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APPENDIX C

THE WATER SUPPLY OF NEW YORK CITY

A Brief History of Its Development from the Earliest Days to the Present Time

THE WATER SUPPLY OF NEW YORK

I

The Era of Springs, Wells and Pumps

The natural water supply of New Amsterdam and of New York City in its early years was derived from the ponds, brooks and springs which abounded on the Island of Manhattan before they were obliterated by the construction of streets and buildings. Some of the ponds afforded good fishing, and there are people living to-day who remember the existence of Sunfish Pond at Madison avenue and 32d street, Stuyvesant's Pond and Cedar Ponds, which as late as 1860 were favorite resorts for skating. (Haswell's Reminiscences, p. 541.) Most of these ponds, springs and streams which once sparkled in the landscape have been obliterated by modern improvements, but a few of them may still be observed in Central Park, and on the unbuilt portions of the upper end of the island.

The earliest artificial supply was derived from wells. The geological formation of the lower end of Manhattan Island was not favorable for obtaining good water however. The rock bottom of the island is covered with alluvial deposits which appear to have been permeated easily with water from the salt rivers; while at the same time the absence of a sewer system in the early history of the town permitted much unwholesome matter to find its way into the ground. When we read that "tubbs of odour and nastiness" were emptied in the street (Common Council minutes, 1700), it is not surprising that the wells were not only generally unpleasant to the taste, but, as we shall see, were also undoubtedly at times highly unsanitary.

The wells were of the kind in use in the old country at that period, surmounted by a long pole, balanced at one end with a counterpoise and having at the other end a chain or rope to which the bucket was attached.

As may well be imagined, the abundance of water from both the wells and the natural springs was subject to fluctuations on account of the weather. As a single instance, we may cite the experience of the troops on the upper part of the island in the year 1782. In September of that year, there was a great drouth which greatly inconvenienced and alarmed the troops. Lieut. Von Krafft of Von Donop's Hessian regiment, who kept a diary, records under date of September 3, of that year:

"This afternoon our foragers and sharpshooters returned. They had measured at the camp but could find no water on account of the great heat of this year which had dried up everything."

The next day men were sent out to dig wells, but they could not find anything but the faintest and poorest springs, even at a depth of 30 or 40 feet. "All the wells and ditches round about were dried up." On September 27, "There was a general complaint that all the men would die soon for want of water."

The earliest wells were private enterprises, dug within the owners' enclosures, although it was the custom for several neighbors to join in meeting the expense of a well which they used in common. The first public well was projected in 1658 during the incumbency of Peter Stuyvesant as Director General. At the meeting of the Burgomasters held on July 11, 1658, the "Burgomasters resolved to communicate with the General relative to having a public well made in the Heere straat." (Records of New Amsterdam, vii, 190.) The Heere straat was Broadway. The records do not clearly indicate whether the well was built at this time.

In 1677, under the English, the Common Council began the systematic construction of wells in the public streets. On February 16, 1677 (N. S.) they ordered that "Several Wells bee made in the places hereafter menconed (for the publique good of the Cytie) by the inhabitants of Each Streete where the said Wells shall bee made, Viztt:"— one in the street opposite the butcher Roeliff Johnson's house; one in Broadway, opposite Hendrick Van Dyke's; one in Smith street opposite John Cavileere's; one in the Water Side opposite Cornelis Van Borsum's; and one in the back yard of the City Hall at 73 Pearl street.

On September 10, 1686, the Common Council ordered nine more wells to be built. These were built of stone, "one halfe of the Charge of them to be borne by the inhabitants of every Streete proportionably and the other halfe by the Citty." One or two citizens were appointed to have charge of each well. The practice of dividing the expense between the beneficiaries and the city was continued as long as the public well system existed.

Some of the wells at the end of the 17th century became well known by name and their locations have been pretty well identified. Among them were the following:

Name	Location
De Riemer's Well	Whitehall street near Bridge.
Wm. Cox's Well	Near Stadt Huys at head of Coenties Slip.
Ten Eyck and Vincent's Well	Broad street between Stone and South William streets.
Tunis de Kay's Well	Broad street, north of Beaver street.
Frederick Wessel's Well	Wall street, west of William street.
Rombout's Well	Broadway near Exchange Place.
Suert Olpherts' Well	Near last mentioned.

Many other wells were dug in later years and may be identified by reference to the Common Council minutes and maps.

Pumps came into fashion in the first half of the 18th century and rapidly displaced the old well-sweeps. After the city had bought its first fire-engines mentioned hereafter, it became particularly necessary to maintain the water supply, and in November, 1741, the Assembly enacted a law (chapter 719) entitled "An act for mending and keeping in repair the publick wells and pumps in the City of New York." This law provided for the appointment of Overseers of Wells and Pumps, the levying of taxes for their maintenance, etc. Disorderly persons frequently cut the ropes of the wells, broke the pump-handles and did other mischief of a similar nature, and the same law provided penalties for such offences.

Sometimes a public spirited citizen would give a well and pump to the city if the corporation would agree to keep it in repair. Henry Rutgers made such an offer to give a well and pump in the Out Ward in December, 1785. But generally the expense of the well and pump was jointly borne by the city and the neighborhood.

To give an idea of how these matters were managed at the beginning of the American period after the evacuation of New York by the British we may cite a few transactions of the Common Council.

On August 26, 1784, for instance, the inhabitants of Frankfort street petitioned for a well and pump and it was granted. The city's share of the first cost of this well and pump was £39:16:15. The cost of digging a well varied according to circumstances. In October, 1784, Silvanus Seely was paid £4:11:3 for digging a well in the South Ward, but Phil Arcularius was paid £40:19:6 for digging one in Frankfort street in 1785. On November 11, 1784, the Common Council authorized a well in Catharine street and voted to contribute £7 toward it, later adding £8 more. In July, 1785, the inhabitants of Greenwich street were given permission to sink two wells at their own expense, the Corporation furnishing the pumps. In a similar way in August, 1785, the inhabitants of Chambers street were permitted to make a well and stone it at their expense, the pump being at the expense of the Corporation.

These street pumps were landmarks, very much like street monuments today, and formed convenient points of reference. For instance, when the Common Council decided in May, 1785, to grade Broadway southward from Exchange Place, it voted that there should be a "gentle descent from the upper pump to the Bowling Green." The "upper pump" was at Broadway and Exchange Place.

On April 5, 1785, Wm. Smith contracted to keep the wells and pumps in repair at the rate of £140 per annum; but Smith's job was not a profitable one; the number of pumps and wells was rapidly increasing and the cost of repair mounting with equal pace. The Common Council, therefore, devised the system of electing two Overseers of Pumps and Wells for each ward; but evidently these new functionaries occasionally neglected their duties, for on September 16, 1789, the Common Council "Ordered that whenever the Overseers of the Public Wells & pumps neglect or refuse to do their Duty that the Ald^{n} & Assist of the Ward direct the necessary Repairs; lest by the Want of Water from the public Wells and pumps the City may be endangered in case of Fire."

During the year 1789 the Common Council approved for payment bills for repairs to wells and pumps amounting to £408:15:5½.

The Tea Water Pump

The water from the wells in the lower part of the City served well enough for ordinary domestic uses, except drinking, but as we said before was brackish and disagreeable to the taste. Some time during the first half of the 18th century, however, a spring of fresh water on the north side of the present Park Row, between Baxter and Mulberry streets, began to attract popular attention. This spring was probably supplied by the same underground sources that supplied the neighboring Fresh Water or Collect Pond. This water was so desirable for making tea that it became famous in history as the Tea Water Pump. Indeed, it became a regular landmark and has left its impress on the real estate records of that neighborhood. The property described in deeds as the "Tea Water Pump" was a parcel 75 feet by 120 feet on the north side of Chatham Street (Park Row), beginning 28 feet east of Baxter Street. A deed containing a reference to it as the "Tea Water Pump", is dated June 1, 1795, (liber 170 of deeds, page 7,) and there is another of the same description in liber 169, page 334. The description there is: "Which said three lots, pieces or parcels of ground are known by the name or description of the 'Tea Water Pump' or the Estate of Gerardus Hardenbrook, Sr., deceased." The same description or a similar one is found in later deeds, among which are those to be found in liber 55, page 395; liber 65, page 102; liber 66, page 454, and liber 68, page 225. The property was afterwards sold in parts. Gerardus Hardenbrook left a will dated 1755 and recorded in liber 33 of wills, page 533. About 1796 William C. Thompson, a grandson, acquired the majority interest and is undoubtedly the Mr. Thompson referred to hereafter and in Valentine's Manual for 1856, page 438. Abraham Shoemaker referred to hereafter and on the same page in Valentine's Manual afterwards acquired at least the central part of the 75 foot tract from Thompson and others. Valentine's authority for designating the property as No. 126 Chatham Street (the old name for Park Row) does not appear. No. 126 Chatham Street as shown in deeds of the middle of the nineteenth century would be east of Mulberry Street. If there was a numbering of the street that would bring No. 126 near Baxter Street, it has not been found. The site of the pump, however, is well established by the deeds referred to.

The first mention of the Tea Water spring is in the diary of Professor Kalm, a learned and observant man who visited the City in 1748. He says:

"There is no good water to be met with in the town itself; but at a little distance there is a large spring of good water, which the inhabitants take for their tea and for the uses of the kitchen. Those, however, who are less delicate on this point make use of the water from the wells in town, though it be very bad. The want of good water lies heavy upon the horses of the strangers that come to this place for they do not like to drink the water from the wells of the town."

Shortly before the Revolution the Tea Water spring and its vicinity were made into a fashionable resort at which beverages adulterated with pure water could be obtained. A high pump with a prodigiously long handle — judging from pictures — was erected over the spring, and the grounds around it were laid out in ornamental fashion and called the Tea Water Pump Garden.

The tea water from this source was so popular that not only did people come to the pump for it, but it was delivered around town in carts which looked something like modern sprinkling-wagons without the sprinkler. The distributors of this water were called "tea-water men", and became so numerous and active that on June 16, 1757, the Common Council had to pass "A Law for the Regulating of Tea-water men in the City of New York."

At length, the big pump projecting over the street and the crowd of water-wagons gathered there became so great an obstruction to the street that in 1797 a petition for an abatement of the nuisance was presented to the Common Council. The committee to whom the subject was referred reported as follows:

"The committee on the subject of the petition complaining of the obstruction in Chatham street caused by the Tea Water Pump delivering its water in the street and by the water carts being drawn up across the street when about to receive water, report that they have viewed the premises and find the matters and things set forth in the petitions to be true. That the committee have maturely considered the premises and are of opinion that the said obstruction may be removed at no great expense to Mr. Thompson, the present occupant and part proprietor of the premises, by causing the spout of the said pump to be raised about two feet and by lengthening it so as to deliver the water at the outer part of the paved walk, which would permit passengers to pass under without inconvenience; and if the water carts were ordered to draw up abreast of the spout near the gutter and receive the water in rotation it would remove the obstruction in the street. The committee recommended also that the sidewalks in that vicinity be paved."

The recommendations of the committee, except that relating to paving, were adopted, the paving being postponed for the time being.

In 1805 Abram Shoemaker petitioned to the Common Council for leave to erect works so as to conduct the water of the late Tea Water Pump into carts in Orange street (now Baxter street) as they formerly took the water from Chatham street, by which inconvenience would be avoided, and the petition was allowed during the pleasure of the Common Council.

It is amusing, in these modern days when the City authorities are concerning themselves with a great aqueduct system capable of delivering 500,000,000 gallons of water a day to the City, to read of the Common Council passing solemn resolutions about the length of the Tea Water Pump spout.

II

THE PRIMITIVE FIRE DEPARTMENT

While the primitive conditions of the water supply just described existed, there was an equally primitive system of fire extinguishing. When one recalls the inflammable character of the earliest buildings in New Amsterdam and the inadequate means for fire protection, it is a wonder that the infant city was not destroyed several times.

During the Dutch regime there were a few stone store-houses; and several brick houses belonging to the more wealthy residents; but most of the buildings were of wood. To add to their inflammability, the roofs of a majority of the early houses were thatched with straw or reeds, and their chimneys were made of wood or of interwoven twigs plastered with clay.

No machine for projecting water upon a fire existed in New Amsterdam. If a fire broke out, a bucket brigade was formed. Men stood in single or double file between the fire and the nearest source of water, and passed buckets filled with water to the scene of the conflagration, sending the empty buckets back by the second line of men if there was a second line.

Twenty-two years after New Amsterdam was settled, the occurrence of fires in two houses, owing to carelessness in the care of fireplaces and chimneys, aroused the authorities to the necessity of organizing means of protection. They therefore ordered on January 23, 1648, that from that time forward no more wooden or platted chimneys should be erected between the "fort and the fresh water," — that is to say, between the sites of the present United States Custom House and the Tombs Prison,— and four Fire Wardens were appointed to see that the ordinance was enforced. The fines for violating this ordinance were to be devoted to the purchase of fire ladders, hooks and buckets, to be procured in Holland at the first opportunity. In 1657, the following notice was given:

"Notice is hereby given, that for the purpose of preventing calamities by fire, they long since condemned all flag roofs, wooden or platted chimneys within this City, and to that end they appointed Fire Wardens and Inspectors of Buildings, which ordinance has been and is at present neglected by the inhabitants and in consequence thereof several fires have occurred and more are to be apprehended — yes, indeed, to the entire destruction of the City,— so that it is necessary to make provision in the case. To which end, the Director General and Councillors do ordain that all flag roofs, wooden chimneys, hay barracks and hay stacks shall be taken down and removed within four months after the publication of these presents, under the penalty of twenty-five guilders for every month's delay; and this penalty shall be claimed for every house, great or small, with reed roof, hay barrack or hay stack, or wooden chimney within the walls of the city. Hen-houses and hog-pens shall be included."

