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THE TROY WATER WORKS EXTENSION.

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[*Read March 11, 1908.*]

HISTORICAL.

The city of Troy is located on the easterly bank of the Hudson River, at the head of navigation. It occupies the river plain for a distance of about six miles north and south and extends back upon the hills to the eastward from one to two miles. The river plain has a general elevation of about 30 feet, while the hills occupied on the east rise to elevations of from 300 to 500 feet above tide-water. At the time the water works system was first undertaken, the city had a population of about 12 000; it now has a population of about 77 000.

The Troy Water Works Company, a private concern, was incorporated by act of the Legislature, April 18, 1829. This company intended to supply water for domestic purposes only and seems to have accomplished very little.

About a year after the company above referred to was incorporated, the Common Council of the city passed a resolution creating a committee with instructions to make surveys, plans, and estimates for bringing " a suitable supply of good water " into the city. On August 11, 1830, this committee reported upon two plans, — one to take water from the " Gorton Springs," at an estimated cost of $60 000; the other to use the " Piscawen Waters," at an estimated cost of $80 000.

In May of the following year a committee was appointed to see what arrangements could be made with the Troy Water Works Company to supply the city with water for extinguishing fires, watering streets, etc., and to learn upon what conditions the company would transfer its charter rights to the city, provided the necessary legislation could be obtained. The committee reported, March 26, 1832, that they could not make satisfactory arrangements with the Troy Water Works Company for the supply required, but that the company had agreed to surrender its charter to the city upon the payment of the amount actually paid out by them, $174.34. The committee further reported that the legislature had already passed the necessary bill for the transfer, by an act entitled," An Act in Relation to the Troy Water Works Company and for insuring the City of Troy a Supply of Water for the Extinguishment of Fires and for Other Purposes."

Acting upon this report, the Common Council ordered a house-to-house canvass to be made to ascertain the sentiment of the people in regard to the matter. As a result of this canvass, it was found that 637 were in favor, 8 opposed, and 18 indifferent to the project. One hundred and seventy-eight agreed to take water when it was brought into the city.

Surveys for the construction of the reservoirs upon the Piscawankill were begun in March, 1833, and contracts for the work were immediately made. A contract was also made with Samuel Richards, of Philadelphia, to furnish cast-iron pipe and castings at the following rates delivered in Troy: 12-inch, $1.85 per foot; 10-inch, $1.50; 8-inch, $1.30; 6-inch, $0.90; 4-inch, $0.50; 3-inch, $0.40 per linear foot, and branches and other castings, $62.50 per ton.

The works were completed in 1834 and consisted of a diverting dam across the Piscawankill; two open and one covered reservoirs, having a combined capacity of about 1 000 000 gallons, and a 12-inch main leading from the covered reservoir to the city. The ruins of these old reservoirs are still to be seen just easterly of the Boston & Maine Railroad near Eddy's Lane.

The work had been completed but two years when it became evident that some means should be devised to increase the supply. In 1839 land was purchased and a dam known as the Fire Dam was built for the purpose of storage upon the site now occupied by the low-service distributing reservoir. This reservoir appears to have been insufficient, for the next year the committee in charge suggested pumping water from the Hudson River.

The idea of pumping seems to have been abandoned for some reason, and in the fall of 1840 the right was obtained to erect and maintain a dam at the site now occupied by the dam of the Brunswick reservoir for the term of two years, with the privilege of buying the property outright at the end of that period if the city elected to maintain a permanent reservoir at that point. The dam was built and all the property rights were later acquired.

The full development of the Piscawankill watershed as a water supply was finally accomplished by building the present "Upper Oakwood" reservoir in 1859–1860, the "Lower Oakwood" in 1861–1862, and the "Vanderheyden" reservoir in 1868. These reservoirs, together with the "Brunswick," gave a total available storage capacity of about 281 000 000 gallons.

In 1872, Wm. J. McAlpine, civil engineer, who was employed to examine all the feasible sources of water supply for the city of Troy, and report on the cost of procuring the same, made a report in which he suggested five sources of supply, namely, the Tomhannock, the Poestenkill, the Hudson River, the Deepkill, and the Wynantskill. In concluding his report, he says: "The Tomhannock plan possesses advantages over all of the others in the economy of its cost and the purity of its water, and is equal to any of the others in the abundance of water." None of the schemes suggested by Mr. McAlpine was carried out.

In 1877 and 1878, Prof. D. M. Greene, civil engineer, presented reports and plans for pumping water from the Hudson River, and in 1879 a pumping plant was built under his direction. This plant consisted of two Holly duplex pumps, each of 6 000 000 gallons daily capacity, together with the necessary intake crib in the river, a tunnel to convey the water from the intake to the suction well, and a 30-inch cast-iron force main extending from the pumping plant to the "Lower Oakwood" reservoir, a distance of about three miles.

The water was pumped from the river into the "Lower Oakwood" and allowed to flow by gravity from there to the distributing reservoir.

The low-service distributing reservoir was built in its present form in 1883, at which time a 24-inch supply main was laid from it to connect with the distributing system of the city. This line of main pipe crossed the stone arch just below the reservoir and connected with the 20-inch main of the old system near the old covered reservoir. Provision was also made at the new distributing reservoir for another 24-inch main. This was laid down

Eddy's Lane, or Glen Avenue, and Seventh Avenue to Park Street, connecting with the distributing system, in 1885.

The middle service system was connected with the "Upper Oakwood" Reservoir in 1879, and the high-service system was taken from a small new reservoir, known as the High Service Distributing Reservoir, built especially for that purpose during the same year.

