necessitated an entire relocation of the systems of roads and the construction of a large number of costly bridges to carry these roads over various arms of the lake. These crossings include a 124½-foot bridge; two spans of 217 feet; one of 310 feet, one of 396 feet, and

MAP OF CATSKILL AND CROTON WATERSHEDS, SHOWING THE NEW CATSKILL AQUEDUCT.

a handsome cantilever structure with a central span of 384 feet. The system of new roads extends for 50 miles around the lake. These supplemental works, together with the cost of the real estate, etc., brought the total cost of the whole scheme up to a round sum of about $12,000,000.

During the construction of the new Croton dam the city undertook the building of the Jerome Park reservoir, lying near the northerly limits of New York city, which is designed to act as a storage and distributing reservoir within the city limits. The reservoir as designed has an area of 239 acres and a depth of 26½ feet. The excavation involved the taking out of about 11 million cubic yards of material, most of it rock. It is divided by a wall that runs through it in a north and south direction; and the easterly half, which has been completed and entirely lined of concrete, has a maximum full capacity of 773,400,000 gallons.

Subsequently to the completion of the Croton dam a large reservoir known as Cross River, holding 10,308 million gallons, has been completed, and another, the Croton Falls reservoir, with a capacity of over 14 billion gallons, is under construction. When the last-named is completed there will be ten separate dams in the Croton watershed, with an aggregate capacity of 104,530 million gallons.

During last winter, from November 6 to March 15, all the reservoirs on the watershed were full and overflowing, and during this period over 80 billion gallons of water ran to waste over the spillway of the new Croton dam. With a view to storing a portion of such waters as would overflow in the future, it is proposed to build one more dam in the upper reaches of the watershed, which will have a capacity of 20 billion gallons and will be known as the Patterson reservoir.

From what has been said it will be seen that the limit of the storage capacity of the Croton watershed has about been reached. The daily average flow of the Croton River during the past forty years has been 402,330,000 gallons. The present daily consumption of water in New York city is about 325,000,000 gallons. Taking into consideration the increasing rate of growth of population of the city, and the fact that the annual increase in water consumption is at present at the rate of 15 million gallons daily per year, it can be seen that within a few years' time the consumption of the city will have exceeded the daily river flow and the capacity of 380 million gallons of the two aqueducts leading from Croton reservoir to New York. As the result of an exhaustive examination by various boards of engineers, it was found that the nearest available source for a new water supply was to be found in the region of the Catskill Mountains; and a gigantic scheme has been approved and is now being carried through for bringing a supply of fresh mountain water into New York city from the Catskills, to the extent of 500 million gallons daily, at a total cost of $161,000,000.

THE CATSKILL WATER SUPPLY.

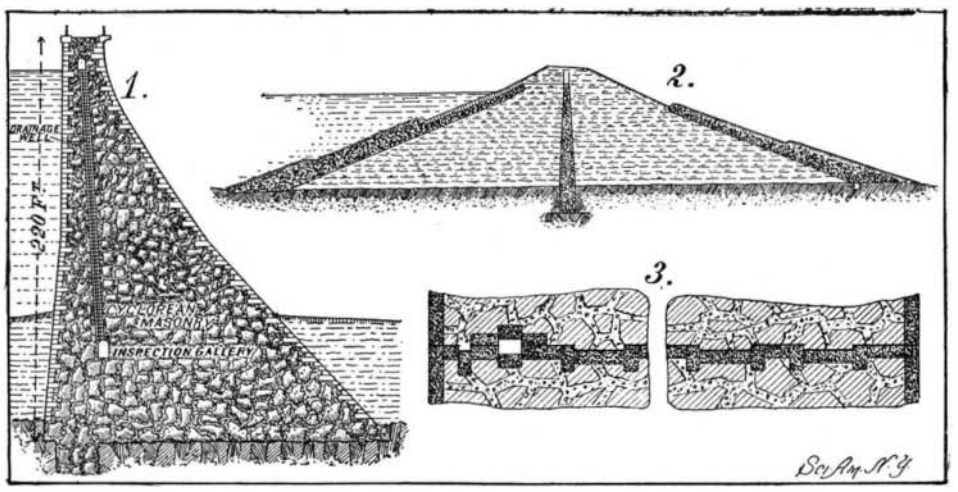
In selecting a new source of water supply the engineers of the board realized that the conditions surrounding New York city were unusually perplexing. To the east the city is shut in by the Atlantic Ocean and to the west it is excluded by the laws of New Jersey from tapping any of the water sources of the State. A most excellent supply might have been drawn from the sources of the Housatonic River, had the district not been excluded from consideration because of its location in the State of Connecticut. Hence, the city has been driven by its geographical and legal restrictions to go far afield in its search, even to the regions of the Catskill Mountains. The disadvantages of distance, however, are compensated by the fact that the watersheds are sparsely inhabited, and that the water supply is not only abundant but is of excellent quality. By reference to the accompanying map, it will be seen that when the whole scheme has been developed water will be taken from four separate districts. The first of these, the Esopus Creek watershed, has an area of 255 square miles. Its waters will be impounded by the construction of a huge dam 220 feet in maximum height and 5,650 feet in length, which will be built across the valley of the Esopus at what is known as the Olive Bridge site. The dam will create what will be known as the Ashokan reservoir, which will be 2½ miles in width, with a full level capacity of 170 billion gallons, and will be capable of supplying the city, with 250 million gallons of water a day.

