canal line for storage of water during the non-irrigation season.

Figs. 47, 48, 49, 50, 51, and 52 illustrate the construction of these notable dams, and Fig. 53 shows the type of head-gates successfully

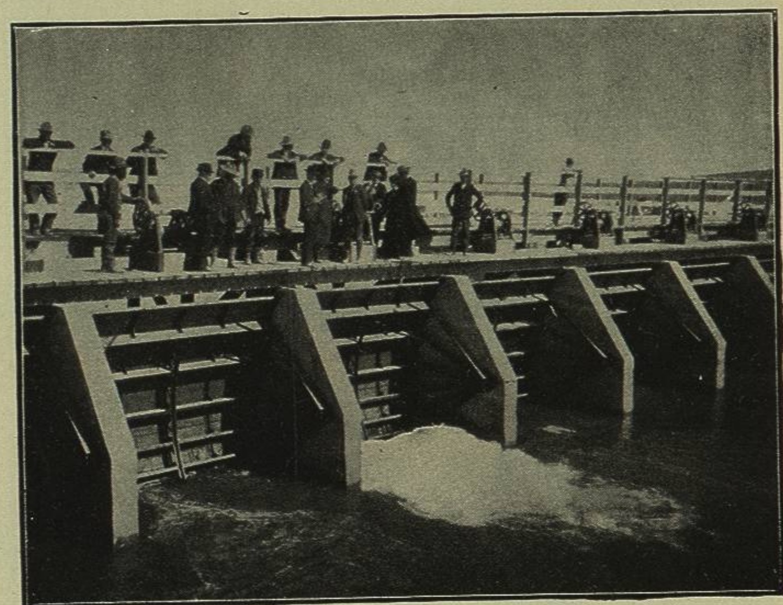

Fig. 53.—First Opening of Head-gates of Twin Falls Canal, March 1, 1905.

used in the canal. They are eight in number, each 12 feet wide and 11 feet high. For description of hydraulic filling of these dams see pages 125 and 126.

The Zuñi Dam, New Mexico.—Near the western boundary of New Mexico, on the Zuñi Indian Reservation, 45 miles south of Gallup, a coal-mining town on the line of the Santa Fé railway, the United States Indian Bureau has built a dam 70 feet in height for the storage of water to be used in the irrigation of the lands of the Indians. The work was done under the general direction of W. H. Code, Chief Engineer United States Indian Service, by J. B. Harper, C.E., Superintendent of Irrigation, the writer acting as consulting engineer. As originally planned the dam was designed to be an earth-fill throughout, the material to be placed by hydraulic sluicing. In view of the torrential character of the stream and the possible occurrence of freshets exceeding the capacity of the outlet tunnel during construction, it was finally decided to change the