The supply thus provided proved to be adequate until about 1893, when Prof. W. G. Raymond and Elnathan Sweet were employed to investigate and report upon a new source of supply. These engineers made a report upon the development of the Poestenkill and Quackenkill, two streams lying to the southeast of the city. Nothing further seems to have been done toward procuring an additional supply until 1900. In the meantime Professor Raymond's attention was directed to the Tomhannock Creek, a stream of considerable size flowing through the towns of Pittstown and Schaghticoke into the Hoosick River. He found upon investigation that a very large storage reservoir could be made there at comparatively small expense.

The Tomhannock Reservoir would not, however, be at a sufficient elevation to supply more than the low, middle and Lansingburgh services. Therefore it was finally decided to develop the Tomhannock for these services, and the Quackenkill for the high-service supply.

Authority to expend $1 250 000 for an additional water supply was obtained from the legislature in 1900, and the work was immediately undertaken under the direction of Prof. W. G. Raymond as consulting engineer.

THE QUACKENKILL.

The Quackenkill drainage area is located on the mountains east of Troy in the town of Grafton. It consists largely of grazing and wooded lands and contains several lakes of considerable size. These lakes are located in the more elevated portions of the area, are fed largely by springs, and contain water of very good quality. Streams flowing from the lakes join to form the Quackenkill. On account of its great elevation above the city it affords an excellent source from which to obtain, by gravity, an additional supply for

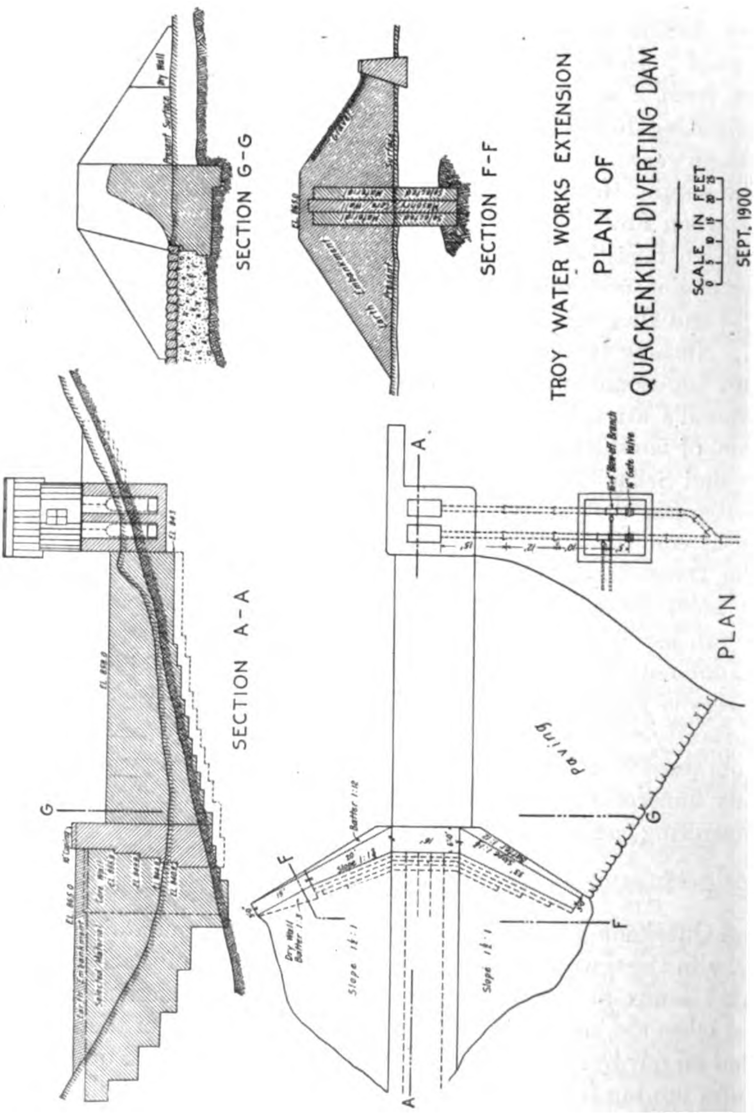

SECTION A-A
SECTION G-G
SECTION F-F
PLAN
TROY WATER WORKS EXTENSION
PLAN OF
QUACKENKILL DIVERTING DAM
SCALE IN FEET
SEPT. 1900

FIG. 1.

FIG. 1. Quackenkill Diverting Dam and Gate House.

FIG. 2. Tomhannock Dam Site with Culvert Completed.

the high-service system of the city. The original plans contemplated the full development of about 17½ square miles of the drainage area around the headwaters of the Quackenkill.

To accomplish this it was proposed to build dams at the outlets of the lakes so as to increase their storage capacity; two large storage reservoirs, one about 2 miles and the other about 5 miles below the lakes; a diverting dam near the town line between Grafton and Brunswick; one or more conduits from the diverting dam to the large storage reservoir, known as the "Brunswick," about 3 miles distant from the city; and a conduit from the "Vanderheyden Reservoir," to connect with the old high-service conduit at the old high-service distributing reservoir. Up to the present time the only work carried out under these plans consists of the building of the diverting dam, a single conduit from it to the storage reservoir, and a single conduit from the storage reservoir to connect with the old high-service main.

The diverting dam (Fig. 1, and Plate I, Fig. 1) consists of a concrete spillway and gate chamber, and an earth embankment with concrete core-wall. Although only one conduit has been laid from the dam to the storage reservoir, the proper connections, valves, etc., have been built into the dam for a second one, if it should ever be needed.

The conduit from the diverting dam to the "Brunswick Reservoir" consists of 29 550 feet of 16-inch, and 3 167 feet of 12-inch cast-iron pipe designed to have a carrying capacity of about 5 000 000 gallons per 24 hours. The outlet of this conduit is taken some distance into the reservoir, where it terminates in a bell-shaped concrete mouthpiece. This mouthpiece turns upward and serves to a small degree as an aërating fountain.

