coarser, there was no gradation from fine to coarse, and consequently a comparative lack of drainage. The break occurred on the line of contact between the sluiced clay and the material deposited by cars. This method of building the levee was employed only east of the center of the dam.

The conditions of solidity and maturity in the clay core shown in this case is a most reassuring endorsement of the superiority of the hydraulic sluicing method of dam construction.

A similar demonstration was made in very much the same manner of the stable and satisfactory condition of the clay core of the Necaxa dam a few months ago. The pond on top of the dam was accidentally emptied by a cutting down of the overflow channel, causing a loss of a quantity of soft, immature material, but showing a bank of firm clay formed a few feet beneath the surface. It is somewhat difficult to conceive of percolation through such a mass of clay as is usually segregated and assembled in the center of hydraulic-fill dams after it has matured. It must be even superior in impermeability to such a puddle core as was built in the north and south dikes of the Wachusett dam, which consisted of 6-inch layers of fine loam soil, well sprinkled and rolled. Recent experiments to determine the permeability of this type of earth or loam core in an earth dam have been made by means of a series of pipes driven into the embankments of the Wachusett dikes. The results as reported by the *Engineering Record*, July 18, 1908, indicate that while the plane of saturation on the reservoir side of the loam core was level with the water in the reservoir, it dropped immediately below this core to a level slightly above the base of the dam. Weekly measurements proved that the amount of water draining out of the dike was not in excess of what might be expected, as the natural drainage from precipitation on the area of the dike itself. No masonry or concrete core-wall ever built in an earth dam can show better results than these, and few can compare with them in the absence of percolation from the reservoir. The dike type of dam is undoubtedly a reliable type, when properly made with suitable materials, especially where the core can be sluiced out of the available material and deposited under water.

A High Japanese Dam.—Fig. 378 is a contour plan of a dam of unusual height projected as a hydraulic-fill structure, to impound water for power purposes on the Oigawa river, in Japan. The dam has been planned by J. M. Howells, chief engineer of the Anglo-Japanese Hydro-Electric Company, and is to be 300 feet in height above the river-bed at its up-stream toe, or 325 feet in maximum height. It will occupy a narrow gorge, whose width at the low-water line of the river is 200 feet, and at the crest of the dam but 700 feet.

The volume of water to be cared for during construction in by-pass tunnels may reach 80,000 to 100,000 cubic feet per second in time of extreme flood. Three tunnels, each 30′×24′, are planned for this purpose.

A section of the dam as proposed by the board of consulting engineers, of which the author was a member, who were called upon to review the general plans of the project for power development, is shown in Fig. 379. From this section it will be seen that two concrete cut-off walls are proposed to be carried down to bed-rock through the gravel deposit of the channel, both above the center line. The upper wall is to be at the down-stream toe of the temporary coffer-dam of loose rock, faced with plank, which will form the up-stream toe of the large dam.