The rate of growth of Greater New York is so rapid that it cannot be many decades before the watersheds of the Rondout, the Schoharie, and ultimately of the Catskill rivers will in turn be brought into service. The Rondout watershed covers 176 square miles, and would be capable of yielding 130 million gallons daily. This water will be stored in what will be known as the Napanoch reservoir, from which its waters will be led by an aqueduct into the main Catskill aqueduct a couple of miles below the Ashokan reservoir. Later, the Schoharie watershed will be brought into service by the construction of the Prattsville reservoir, its waters being brought into Esopus Creek by means of a tunnel through the divide. Lastly, the Catskill water will be impounded in several reservoirs located along that stream, and brought into the Ashokan reservoir by an aqueduct whose location is shown on the accompanying map. Altogether, when the whole scheme is completed, New York city will have at command over 700 million gallons daily water supply from the Catskill Mountain watershed in addition to the 375 million gallons daily already available in the Croton watershed.

The Ashokan dam, like the Croton dam above described, will take rank as one of the greatest structures of its kind in existence. It will be built partly of solid masonry and partly of earth. The masonry portion, which will extend for about 1,000 feet and occupy the center of the dam, will be built of the general cross section shown in the accompanying engraving. The width of the base will, of course, vary with the depth of the foundations; but at the center it will be not far from 200 feet. Its height taken at the same point will be 220 feet. The earth-and-core-wall portions of the dam will extend from the masonry middle section to a junction with the valley on one side, and some high ground on the other. The total length of the dam will be 5,650 feet. In addition to the dam there will be a series of dikes which will be built across depressions in the country and serve to hold the water at the desired level. Beyond the dikes will be a large waste weir. The dikes will constitute a very important work, for together with the waste weir they will have a total length of 3.8 miles. One of our illustrations shows the preliminary excavation work for the dam and the means adopted for by-passing the flow of the Esopus Creek during construction, which is being done by means of two 8-foot steel pipes which will be sufficient to accommodate the creek at its ordinary level. Subsequently, as the excavation is carried further down, the water will be diverted through a channel formed along the side of the valley. Ultimately, during the erection of the masonry of the dam, the water will flow through a tunnel, which will be left open for that purpose and closed when the dam is completed.

From the dam the water will flow by gravity through a huge steel-and-concrete aqueduct 17 feet in the clear

(*Continued on page 414.*)



1. Cross-section of masonry portion of dam. 2. Cross-section of earth-and-corewall dam. 3. Horizontal section through an expansion joint in dam.

PLAN AND DETAILS OF THE ASHOKAN RESERVOIR AND DAM.

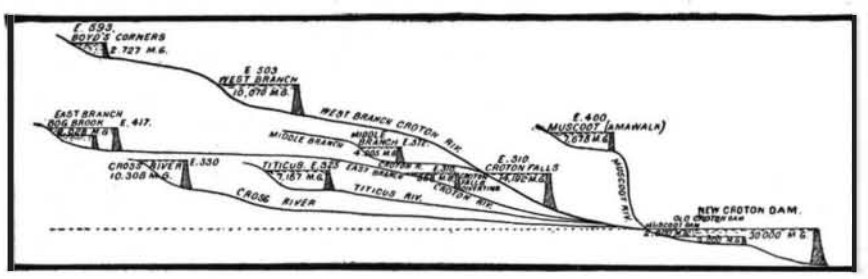
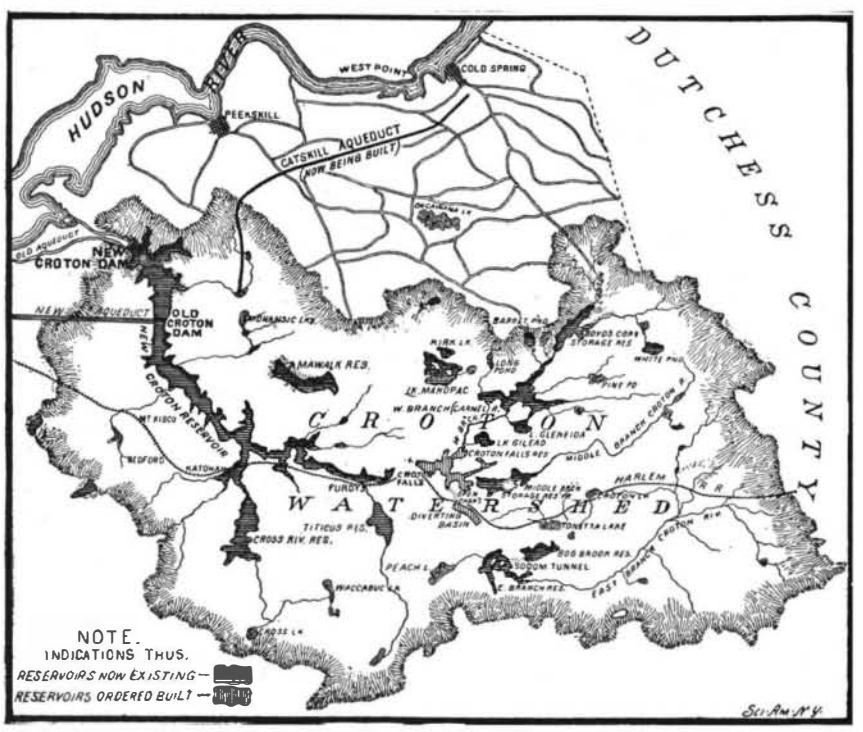