From the "Brunswick" the water passes over a weir or through pipes in the embankment into the "Vanderheyden Reservoir." A new intake gate-house has been constructed at the dam of this reservoir. It was built with hollow brick walls filled in solid with concrete. Vitrified paving brick were used below the high-water line, and ordinary hard burned building brick above that line. A 20-inch conduit was laid from this gate-house to a connection with the old high service conduit. This conduit is 9 000 feet in length and gives an additional static head of about 90 feet.

It also eliminates the possibilities of contamination, which so largely existed in the open channel, through which the water formerly flowed.

THE TOMHANNOCK.

The Tomhannock drainage area is located northeasterly of the city and comprises above the reservoir dam an area of 67.3 square miles. The surface is very uneven, being of a rolling or mountainous character. It is largely a farming district, only about 15 per cent. of the area being covered with forest growths. There are about 600 houses on the drainage area and a resident population of about 2 500, or 35 people per square mile.

The location selected for the reservoir is about 10 miles northeasterly of the city. Here the valley of the Tomhannock, for a distance of 5 miles, has an average fall of about 8 feet per mile and an average width of about three quarters of a mile. At the point selected for the dam, the hills on either side of the valley approach each other until only a narrow ravine lies between them.

The hills surrounding this valley are of a shale formation with only a thin covering of earth. The valley is covered with glacial drift a few feet in depth, with here and there a deposit of considerable magnitude. Bed rock is found below this glacial deposit in the upper part of the valley of the same general character as in the hills around it.

At the dam site and for a distance of three quarters of a mile upstream, where the bed rock drops off abruptly, the material underneath the glacial deposit consists of a thin layer of yellow clay overlying an extremely hard and compact blue clay and gravel, extending to a depth of more than 150 feet, as shown by borings.

The crest of the spillway dam is located at Elevation 390, Troy City datum, at which elevation the reservoir has an area of 1 685 acres. The maximum depth of water near the dam is 55 feet, and the average depth over the whole area, 22.4 feet. The total capacity of the reservoir is 12 310 000 000 gallons, 95 per cent. of which is available for use.

Of the area flooded, 250 acres were covered with woods and brush, the remainder being largely lands under cultivation. The trees and brush were all cut and removed from the area. The farm buildings, of which there were seventeen sets, were entirely removed and the areas occupied by them carefully cleaned up; 22 000 cubic yards of muck and decaying vegetable matter were excavated and removed from the area flooded.

The question of stripping the soil from the entire area covered by the reservoir was carefully considered by the writer. The conclusion was finally reached that while stripping would be a very good thing, better and more far-reaching results could be obtained for about one half the cost by a reasonable sanitary treatment of the drainage area, and by installing a proper filtration plant.

Several highways crossed the reservoir site, and it was therefore necessary to construct about seven miles of new highways to replace those abandoned. The alignment of these roads has been made to conform in a large measure to the contour of the ground. The maximum grade allowed was 5 per cent. The subgrade was shaped so as to have a crown of 6 inches, over which was spread a gravel surfacing 9 inches in thickness at the crown and 6 inches at the shoulders, thus giving the finished surface a crown of 9 inches. The finished width of traveled way is 20 feet. The gravel surfacing was thoroughly rolled with a grooved roller and wet when found necessary to thoroughly compact it. Side gutters 2 feet in width at the bottom and 1 foot in depth extend through all excavations. A ditch was also constructed along the side hill above all excavations, with a berm of not less than 6 feet between it and the top of the slope. All embankments exposed to the wash of the reservoir are covered with riprap or stone paving. Substantial guard rails have been erected along all embankments 3 feet or more in height.

The culverts consist of 6-, 10-, 15-, and 24-inch vitrified clay pipe with concrete or cobblestone headwalls. These culverts have not been entirely satisfactory, especially in clay soil or where a small trickling stream flows all the time.

There are five bridges on the highways, with spans varying from 16 to 80 feet. The 16-foot span bridge was built with rolled I-beams. Three others were built with lattice girders, and floor systems of rolled I-beams. The fifth, an old bridge, was raised 4 feet and new abutments built under it. All abutments were built of 1 to 6 gravel concrete.

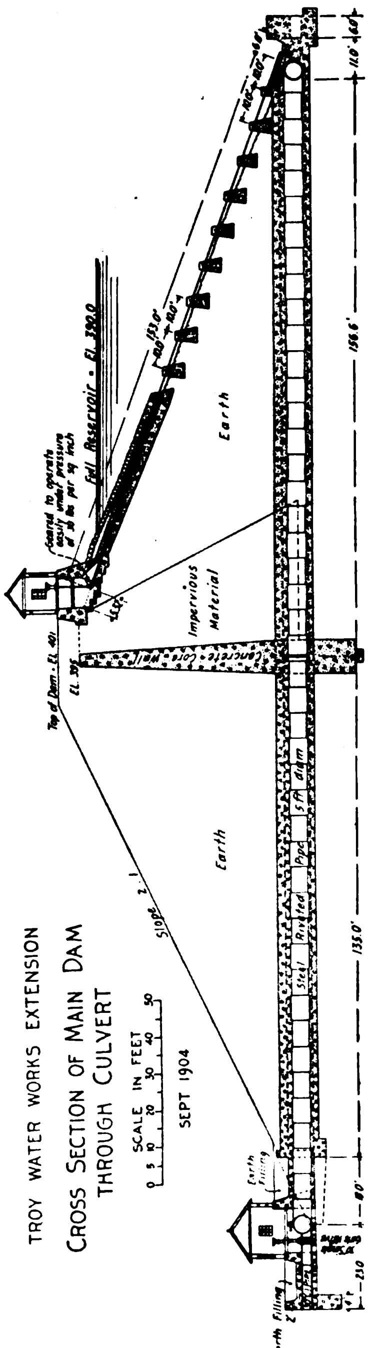


FIG. 2.