But the safety of the City was not to be secured by ordinance alone. Fire-extinguishing apparatus was necessary. Therefore, in December, 1657, the Burgomasters and Schepens adopted the following order, reflecting the custom of the old country in that matter:

"Whereas, in all well-regulated cities it is customary that fire-buckets, ladders and hooks are in readiness at the corners of the streets and in public houses for time of need, which is the more necessary in this City on account of the small number of stone houses and many that are built of wood; therefore it shall be required immediately that for every house small or large there shall be paid one beaver or eight guilders in seawant,* out of which funds shall be procured from fatherland 100–150 leather fire-buckets; and we shall also have made some fire ladders and fire-hooks. In order to maintain the same in good order, there shall afterwards be a yearly demand of one guilder for every chimney in a house."

It was proposed that instead of sending to Holland for the buckets they be made in the City, and on August 1, 1658, four shoe-makers of the town,— an important as well as necessary craft at that time,— were requested to meet the authorities and consider the matter. The contract was tendered to Coenraet Ten Eyck, but he declined it. Pieter Van Haalen declared that he had not the materials with which to make the buckets. Reinout Reinoutsen, however, undertook to make 100 buckets and Arian Van Laar 50 buckets between that date and All Saints Day (November 1). The buckets were all to be made of tanned leather in the most complete manner, and for each they were to be paid six

* Wampum.

guilders and ten stuyvers, half in beaver-skins and half in wampum. By January 20, 1659, 125 of the 150 buckets were finished, taken to the City Hall or Stadt Huys at No. 73 Pearl street and numbered.

It was ordered that the 150 be distributed as follows, the total assignments really totaling 152:

From 1 to 50.	In the City Hall		50
From 50 to 62.	Daniel Litscho		12
From 63 to 74.	Abraham Planck's house in Smith's valley		12
From 75 to 86.	Joannes Pietersen Verbruggen		12
From 87 to 98.	Paulus Leenderzen vander Grift		12
From 99 to 110.	Nicasius de Sille in the Sheeps pasture		12
From 111 to 122.	Pieter Wolferzen van Couwenhoven		12
From 1 to 12.	Jan Janzen the Younger		10
From 13 to 24.	Hendrick Hendrickzen Kip, the Elder		10
From 25 to 36.	Jacobus Backer		10

David T. Valentine, in his Manual for 1856 at pages 253–254, locates the above places with reference to modern streets as follows: Litscho's tavern in Pearl street near Wall; Planck's (or Verplanck's) house in Pearl street near Fulton; Verbruggen's in Hanover Square; Van der Grift's in Broadway nearly opposite Exchange Place; DeSille's on the southeast corner of Broad street and Exchange Place; Van Couwenhoven's on the northwest corner of Whitehall and Pearl streets; Kip's on the north side of Bridge street between Whitehall and Broad; and Backer's on the east side of Broad street between Stone and South William.

Under the English regime the pump, well and bucket system was somewhat elaborated in detail, but remained the same in principle for many years. In 1687 every inhabitant who had a house with two chimneys was required to provide one fire-bucket for his house, and if he had more than two hearths he was required to keep two buckets. Bakers were obliged to have three buckets and brewers six. At an alarm of fire, everybody who had buckets ran to the scene, and it was inevitable that their buckets should get mixed up. It was therefore customary after a fire for the Town Crier to give notice of a general exchange of buckets which had gotten into the wrong hands.

As the eighteenth century advanced, the inadequacy of the "bucket brigade" began to impress itself on the citizens as the news of Newsham's pumping engines in England became better known, and on October 17, 1730, the sentiment in favor of the introduction of fire-engines into this country took shape in an act passed by the Assembly (chapter 550) which contained the following declaration among others:

"The Repairing of the said City Hall.* Repairing and Enlarging the Goals and Prisons, Erecting of Watch-houses and defraying other Necessary and Contingent Charges for the keeping of the Peace and Preserving good Rule and Government within the said City, and the purchasing of two fire Engines which are greatly wanted for the better Securing the said City from the Danger & accidents of fire, will amount to a Larger sum of money then the Yearly Revenue of the said Corporation can Supply."

Therefore it was enacted that the City be authorized to raise money for those purposes by taxation. This legislation was promptly followed up by an ordinance of the Common Council, adopted May 6, 1731, levying the necessary tax. On the same day, the Common Council adopted the following:

Resolved that this Corporation do with all Convenient Speed Procure two Compleat fire Engines with Suction and Materialls there unto belonging, for the Publick service. That the Sizes thereof be, of the fourth and sixth sizes of Mr Newshams fire Engines, and that Mr Mayor, Alderman Cruger, Alderman Rutgers and Alderman Roosevelt or any three of them be a Committee to Agree with some proper Merchant or Merchants to send to London for the same by the first Conveniency and Report upon what Terms the said Fire Engines &c: will be delivered to this Corporation.

On June 12, 1731, the committee reported that Stephen De Lancey and John Moore were willing to send to London by the ship Beaver for two engines of Mr. Newsham's "New Invention of the fourth and sixth Sizes, with suctions, Leathern Pipes and Caps and Other Materialls thereunto belonging," charging the City 120 per cent advance on the invoice price; and the committee was authorized to order the engines accordingly. The commission was promptly executed and in a few months the novel machines were in the City. On November 18, 1731, the Common Council ordered that provisions be made for keeping hooks, lad-

* The second City Hall, in Wall street at the head of Broad street.

ders, buckets and the fire-engines in convenient places, and on December 1 workmen were employed to fit up a convenient room in the City Hall for the engines. A couple of weeks later Alderman Johannes Hardenbroeck and Assistant Alderman Gerard Beekman were appointed a committee "to have the Fire Engines Cleaned and the Leathers Oyled and put into Boxes that the same may be fitt for Immediate use."

The engines thus procured consisted each of a wooden box tank on wheels, upon which was mounted a suction pump. One of them was operated with a long handle-bar by men standing on a platform on top of the tank. See Stoutenburgh's sketch, plate 46. The other was operated with a long crank-handle protruding from the side of the tank by men standing on the ground. Sometimes the water was conveyed to the engine by the bucket brigade and forced through leather hose upon the fire; sometimes the engine was placed close to a pump so that the water could be pumped into the tank; and sometimes a suction hose was used to draw water from a well.

The next important step in the evolution of the fire protection system was the establishment of a regular Fire Department. This was done pursuant to an act (chapter 670) enacted December 16, 1737. This law provided that the Common Council could elect a sufficient number of "Strong able Discreet honest and sober men" not exceeding 42 in number, who should be ready at a call by either night or day to use the fire-engines and other tools and instruments for extinguishing fires." It was provided that these persons "shall be Called the ffiremen of the City of New York." These were in addition to the engine-men who were regularly employed. The firemen were exempt from jury and militia duty and from serving as Constables and Surveyors of Highways. The same law provided that when a fire broke out, the Sheriffs, Constables and Marshals should "immediately repair to the place where the said ffire shall happen with their Rods, Staves and other Badges of their Authority," to aid the firemen and to cause other people to do the same, in extinguishing the fire and protecting goods from theft.

In such humble ways the great Fire Department of the City of New York, now the finest in the world, began. It would require a volume in itself to follow the growth of the department through the stage of hand-pumping engines to steam, chemical and automobile engines and the high pressure water system which represent its highest development to-day. But enough has been said with respect to water supply for domestic use and fire extinguishing purposes to indicate how poorly equipped the early City was for the prevention of disease and fire by water.

III

EARLIEST PIPE LINE PROJECTS

Christopher Colles' Water Works

The earliest proposal to supply the City with water conducted underground through pipes was made by Christopher Colles just before the War of the Revolution.* On April 22, 1774, he proposed to erect a reservoir near the Collect or Fresh Water Pond where he had reason to believe that he could get an adequate supply of fresh water, and to distribute it through the streets by means of pipes made by boring a hole longitudinally through the trunks of small trees. The water was to be pumped into his reservoir from a well by a steam-engine, and to flow by gravity through the pipes.

When the proposition first came to the Common Council it was so novel that there was uncertainty as to its practicability and advisability. The Council therefore put the subject off and considered it for three months. When it came up for action on July 21, opinion was still divided; but the majority were in favor of the experiment and voted 8 to 2 to undertake it. At the same time, they voted to issue notes to the amount of £2,600 for the undertaking. Subsequent issues brought the amount up to £9,100.

These notes were about the size of the "shin-plasters" of the Civil War period, being about $2^1/_3$ by 4 inches in size. A specimen, of which we have a copy before us, bore on its face the following inscription:

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* Colles was born in Dublin on May 9, 1739, and landed in Philadelphia, Pa., August 10, 1771. There is a biographical sketch of him with erroneous dates by John W. Francis in "The Knickerbocker Gallery," 1855, and there is a portrait of him by Jarvis in the New York Historical Society. Colles was a man ahead of his time. He conceived many ideas for which others received credit. As early as 1784 he petitioned to the Legislature to connect the waters of Lake Ontario with the Hudson river by a canal through the Mohawk valley. He died October 4, 1816. Francis is wrong in saying that he was buried in the old Hudson street cemetery (now Hudson Park). We are informed by Mrs. Robert W. de Forest, a collateral descendant of Colles, that his grave is in St. Paul's churchyard. See note on page 454.

NEW YORK WATER WORKS
(No. 1911.)

This Note shall entitle the Bearer to the Sum of
Four Shillings
current money of the Colony of New York, payable on Demand, by the Mayor, Aldermen and Commonalty of the City of New York, at the office of Chamberlain of the said City, pursuant to a Vote of the said Mayor, Aldermen and Commonalty, of this Date. Dated the Sixth Day of January, in the Year of our Lord One Thousand Seven Hundred and Seventy-six.

By order of the Corporation. N. Bayard
J. H. Cruger

On the back of the note was the picture of a pumping engine and two fountains.

It cannot be said that the Common Council proceeded with rash haste in this enterprise, for when Augustus and Frederick Van Cortlandt offered to sell to the City a site for the reservoir on the east side of Great George street, now Broadway, between Pearl and White streets, at the rate of £600 an acre, they personally went to the new well sunk on the property and tasted the water. One can almost imagine these dignified gentlemen going to that then remote spot on the west side of the Fresh Water Pond, adjacent to the marshy Lispenard Meadows abounding in bull-frogs and game birds in season; sipping the water from the new well like connoisseurs of some rare vintage, smacking their lips, looking at each other wisely, and finally pronouncing a favorable verdict. Concluding "the same to be of very good quality," they accepted the Van Cortlandts' offer and told Mr. Colles to go ahead with his work.

On August 29, 1774, the Common Council appointed a committee of eight members to superintend the construction of the works, and in November they contracted with Isaac Mann and Isaac Mann, Jr., of Stillwater, now in Saratoga county, to furnish 60,000 linear feet of pitch or yellow pine timber for the making of the pipes. The original contract, which is on file in the Document Room of the City Clerk in the Municipal Building, provided that the logs should be from 14 to 20 feet long and that one-fourth of them should be 12 inches in diameter at the small end of the log "exclusive of the sap thereof" and three-fourths 9 inches in diameter at the small end, and all should be "streight and free from shakes and large knots." The contractors were to deliver one-third of the timber on July 1, 1775, one-third on August 1, and one-third on October 1, and were to receive therefor £1,250.

While waiting for the timber for the pipes, Mr. Colles went ahead diligently with the construction of his well, reservoir and pump-house on a slight eminence just west of the present Tombs Prison and Criminal Courts building. The reservoir had a capacity of 20,000 hogsheads. The well was 30 feet in diameter. And the engine pumped 200 gallons of water 52 feet high per minute. After the war, Josiah Hornblower was paid £12 for "attending and examining and making report of the fire-engine for the water works about to be erected in 1775." The pump-house was a substantial structure, roofed with pantiles — curved tiles, laid alternately with the convex and concave sides upward — and the bills for iron-work, braziers' work, rope, etc., which the City had to pay after the war, indicate that all the works were built in a durable manner.

But while the water-works were being built, and apparently before any of the wooden pipes had been laid, the City was thrown into a turmoil of excitement by the news from Lexington and Bunker Hill. The work of construction, however, continued into 1776; but with the critical events of that year, the project was completely interrupted, never to be renewed. Mr. Colles with his family fled from the City and endured great privations, rather than submit to the British rule; and during the period of the war his water-works became totally ruined.

After the war, he returned to New York and soon after the Common Council assembled he presented a petition for the payment of moneys due him. His original memorial, dated October 27, 1784, is in the Records Room of the City Clerk in the Municipal Building. It has never been published and we give it herewith as a document of peculiar historical interest:

To the Honourable the Mayor, Aldermen and Common Council of the City of New York.