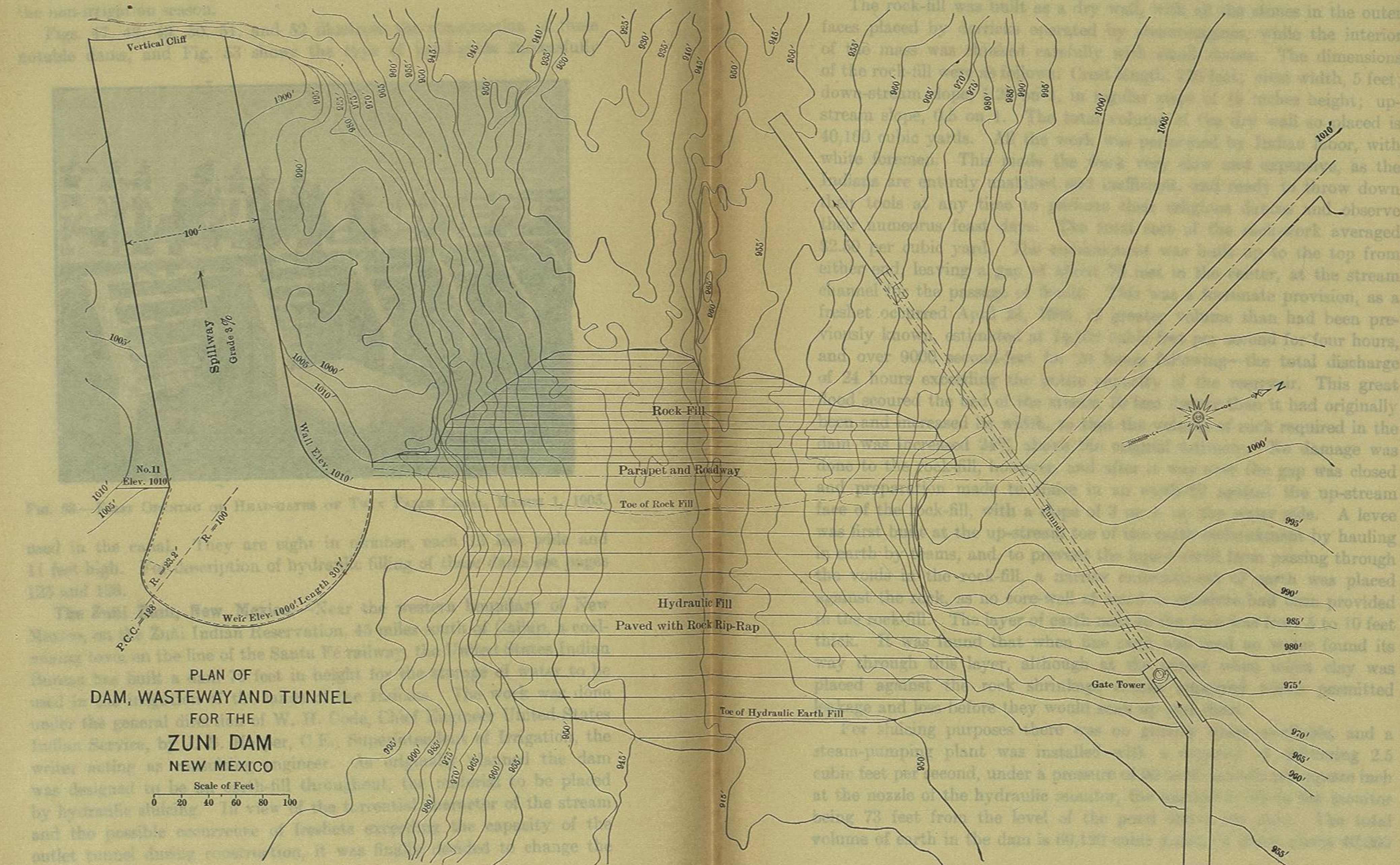

Fig. 54.

[*To face page* 74.]

plan to the combination type of rock-fill and hydraulic-fill. The fact that there was an abundance of basaltic rock on the site of the dam, overlaid by fine earth of a suitable character for hydraulic sluicing, rendered the selection of these materials in combination a natural one.

The rock-fill was built as a dry wall, with all the stones in the outer faces placed by derricks operated by steam-engines, while the interior of the mass was chinked carefully with small stones. The dimensions of the rock-fill were as follows: Crest length, 720 feet; crest width, 5 feet; down-stream slope, 1.25 on 1, in regular steps of 18 inches height; up-stream slope, 0.5 on 1. The total volume of the dry wall so placed is 40,160 cubic yards. All the work was performed by Indian labor, with white foremen. This made the work very slow and expensive, as the Indians are entirely unskilled and inefficient, and ready to throw down their tools at any time to perform their religious dances and observe their numeorus feast days. The total cost of the rock-work averaged $2.50 per cubic yard. The embankment was built up to the top from either end, leaving a gap of about 75 feet in the center, at the stream channel for the passage of floods. This was a fortunate provision, as a freshet occurred April 24, 1905, of greater volume than had been previously known, estimated at 14,000 cubic feet per second for four hours, and over 9000 second-feet for 20 hours following—the total discharge of 24 hours exceeding the entire capacity of the reservoir. This great flood scoured the bed of the stream 10 feet deeper than it had originally been and increased its width, so that the volume of rock required in the dam was increased 24% above the original estimate. No damage was done to the rock-fill, however, and after it was over the gap was closed and preparation made to sluice in an earth-fill against the up-stream face of the rock-fill, with a slope of 3 on 1, on the water side. A levee was first built at the up-stream toe of the earth embankment by hauling in earth by teams, and, to prevent the liquid earth from passing through the voids in the rock-fill, a narrow embankment of earth was placed against the rock, as no core-wall of wood or concrete had been provided in the rock-fill. The layer of earth next to the rock was from 5 to 10 feet thick. It was found that when fine sand was used no water found its way through this layer, although at the outset when moist clay was placed against the rock shrinkage cracks appeared which permitted leakage and loss before they would soak up and close.