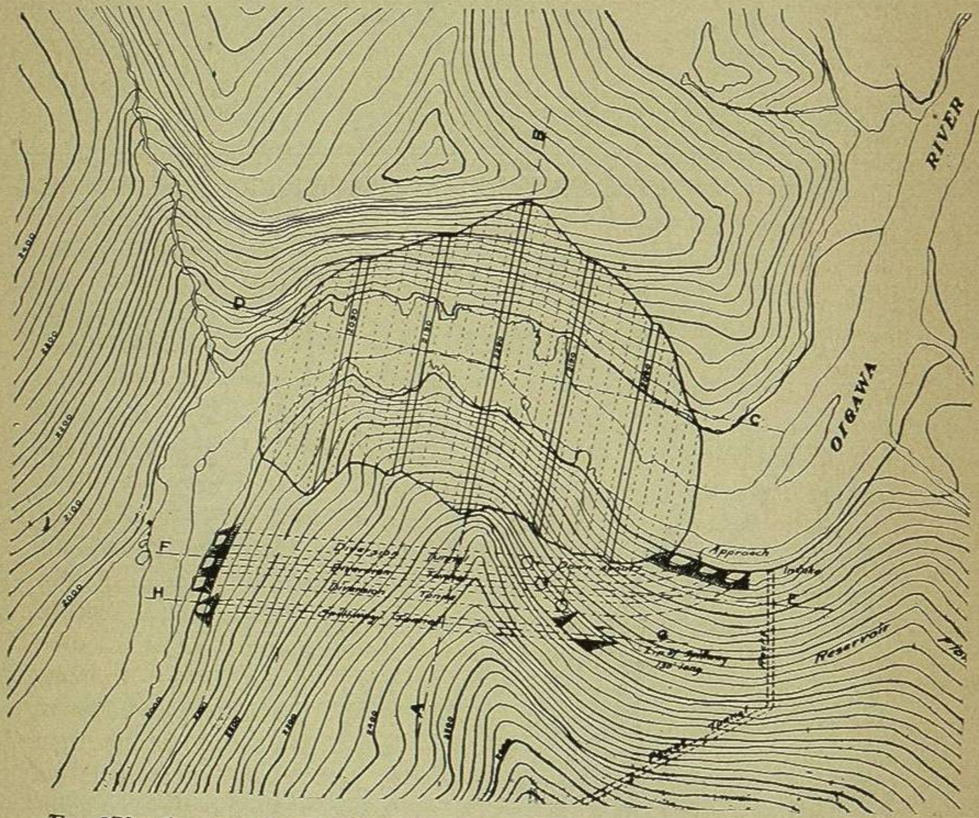

FIG. 378.—CONTOUR PLAN OF HYDRAULIC-FILL DAM PROJECTED FOR POWER STORAGE AT IKAWA ON THE OIGAWA RIVER, JAPAN.

On top of the concrete wall a diaphragm of sheet steel plates is to be built to the height of 100 feet, reaching to the face of the dam on the

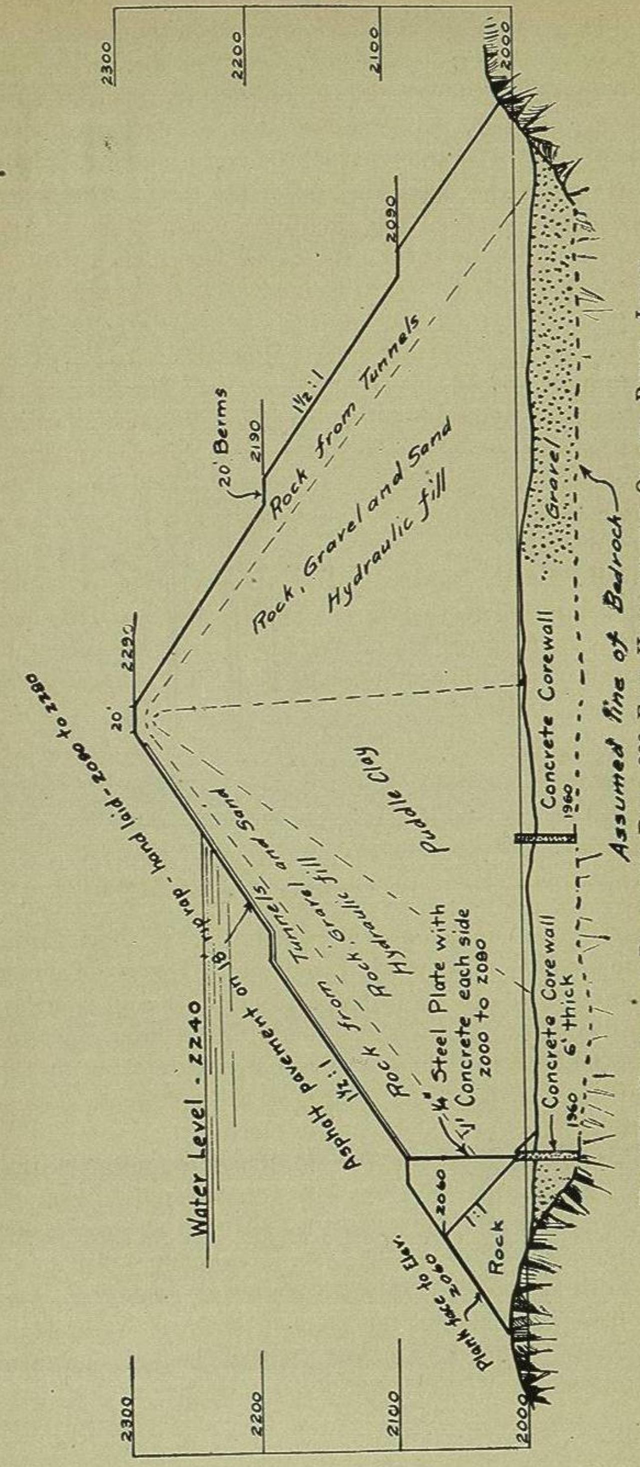

FIG. 379.—SECTION OF PROJECTED DAM, 320 FEET HIGH, ON THE OIGAWA RIVER, JAPAN.