The Humble Memorial of Christopher Colles of said City Engineer Sheweth

That your Memorialist in the year 1774 presented a proposal to this honourable corporation for erecting works for supplying this city with water for the sum of eighteen thousand pounds.

That this honourable board after sufficient enquiry concerning the practicability of the design Resolved to agree with the said proposal & directed your memorialist to proceed in the execution of the work.

That your memorialist did accordingly proceed in the execution of the work & erected a Reservoir capable of containing twenty thousand hogsheads of water; dug, walled cover'd & completely finished a well of thirty feet diameter at the inside, from which he pumped by means of a steam engine which he also erected, Two hundred gallons of water, fifty two feet high perpendicular per minute, into the said reservoir.

That previous to the said resolve of the corporation your memorialist furnished them with an estimate of the expence of the different parts of the work, agreeable to which the part executed amounted to the sum of Three thousand six hundred pounds.

That the several sums advanced for the prosecution of the work amounted to Three thousand pounds, consequently, that there remains a ballance of six hundred pounds, One hundred & fifty pounds of which is due to different artificers for work & and the remaining Four hundred & fifty pounds is due to said Colles.

That your Memorialist in common with other citizens, friends of society & the interest of mankind, suffer'd the most poignant afflictions during the late war, & with the utmost difficulty procured the common necessaries for his family; & being now returned to the city, where he hopes to devote the remainder of his days in promoting the welfare of the city & country, he prays the corporation to use their endeavors to pay him the ballance above referred to, by which he may be enabled to support his numerous family in credit, & in some degree of comfort.

May it therefore please your honours, to take the premises into consideration, & grant him that Justice & Assistance, which to your judgment shall seem meet.

CHRISTOPHER COLLES

The Common Council did not at first act on this petition and on July 20, 1785, Mr. Colles begged the Board again to give him relief declaring that "his distresses are of such a poignant nature as to compel him to request some (tho' small) yet present assistance." (Original in Records Office of City Clerk, Municipal Building.) In August, 1785, the Council granted him £100 on account.

On November 23, 1785, he appealed to the Council for £50 more on account. This petition gives an interesting indication of Mr. Colles abilities. He said that he was desirous of applying part of the money "so as to enable him to support his family with credit," and to that end "he has erected a horse-mill and other works for the purpose of carrying on in this City the Manufacture of Fig blue, which manufacture he proposes to have carried on by his eldest son in case he shall be engaged in the prosecution of the Navigation of the Mohawk river." He said that he had already made and sold to grocers and others this product "which upon trial is proved to be fully equal in quality to any imported, altho' he can afford to sell it at less price."

The foregoing petition was granted and he was given the £50 asked for. Finally, on January 16, 1788, he consented to accept £150 in settlement of all demands. Meantime, the corporation had allowed him to use the room at the Exchange to give lectures on gunnery, drawing, mathematics, etc., which indicate that the delay and apparent penuriousness in paying him were not due to any underestimate of his character and abilities.

Projects of Ogden, Livingston and Rumsey

While the Common Council was still paying bills for the dead enterprise of Mr. Colles, it received successive propositions of a similar nature from other sources.

The first, dated March 24, 1785, came from Samuel Ogden. The original document, which is in the Document Room of the City Clerk in the Municipal Building, reads as follows:

To the Mayor, Aldermen and Commonalty of the City and County of New York in Common Council.
The Memorial of Samuel Ogden of said City
Sheweth

That as the late War hath totally ruined the Fire Engine and Water Works which were erected for the purpose of Supplying this City with Water, your Memorialist begs leave to propose to the Consideration of the Corporation the following proposals. That he will at the expence of Himself and Associates erect and establish at or near the Place where the former one was Built* which shall supply the Reservoir with 144,000 Gallons of Water per day, and that He will in pipes lead and conduct the same water through the streets of This City, in such manner as shall be hereafter explained Provided such Compensation and reward be secured to Your Memorialist and his Associates as shall hereafter be agreed on. On the Subject of which Your Memorialist begs a Conference at such Time and Place as You may think proper to appoint.

SAML. OGDEN

New York, March 24th, 1785.

This petition came before the Common Council April 5, and Aldermen John Broome and William Neilson and Assistant Alderman Daniel Phoenix were appointed a committee to confer with him.

Before any conclusion was reached on this proposition, and on January 30, 1786, Chancellor Robert R. Livingston, who later encouraged Robert Fulton in his steamboat invention and who had a considerable interest in mechanical engineering himself, made a proposition to the Board to contract to convey fresh water to the City. Aldermen John Broome and Jeremiah Wool and Assistant Aldermen William Malcom, George Janeway and Abraham Van Gelder were appointed a committee to confer with him.

On February 6, 1786, both committees made reports, but consideration was postponed; and on February 15, Chancellor Livingston and John Lawrence, who was associated with him in his proposal, appeared before the Board in support of their proposals. On the latter date, the Board decided to return the proposals previously received and to advertise for new ones, to be received prior to January 1, 1787. The latter date was subsequently changed to April 20, 1786.

On April 19, 1786, the day before the date set for opening proposals for the water works, a strong sentiment was shown at the Common Council meeting against letting out the water supply to private enterprise. The Clerk reported that he had received three sealed packets containing proposals to erect the water works; but the Board ordered that they remain unopened until further orders. Meanwhile, the Aldermen and Assistants were requested

* The word "works" evidently omitted.

" to set on foot in their respective wards representations to this Board in writing and subscribed by the citizens in order more fully to ascertain their sense whether the Corporation ought to grant to individuals the privilege of supplying the City with water or whether the same ought to be undertaken by the Corporation and that the monies necessary for the purpose should be raised by a tax on the citizens."

Nothing, however, came of these projects and the matter dragged along almost two years without any further progress or further movement on the part of the citizens. On February 27, 1788, a large number of inhabitants represented to the Common Council " the inconveniencies which arise from the present mode of supplying the City with water " and prayed the Board " to adopt such Measures for supplying it with Water by means of Pipes agreable to a Plan or proposal set on foot by Christopher Colles or such other Plan as to the Board shall appear most expedient." But this petition was as ineffectual as its predecessors. The fact was, that the City was passing through a period of reconstruction after the war. The minds of the members of the Common Council and the financial resources of the corporation were engaged to the limit with other municipal improvements — the laying out of streets, the laying of pavements, the building of sewers, the remission or settlement of rents, and the straightening out of the numerous affairs tangled by the interruption caused by the war. It is not surprising therefore that the water-works improvement was held in abeyance.

On January 30, 1789, the Common Council received a letter from Benjamin Wynkoop, Levi Hollingsworth and G. Turner, the Corresponding Committee of the Rumsian Society of Philadelphia, stating that Mr. Rumsey had invented an engine superior to any other for supplying towns with water; that he had applied to the Legislature for a patent; and when it was granted, the Society would come forward with proposals for supplying New York with water by contract. The Board received the suggestion with every encouragement, but declared that it had no moneys which it could use for the purpose at that time.

During the next nine years, the subject was taken up fitfully by the city government and by individuals, with no better results.

In February, 1792, Zebrina Curtis and others made proposals which were referred to the Street Committee and were heard of no more. In March, 1795, Amos Porter made a like proposal. This year, Samuel Crane submitted a specific plan to lead water from the Tea Water Pump through Roosevelt street; and Benjamin Taylor advanced still a different project. In February, 1796, the Common Council directed a committee to advertise for proposals; and in December, Dr. Joseph Brown and associates offered to supply the City with water through pipes. Again in 1797, sealed proposals were advertised for, and seven or eight applications were received. One of them was from Christopher Colles. They were referred to a committee and lost sight of. In 1798, R. J. Roosevelt and Judge Cooper of Otsego made new applications; and so did Dr. Joseph Brown. The latter was so novel at that time that it is entitled to consideration under a separate head.

Bronx River Suggested in 1798 as Source of Water

The originality of Dr. Joseph Brown's project in 1798 lay in the fact that he proposed to go to the Bronx river for the water, and this was apparently the first suggestion of going off the Island of Manhattan for this purpose. On December 17, 1798, the committee of the Common Council which was appointed to investigate this suggestion reported in its favor, and made three specific recommendations:

First, that William Weston, who had been the engineer for the canal companies in this State and was a man of known abilities, be requested to examine the river, the grounds for the aqueduct, etc., and report his opinion;

Second, that in view of the importance of the matter to the comfort and health of the inhabitants, and the fact that private parties would not undertake the enterprise except with the prospect of gain at the expense of the citizens, the water works should be under the control of the corporation as the immediate representative of the citizens in general; and

Third, that the Legislature be requested to pass a law giving the City power to undertake the work and to raise the necessary funds by taxation.

Mr. Weston was consulted, as above suggested, and on March 14, 1799, he made a report which is of great civic and historical interest, and also gives an indication of the state of hydraulic science nearly a century and a quarter ago. It is as follows:

City of New York, ss:

At a Common Council held on Saturday, the 16th day of March, 1799, the following Report of William Weston, Esq., on the practicability of introducing the water of the River Bronx into this city, made at the request of this Board was read, and ordered to be printed, viz:

Sir: In compliance with the request contained in your letter of the 18th of December last, I have taken the earliest opportunity which my engagements and the state of the weather would permit, to ascertain the practicability of introducing the water of the Bronx into the City of New York; the result of which investigation I have now the honor of transmitting to you, requesting that you will lay the same before the Common Council, who, as the immediate guardians of the City, must feel peculiarly anxious to possess such information on the subject as may enable them to determine upon the propriety of the measures necessary to be taken to accomplish that important object.

I am sensible that estimates of the expense attendant on the execution, would have been a desirable piece of information, but a wish to render them as accurate as the uncertainty of the business will admit, induces me to request a further indulgence of time to procure information on several material points, essential to be known, previous to the completion of the necessary calculations, but with which I am at present unacquainted.

Though the amount of the expense ought, and doubtless will, have a proper degree of influence on the final decision, yet perhaps it is not a disadvantage, in the first instance, that the question should be determined on its abstract merits alone.

In an object of this nature, the first point to be fixed, is the quantity of water necessary to be delivered in a given time: was nothing more required than a sufficiency for culinary and other domestic uses, the matter might be easily ascertained. But as the principal object of this undertaking is the introduction of a copious and constant supply for cleansing and cooling the streets, it becomes a question of importance to determine, as near as may be, the amount of the required demand. Several specific quantities have been mentioned, but in my opinion they are all inadequate to the contemplated purpose. In this, as in all other undertakings, I conceive it to be an object of the first consequence to have the effect dependent on the will, and where, from the nature of the thing, no certain conclusions can be obtained, it is wisest to err on the safe side.

Whatever doubts may be entertained of this deduction as a general principle, I believe there can be none, respecting the propriety of it in the present instance; for, however great the amount of the surplus water may be, there are a variety of useful and productive purposes to which it may be advantageously applied. Proceeding on this ground, I have endeavored to calculate, as near as the want of sufficient data would enable me, the minimum quantity necessary to be introduced in twenty-four hours.

Though conclusions deduced from hydraulic principles of the expense of water issuing from pipes of given diameters, placed on the summits of the several streets, would have been much preferable to vague guesses; yet the infinite variety of cases, arising from different degrees of depression below, and distance from, the principal reservoir, would have rendered the operation a very laborious one, and, from a variety of causes, the result very uncertain. Indeed, every mode with which I am acquainted, may be objected to on the latter principle; but though it is perhaps impossible to ascertain the exact truth, we must endeavor to approximate as near thereto as possible. Conceiving it to be the intentions of the gentlemen who have recommended the measure of washing the streets, as essential to the health of the citizens, to have a regular and plentiful current of water running at least twelve hours every day, through all the streets, by means of pipes placed at their respective summits, producing an effect similar to what we may observe to be done by a moderate shower of rain of the same duration; calculating, therefore, the area of the city, the quantity of water usually descending in the time above mentioned, and making due allowance for such parts of the general surface as are pervious to water, we shall obtain a result that perhaps on the whole will be as near the truth as can be done by any other mode, and sufficient to answer every purpose required. I find that the area of the city, bounded by the East and North rivers, and the intersection of them by Grand street, is upwards of 750 acres, and, making an allowance of 350 for public squares, gardens, and other unpaved surfaces, we have a remainder of 400 acres, which, being unpenetrable to the rain, all that falls on that surface must be discharged by means of the channels of the different streets into the adjacent rivers. I have made various inquiries, but have not as yet received any correct information of the quantity of water produced by a moderate shower of twelve hours' continuance; I am, therefore, under the necessity of assuming as a fact, what may hereafter be proved to be erroneous, though I have reason to believe that my calculations will not be found to be overrated.

Fixing, therefore, the depth, as shown by the rain-gage at one-fourth of an inch, we shall find the total amount to be 363,000 cubic feet, or 2,221,560 ale gallons, and adding to this, 778,440 gallons as an adequate supply for domestic consumption, we shall have three millions of gallons to be introduced into the reservoir every twenty-four hours.