For sluicing purposes there was no gravity water available, and a steam-pumping plant was installed with a capacity of delivering 2.5 cubic feet per second, under a pressure of 90 to 95 pounds per square inch at the nozzle of the hydraulic monitor, the maximum lift to the monitor being 73 feet from the level of the pond above the dam. The total volume of earth in the dam is 60,120 cubic yards, of which about 40,000

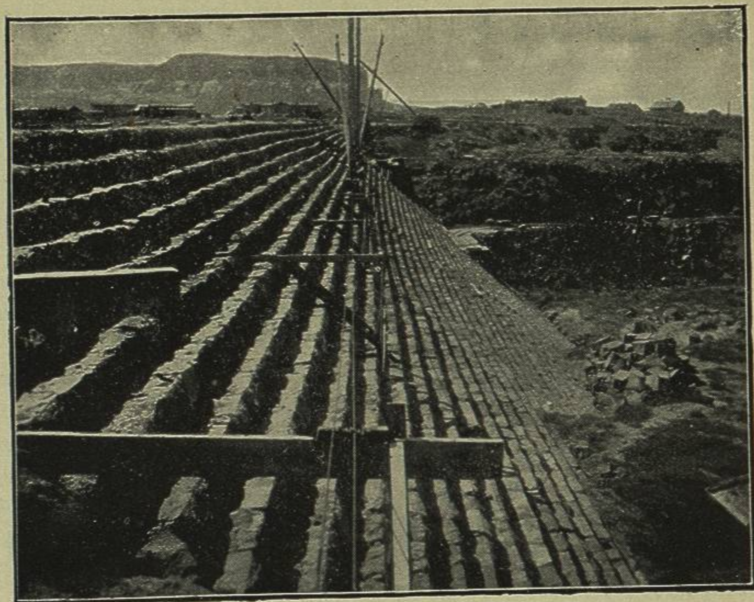

FIG. 55.—DOWN-STREAM FACE OF ZUÑI DAM. SHOWING CHARACTER OF DRY MASONRY IN THE ROCK-FILL.

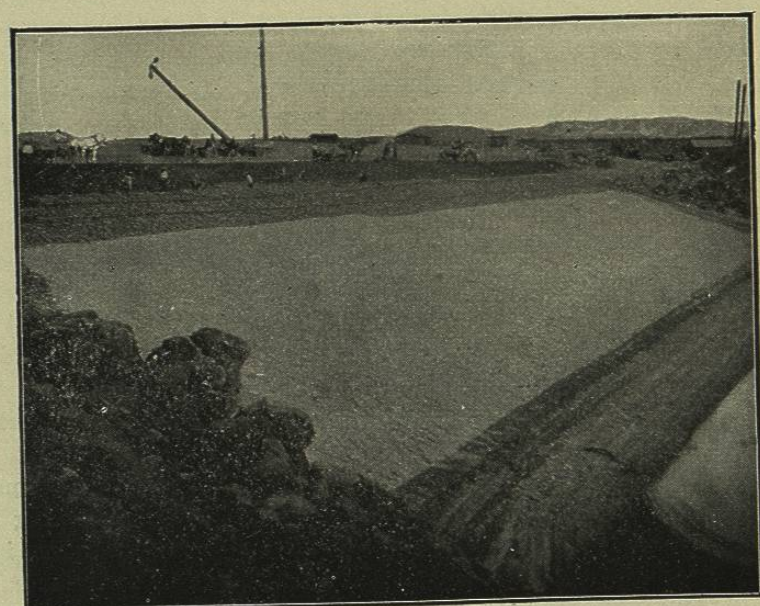

FIG. 56.—HYDRAULIC-FILL SIDE OF ZUÑI DAM. SHOWING GRAVEL COVER OF STONE RIPRAP.

yards were placed by the sluicing process. This work was accomplished in a total working time of 800 hours, distributed over 232 working days. The average ratio of solids delivered to water pumped was 15% and the total cost of the work, including labor, pumping, fuel, and operation