At the point selected for the dam the ravine is about 200 feet in width at the bottom and 500 feet at the top of the dam. An examination of this site had revealed the fact that it would be impracticable to reach bed-rock. Test pits dug along the proposed center line of the dam showed a depth of from 1 to 5 feet of loam and gravel, followed by a blue clay and gravel of unusual hardness and tenacity. This latter material is of great depth, as shown by the borings, and the formation was considered exceptionally good for an earth dam.

The general cross-section of the dam finally adopted, as shown in Fig. 2, has a top width of 24 feet, finished off as a highway; a back slope of 2.4 to 1; a front slope of 2 to 1; and a maximum height of about 70 feet. The back slope is paved to a point 15 feet below flow line and the remainder is covered with riprap.

The dam site was stripped of all loam and gravel down to the yellow clay. The area to be covered by the selected hard material was excavated down to and about 6 inches into the hard blue clay and gravel. There was also a cut-off trench 4 feet in width and 2 feet in depth excavated along the toe of the up-stream slope, and another about midway between the toe and the selected hard material. The trench for the core wall was excavated to a depth of not less than 16 feet into the hard blue clay and gravel. At the westerly end, as the excavation was extended into the hill, a pocket of loose blue clay and gravel of a very porous nature was encountered, and it was found necessary to excavate to a depth of about 60 feet to procure a suitable foundation.

To provide for the flow of the stream during construction, a culvert 6 × 6½ feet, horseshoe-shaped, was built of concrete along the westerly side of the stream and the water turned into it by means of a canal and small cofferdam. It was the intention of the designer of the work to eventually close this culvert with concrete and gravel. With this in view two 36-inch sluice gates were placed at the upper end to control the flow through the culvert. These gates were of sufficient size to take the ordinary summer flow of the stream. Before the completion of the work, however, it was considered advisable to have a permanent opening through the dam at this culvert in order to unwater the reservoir should circumstances require it; a wise precaution in this particular case, as will appear later. This culvert is shown in Plate I, Fig. 2.

The plan followed for converting this culvert into a permanent opening was to build into and through it a 5-foot diameter steel riveted pipe ½ inch in thickness. At the upper end of this pipe is a T carrying three sluice gates, each having a clear opening of 1½ x 4½ feet. These gates were made narrow and long, so as to build them into and disturb the old work at the upper end of the culvert as little as possible. The gate stems were carried up the slope on bronze rollers, supported by concrete piers, to a gate-house located at the top of the dam. At the outlet end of the pipe is placed another T, carrying four 30-inch gate valves. This arrangement furnishes a means of regulating the flow through the pipe in case of accident to the sluice gates at the upper end, and of relieving the pressure upon them should it be necessary. A substantial brick gate-house is built over these gate valves.

The core wall of the dam is of concrete consisting of one part

Portland cement to five parts sand and gravel. The wall is 9 feet in thickness at the base and up to Elevation 340, from which point it batters uniformly on both sides to the top, at Elevation 395, where it is 3 feet in thickness. The concrete was deposited in 6-inch layers and thoroughly rammed. Above the surface of the ground the forms for the concrete were tied together with half inch rods. On the up-stream side a wooden washer in the shape of a truncated pyramid of four sides, about 2½ inches in height, was placed over the rod on the inside of the form. When the forms were removed the washers were taken out, the rods cut off at the bottom of the depression, and the space filled up with rich cement mortar.

The embankments on both sides of the core wall were carried up simultaneously with the wall, but the core wall was always kept at least one foot higher than the embankments, and usually much more than that. The embankments were always kept higher at the outside edges than at the center. The material for the embankments was brought from borrow pits in dump wagons and placed one load after another the whole length of the dam. After a line of loads had been completed, a road machine was used to scrape them down to a 4-inch layer. The layer was then watered and rolled thoroughly with a grooved roller weighing 1 000 pounds per linear foot. The teams were also kept from driving in one place as much as possible and thus aided in compacting the earth. The material from the borrow pits was not uniform in character, being at one place yellow clay and sand and at another almost wholly very fine sand or coarse gravel. As the loads came to the dam they were inspected and only the best material placed on the up-stream side.

The selected hard material for that part of the embankment next to the core wall, on the up-stream side, was to have been of the hard blue clay and gravel underlying the valley. As it was found impractical to reduce it to a sufficient degree of fineness to puddle satisfactorily, a fine blue clay was substituted. This material was deposited and compacted in much the same way as the other material, except that greater care was taken with it. After the road machine had leveled off the loads and a disk harrow had been run over the material until all lumps were broken up, it was thoroughly soaked with water and rolled. Near the core wall the lumps were broken up with mattocks and the material thoroughly compacted with hand rammers.

The embankments were carried 6 feet higher than the core wall and 11 feet higher than the crest of the spillway dam. Along the top of the embankment, on the up-stream side, a concrete curb was built, upon which was erected an iron pipe guard rail, while along the down-stream side the iron guard rail was placed on concrete blocks.

The spillway dam is located in a depression in the hills about 1 000 feet southwesterly from the main dam. It is built of concrete of the general cross-section shown in Fig. 3. The maximum depth of the cut-off wall is 25 feet below the crest. Back of this dam an 18-inch cobble paving is laid for a distance of 14 feet, with a slope of 2 feet in that distance. Beyond the paving the earth is excavated on a descending grade of 1 per cent. until it intersects the original surface.