DIAGRAM SHOWING ELEVATION AND CAPACITY OF CROTON RESERVOIRS.



PLAN OF THE CROTON WATERSHED, SHOWING LOCATION OF THE RESERVOIRS.

THE CATSKILL WATER SUPPLY.

(*Continued from page 396.*)

in height and 17½ feet wide, which will be built partly by the cut-and-cover method and partly in tunnel. It will extend to the westerly bank of the Hudson River, which will be reached at a point between Cornwall and West Point. Originally it was the intention to carry the aqueduct below the Hudson River at New Hamburg; but the preliminary borings at this and other sites proved that it would be difficult to find a rock sufficiently clean from fissures and other imperfections. An examination of various sites by geologists led to the ultimate selection of the crossing near Cornwall, where it was believed that a thoroughly sound and suitable rock would be found at a depth not too prohibitive. The aqueduct passes through the mountains and reaches the westerly shore of the Hudson River at an elevation of 400 feet above tide level. Here a vertical shaft will be sunk to a depth of probably not less than 700 feet below the river surface, or 1,100 feet below the level of the aqueduct. In the bottom of the shaft a tunnel will be driven horizontally beneath the river to connect with another vertical shaft of practically equal depth on the easterly bank of the river. From this point it will be constructed through the mountains until it reaches the new Croton reservoir. Here connections will be made to enable the water to be drawn directly from the Ashokan reservoir into the Croton reservoir, with a view to augmenting the Croton supply until such time as the aqueduct from Ashokan to New York city shall have been completed.

From the Croton reservoir the aqueduct will be continued south to Kensico reservoir, which will be enlarged to include Rye Pond and will form an auxiliary storage reservoir at an elevation of 355 feet above mean tide, capable of containing 25 billion gallons, or sufficient to supply the city at the rate of 500 million gallons per day for a period of fifty days. About four miles south of Kensico, at Scarsdale, there will be built a large filtering plant, and at Hillview, six miles to the south of this, will be another storage reservoir. With these two auxiliaries or emergency reservoirs provided, the city will be secured against any sudden interruption of its supply through failure of the 69 miles of aqueduct lying to the north of them. By the construction of a tunnel of 200 million gallons daily capacity below the East River, Brooklyn and Staten Island will be provided with a supply of 100 million gallons daily, and this aqueduct will terminate in a large reservoir to be constructed in Forest Park. From the point where this tunnel reaches the shores of Long Island, a line of 20 million gallons capacity will be built through Brooklyn and below the Narrows for the supply of Staten Island.

TUNNELS AND SUBWAYS.

(*Continued from page 405.*)

the shield it was customary to allow the silt, etc., to pass into the interior of the tunnel as the shield was advanced, and take it away in cars. The Hudson Companies' engineers decided, however, to try the plan of pushing the shield ahead by displacement; that is to say, they closed the doors in the front face of the shield, and tried the experiment of pushing the shield bodily through the silt, causing the latter to flow over and around the tube by displacement. The plan succeeded beyond expectations, and the later work was all done by this method.

One of our illustrations shows the way in which the engineers overcame a serious obstacle, in the shape of a ledge of rock, which projected from the river bottom and covered the lower half of the path through which the tunnel was to be driven. To meet the emergency, a heavy iron working roof was built in front of the shield, and under this the workmen were enabled to set up their