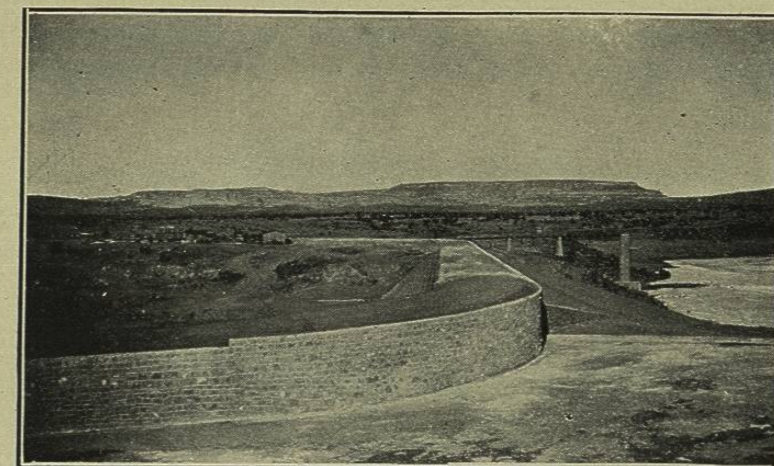

FIG. 57.—ZUÑI DAM, N. M., LOOKING NORTH, SHOWING TOWER AND BRIDGE IN DISTANCE, SPILLWAY GUARD-WALL IN FOREGROUND.

of sluicing was 12 cents per cubic yard, of which one-third was for pumping. The material was delivered along the dam by a "V" flume, measuring 20 inches on the sides, laid on a grade of 3%, and consisting of a

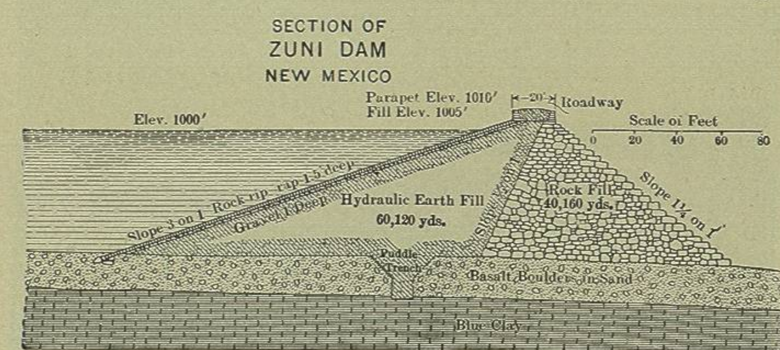

FIG. 58.

succession of sections, each 16 feet long, overlapping at the ends, and made to deliver material at any point by lifting out a section and inserting a lateral flume, directing the stream to either side as desired. Nearly one-half the entire amount of earth sluiced was deposited in the month of May, 1907, when the average delivery was 750 cubic yards per day of 8 hours. During this period the ratio of solids was nearly 28% of the water used.

Owing to the fact that all of the earth used was either very fine sand or clay, both equally impervious in an embankment placed and solidified

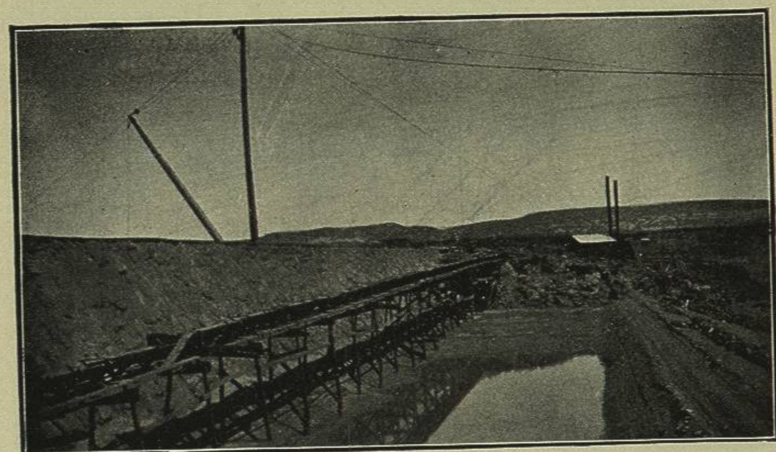

Fig. 59.—Zuñi Dam, N. M., Illustrating Method of Delivery of Sluiced Materials by "V" Flume, against Face of Rock-fill.

by water, no attempt was made to separate the particles, or segregate the clay from the sand, as is customary in building hydraulic-fill dams,