The crest of this dam is 300 feet in length, and at each end are retaining walls rising to a height of 10 feet above the crest, to protect the earth embankment necessary to complete the dam. For a distance of 75 feet from the dam there was originally laid a vitrified brick pavement on 6 inches of gravel concrete, with a cut-off wall at the lower end. The retaining walls at each end of the dam are extended along and terminate in a twist wall at the end of the paving. From the spillway dam a canal is built around the hill at the westerly end of the main dam and enters the creek about one-half mile below. At the dam it was 300 feet in width, but narrowed down to 40 feet in going the first 800 feet. The canal was made in part by excavation and in part by building embankments. The embankments are 12 feet in width at the top and thoroughly rolled and compacted. At a point about 1 000 feet from the spillway dam the canal makes a descent of about 20 feet. To overcome the abrading action of the water at this point, two flights of stone masonry steps with retaining walls of concrete on either side were built. The upper flight consists of 7 steps of 1 foot rise each, and of width varying from 1 to 3 feet. The lower flight consists of 13 steps of 1-foot rise each and of width varying from 1 to 4 feet. Between the two flights of steps, a distance of

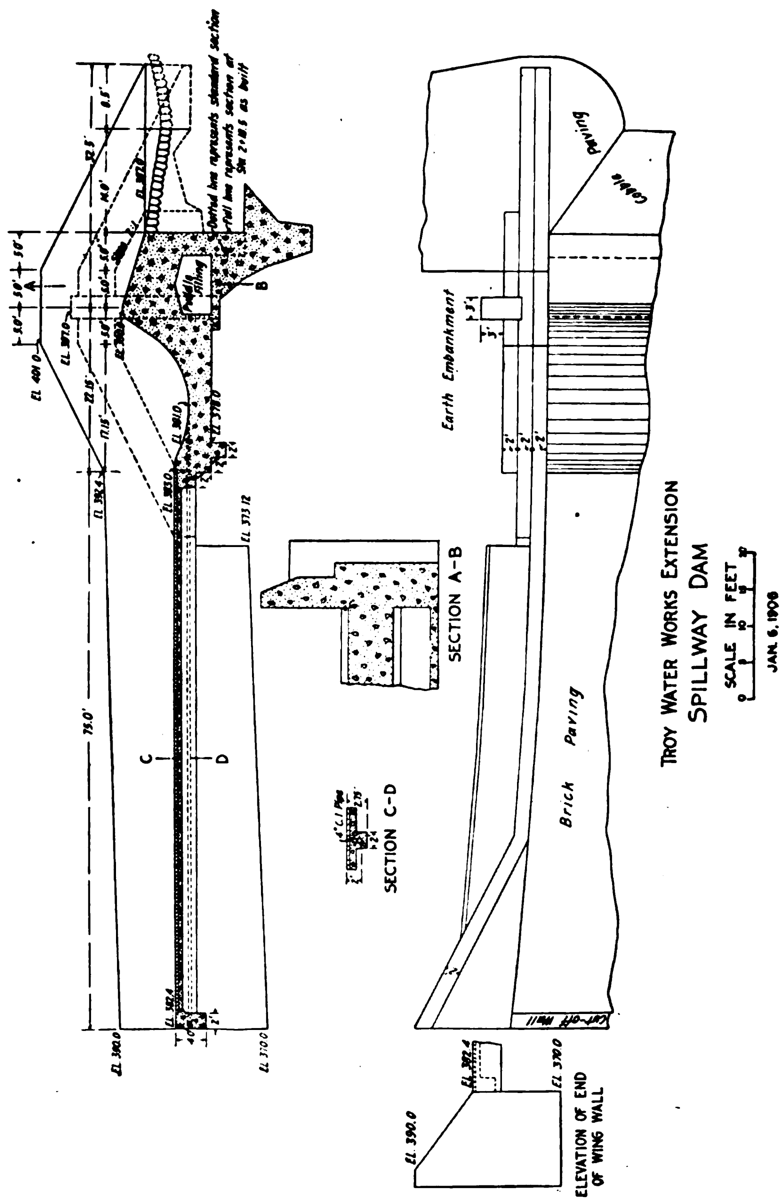

TROY WATER WORKS EXTENSION
SPILLWAY DAM
SCALE IN FEET
JAN. 6, 1906
SECTION A-B
SECTION C-D
Earth Embankment
Brick Paving
Cobble Paving
Cut-off Wall
Puddle Filling
Dotted line represents standard section
Full line represents section at
ELEVATION OF END OF WING WALL
EL. 390.0
EL. 370.0
75.0'

FIG. 3.

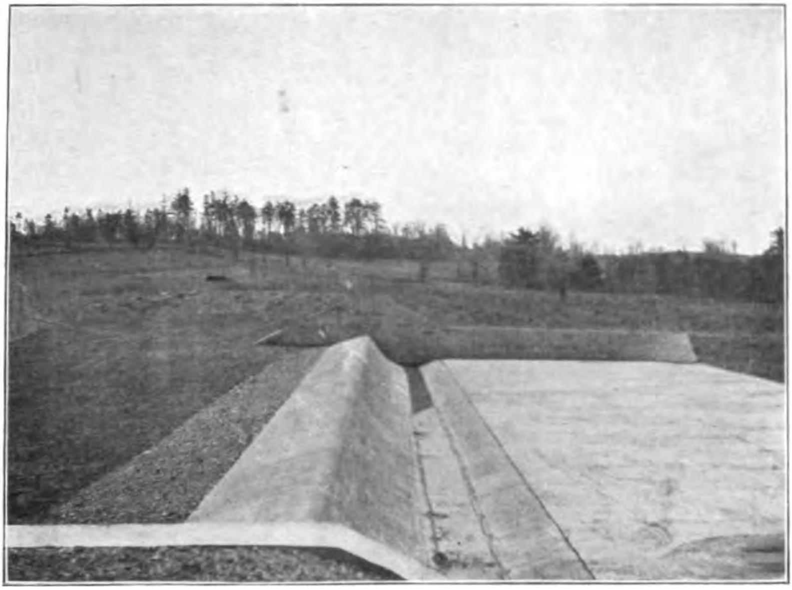


FIG. 1. Spillway Dam.