reservoir side. This diaphragm is to be continued in the form of a watertight asphalt pavement up the slope to the crest of the dam. The core of the dam will consist of clay, while the outer thirds will be formed of rock, slaty gravel, and sand, to be sluiced from an extensive deposit of loose material of most favorable character, lying in a high plateau or valley, some 200 feet higher than the top of the dam. The contracted situation of the dam compelled the adoption of side slopes of 1.5 on 1 on each side. The crest, however, will be 50 feet higher than the lip of the spillways. Fig. 380 is a longitudinal section through the dam-site.

The dam will contain 2,450,000 cubic yards, all of which, except the spoil from the tunnels, will be sluiced into position. The site is a remarkably favorable one for hydraulic-fill construction, because of the heavy gradients which can be given to the sluices, the superior quality of all the materials, and the abundance of water. The annual rainfall recorded at the dam-site for eight years averages 11.7 feet, with a maximum of nearly 16 feet.

Dixville, N. H., Earth Dam.—A dam of novel type is under construction to be completed in the current year of 1908, at Dixville, New Hampshire. It is built of earth with reinforced concrete core-wall resting on steel sheet piling. The dimensions given in *Engineering Record*, April 25, 1908, are as follows:

Maximum height	76 feet
Top width	25 "
Length on crest	500 "
Up-stream slope	2 on 1
Down-stream slope	1½ on 1

The structure when completed will contain 80,000 cubic yards, and about 3500 cubic yards of reinforced concrete. The sheet piling was driven to depths of 10 to 32 feet in the bottom of a 6-foot trench. The tops of the piles were incorporated into the bottom of the concrete core-wall, which was made 3 feet thick at base, 10 inches thick at top. It is located 3 feet down stream from the top of the up-stream slope. The concrete cost about $4.50 per cubic yard in place.

On the up-stream side of the core-wall is a puddled earth core, 20 feet thick at the base battering to 8 feet at the top, composed of a mixture of clay and gravel, puddled and rolled. All earth on the upper slope was put in in layers 6 inches thick, thoroughly rolled and compacted. This work showed a cost of 25 cents per cubic yard by force account. The dam was built on the plans of Arthur W. Dudley, C.E., of Manchester, N. H., approved by Prof. Robert Fletcher, of Dartmouth College, consulting engineer.