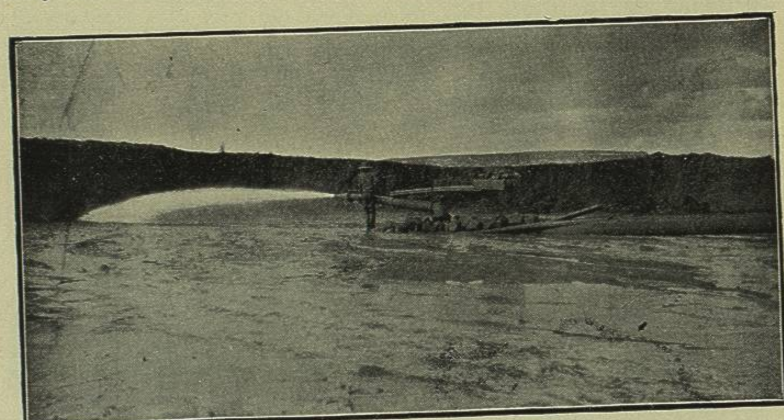

Fig. 60.—Zuñi Dam, New Mexico, Showing Hydraulic Monitor in Action.

where the available materials are an admixture of gravel, rock, clay, and sand. Hence it was immaterial at what point against the rock-fill the material was discharged, so long as no horizontal stratifications appeared.

Fuel for producing steam was obtained from a coal-mine opened for the purpose on the reservation, a few miles above the dam. The power thus provided averaged about 120 H.P.

The geological formation of this locality is quite peculiar. The Zuñi River has here broken through a sheet of lava which at some remote period flowed from a volcano to the north of the valley and spread in a wide, horizontal blanket over the country, covering the alluvial soil to a depth of about 30 feet. Underneath the lava cap (the top of which is at the crest of the dam) are successive layers of sand and clay, while at a depth of 20 feet below the river-bed dense blue clay is encountered, forming the impervious sub-floor of the reservoir. The erosion of the sand strata in the canyon and the breaking down of the lava cap by undermining had left the stream-bed filled with masses of hard basalt. This gave the impression of a canyon cut in rock from top to bottom, and was good ground for the presumption that a masonry dam would be best adapted to the site. Excavation, however, proved the unsuitability of the foundations for such a structure, and led to the final adoption of a type of dam which is flexible, and at the same time impervious to water. A spillway has been excavated in the solid rock on the south side of the dam, 100 feet wide, 10 feet deep.

The reservoir has a capacity of 16,000 acre-feet (700,000,000 cubic feet) covering an area of 623 acres, and receiving the run-off from 650 square miles of watershed, whose maximum elevation at the Continental Divide is 9200 feet.

The measured run-off of this shed at the dam was 15,115 acre-feet in 1904, and 106,630 acre-feet in 1905.

Fig. 58 is a section of the dam, and Figs. 55, 56, 57, 59, 60, and 61 are photographs taken during construction.

The Minidoka Rock-fill Dam, Idaho.—One of the projects of the United States Reclamation Service for the ultimate irrigation of about 150,000 acres from Snake River, involved the construction of a diverting dam, located about 8 miles southwest of Minidoka, Idaho, at a cost of $425,923.

The dam is a rock-fill structure, with earth facing and concrete core-wall. The length of the dam is 625 feet, its maximum height 80 feet above bed-rock, and about 60 feet above the original bed of the stream. The width on the crest is 25 feet, its base averages about 300 feet, and its total volume 191,000 cubic yards. The concrete core-wall is built upon a solid rock foundation throughout the entire length of the dam, and at each end reaches to within about 11 feet of the top of the earth and rock part of the dam, while through the central portion its top is 44 feet below the crest of the dam. The down-stream portion of the dam was built of large rocks, of 1000 pounds minimum weight, dropped in place from a cableway stretched across the stream.

In construction, a diversion channel was first excavated, and then two separate lines of fill were extended across the river about 150 feet apart, the upper one of earth, the lower of rock. By this means the natural channel was gradually contracted and the water forced through the by-pass channel. When the rock-fill was thus carried across, the leakage through it was estimated at 1000 second-feet, but this was gradually cut off by dumping gravel and earth on the up-stream slope