I beg leave to observe, that an increase or diminution of the above quantity may be effected by one of the plans submitted to your consideration, without materially altering the design or enhancing the estimate, while by the other, the expense will be nearly proportioned to the quantity required. I offer the preceding calculations merely as an essay to determine a point, which as yet has remained undiscussed, though of such importance that I deem it the basis of the whole work. I shall readily yield to any valid reasons that may be produced in support of variations from the above conclusions.

The quantity requisite being determined, the next point to be ascertained, is from what sources it can be most conveniently derived. I am acquainted with but two modes that deserve any consideration. The first is the introduction of a part or the whole of the waters of the Bronx; the second is a supply obtained from the springs of the Collect. As this question has much agitated the public mind, and each plan in its turn been extolled or decried by their respective advocates and opponents, it has produced (what is too frequently the effect of a collision of sentiments) a more obstinate attachment to preconceived opinions. I do not, therefore, expect that any arguments which I shall produce, will reconcile the jarring interests; yet I trust that the statement I shall offer, (and it is the result of some experience and reflection,) will enable those whose province it is to judge of the merits and disadvantages of the different plans, to select that which, on the whole, shall be most conducive to the public welfare.

In order to form a correct opinion on the subject, it is necessary to take into consideration the efficiency of supply — the quality of the water, as it respects the different uses to which it is to be applied, and the expense of execution.

On the first of these heads, I am aware that it has generally been believed, and pretty confidently maintained, that at those seasons when the demand will be greatest and most essential, that the waters of the Bronx are wholly inadequate; these assertions have been made with a degree of positiveness that would induce one to believe they were founded on the most careful and accurate experiments, which I have every reason to imagine have as yet never been made, instead of which, I have no doubt they are the random guesses of superficial observation. The question is of such importance, that we ought to be very careful that we proceed upon the most certain ground. In a matter of this consequence, I may be allowed to be a little diffuse.

It is evident that at the period when the greatest supply of water is wanted, there will, from natural causes, be the least quantity furnished; this is a common principle, applicable to all rivers and springs; the very few examples to the contrary, are mere exceptions to the general rule. This circumstance has created doubts in the minds of many persons of the efficiency of the Bronx. Previous to my examination of that stream, I had regretted that proper experiments had not been made at the season above alluded to, as then the fact would have been ascertained beyond all dispute. It is universally allowed that, for the greatest part of the year, there is a superabundant quantity; what the diminution may be, is not now easily ascertained; we must rely altogether upon the information of those persons whom a long residence has afforded the best opportunities of judging of its usual decrease; but, as not materially interested on the subject, we cannot expect any considerable degree of accuracy in their observations. Allowing for this circumstance, I have been careful to take the lowest average of the results of three distinct cases, founded on the best data I could procure, and applying to them well-known hydraulic laws, I am persuaded that the natural stream of the Bronx alone, if conveyed without waste, would be fully adequate to the supply before mentioned; but, fortunately, a minute accuracy is not required, as will appear by the following account of the River Bronx, whose principal source is from a lake, about four miles to the northward of the White Plains, known by the name of Rye Pond. This is a beautiful sheet of water, upwards of a mile in length, containing, as appears from an old survey, upwards of 500 acres of water, which, flowing from the outlet, is received into another pond, a short distance below, whose area exceeds fifty acres. From this pond it descends, with a rapid current, upwards of a mile to Mr. Robins' mill; a few rods below which, it unites with the other branch of the Bronx. This last, which has its origin in a swamp a few miles to the northward, retains the name of the Bronx to its source; yet it is the least considerable stream, particularly in the summer, when it is reduced to a small current; while the other branch is sufficiently large to turn an overshot wheel twelve hours out of twenty-four, in the driest times. Rye Pond is bounded by high and bold shores, which, tending towards each other at the outlet, are admirably calculated for the formation of an immense reservoir. This being filled during the winter and spring, may be retained until the month of July, when the natural supplies begin to diminish; it may then be discharged periodically, so as to afford any given quantity of water that may be requisite for the use of the City.

This lake is supplied wholly by springs, many of which are internal, and few of the others originate more than a mile from the head. These are so constant and copious, that no doubt can arise of their capacity to fill the reservoir to the contemplated height of six feet, which may easily be effected by throwing a dam across the outlet of the lower pond. This would form a sheet of water of more than 600 acres in extent, containing 959,713,920 gallons of water; affording (independent of the natural stream of the Bronx,) a diurnal supply of nearly eight millions of gallons for 120 days, three-eighths of which quantity is sufficient for our purpose. The surplus five millions, may be given to the mills below the point of partition; so that, instead of injuring (and consequently recompensing them for the damages) the mills on the Bronx, as has been generally apprehended, they will derive essential benefits from the measure.

Having, I flatter myself, removed the doubts of the most incredulous, respecting the efficiency of the supply to be derived from the Bronx; it remains to examine the competency of the waters of the Collect. The general bias of opinion seems to lean in favor of this scheme; and if it can be made satisfactorily to appear that the required supply can be obtained from this source, I am ready to allow that it is a work that would be soonest accomplished, and attended with the least expense. But we ought to be extremely cautious in hazarding an experiment where the cost would be so great, and the event so doubtful. The question is of infinite importance, and, unfortunately, one that cannot be determined by abstract reasoning. The capacity of the Collect has been attempted to be proved by its present extent; but that, in my mind, is a most fallacious mode of reasoning; for, however great that may be, a powerful steam engine would soon exhaust it, unless replenished with numerous and copious springs. On these alone, therefore, it is evident we must depend, and I know of no other mode of estimating their combined effect than by calculating the quantity of water issuing from the outlet of the Collect, which, even at this time, is so inconsiderable as scarce to deserve attention, and, if my information is correct, it ceases to flow altogether in the summer. I am sensible that we should not too hastily conclude that the above is the total amount of the supply that may be derived from this source. I think it very probable that, from the nature of the surrounding ground, which is a coarse and porous gravel, a considerable portion thereof may percolate through, into the adjacent rivers. Much, and perhaps the greatest quantity, is also daily drawn off by the Teawater Pump, which, from its vicinity, I have no doubt, is supplied from the same source. It is true, that by sinking deeper into the earth, an augmentation of quantity would be procured; yet, if we went lower than the surface of the tide-water, I apprehend that the quality would be materially injured.

Leaving the question, as I fear it will remain, undetermined, we next proceed to examine the quality of the respective waters. To appreciate their merits fairly, we should judge of their utility by the extent of their application. Proceeding on this ground, I believe it may be safely affirmed that the water of the Bronx is at least equal to that of the Collect, though this is contrary to the general opinion; the only reason that I can perceive for the preference usually given to the last mentioned, arises solely from its superior coolness; however grateful this may be to our feelings, it does not follow that it is equally conducive to our health; for whatever degree of purity it may now possess, the period is not very remote when, from the natural increase of the City, these springs must be subject to those contaminations which have already rendered so many wells unfit for use; an evil that is daily increasing, and to which no effectual remedy can be applied. This, to me, has ever appeared an insurmountable objection. The idea of supplying a large city with pure water from a reservoir in its centre, has always been a very strange one to me. From the representations made respecting the water of the Bronx, I believe many persons have hastily concluded that it was unfit for use. When it is considered that the principal cities in Europe are necessarily supplied from rivers, and with water generally taken from those parts which, from a variety of causes, are most impure, and yet that the experience of ages has not evinced any known ill effects arising from the practice, I conceive that little fears will be entertained of the salubrity of the water of the Bronx, which is a collection of innumerable springs, issuing from a rocky and gravelly country, and running, with a rapid current, over a bed of the same materials. It will be conveyed into the City without any additional impurity, and, ere it is distributed from the reservoir, will, by a mode of purification hereafter described, be rendered as clear as spring water.

The next object to be ascertained is the practicability and probable expense of accomplishing the respective plans. And here it may not be amiss to observe that in a matter of such immense consequence to the present and future convenience and welfare of the City, every local view, every subordinate consideration, should yield to the general good — that a regard to the primary object alone should decide the question, regardless of a paltry difference of expense, or the immediate emolument to be derived from the undertaking. On the first of the above-mentioned heads there have been a diversity of opinions, which previous to an

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actual survey, was not to be wondered at. These doubts must now be removed, as it appears from the examination that has been recently made, that the Bronx is sufficiently elevated above the highest parts of the City to introduce its waters therein without the aid of machinery; and the intermediate ground, though very irregular, presents no obstacles which art and industry may not surmount. A general view of the subject is all that I am now able to present, and all that is necessary to be known, in this stage of the business. An outline of the plan I would recommend for adoption, as best adapted to the varying face of the country, will be sufficient to enable you to form a tolerably correct idea of the eligibility of the measure. The best situation I have yet seen to draw the water from the Bronx, is a short distance above Mr. Lorillard's snuff-mill.* A break in the western bank enables us to divert the stream, by means of a dam thrown across it, without any difficulty. The water being raised six feet above its natural level, will flow over a small swamp, from which originates the little rivulet called Mill brook; following the direction of this stream, a canal may be drawn along its northern bank at a small expense, for the distance of three miles, when the ground falling off rapidly, renders it necessary to cross the valley in which Mill brook runs, by means of an aqueduct, to the opposite rising ground, along which the level may be preserved to the heights above Harlem river. An open, walled canal, will be the cheapest mode of conveying the water so far: a little loss is not material, as a small increase in the section will remedy such waste. A declivity of six inches in a mile, with a section of 1152, and linear border of 89 6/10th inches, will occasion a velocity in the current sufficient to introduce into the small reservoir at the extremity of the canal 6 cubic feet of water per second, which is more than the quantity required, supposing the daily supply to be three millions of gallons. The most difficult and expensive part of the route will be the conveyance of the water across Harlem river. The most eligible mode of effecting this, appears to me to be by means of cast iron cylinders, of two feet diameter, with a difference of 8 feet between the extremities. This descent will produce a velocity of 22¾ inches per second, yielding, in that time 5 95/100ths cubic feet, while the required quantity is only 5 65/100ths. From the cylinder to the reservoir it is a matter of consequence to preserve as much of the water as possible; to effect this object, the bottom and sides should be rendered impervious to that element. An absolute necessity to preserve a regular and uniform descent, leaves us little room in the choice of our route, which will be chiefly along the shore of the North river. The quality and make

* Site now in Bronx Park, 1917.

of the ground vary much. The greatest impediments are occasioned by the numerous ravines which intersect the line of the canal. Over all these, aqueducts must be constructed. The level may thus be preserved upwards of six miles, or within two miles of the City; there it descends so much, that unless higher ground can be found, it will again be necessary to have recourse to iron cylinders to convey the water into the Grand Reservoir, which may either be placed in the Park,* or a vacant piece of ground to the northward of the Hospital, either of which are sufficiently elevated to distribute the water through all parts of the City. The total distance from the Bronx to the Park is 14 miles, 7 furlongs, and the descent twenty-three feet. It is to be observed that the principal object of this survey being to ascertain the practicability of the plan, and neither my time nor the season permitting that minute investigations which is necessary to be made, previous to the commencement of any operations, there is a probability that advantageous deviations may be made from the route pursued.

Although the form and dimensions of the reservoir are objects of importance, it is now premature to point the particular mode of construction I would recommend to be adopted. Yet it may not be improper to give a general outline thereof, as perhaps it may tend to remove many of the prejudices which have been entertained against the supposed impurities of the waters of the Bronx. It is proposed to divide the reservoir into three parts, two of which will again be subdivided, each of these minor divisions capable of containing a daily supply of water. The first division, or reservoir of reception will contain the water as immediately delivered by the cylinder of discharge. While one of its subdivisions is filling, the other, in a quiescent state, will be depositing the adventitious matter, with which the water may be intermixed. After so remaining twenty-four hours, it will be drawn off by an aperture near the bottom, (so as to prevent any bouyant particles from entering,) into the reservoir of filtration, where it will still further purify itself, by gradually depositing the remaining sediment, until it is finally received into the reservoir of distribution, after percolating through a bank of washed sand and gravel, in imitation of that natural process to which all water owes its purification. This last reservoir it is proposed to arch over, so as to preserve the water pure and cool; from hence it will be distributed, in separate and distinct pipes, through every part of the City.

The water destined to cleanse and cool the streets may be taken immediately from the reservoir of reception, as I conceive it is not necessary that it should be very pure.

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* Present City Hall Park.

The surplus water, which for a considerable part of the year will not be wanted for washing the streets, may be applied to a variety of purposes, but perhaps to none more useful or advantageous than the supplying of dry-docks, which may be constructed to receive the largest ships.

