without wasting water. It has a gravity Ogee section of cyclopean concrete masonry, and is very broad at the base on account of the severe floods. The maximum flood will overtop the crest about 23 ft. The foundation is a very hard and tough diorite rock, locally called greenstone. The bottom of the river was covered with large boulders and gravel, which had to be excavated. The lowest point of the foundation is 45 ft. below the original water level. In constructing the dam a new camp and quarters were built. Four Lidgerwood cableways were used and a large new rock crusher plant and concrete mixing plant installed. Of course, it is intended, as explained before, that this dam will ultimately be built 90 ft. higher.

Tunnels.—As was shown on the map, the old tunnel of the Big Bend Mining Co. only discharged into Dark Canyon, and did not go completely across the neck of land to to the main river below. This old tunnel has quite an interesting history. It was started in 1883 at the time placer gold mining was booming in that part of California, the idea being to divert all the dry season flow of the river through the tunnel of 12,300 ft. long to Dark Canyon, and leave the river around the bend dry, thus allowing the company during the summer to work the gravels and sand in the river bed and extract the gold which was supposed to be there.

The tunnel was started from the Dark Canyon end, and required three years to complete. It was about 8 ft. high by 13 ft. wide, and had a grade of 5 per 1,000. The progress was rapid, 400 ft. being made one month. A timber diverting dam was built across the river just below the intake, but when the water was turned through the tunnel it was found that unfortunately the tunnel had not been made large enough, and would not take nearly all the summer flow. It was then enlarged, requiring another year, by taking 4 ft. more from the roof of the tunnel, making it 12 ft. x 13 ft. in cross-section. The cost of the complete tunnel was then $750,000.

Work was started prospecting the river in 1888, but with poor success. The next year the company spent $100,000 to obtain about $40,000 worth of gold, hardly a paying proposition, so the project was abandoned. The tunnel then lay idle until purchased by the Great Western Power Company to be used as part of their development.

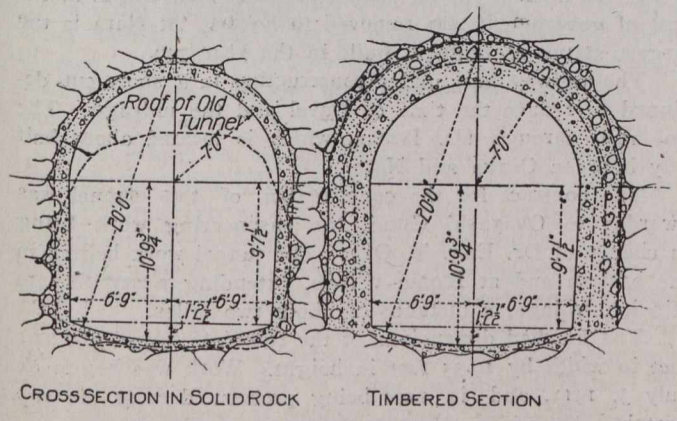

Fig. 3.—Typical Sections of Enlarged Tunnel.

The maximum flow required in the tunnels is 2,500 sec. ft. The maximum allowable velocity decided on was 11 ft. per second, so the net cross-section was made 220 sq. ft. inside the concrete lining. The old tunnel measured about 12 ft. x 13 ft., so it had to be considerably enlarged. It was made of a horseshoe section 18 ft. high x 14 ft. wide inside the lining, or 20 ft. by 16 ft. outside the lining, Fig. 3. The enlargement was made by taking from 5 to 6 ft. from the roof and by trimming 2 to 4 ft. from one side. This is the reason for making the section so high in comparison with its width, as it was considered more economically in making the enlargement to take as much from the roof as possible.

The 3,400 ft. extension, or new tunnel, being entirely new, could be made a better section. As shown, Fig. 4, it is 16 ft. wide x 16 ft. high inside the lining, horseshoe shape, but the same net area.

The concrete lining is intended to be 12 ins. thick. The minimum allowed on the sides and arch was 6 ins., and 4 ins. on the invert. From careful cross-section taken with a sunflower the actual thickness averaged 21 inches.

At the intake the invert is 54 ft. below the present crest of the dam; throughout the new tunnel and in the header pipe about 120 ft. below. When the dam is raised to its final height, the header pipe will be 200 ft. below, and the tunnel has to withstand the internal pressure due to this.

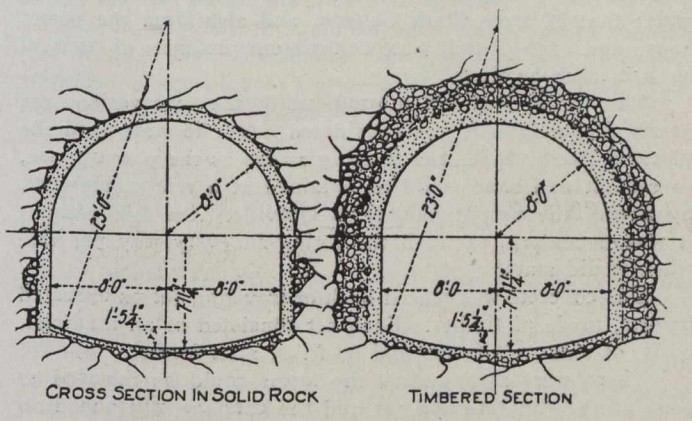

Fig. 4.—Typical Sections of New Tunnel.

The ground is solid rock throughout. The new tunnel and both ends of the old tunnel are through shale, but about 6,000 ft. in the middle of the old tunnel is through a very hard and tough blue trap, really a diorite.

The surface of the ground is mostly from 400 to 1,500 ft. above the tunnel and all rock. The few springs encountered in the tunnel or appearing along the canyon side, tended to show that the ground water level was much higher than that necessary to counteract the internal pressure in the tunnel. On this account weepers (2-in. diam. pipe) were placed in the lining to relieve any pressure from the outside, one for each 100 sq. ft. of lining, and extra ones where any springs were encountered. However, the tunnel was very dry, and none were struck which gave more than what a 1-in. pipe would carry.

There were, however, three exceptions where all weepers were omitted and the lining was made at least 24 ins. thick. First, for about 200 ft. in from the intake. Second, for about 400 ft., where the new tunnel branched off from the old and ran under Dark Canyon. At one point here there is only 80 ft. of rock overlaying the tunnel. Third, for about 373 ft. in from the header pipe or to a point 500 ft. away from the portal above the power house. Great care was taken at these places to secure dense concrete closely packed against the rock.

In the other parts of the tunnel the rock is depended on to take the pressures, and the lining is considered merely as a means to obtain a smooth tube with small hydraulic losses. In fact, one engineer seriously proposed lining the tunnel with planed red-wood timbers supported on concrete cradles.

The proportions of the concrete mix were 1:3:5. Puddling stones were embedded in the concrete where possible, keeping them 6 ins. from the face. Very little timbering was necessary except at each portal. At the intake end and throughout the tunnel the timbering was all left in place; but at the portal above the power house it was removed, before the lining was placed.