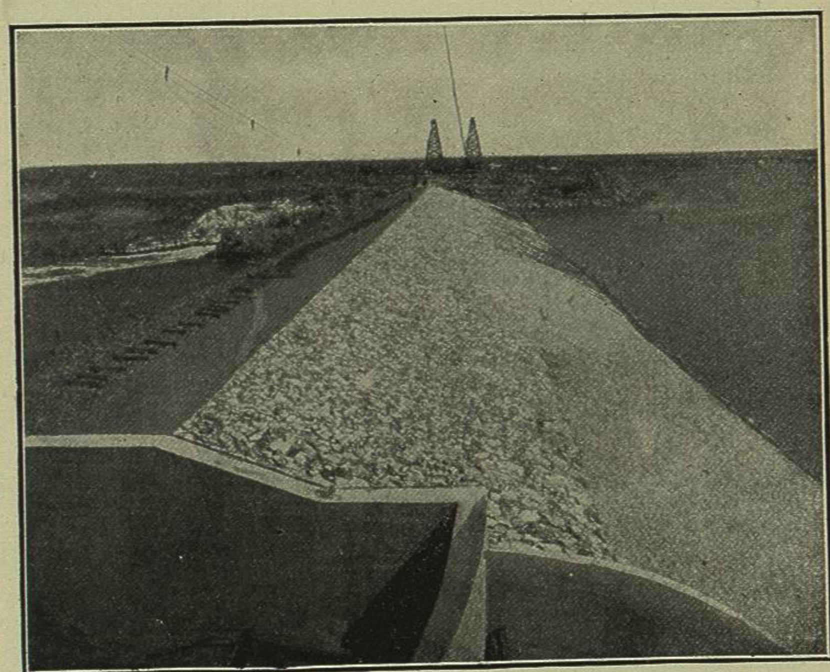

FIG. 61.—MINIDOKA DAM, IDAHO, LOOKING NORTH.

from cars running on a track laid across the rock-fill. The earth-fill was then made by a second cableway and by cars, and the core-wall was built in the trough between them. Upon its completion the fill was carried up on both sides and over the top of the core-wall until the required dimensions of the dam were made. The earth and gravel used in the fill were loaded into cars by means of a steam-shovel. The closure and diversion by the rock-fill were made in April, 1906, and the entire flow discharged through regulating gates, and the dam was completed Sept. 14, 1906, under the supervision of F. C. Horn, construction engineer. The dam was planned by John H. Quinton, M. Am. Soc. C.E.

The dam is provided with a concrete spillway of irregular alignment, built on solid lava rock, and having a maximum height of 14 feet and a crest length of 26,000 feet, containing 4000 cubic yards of concrete. The crest of the spillway is 10 feet below the top of the dam, 7 feet above the sill of gates of the north side canal, 6 feet above the grade of the south side canal, and 48 feet above the bottom of the diversion sluice-way, in which a concrete dam is built with five Coffin sluice-gates, each 8 feet wide, 12 feet high. This structure is provided with penstock openings for the future development of power to be utilized for pumping water to higher lands above the south side gravity canals. It is estimated that 10,000 to 30,000 H.P. may be so developed.

About 70,000 acres of land are irrigable by the gravity canals, mostly on the north side, and 80,000 acres may be watered by pumping to higher levels on the south side.

The entire project is estimated to cost $2,600,000.

The Alfred Dam, Maine.—The highest dam in the State of Maine was completed in December, 1905, at Alfred, Maine, to provide storage

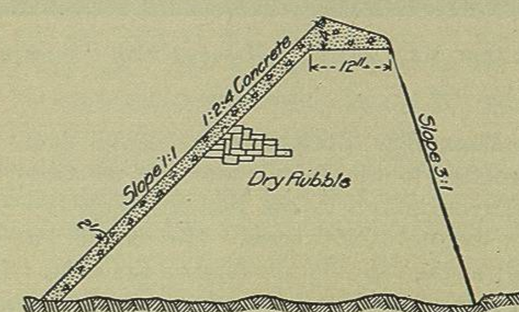

FIG. 62.—SECTION OF ALFRED DAM.

to equalize the flow of the Mousam River for power purposes for the Alfred Light & Power Co. The dam is of rather novel design, as it consists of dry rubble, built with split stone, the three lower courses laid in Portland cement and the up-stream face and crest covered with concrete 2 feet thick. See section Fig. 62.

The dam is 39 feet high, 995 feet in length, with a spillway section in center 580 feet long. It contains 12,150 cubic yards of dry rubble, and 2790 cubic yards of concrete. The stream was handled during construction by diversion through the penstocks of the power plant, by a coffer-dam thrown across the entire river.

The rock being dimension stone, laid by hand, the dam is not strictly to be classed as a rock-fill, but is interesting as a cheap type of permanent construction of a better grade than the ordinary rock-fill.