If the water in the Collect is deemed adequate to all purposes of domestic consumption, it must be raised, by means of a steam engine, into a reservoir. The situation before mentioned will, in this case, be very convenient. Although one engine, might be constructed so as to raise both the water for washing the City and for family use, yet, as from the quantity necessary to be raised, it would be unwieldy in its parts, and more liable to accident, and, also, as two-thirds of its power would be useless the greatest part of the year, I believe it will be most advisable to erect two. The first, destined to raise the water for cleansing the streets, placed at the foot of the hill to the northward of the Hospital, which would be supplied with water from a reservoir made in the adjacent low ground. This would be replenished twice in twenty-four hours by the tide, by means of an open canal, or culvert, communicating with the reservoir. The small engine might be placed near the other, the pump well being supplied with water from the Collect, conveyed in a culvert or pipes. The following calculations of the dimensions of the largest engine will be found sufficiently correct to enable you to form a tolerable idea of the annual expense attendant on it. Admitting the quantity (as before calculated) to be sufficient, we find that 2,200,000 gallons, or 359,640 cubic feet, must be daily raised. Supposing the engine to work sixteen hours out of twenty-four, we have 22,477 feet to be raised every hour, or nearly 375 every minute; estimating ten strokes to be made in a minute, each stroke must yield 37½ feet; but as pumps generally fail in producing the calculated quantity, say 40 feet per stroke; and if the lengths of the strokes are 8 feet, it will require a pump of 30 27/100ths inches diameter. But a pump of that dimension would not answer in practice; it will be necessary, therefore, to diminish the diameter, and increase the number of pumps; six of 12 3/10ths inches will be equal in area to that before mentioned. As the water would be raised about 50 feet, the weight of the column would be 15.613 lbs., which would require a cylinder of 44 2/10ths inches diameter (allowing the active power of Mess. Bolton & Watts's engines to be 8 lbs. on every circular inch). Such an engine would consume about 330 lbs. of coal per hour.

Having thus given you every information necessary to be known for your guidance, I shall conclude by remarking that my objections to the Collect — being founded on the doubts I entertain of its efficiency to suply the annually increasing demand of this improving city, and to the contamination its waters will be subject to — will be done away altogether, when it shall be made to appear that they are groundless. In such a case, there can be no question which plan is most eligible, as it respects the time and expense of execution.

I am, sir,
With respect,
Your ob't serv't
Wm. Weston

The Hon'ble Richard Varick.
New York, March 14th, 1799.

Printed by order of the Common Council.

Robt. Benson,
Clerk.

IV

THE MANHATTAN COMPANY'S WATER WORKS

The first successful pipe-line system of waterworks was that of the Manhattan Company, which was incorporated in 1799. Upon the assembling of the Legislature that year, Aaron Burr and several other men applied for a charter for the purpose of "supplying the City of New York with pure and wholesome water", and on April 2, 1799, the bill was passed, incorporating the Manhattan Company. The capital of the corporation was $2,000,000 — a great sum for those days — and as the cost of the proposed water system could not accurately be foreseen, there was a clause in the charter permitting the company to employ its surplus capital in financial transactions not inconsistent with the constitutions and laws of the State of New York and the United States.

It has been a common tradition that the banking privilege contained in this charter, apparently as a subordinate feature, was really the main object of the projectors, and was thus introduced covertly to avoid the opposition which Burr was certain to encounter from Alexander Hamilton and the Federal party. Hamilton had organized the first banking organization in New York when in 1784 he formed the Bank of New York which was chartered in 1792. For fifteen years, Hamilton's bank and the Branch Bank of the United States were the only banks doing business in the city and State of New York. This monopoly was of value to the political party which was then in control and with which Hamilton was allied, and consequently Burr's effort to obtain a charter, which was quickly perceived to contain a clause which permitted banking, was earnestly opposed. The opposition was unsuccessful, however, and the Manhattan Company secured its charter.

Whether the tradition before mentioned as to the leading motive of Burr and associates was well founded or not, the fact remains that the Company did go ahead with the water-works undertaking, built reservoirs, and laid an extensive system of distributing pipes in the then small city. These pipes were hollow logs, many of which have been dug up in recent years in the streets south of Chambers street. The first meeting of the Directors was held at the house of Edward Barden, inn-keeper,* on April 11, 1799, when there were present Aaron Burr, John Broome, who was long an Alderman; John B. Church, who fought a duel with Burr on September 2, 1799; John B. Coles, Richard Harrison, who was Recorder of the City; William Laight, Brockholst Livingston, Daniel Ludlow, Samuel Osgood, Pascal N. Smith, John Stevens and John Watts. The only absentee was William Edgar. Mr. Ludlow was elected President.

At the meeting of April 11, 1799, a resolution was adopted declaring that the principal object of the corporation was to obtain a supply of pure and wholesome water for the city and a committee was appointed to report means for obtaining such a supply. So rapidly did the plans mature that on May 6 following the water committee was empowered "to contract for as many pine logs as they may think necessary for pipes and also for boring the same."

Meanwhile, if the water supply was the chief object of the company, the banking privilege was not neglected, and on April 17, 1799, a committee was appointed "to consider the most proper means of employing the capital of the Company". On June 3 the committee reported in favor of opening an office of discount and deposit and a house was bought on the site of the present No. 40 Wall street (then having a different number), in which, on September 1, 1799, the bank of the Company began business. This venerable corporation is still doing business at No. 40 Wall street under the style of the Bank of the Manhattan Company.

In prosecuting the water-works business, the company sank a number of wells, built tanks and reservoirs, and extended its distributing system generally throughout the city below Chambers street. In 1836 the system was extended northward along Broadway as far as Bleecker street, when the company had about 25 miles of mains and supplied about 2,000 houses. The company continued to operate its system until about the time the Croton system came into use in 1842.

One conspicuous landmark of the old water works was the Chambers Street reservoir. It had sloping walls, similar in style to the Croton reservoir which formerly stood on the site of the present Public Library on the west side of Fifth avenue between 40th and 42d streets. It stood on the north side of Chambers

* The Merchants Coffee House.

street between Broadway and Park Row. Its facade was unrelieved except by an entablature which was supported by four Doric columns and upon which was a figure of "Oceanus, one of the sea-gods, sitting in a reclining posture on a rising ground pouring water from an urn which forms a river and terminates in a lake." This was the physical embodiment of the device of the corporation seal of the company adopted May 8, 1799.

Another landmark of the company was the tank which stood on the northwest corner of Reade and Center streets until July, 1914, when it was demolished. This tank, which was erected over one of the earliest wells of the company, was circular in form and measured 41 feet in diameter. It consisted of a massive stone foundation rising 23 feet above the original ground level, and was surmounted by a circular tank, 41 feet in diameter and 15 feet high, the sides and bottom of which were composed of iron plates bolted together. Later the reservoir was enclosed in a building consisting of three stories and cellar which was owned by the company. We will describe the reservoir with reference to the stories of this building.

The stone foundation of the reservoir consisted mainly of a circular central column of a solid masonry 10 feet in diameter, and a circular outer wall 4 feet thick. The inner space, 11½ feet wide between the central pier and the outer wall, was divided into eight symmetrical segments by radial partition walls, 3 feet thick, perforated next to the central pier by arched passage ways 4 feet 6 inches wide and about 17 feet high. On the ground level (in the cellar of the surrounding building) the outer wall of the foundation of the reservoir was penetrated by four arched doorways, about 3½ feet wide and 6 feet high, equidistant, and located adjacent to the alternate radial partitions.

The lowest 10 feet of the foundation was in the cellar of the surrounding building, the first floor at the modern street level being 10 feet above the old cellar ground level. The next 10 feet of the foundation was included in the first story of the surrounding building. At the first floor level was one doorway 3½ feet wide, 6 feet high, with flat lintel, apparently not contemplated in the original plan. The wooden flooring had been extended into the interior of the foundation and was used, as was the space below, for storage purposes. Each of the other seven sections of the circular wall above this floor level was pierced by a circular opening about 2 feet in diameter and lined with brick. These circular openings were about 5 feet above the floor or 15 feet from the ground. The archways in the interior partition walls were 7 feet above the floor or 17 feet from the ground.

Above these archways there was about 6 feet of solid masonry from center to circumference. Upon this was a thin layer of sand, to equalize the superincumbent weight, and upon the sand were laid the bottom plates of the reservoir.

The upper 3 feet of the foundation and the lower 7 feet of the iron tank appeared in the second story of the surrounding building.

The upper 8 feet of the tank appeared in the third story, there being just room enough between the top of the tank and the roof timbers of the building to permit a person to look into the tank.

The bottom of the tank consisted of flat rhomboidal segments of iron plates, bolted together at their flanges. (See illustrations in our 1915 Report.) The cylindrical side consisted of three tiers of rectangular iron plates, 5 feet high, 2 feet 4 inches wide, slightly curved, and similarly bolted together by their raised flanges. At the flanges the plates were 3 inches thick. The design of each plate was divided into 2 panels. In the illustration in our 1915 Report two rectangles, one above the other, represent one iron plate. A projecting hook in the center of each plate indicated that each tier of plates was reinforced by a circular band of iron.

When the tank was taken down in July, 1914, the black sediment on the bottom of the reservoir — the accumulation of dust which had slowly settled in the tank notwithstanding it was surrounded and covered by the building — was about 1 foot thick.

Connected with the tank were certain inflow and outflow pipes of no particular interest. Water was originally pumped into the reservoir by means of a steam engine.

Among the traditions which grew up around the old reservoir was one to the effect that the Manhattan Company was obliged to pump water into the tank every day in order to keep alive its charter. As the reservoir is now gone and the company continues to do business, the tradition appears to be effectually set at rest.

During its later history, while this tank was enclosed in the three-story building its existence was known only to antiquarians and a few others. When the building and tank were torn down in 1914 to make room for a modern building, the old reservoir was exposed to view and excited the liveliest public interest. All sorts of strange tales were circulated about it. One story alleged that it had been a fort in the War of the Revolution and another that it had been an ancient prison, neither of which legends was true.

The wooden pipes of the old Manhattan Company are frequently met with in excavating for modern water-mains, gas-mains, sewers, electric conduits and subways; and sections of them are preserved at the New York Historical Society building and elsewhere as great curiosities. One of the latest sections to be exhumed to the knowledge of the present writer was located at Dey and Greenwich streets and was removed by the contractors for the new subway in April, 1916.

V

FROM THE MANHATTAN TO THE CROTON SYSTEMS

The course of events from the establishment of the Manhattan Company's works to the authorization of the Croton system is summarized in the following chronology taken from Valentine's Manual of 1854.

1804. Under the mayoralty of De Witt Clinton, a committee was appointed to report upon the practicability of supplying the city with pure and wholesome water, and especially to confer with the Manhattan Company as to the terms upon which they would cede to the Corporation their works and privileges of supplying water; but nothing seems to have come of it.

1816. A committee was appointed in March, to consider and report upon the propriety of making an application to the Legislature, to invest the Mayor, Aldermen and Commonalty with all necessary powers to supply the City with water. The minutes contain no report from this committee.

1819. Robert Macomb presented a memorial for permission to supply the City with water (collected at a reservoir at Harlem River), for all domestic purposes. The scheme of Mr. Macomb and associates was to bring the water from Rye pond, and they professed their ability to complete the work in two years, without any aid or compensation from the Common Council, asking only the privilege of laying down the pipes and selling the water. For the consideration of this subject, they asked the appointment of a committee, and one was appointed to confer with them. After repeated conferences with Mr. Macomb, and being satisfied that he and his associates had the requisite means to carry their project into effect, they in the spring of 1820, reported in favor of the project, with some resolutions which were agreed to. The minutes, however, show nothing further.

1821. Stephen Allen, Mayor. Another resolution of inquiry into the best means of supplying the City water was adopted, and a committee appointed to procure plans, estimates, &c., provided the expense should not exceed two hundred dollars.

1822. The Mayor again brought the subject before the Common Council, and it was referred to a committee, of which he was one. At a meeting in April, they made a report of their observations, and recommended the appointment of an engineer to survey and profile the whole line between the City and the main source of the river Bronx. The recommendation was concurred in, and Canvas White was employed to make the survey and estimate.

1823. A scheme was started to bring the water of the Housatonic river to New York in an open canal, and an act of incorporation was obtained in Connecticut for this purpose. The Sharon Canal Company was chartered by the state, and among its duties was that of supplying the City with water. The work was not undertaken however.

1824. Mr. White made his report in favor of bringing the water of the Bronx to the City, taking it from the river at the West Chester cotton factory pond. The cost of bringing the water to a reservoir near the Park was estimated at $1,949,542.

1825. A company called the New York Water Works Company was incorporated by the Legislature, with authority to supply the City with pure water. Canvas White was appointed engineer to this company and in his report he recommended taking the water of the Bronx at Underhill's bridge, at an estimated expense of $1,450,000.

1826. The charter of the New York Water Works Company proved so defective in practice that they were unable to proceed under it, and applied to the Legislature for necessary amendments, in which they were opposed by the Sharon Canal Company, who claimed in their charter all the water on the route of the canal.

1827. The Water Works Company, unable to proceed, surrendered its charter, and the Legislature incorporated the "New York Well Company." The water was to be procured on the island by sinking wells in the most elevated grounds. The company made several attempts to procure water, but being satisfied by their experiments of the impracticability of the undertaking, the enterprise was abandoned.

1828. Levi Disbrow's plan of sinking an artesian well and reservoir in each ward of the City was the next plan. Though partially successful, the cost and uncertainty of supply forbade the prosecution of this plan.