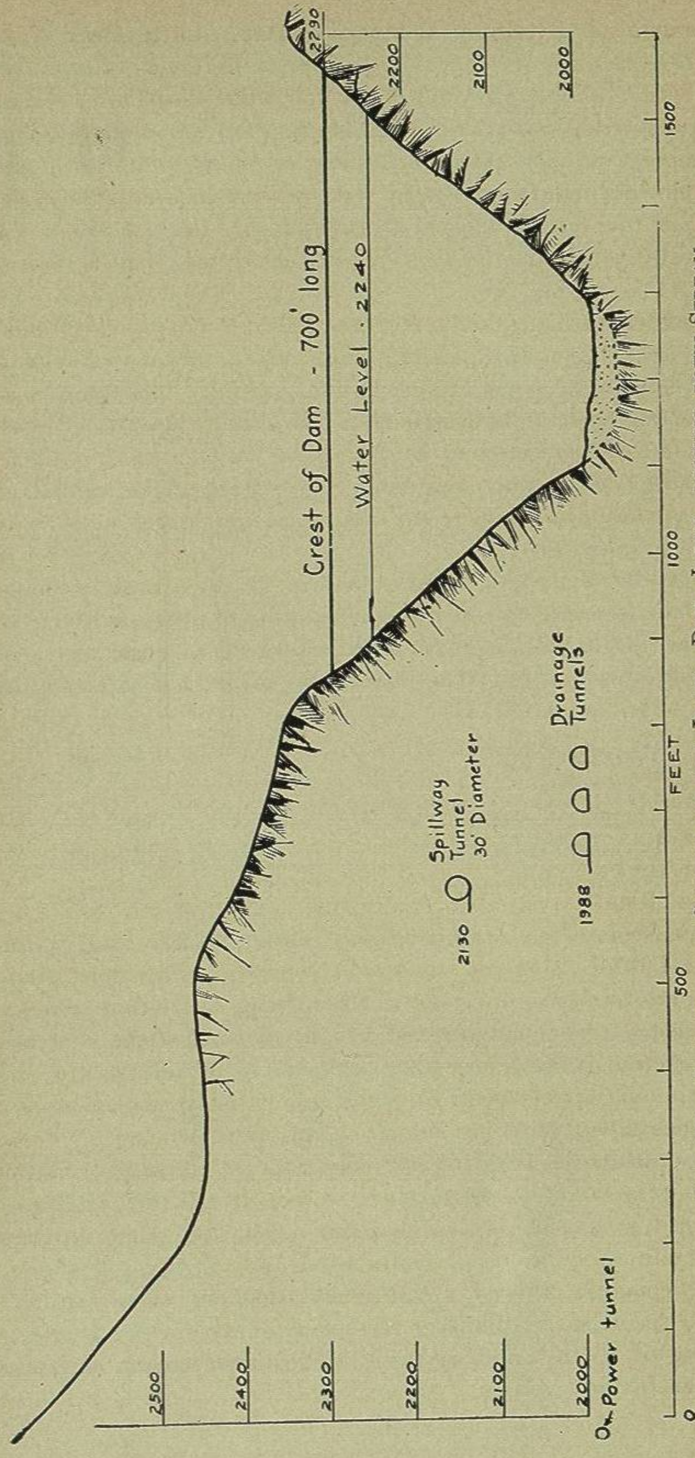

FIG. 380.—LONGITUDINAL SECTION OF THE IKAWA DAM, JAPAN, LOOKING DOWN STREAM

Arrowhead Reservoir Company's Dam, Little Bear Valley, California.—On page 180 a brief description is given of the combination dam with concrete core-wall and earth which has long been under construction in the San Bernardino mountains. An illustrated account of the general project appears in *Engineering Record*, April 4, 1908. In the following month of August the local press recorded the signing of a contract to add 12 inches of concrete to the up-stream face of the core-wall to stop the leakage taking place and remedy defects in the wall.

Leakage through Concrete Core-walls.—An earth dam built at Lynn, Mass., in 1903, with a concrete core-wall, has been found to leak from about 239,000 to about 448,000 gallons per day, depending on the water-level of the basin. As described in *Engineering Record* of March 7, 1908, the dam is 2200 feet long, 45 feet high, 52 feet wide at the crest, and has a core-wall of concrete 4 feet 8 inches thick at the top, 9 feet 6 inches thick at the bottom. The core-wall contains 22,000 cubic yards of concrete. It extends to a depth of 25 feet below the base of the dam. The front face of the wall was plastered with a 1:1 mortar. The core-wall was built between two rows of 6-inch sheet piling, driven by steam-hammer in the bottom of the trench to a depth of 26 feet, or about 18 feet below the bottom of the concrete wall, where the piles brought up against hard material. The earth in the dam "was deposited in layers and puddled or rolled where necessary." The slopes of the dam are $1\frac{3}{4}$ on 1 each side.

The fact that a dam with a core-wall of the thickness described and plastered as it was, should leak is significant of the untrustworthiness of concrete or masonry core-walls in general.

The John Day's Dam, California.—This is a concrete and earth structure completed on the South Fork of Eel river, in Mendocino county, California, in the summer of 1907. The concrete portion of the dam is an overfall spillway section 350 feet long, with an extreme height of 73 feet. The remaining 280 feet is an earth embankment having a thin concrete core-wall, resting partly on rock and partly on a sandy earth foundation. The earth embankment is 10 feet wide on top, and has slopes of 3 on 1 up stream and $2\frac{1}{2}$ on 1 down stream. Where the core-wall is on the rock it is 4 feet thick at top, battering 1:12 on each side. Where it is on earth foundation it is reduced to 8 inches thickness, reinforced with a diaphragm of expanded metal, and resting on a base of concrete 3 feet wide, 2 feet thick.