FIG. 2. Condition of Apron of Spillway Dam after the Flood of June 23, 1906.

134 feet, and for 50 feet above the upper and 50 feet below the lower steps, the bottom of the canal is paved with vitrified paving brick laid on 6 inches of gravel concrete. A view of this dam is shown in Plate II, Fig. 1.

On the afternoon of Saturday, June 23, 1906, a shower of unusual magnitude occurred on the drainage area, being especially severe in the southerly part along the Grafton Mountains. At this time the water in the reservoir had just reached the elevation of the crest of the spillway dam. The water in the reservoir had not begun to rise at 6 o'clock Saturday evening, but at 9 o'clock the next morning it had risen to a height of 14 inches above the crest of the spillway. As soon as the high stage of the water was learned, the gates of the " Permanent Opening " through the main dam were opened and the water drawn down, thus relieving the spillway of a large quantity of water, and undoubtedly preventing a great amount of damage. Measurements showed the flow into the reservoir between 6 o'clock at night and 9 o'clock the next morning to be at the rate of 2 200 cubic feet per second, equivalent to 32.7 cubic feet per second per square mile, while the maximum flow over the spillway was about 1 300 cubic feet per second. The effect of this rush of water through the spillway canal was very disastrous under the existing conditions. Before the water could be entirely diverted from the spillway, the cut-off wall and a considerable portion of the brick paving below the dam had been undermined and destroyed, the canal had been badly eroded, and the highway bridge abutments undermined, as shown in Plate II, Fig. 2.

The canal is being reconstructed and widened. The plans now being carried out contemplate the widening of the narrow part of the canal to twice its former width, and the introduction of more steps and rollways so as to eliminate the steep grades in the canal that previously existed.

The city supply is taken from the reservoir through a tunnel 5 900 feet in length, the entrance to which is located about 1¼ miles southwesterly from the main dam. The gate-house at the entrance to this tunnel contains two chambers, each having three 36-inch sluice gates arranged at different elevations, so that water can be drawn at 8 feet, 21.5 feet, and 35 feet from the surface.

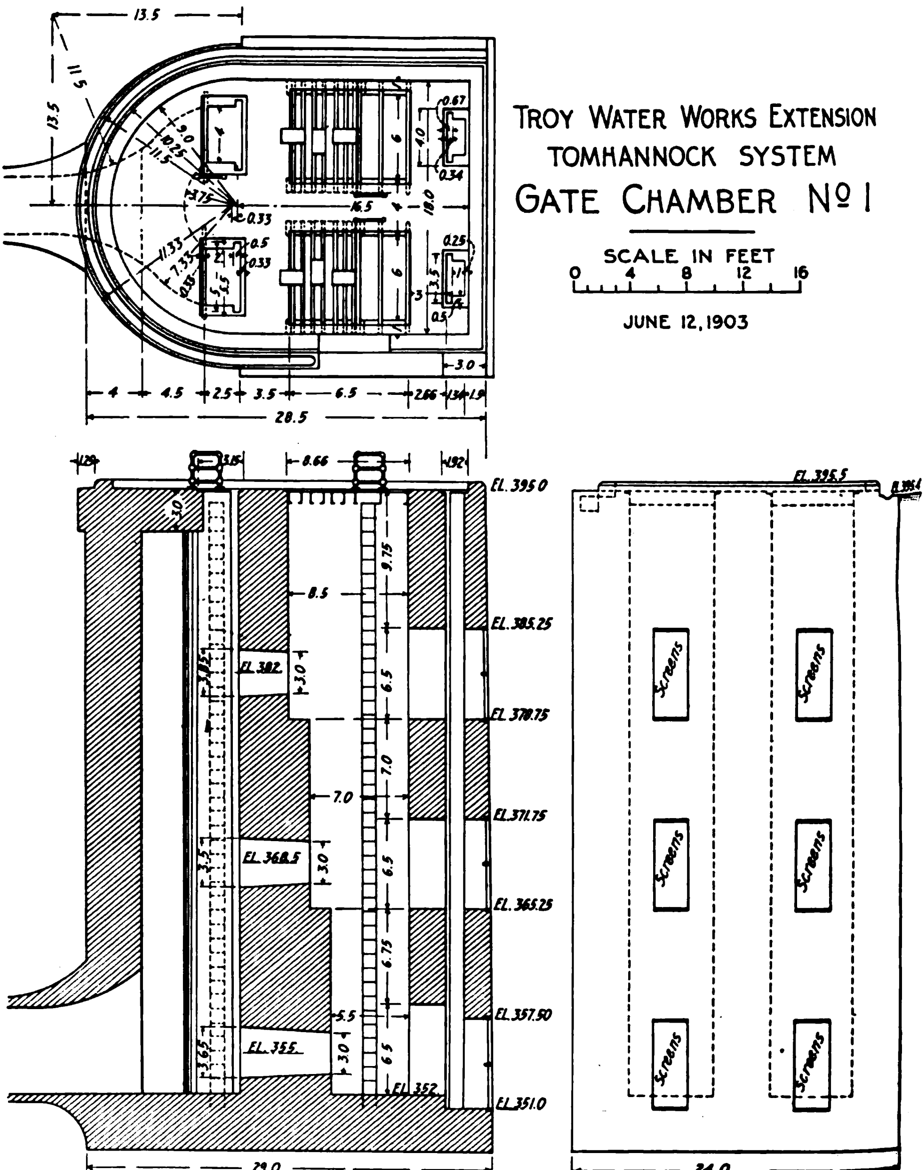
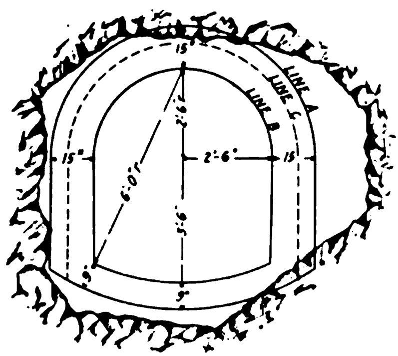
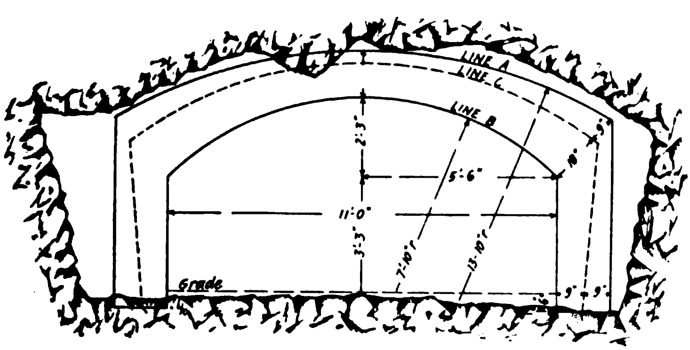