1829. A report, made to the Common Council by Alderman Samuel Stevens in favor of the establishment of a well and reservoir in Fourteenth street whence water might be distributed in iron pipes, was accepted and acted upon. The Committee did not omit to urge, as an additional motive for laying down iron pipe, that whenever the long desired object of supplying the City with water for domestic purposes should be carried into effect, these same pipes would serve. A reluctant assent was wrung from the Common Council to these recommendations, and a committee was empowered to provide the necessary site for a reservoir, and to contract for iron pipes. From this reluctant, feeble and economical beginning, sprang the Croton Aqueduct.

1830. A motion was made in the Common Council to apply to the Legislature for all needful power to supply the City with water, and to create two millions of stock to defray the expense thereof, but did not prevail. May 17, a memorial from Francis B. Phelps proposed four different sources of supply: First, to bring the water the whole distance from Rye Pond in twenty-eight inch iron pipes; Second, to bring the Croton river, by open canal, or by iron pipes; Third, to bring the water of the Passaic, taken above the falls, at Patterson, New Jersey, and cross the Hudson by iron pipes laid on the bottom of the river; Fourth, by a plan of his own, probably wells and springs on the island.

1831. The Common Council referred the subject with the various communications to their Committe on Fire and Water, in the Board of Aldermen, consisting of Messrs. James Palmer, Samuel Stevens, and William Scote, who presented a report adducing facts and arguments sufficient to prove the practicability of the project, and the ability of the Corporation to meet the expense, and appended to their report was a letter directed to the Corporation and signed Cyrus Swan, who was "President of the New York and Sharon Coal Company," in which it was asserted that the Croton river could be carried into the City of New York, and that without it a supply adequate to the present and future wants of the City could not be obtained.

1832. The Committee drafted an "Act" for the Legislature to pass, which was approved by the Common Council and presented to the Legislature, but which failed in becoming a law. In November a report was made by Timothy Dewey and William Serrell to Benjamin Wright, recommending the Bronx as a sufficient source. The above-named Committee on Fire and Water, with Myndert Van Schaick, at that time a member of the Board of Aldermen, pursued the subject with energy. In December, De Witt Clinton, of the United States Corps of Engineers, made a report in which he arrived at the conclusion that an adequate supply could only be obtained from the Croton river. He proposed an open aqueduct, and estimated the cost at $2,500,000.

1833. February 26. The Legislature passed an act in compliance with the request of the Common Council providing for the appointment by the Governor and Senate of five persons as Water Commissioners, whose duty it was "to examine and consider all matters relative to supplying the City of New York with a sufficient supply of pure and wholesome water for the use of its inhabitants, and the amount of money necessary to effect that object." This act, giving the first effectual impetus to the work, was drawn up by Myndert Van Schaick, then a member of the Senate from the City of New York. The following named gentlemen were appointed under this law the Board of Water Commissioners: Stephen Allen, William W. Fox, Saul Alley, Charles Dusenberry, and Benjamin M. Brown. The Commissioners were directed to report the result of their examinations both to the Common Council and the Legislature, the City to defray all reasonable expenses. The Common Council having on the 5th of June appropriated $5000 to enable them to carry into effect the objects of the appointment, the Commissioners engaged Canvas White and Major Douglass to undertake the requisite surveys, examinations and estimates. Mr. White was prevented from acting, and Mr. Douglass commenced his surveys late in June, and they occupied him and his party till late in September, and the result was a firm conclusion that the Croton should be the source of supply. The plan of construction recommended was a continuous tunnel or aqueduct of masonry.

1834. In February, the Common Council adopted a resolution accepting the proposal of the Manhattan Company to enter into a negotiation for the sale of the company's immunities, rights, and privileges of every kind, relative to the supply of the City with water. May 2 an act prepared like the former by Myndert Van Schaick, was passed by the Legislature, giving additional powers to the Commissioners, and requiring them to report the result of their investigations to the Common Council on or before the first day of January, 1835. In case the plan adopted by the Commissioners should be approved of by the Common Council they should submit it to the electors. It further authorized the Common Council to raise $2,500,000 by the creation of a public fund or stock to be called "The Water Stock of the city of New York." The Governor and Senate reappointed the same commissioners, who, after thoroughly examining their former work, decided that the Croton river was the only source that would furnish an adequate supply. The engineers now employed were David B. Douglass, John Martineau, and George W. Cartwright. Various plans were again proposed to the Commissioners; among them that of Mr. Bradford Seymour of Utica, who proposed to erect a permanent dam in the Hudson river, extending from the foot of Amos street to the Jersey shore. Seymour's plan was to raise the water on the up-stream side of the dam from 18 to 24 inches, and by its fall generate 30,000 horse-power. Of this energy, 3,000 horse-power was to be used for pumping water to a reservoir on Manhattan island, leaving 27,000 horse-power for industrial purposes. Locks for the passage of shipping were included in his plan. He argued as another advantage that it would provide "an easy and safe communication between New York and Albany on the ice for three months of the year." He gave no estimate of the cost of this visionary project. Messrs. Martineau and Douglass expressed themselves in favor of a closed aqueduct of masonry from the Croton, estimating the cost at $5,412,336.72.

1835. A Committee of the Common Council to whom was referred the report of the Water Commissioners, approved the plan adopted by the Commissioners, and recommended a reference of the subject to the electors at the ensuing election. These resolutions were adopted by the Common Council, and at the election in

April the question was submitted to the electors with the following result.

Wards	Yes.	No.
1	1,417	27
2	1,248	25
3	1,456	42
4	1,794	51
5	1,675	152
6	1,305	103
7	1,303	561
8	1,511	702
9	631	1,015
10	966	1,030
11	880	873
12	545	136
13	654	739
14	1,233	209
15	712	297
	17,330	5,963

1836. In July the Common Council ordered pipe to be laid preparatory to the introduction of the water, and in October Mr. Douglass was superseded by the appointment of John B. Jervis as Chief Engineer.

1837. Work on the Aqueduct commenced in the early part of this year.

Great Fires and Epidemics

In the course of the events heretofore described, several great fires and epidemics had occurred, greatly influencing public opinion in favor of a more copious water supply.

On September 21, 1776, six days after the British captured the City, a fire broke out at the foot of Whitehall street and spread to Broadway, burning up on the east side as far as Mr. Harrison's brick house and on the west side to St. Paul's chapel. Trinity Church and 493 houses were destroyed.

On August 7, 1778, a fire originating on Cruger's Wharf (in the block now bounded by Water and Front streets, Old Slip and Coenties slip) consumed about 50 houses in that vicinity. This was during the British occupation and the military took exclusive control of the situation.

On December 18, 1804, a fire broke out on Front street south of Wall street and burned the whole block in Water street from Coffee House Slip at the foot of Wall street to the next door to Gouverneur's Lane, including all the buildings in Front street to the water; and also some buildings on the northeast side of Coffee House Slip. The famous old Merchants Coffee House, built in 1737, on the southeast corner of Wall and Water streets, was burned.

On May 19, 1811, a fire began near the northwest corner of Duane and Chatham street (now Park Row), and spread rapidly with a wind from the northeast. Between 80 and 100 buildings were burned. The steeple of the old Brick Church, in the block bounded by Beekman street, Park Row, Printing House Square and Nassau street, and the cupola of the old jail in City Hall Park, caught fire, but were not seriously damaged.

The "Great Fire" broke out on the night of December 16, 1835, in the premises of Comstock & Andrews, at No. 25 Merchant (now Beaver) street and burned over the area bounded approximately by the south side of Wall street from William street to the East river, by William and South William street to Coenties Lane; by Coenties lane and slip to the river; and by the river from Coenties slip to Wall street. In this area, 674 stores and other buildings were destroyed, causing a loss stated at $17,000,000. The Merchants Exchange (site of the National City Bank) and the old Dutch Church in Garden street (now Exchange Place) were among the structures destroyed.

In this connection, we may anticipate our story somewhat and mention that a notable fire which happened in the early years of the Croton system occurred on July 19, 1845, when 345 buildings were destroyed and about $5,000,000 loss was caused in lower Broadway, Whitehall street, New street, Broad street, and in Exchange Place and other cross streets to the southward.

There were epidemics of yellow fever in 1795, 1798, 1805, 1819 and 1822, and of cholera in 1832, 1834, 1849 and 1855. The epidemic of 1805 was particularly severe. John Lambert's diary says that in that year 26,000 persons moved from the interior of the City to escape the plague. Those who could not go far went to Greenwich village on the west side of the island "about two or three miles from town" where merchants and bankers had other offices for the transaction of business.

VI

THE CROTON AQUEDUCTS

The Old Croton Dam

The work on the old Croton Aqueduct which was commenced in 1837 began at a point on the Croton river about six miles from its mouth with the construction of a dam. This dam was designed to raise the water 40 feet above the level of the head of the aqueduct and 166 feet above mean tide.

The rock formation at the site is Fordham gneiss, and the rock bottom of the river was so deep as to give the engineers trouble at the very start. Even after shifting their plans, it was necessary to make an artificial foundation for part of the dam where they could not build it on the living rock. The southern abutment was of natural rock, and the aqueduct being on the southern side of the river, the water was conducted to its head by a tunnel cut 180 feet through the rock. The gateway was also located in the solid rock, unexposed to the floods of the river. A waste culvert was built in the north abutment, with suitable gates for drawing down the reservoir for repairs and to discharge the river at ordinary times during the course of construction. From this abutment the old channel of the river was filled by an embankment, with a heavy protection wall on the lower side which was raised fifteen feet above the waste-weir of the dam and designed to be fifty feet wide on top. While this was in course of construction in January, 1841, the water rose until, when near the surface, it began to pass between the frozen and unfrozen earth about 20 inches from the top. Then, after the breach was made, heavy masses of ice came down from the reservoir and broke down the unfinished protection wall, with the result that the whole embankment was carried away. The masonry of the dam and abutment, however, suffered little damage. It was then decided to fill the breach thus made, about 200 feet long, by a structure of hydraulic stone masonry, adapting 180 feet of it for a waste weir. This was effected with great difficulty in those days, it being necessary to lay an artificial foundation. The greatest height of the dam was 40 feet above low water level and 55 feet above the bed of the river. The masonry at low water line of the river was 61 feet long.

Three hundred feet below the main dam a second dam, 9 feet high, was built for the purpose of setting the water back over the apron of the main dam to form a pool of water which should receive the impact of the water passing over the main dam.

The Croton dam impounded the water of the river in a reservoir five miles long and covering about 400 acres.

High Bridge

From the Croton dam a masonry aqueduct was built through the country and the villages of Sing Sing, Tarrytown, Dobbs Ferry, Hastings and Yonkers to the Harlem river opposite 174th street, a distance of 32.88 miles. At this point, the next monumental structure of the aqueduct, namely High Bridge, was erected. The valley of the Harlem river here, at the aqueduct level, is 1450 feet wide, and it required a structure of that length to conduct the water across the river to the Island of Manhattan. The width of the river at ordinary high water mark was then 620 feet, but at low ebb tides was reduced to about 300 feet. The southeastern shore is bold and rocky, rising from the water's edge at an angle of about 30° to a height of 220 feet. On the northwestern shore, a strip of table land extends back from the water about 400 feet to the foot of a rocky hill which rises at an angle of about 20° to a considerable height above the level of the aqueduct.

Across this interval was constructed a picturesque masonry bridge, supported in the Roman style, by piers connected by half round arches. There are fifteen of these arches. Eight of them, over the river proper, have a span of 80 feet each. The others are of 50 feet span. Across the structure, above the arches and below the roadbed, were originally laid two 36-inch cast iron pipes. The Chief Engineer, John B. Jervis, explained that "the object of using pipes in this case is more effectually to secure the conduit from leakage that might eventually injure the masonry of the bridge, and it incidentally allows the bridge to be constructed of less height."

The whole length of High Bridge is 1450 feet; the height of the river piers above high water mark is 60 feet to the spring of the arches; the height from high water mark to the under side of the arches at their crown 100 feet. The height to the top of the cornice was originally 114 feet above high water and 149 feet above the lowest foundation of the piers, but it was raised about six feet in 1860–63. The width across the top is 21 feet.

High Bridge was not completed until about six years after the other parts of the aqueduct had been finished, and water did not pass over it until May, 1848. Meanwhile the water had been carried through an inverted siphon under the Harlem river so that it was introduced into the City in 1842, as stated hereafter. The cost of High Bridge was stated in 1849 to have been $963,427.80. The following inscription is on the southern face of one of the eastern piers of the bridge:

Aqueduct Bridge

Begun 1839 Finished 1848

Stephen Allen
Saul Alley
C. Dusenberry
W. W. Fox
T. T. Woodruff } Water Commissioners

John B. Jervis, Chief
H. Allen, Princ. Assist.
P. Hastie, Resident
E. H. Tracy, Assistant } Engineers

George Law
Samuel Roberts
Arnold Mason } Contractors

On the south face of the westernmost pier is the following inscription:

Aqueduct Bridge

Finished December 31, 1848.