The concrete portion of the dam is designed to withstand floods of 100,000 second-feet, or more, passing over its crest, giving a depth of overflow of 20 feet and upwards. The down-stream face of the dam has been built in vertical and horizontal steps, most of which are 5 feet in height and the same in width. Eel river has a watershed of 324 square miles area above the dam.

The dam was designed by Edwin Duryea, Jr., M. Am. Soc. C. E., of San Francisco.

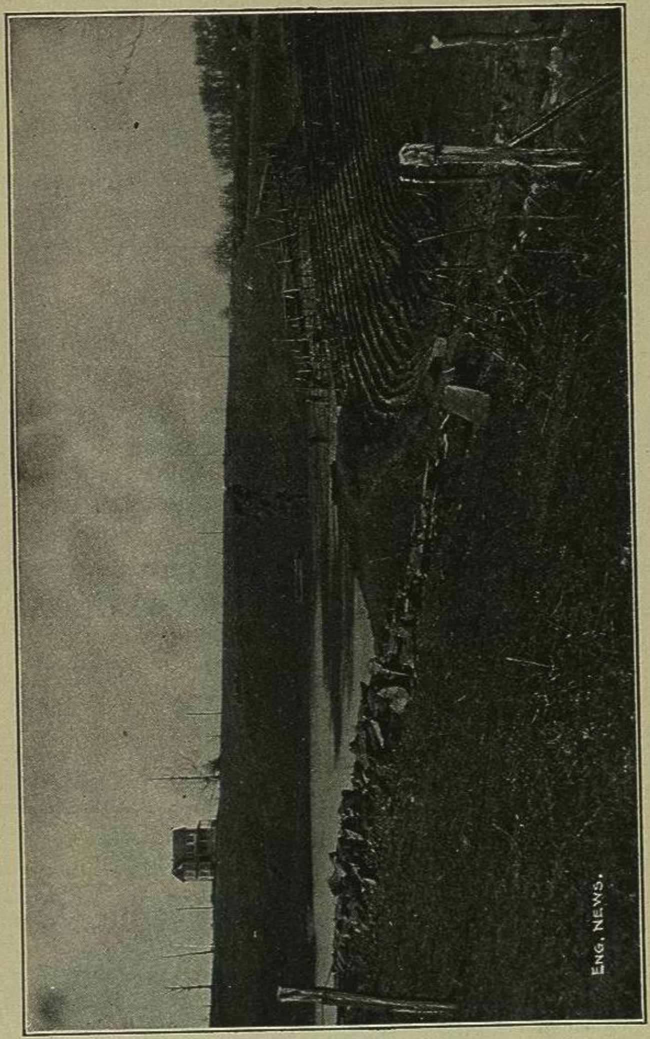

Fig. 381.—Roland Park Hydraulic-fill Dam, Baltimore, Md.

Eng. News.

Roland Park Hydraulic-fill Dam, Baltimore, Md.—An interesting application of the hydraulic-sluicing method to the grading of a hill and the building of a small dam is described in *Engineering News*, June 11, 1908. The grading of the hill required the removal of 50,000 cubic yards of earth. This was placed in a dam 400 feet long, 24 feet high, all of which was constructed by the hydraulic process, the earth being deposited along the face of the dam by means of flumes, and held in place by the use of 1″×12″ boards, 16 feet long. These boards, set on edge, were held in position by stakes driven into the earth composing the fill. Each tier of boards was set so that they lapped, vertically, over the next lower tier by 2 inches, thus forming a backing for the earth and water to fill against. The earth thus held was built up on a slope of 2 on 1. The engineer who designed the plant and built the dam was Mr. John H. Walzl. This method of holding the slopes is known as the "shear-board method," and is successfully and extensively used in controlling the fills made of sluiced clay and sand in the regrading of Seattle, Wash., described and illustrated on pages 509 to 514 inclusive. Bulkheads are thus formed on average slopes as steep as 1.5 on 1.