TROY WATER WORKS EXTENSION
TOMHANNOCK SYSTEM
GATE CHAMBER No 1
SCALE IN FEET
0 4 8 12 16
JUNE 12, 1903
Screens

FIG. 4.

Provision is made for stop planks on each side of the gates to assist in making repairs. The openings into the gate chamber are guarded by heavy bronze screens. (See Fig. 4, and Plate III, Fig. 1.)



FROM STA. 5+90 TO STA. 66+55
ROCK SECTION TAKEN AT STA. 49+75



FROM STA. 2+0 TO STA. 5+90
ROCK SECTION TAKEN AT STA. 4+20

TROY WATER WORKS EXTENSION
TOMHANNOCK SYSTEM
STANDARD SECTIONS FOR CONCRETE LINING
SCALE IN FEET
0 1 2 3 4 5
SEP. 12, 1903

FIG. 5.

The first 5 470 feet of the tunnel was originally intended to have a cross-section of about 4 × 6 feet, and be unlined, while the remaining 430 feet was to be about 6 × 11 feet to allow of laying two conduits through it. It was afterward decided to line the tunnel with concrete. The cross-section adopted for the small tunnel has a semi-circular arched roof and is 5 × 6 feet inside measurements, and for the large tunnel 5.5 × 11 feet inside measurements, with segmental roof. (Fig. 5.) At the junction of the large and small sections of the tunnel a gate chamber is built, containing the gates which control the flow into the conduits. Access is had to the large tunnel through a well 5 feet in diameter, built at the opposite end from the gate chamber. All the structures connected with the tunnel below the surface of the ground are of concrete of the same proportions and material as used in the dam. The gate-houses above the ground are built of brick.

The tunnel extends its entire length through what is known as Hudson River shale. Near each end it appears laminated and has occasional soft seams, but as the tunnel penetrates further into it the rock becomes harder and the laminations are not so distinct. The dip of this rock is very irregular.

Excavation was carried on through four shafts and the opening at the end toward the reservoir. Steam was used for drilling during the sinking of the shafts and the driving of a few feet of the tunnel each way from them, but the greater part of the work was done with compressed air.

Only one conduit has been laid, although provision has been made in the tunnel for the second when it shall be needed. It consists of about $6\frac{2}{3}$ miles of 33-inch riveted steel pipe, connnecting with the old 30-inch cast-iron force main at Twenty-first Street, in the former village of Lansingburgh. From this point to the lower Oakwood Reservoir the old force main was utilized. The conduit has a carrying capacity of from 15 000 000 to 18 000 000 gallons daily. Automatic air valves have been placed at all summits, and blow-offs at all low points. Manholes are provided every 500 or 600 feet in the steel conduit. It is also provided with seven gate valves placed at approximately equal intervals along the line. At five points these gate valves are placed at summits in the conduit line and, together with the air valves, are enclosed in small brick gate-houses. At the other two points the gates are in the street and the gate chambers are entirely underground. Access is had to these gate chambers through manholes built on the side. (Fig. 6.)

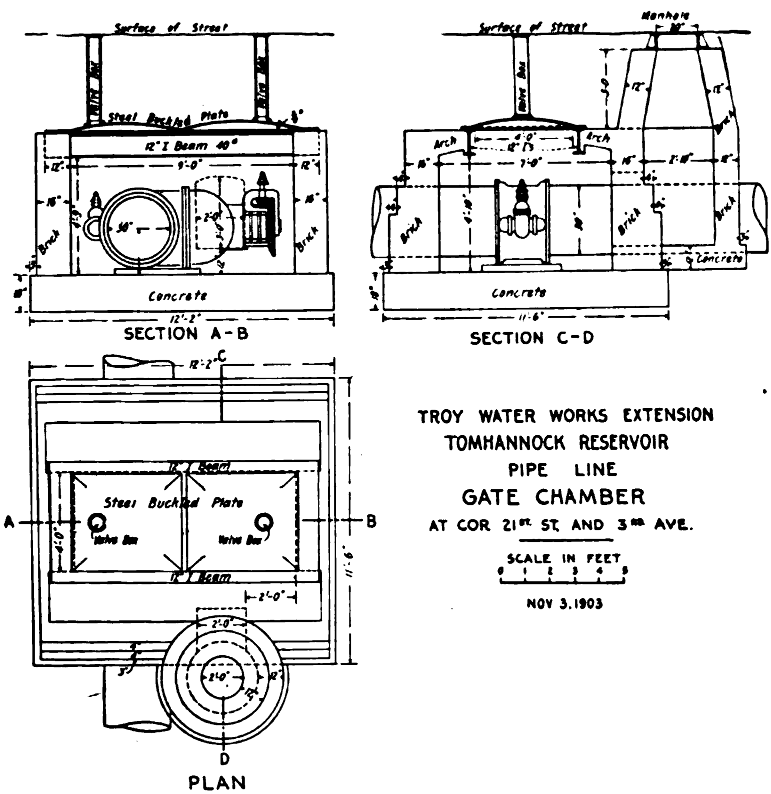


FIG. 6.