Philip Hone
Nathaniel Weed
M. O. Roberts
J. H. Hobart Haws
A. C. Kingsland } Water Commissioners

John B. Jervis, Chief
P. Hastie, Resident
E. H. Tracy, Assistant } Engineers

I. Vervalen, Inspector of Masonry

George Law
Samuel Roberts
Arnold Mason } Contractors

Within 20 years the capacity of High Bridge had to be increased by adding to the original two cast-iron conduits a wrought-iron pipe 90 inches in diameter. In order to cover this additional pipe, the sides of the bridge were raised about six feet and the structure was covered with a flat brick arch which serves as the pavement of the promenade. The latter, although wide enough for vehicles, is restricted to the use of pedestrians. A wrought iron fence 41½ inches high surmounts the cornice on either side of the promenade. The improvement is recorded in an inscription on the gate-house at the Manhattan end as follows:

The improvement of this bridge by adding the large pipe raising the side walls and covering the whole work with an arch was commenced Oct. 1860. The new pipe was put in operation Dec. 1861. The masonry completed 1863.

CROTON AQUEDUCT BOARD

Thos. Stephens
President Commissioner.

Thos. B. Tappen	**Rob't L. Darragh**
Assistant Commiss'r to Dec. 4, 1862	Assistant Commiss'r from Dec. 4, 1862

Alfred W. Craven
Commissioner and Engineer in Chief

Engineers

Geo. S. Greene	Wm. L. Dearborn
Engineer in Charge to Jan. 31, 1862	Engineer in Charge from Feb. 1, 1862

Contractors

Thos. F. Rowland for the pipe	J. P. Cumming for the masonry

High Bridge was the sole means of conveying Croton water from the main land to Manhattan Island up to July 15, 1890, when water was first supplied through a siphon under the Harlem river near Washington Bridge.

The Yorkville Reservoir in Central Park.

From the Manhattan end of High Bridge, the masonry aqueduct continues 2.015 miles along the line of Tenth avenue to the high ground on the north side of Manhattan Valley at Manhattan street. This valley is 0.792 of a mile wide at the aqueduct level below which it descends 102 feet. The names of the landmarks in Chief of Engineers Jervis' description of seventy years ago sound archaic to-day. He says that at Manhattan Valley "the conduit of masonry here gives place to iron pipes which descend into the bottom of the valley and rise again to the proper level on the opposite side; from which point the masonry conduit is again resumed, and crossing the Asylum Ridge and Clendenning Valley is continued 2.173 miles to the receiving reservoir at York Hill."

Asylum Ridge was the name for Morningside Heights where Columbia University now stands and where the Bloomingdale Asylum formerly stood. Clendenning Valley was a depression between 101st and 99th streets, named after John Clendenning whose house was at the present 104th street and Columbus avenue. And York Hill, named after the neighboring Yorkville, is now included in Central Park (which did not then exist) between the lines of 79th and 86th streets.

The old Yorkville reservoir, as it was called, is rectangular in shape, 1826 feet long and 836 feet wide. Its area at the water line is 31 acres, including embankments 35.05 acres, and with accessories 37.05 acres. It has a storage capacity of 150,000,000 imperial gallons, according to Mr. Jervis' figures, but more recently stated at 180,000,000. Of the 37 acres occupied by the reservoir, 27½ acres were common lands of the City, and 9½ acres were acquired in the two blocks of 4¾ acres each from Hickson W. Field and William Matthews. The City paid $11,000 for each of these blocks or $22,000 for 9½ acres. The water was admitted into the Yorkville reservoir with due ceremony on June 27, 1842, in the presence of the Mayor, the Common Council, the Governor, the members of the Court for the Correction of Errors (then the highest court of appeals in the State), and a great gathering of people. A feature of the celebration was the arrival of the boat Croton Maid. This boat, large enough to hold four persons, had been launched at the Croton reservoir thirty-eight miles distant and sent through the aqueduct to High Bridge, where it arrived June 23. On the 27th it was carried across the Harlem and put into the aqueduct again and arrived at Central Park soon after the artillery salute of thirty-eight guns had announced the arrival of the water. The boat was presented to the fire department with an appropriate speech by the President of the Board of Water Commissioners.

On December 17, 1860, the Croton Aqueduct Board assented to the removal of the wall at the southwest corner of the reservoir, where the Belvidere was subsequently erected, on condition that the Park Commissioners should place some suitable monument to mark the line of the aqueduct property; that no public walk be made on the property; and that no objection would be made at any time to the reoccupation of the corner by the aqueduct commissioners.

The Murray Hill Reservoir

From the upper reservoir at Yorkville, a double line of iron pipes 3 feet in diameter was laid to Fifth avenue and thence to the distributing reservoir which formerly stood on the west side of Fifth avenue between 40th and 42d streets. This reservoir was 420 feet square on the cornice of the exterior wall and contained 4.05 acres. It had an average elevation of 44.5 feet above the street level, the greatest height being 49 feet. The walls were of hydraulic masonry, constructed with openings to reduce the quantity of masonry and give a larger base. The reservoir was composed of a double wall. The outer wall had a bevel of one to six and was uniformly four feet thick. The inner wall, which had a vertical inner face, was six feet thick at the bottom and four feet at the top. There were cross walls and arches in the interspace. On the outside walls an Egyptian cornice was laid, which was in keeping with the sloping architecture. The reservoir was designed to hold a depth of 36 feet of water, or a capacity of 20,000,000 imperial gallons. The surface of the water, when the reservoir was full, was 115 feet above mean tide. The water was admitted to this reservoir with formal ceremonies on July 4, 1842. The reservoir was then described as being " at Murray Hill, a short drive from the City." The total length of the aqueduct from Croton dam to this point is 45.562 miles.

In the spring of 1899, a contract was let for the removal of the reservoir to make room for the New York Public Library which now occupies its site, but the process of removal was slow, and portions of the massive walls remained standing long after the library building had been begun. The cornerstone of the library was laid on November 10, 1902, and the completed building was dedicated on May 23, 1911.

Extension to City Hall Park

On October 14, 1842, the water was admitted to the fountain in City Hall Park with still further ceremonies, including a procession seven miles long. The fountain was situated in the triangular area now occupied by the post office. At that time, there was an unobstructed view from the junction of Broadway and Chatham street (Park Row) in front of St. Paul's Chapel to the City Hall. The larger park was embowered with trees, in the midst of which the Croton fountain was for many years a graceful ornament.

In a statement of the real estate belonging to the City of New York published in the Corporation Manual for 1852, the value of the Croton water works was stated as follows:

Croton aqueduct	$14,200,000
Yorkville reservoir	134,000
Murray Hill reservoir.........................	152,000
	$14,486,000

Since that time the Croton water supply and the water works system have been enormously increased, and it would require a volume to follow out its details. One or two further features, however, may be mentioned.

Lake Manahatta in Central Park

One enlargement of interest was the building of the new reservoir or Lake Manahatta in Central Park. In less than a decade after the introduction of the Croton water supply, the City realized that it did not have storage capacity enough in its reservoirs to protect it against a serious drouth, and on February 5, 1851, the Common Council directed the Croton Aqueduct Board "to purchase without unnecessary delay enough suitable ground for a new reservoir of sufficient capacity with those already built to contain a supply for at least sixty days' consumption." The board thereupon carefully examined the island and on February 9, 1852, voted to appropriate for that purpose the rectangular area comprised between Fifth and Seventh avenues and 86th and 96th streets, as those streets were laid out on the city plan by the Commissioners of 1807. On May 21, 1852, the board recommended to the court the following named gentlemen as Commissioners of Estimate of the value of the ground to be taken: Daniel Dodge, Samuel B. Ruggles, Ezra P. Davis, Jacob S. Baker, Jedediah Miller and Anthony J. Bleecker.

Before work was begun on the reservoir, the Central Park was created, including the reservoir area, and the Park Commissioners proposed an exchange of territory by which the new reservoir, instead of being rectangular, would follow natural contours and, by avoiding some rock excavation, would save from $200,000 to $250,000 in the cost of construction. The Croton Aqueduct Board therefore, on June 6, 1857, consented to the change and the reservoir was built as it now exists. The land for this reservoir, purchased under an act of the Legislature of June 30, 1853, comprises 106.726 acres, and the reservoir, which covers ninety-six acres, has a capacity of 1,030,000,000 gallons. On April 14, 1856, the sum of $729,964.50 was awarded for the site.

This new reservoir, called on a map of 1859, Manahatta Lake,* in the records of the Aqueduct Board the Grand Reservoir, and popularly the New Reservoir, was completed in 1862 and the water was admitted on August 19th with due ceremony. The minutes of the Croton Aqueduct Board of that date read as follows:

> "The water was let into the new Grand Reservoir on this day at 3 P. M. The signal was given by Chief Engineer Alfred W. Craven, Esq., when the ten influent gates were raised simultaeously, and the Croton flowed through to the delight of the thousands that were present to witness the great event. His Honor the Mayor then introduced Myndert Van Schaick, who delivered an address, after which Mr. McChesney recited an ode prepared for the occasion, and with an address by Mr. Marsh and music by Mr. H. Dodworth's band the ceremonies ended and the assembled multitude dispersed to pay their respects to the contractors, Messrs. Fairchild, Walker & Company, at their office."

New Croton Aqueduct

On account of the phenomenal growth of the City, it became necessary not only to build additional reservoirs from time to time, but also to build another aqueduct from the Croton Valley

* Mayor Tiemann so named it at the ceremonies attending the induction of the water, saying: "Our new Lake of the Manahatta will far surpass the dimensions of the old Kolch."

to conduct the increased supply of water to Manhattan Island. Such a new conduit was built in 1885–1893. It is almost entirely a tunnel from Croton Lake to the terminal gate-house at 135th street and Convent avenue, a distance of 31 miles. At this gate-house the old aqueduct is connected with the new. The old Croton aqueduct, with a capacity of 90,000,000 gallons a day, and the new Croton aqueduct with a capacity of 300,000,000 gallons a day, were supplemented in 1880 and 1885 by an additional supply of 22,000,000 gallons a day by a conduit bringing water from the Bronx and Byram rivers.

The Cornell or New Croton Dam

When the plans were made in 1882–1885 for an enlarged water supply, they included the project for a high masonry dam across the Croton river about two miles from its mouth, at the site of the old Quaker Bridge. Owing to local opposition to this site, another location was selected about 1¼ miles farther up-stream on the land of A. B. Cornell and others. The dam here constructed was at first called the Cornell dam, but later was designated as the New Croton dam, to distinguish it from the old Croton dam 3½ miles farther up-stream.

The rock at the dam site is gneiss on the north side of the valley and limestone in the center and on the south side.

The contract for building the dam was awarded August 26, 1892; work was begun in the fall of 1892; the first stone in the foundation was laid May 26, 1896; the dam was nearly finished and the gates were closed January 28, 1905, beginning the storage of water; the work was completed January 1, 1906; and by November 5, 1907, the reservoir was full to high water mark.

The total length of the masonry and earth dams across the channel is 1,600 feet; the total height from bottom of foundation about 240 feet; and the maximum thickness of masonry at the bottom 206 feet. The thickness of masonry decreases toward the top until it is only about 15 feet thick under the roadway. The roadway has a width of 19½ feet by being carried out on corbels. The reservoir thus formed is about 19 miles long and stores about 33,815,000,000 gallons.

The plans for the new Croton dam were prepared under the direction of the late Alphonse Fteley, Chief Engineer of the Aqueduct Commissioners. They were modified as the work progressed. The construction was carried on under his supervision until January 1, 1900; then under Mr. William R. Hill until October 14, 1903; Mr. J. Waldo Smith until August 1, 1905; and Mr. Walter H. Sears until completion.

The cost of the dam, not including engineering, land and legal expenses, was $6,886,872.

Even this provision was not adequate to the growing needs of the City, and two more sources were added in 1908 and 1911, making the total storage capacity of the Croton system as follows:

Reservoir	Service begun	Gallons of storage capacity
Old Croton Lake	1842	Included below
Boyd's Corners	1873	2,727,000,000
Middle Branch	1878	4,155,000,000
East Branch (Sodom)	1891	5,243,000,000
Bog Brook	1891	4,400,000,000
Titicus	1893	7,617,000,000
West Branch (Carmel)	1895	10,668,000,000
Amawalk	1897	7,086,000,000
New Croton	1905	33,815,000,000
Cross River	1908	10,923,000,000
Croton Falls	1911	15,753,000,000
		102,387,000,000

VII

THE CATSKILL WATER SUPPLY*

The City of New York is growing at such a rate that each two years it takes unto itself as many people as Jersey City has to-day. Each year it more than adds the equivalent of an Albany, a Bridgeport, a New Haven or a Grand Rapids. Every four years its gain in size would make a Boston, a Cleveland or a Baltimore. New York City at present obtains practically all of its water from the Croton and Bronx watersheds in Westchester, Putnam and Dutchess counties, and the Ridgewood water-shed in Nassau county. Each of these watersheds has already been developed to practically the economic limit. On account of the already high development of these catchment areas very little more water could be obtained from them by the construction of additional works. Greater New York's total average daily consumption of water is at present nearly 550,000,000 gallons, from all sources. Its estimated population is 5,800,000, exclusive of four hundred thousand commuters and other transients.