THE LANSINGBURGH SYSTEM.

The former village of Lansingburgh was annexed to the city of Troy in 1900. At that time Lansingburgh was supplied from three small reservoirs located just easterly of the village. It had also in the process of construction a masonry dam on the Deepkill and a 12-inch pipe line leading from it to the reservoir, to provide an additional supply. When the city of Troy came into possession of the work, Professor Raymond found that part of the new Deepkill dam rested upon rock foundation and part upon piles. After a careful examination of the location and conditions, he decided it would not be advisable to build the dam to its intended height, and consequently the upper 20 feet originally designed were never built.

The dam consists of a concrete core faced upon both front and back with coursed masonry. (Plate III, Fig. 2.)

What appeared to be a leakage under the dam was discovered near the center shortly after the work was completed. An attempt was made to check it by depositing clay and other materials above the dam, but this seemed to have little effect. While the quantity of water escaping was not large, a recent examination indicated some increase in volume, and that it was concentrated at a point a few feet to the right of the mud pipe near the center of the dam. The reservoir is of small capacity and only serves as a diverting reservoir.

The water-shed tributary to this system includes about 10 square miles of very hilly country lying adjacent to and westerly of the Tomhannock watershed.

QUALITY OF WATER.

The general quality of the water from all these sources is very good. During the month of January of this year, 1908, the Tomhannock water gave considerable trouble from algæ. The Quackenkill and Deepkill waters have been in use since 1902, and the Tomhannock since May of 1906. Prior to those dates most of the supply was pumped from the Hudson River into the low service reservoirs. The beneficial effect upon the health of the city of the introduction of the new supply is shown by the following table:

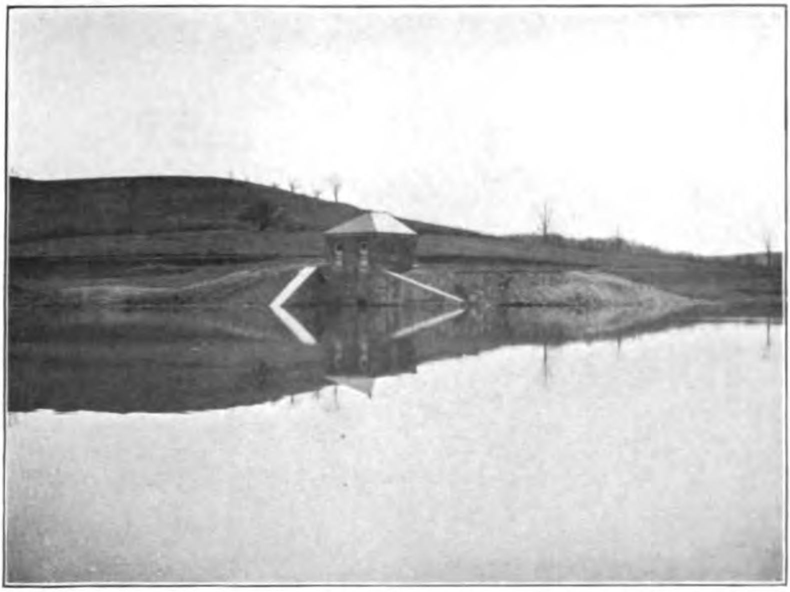


FIG. 1. Gate House at Entrance to Tunnel.

FIG. 2. Deepkill Dam and Reservoir, looking westerly.

Typhoid.				Deaths.			
Year.	Cases Reported.	Deaths.	Rate per 100 000.	Cholera Infantum.	Diarrhoea.	Diseases of Digestive Organs.	Children under 5 Years of Age.
1900	373	92	119.62	91	46	211	398
1901	176	43	55.91	56	45	178	370
1902	149	41	53.31	48	21	142	324
1903	110	23	29.91	19	10	97	315
1904	150	39	50.71	92	13	200	369
1905	160	39	50.17	70	14	184	394
1906*	91	27	35.11	24	12	113	317
1907	66	20	26.00	14	10	120	347

* Tomhannock water turned on May 21, 1906. Stopped pumping river water about May 1, 1906. Fifty cases and 15 deaths from typhoid fever reported before May 1, 1906. Average death-rate, 1901–1905, from typhoid fever, was 48.11 per 100 000. For 1906–1907 it was 30.56, or a reduction of 36½%.

COST.

The cost of construction of the different parts of the entire water works system to January 1, 1908, is as follows:

Original works and extension of Mains	$1 372 513.21
Original Lansingburgh Works	250 855.66
Deepkill System Lansingburgh Supply	150 507.67
Preliminary Investigations, Troy New Supply	25 545.18
Quackenkill System	265 916.75
Tomhannock System	1 337 138.12
Preliminary work on Filtration Plant	10 124.70
Total	$3 412 601.29

The plans for these new extensions were made under the direction of Prof. W. G. Raymond and the work was partially carried out by him. He severed his connection with the work in August, 1903, at which time the writer, who was the principal assistant engineer on the Tomhannock division, was appointed chief engineer.