To keep pace with its growth of approximately 175,000 persons per year, it was long ago recognized that additions to the City's water-supply system would be inveitable. Indeed, additions have been made at irregular intervals ever since the City first became possessed of a general water-supply system. As far back as 1896, the subject of supplementing the existing Croton and Ridgewood systems was taken up by the Manufacturers' Association of Brooklyn and reported on under date of March 15, 1897. In 1901, following the agitation by this association, a bill was introduced by it in the Legislature having for its object the creation of a commission empowered to add to the water-supply of the City. In 1899, Comptroller Bird S. Coler caused an investigation of all the available sources to be made by John R. Freeman, Consulting Engineer. Still later, in 1902, Commissioner of Water Supply Robert G. Monroe appointed the Burr-Hering-Freeman Commission to investigate this question.

* This chapter is reproduced from a pamphlet published by the Board of Water Supply of the City of New York in January, 1916, with figures brought down to January, 1917.

As the result of all these studies, the Legislature on June 3, 1905, under chapter 724 of the laws of that year, authorized the work now being done by the Board of Water Supply. Mayor George B. McClellan on June 9, 1905, appointed the first members of the Board from three lists of three names each submitted at the Mayor's request by the Chamber of Commerce of New York, the Manufacturers' Association of Brooklyn and the Board of Fire Underwriters.

On October 9, 1905, the Board of Water Supply submitted for approval to the Board of Estimate and Apportionment a plan for obtaining from the Esopus, Rondout, Schoharie and Catskill creeks a supply of not less than 500,000,000 gallons of water daily at an estimated cost of $161,857,000. On October 27, 1905, this plan was unanimously approved by the Board of Estimate and Apportionment, and on November 3 of that year application was made to the State Water Supply Commission for its approval, as provided by law. On May 14, 1906, this approval was granted, exclusive of Schoharie, and in less than six months the first construction contract, for 11 miles of aqueduct, was advertised.

The completion of the plan for the delivery of Catskill water to all the boroughs of the City was first approved by the Board of Estimate and Apportionment on December 10, 1909, and again, after exhaustive investigation, under another City administration, on July 1, 1910. This plan for the delivery of water to all boroughs of the City increased the estimated cost by $15,000,000, the original plan of 1905 having included no provision for the delivery of water to the Boroughs of Manhattan, Queens and The Bronx. Such delivery was, of course, contemplated from the beginning, but the problem required prolonged study, and, therefore, a satisfactory scheme could not be elaborated in time to be embraced in the Board's first report, determining the general scheme for a new supply.

The Board of Water Supply also made an exhaustive investigation for an additional supply of water from Suffolk county, Long Island, supplementing work begun by the Burr-Hering-Freeman Commission. The Board's investigations included a complete scheme for adding this water to Brooklyn's present system for supply from Nassau County. So far as engineering and construction operations were concerned it would have been possible to develop additional water in Suffolk county and deliver it to Brooklyn before the Catskill water could be delivered there, if a severe shortage of supply had made this necessary. Consequently, in accordance with the procedure required by law, application was made in 1908 by the Board of Estimate and Apportionment to the State Water Supply Commission, but, necessity for immediate construction having passed, the application has been withdrawn. The work done can, however, be utilized at any future date.

General Description of Catskill Water System

The four drainage areas, or watersheds, from which the City is authorized to draw a new supply, are situated west of the Hudson river, in the Catskill mountains, and lie between lines 75 and 135 miles from New York's City Hall. This region is sparsely settled. In the aggregate these watershels have an area of 914 square miles, and individually, as follows: Esopus, 257 square miles; Schoharie, 314 square miles; Rondout, 143 square miles; Catskill creek, 200 square miles, including several small contiguous areas helping to make up the grand total. From this gathering ground it is estimated that even in a series of extraordinarily dry years 760,000,000 gallons daily can surely be drawn the year through. The figures just given are based upon the additional surveys, rainfall records and stream-flow gagings up to date, and differ somewhat from the earlier figures. To collect these waters for the City's use several large impounding reservoirs are to be created from time to time, as found necessary, and inter-connected by aqueducts. Only the Esopus watershed has been developed, but its sole reservoir, known by the Indian name of Ashokan, is by far the largest and most important of them all. From this reservoir the Catskill aqueduct conveys the water into all the five boroughs of the City. Within the City limits the aqueduct, known here as the City tunnel, lies from 200 to 750 feet below the street surface. It extends to two terminal shafts in Brooklyn whence steel and iron pipe conduits continue into the Boroughs of Queens and Richmond. Although in a series of dry years the Esopus watershed cannot be depended upon to supply more than 250,000,000 gallons each day, the Catskill aqueduct has, for economic reasons, been constructed of at least 500,000,000 gallons daily capacity.

Extended investigations, including topographic surveys and borings, were made downstream from Prattsville on Schoharie creek, and disclosed an excellent dam site at Gilboa. With a dam placed here, a watershed of about 314 square miles can be developed to furnish a dependable daily yield of 250 million gallons or enough to furnish, with the Esopus supply, at least 500 million gallons daily, or the full capacity of Catskill aqueduct. Water from Schoharie reservoir will pass through a 16 2/3-mile tunnel to Esopus creek and flow into Ashokan reservoir. This watershed is to be developed next so as to utilize the full capacity of the Catskill aqueduct. It will take nearly 8 years to make this additional water available in the City.

From the Ashokan reservoir situated in the foot-hills of the Catskill mountains it is almost a 3-days' journey for the water, at the average velocity of flow through the aqueduct to the Silver Lake terminal reservoir in the Borough of Richmond; this borough is Staten Island, surrounded by the sea, at the southerly entrance to New York bay. In this distance of 120 miles the Catskill aqueduct skirts along many a steep hillside, pierces mountains, descends beneath rivers and wide, deep valleys, traverses the Boroughs of the Bronx, Manhattan and Brooklyn, and crosses The Narrows of New York harbor. From Ashokan reservoir to the City's northern boundary there are 92 miles of aqueduct, and between that reservoir and Croton Lake, the principal basin on the Croton watershed, there are 64 miles.

Construction operations have been in progress over nine years. The development of the Esopus watershed is completed, from which a daily yield of 250,000,000 gallons is obtainable.

Work under construction and projected includes a number of superstructures for the chambers containing the apparatus for controlling the flow of water, and accessories of the aqueduct, such as apparatus for pumping out the pressure tunnels.

The Ashokan Reservoir

Ashokan reservoir, about 14 miles west of the Hudson at Kingston, was built under contracts amounting, together with the expense for relocating highways and the Ulster and Delaware railroad, to nearly $20,000,000. The water which this reservoir holds would cover all Manhattan island to a depth of 30 feet; the area of its surface is equivalent to that of Manhattan below 110th street. The Olive Bridge dam, across Esopus creek, the Beaver Kill and Hurley dikes, across smaller streams and gaps between the hills forming the natural walls of the reservoir, the Dividing dike and weir dividing the reservoir into two basins, and the Waste weir over which the surplus flood waters may safely be discharged, are the principal structures of the reservoir.

Olive Bridge dam is a massive structure consisting of a central masonry portion flanked by earth dikes, or embankments, known as the North and South wings. The masonry part, founded on solid ledge-rock, is built of cyclopean concrete with pre-cast concrete face blocks. The wings of the Olive Bridge dam and the dikes are built of selected earth spread in layers 4 or 6 inches thick and compacted by heavy rollers. Each dike has a concrete core-wall extending to ledge-rock or into very compact impervious earth foundation.

The bottoms and slopes of the reservoir basins have been cleared of trees, brush, buildings and other objectionable things. Around the reservoir new highways, aggregating about 40 miles in length, requiring the construction of 10 new bridges all of reinforced concrete, have been substituted for the submerged roads. One of these bridges, at Traver Hollow, is a 3-hinged arch of 200-foot span, and Ashokan bridge, crossing the reservoir on the Dividing weir, is 1,120 feet long and has 15 arches of 67.5-foot span.

Camp and Equipment at Ashokan Reservoir

In all contracts requiring work on the watersheds or along the aqueduct sanitary clauses were inserted so that the health of employees, of local communities, and of people using water from the drainage areas affected by the construction operations would be safeguarded. Employees violating sanitary rules were summarily dismissed and not again employed. Ample supplies of wholesome water were insisted upon, as well as good food and sanitary conditions generally. A brief description of the largest camp will show clearly the scope of these precautions. As administered the sanitary precautions proved effective. The death rate, exclusive of accidents, has averaged only about 3.5 per thousand in the camps.

The work on the dam and dikes at Ashokan reservoir required an army of 3,000 men who lived, many of them with their families, in a camp built by the contractors near the work. The camp was divided into Italian and Negro sections, while white Americans lived separately. There were provided sewerage and water-supply systems, a special plant for the disposal of sewage, good dwellings, generally one-story wooden structures with screens on all doors and windows, well-laid-out streets, electric lights, telephones, savings bank, hospital, general store, bakery, police, fire protection, a kindergarten and schools for children, churches, Young Men's Christian Association and a post-office. The maximum population was approximately 4,500. An evening school for men was one of the features of the camp. Besides the Camp City, there were other smaller camps on outlying parts of the work.

For constructing this reservoir, the contractors assembled plants (machinery, railroads, derricks, etc.), costing much more than a million dollars. These plants included approximately 30 miles of railroad, 33 locomotives, 579 cars, 60 derricks, 7 cableways, 16 steam rollers, 19 steam shovels, a steel trestle bridge 390 feet long and 85 feet high, air-compressors, stone crushers, concrete mixers, etc., etc. Quarries were opened in the nearby hills to obtain stone, and several hills of clayey earth were dug away to build the earth dams.

Statistics of Ashokan, Kensico and Schoharie Reservoirs

	Ashokan	*Kensico*	*Schoharie*
Capacity, total, gallons	132,000,000,000	38,000,000,000	22,000,000,000
Capacity, available, gallons	128,000,000,000	29,000,000,000	20,000,000,000
Water surface	12.8 sq. miles	3.5 sq. miles	1,170 acres
Land acquired	23.8 sq. miles	7.0 sq. miles	
Elevation of top of dam above tide	610 feet	370 feet	1,148 feet
Length of reservoir	12 miles	4 miles	5 miles
Length of shore line	40 miles	40 miles	12 miles
Length of dams and dikes	5½ miles	3,300 feet	2,100 feet
Main dam:			
total length	4,650 feet	1,825 feet	2,100 feet
length of masonry portion	1,000 feet	1,825 feet	1,600 feet
height, maximum	240 feet	307 feet	165 feet
thickness at base, maximum	190 feet	235 feet	
thickness at top, minimum	23 feet	28 feet	
Width of reservoir:			
maximum	3 miles	3 miles	¾ mile
average	1 mile	1 mile	½ mile
Depth of reservoir.			
maximum	190 feet	155 feet	150 feet
average	50 feet	52 feet	58 feet
Villages submerged	7	None	1
Permanent population of submerged area in 1905	2,000	500	350
Cemeteries removed	32	None	3
Bodies reinterred	2,800	Few	935
Railroad relocated	11 miles	None	None
Highways discontinued	64 miles	14 miles	13 miles
Highways built	40 miles	9 miles	13 miles
Highway bridges built	10	4	2 +
Principal items of work:			
earth and rock excavation	2,500,000 cu. yds.	1,480,000 cu. yds.	*725,000 cu. yds.
embankment	7,300,000 cu. yds.	2,110,000 cu. yds.	*681,000 cu. yds.
masonry	900,000 cu. yds.	1,016,000 cu. yds.	*319,000 cu. yds.
cement	1,200,000 bbls.	997,000 bbls.	*350,000 bbls.
Maximum number of men employed	3,000	1,500	

* For dam only.

General Features of Shandaken Tunnel

Length, 18 miles.
Capacity, 570 m. g. d. (C. 150–665 m. g. d.; C. 140–620 m. g. d.; C. 135–600 m. g. d.).
Elevation of intake, 1,050 feet.
Elevation of outlet, 970 feet.
Physical slope, Shafts 1 to 7, .000834 or 4.4 feet per mile, or 1 inch per 100 feet.
Between intake and Shaft 1 is a siphon tunnel — Height, 11 feet 6 inches; width, 10 feet 3 inches.
Number of shafts, intake shaft and seven others. Depth of shafts below original surface of ground:
Intake, 260 feet (165 feet below floor of chamber); Shaft 1, 369 feet; Shaft 2, 319 feet; Shaft 3, 352 feet; Shaft 4, 392 ± feet (may be shifted slightly); Shaft 5, 629 feet; Shaft 6, 616 ± feet (may be shifted slightly); Shaft 7, 378 feet.
Total depth of shafts, 3315 + feet.
Greatest depth of tunnel below surface of 2215 feet under top of mountain just east of Deep Notch.
Portal at Allaben, leading to Esopus Creek.

The Kensico Reservoir

Kensico reservoir, east of the Hudson and 30 miles from the City Hall, contains several months' supply of Catskill water and acts as a storage reservoir, so that the flow into The City will not be interrupted while the 75 miles of aqueduct between it and the Ashokan reservoir are being inspected, cleaned or repaired at any time. It cost approximately $8,500,000. It is on the line of the Catskill aqueduct and will be, in a more distant future, the great wholesale distributing reservoir for the metropolitan district.

This reservoir is formed by the Kensico dam across the valley of the Bronx river, about three miles north of White Plains and 15 miles north of the Hill View reservoir. One mile northwest from the Kensico dam, a low gap in the hills was filled with an earth dike about 1,450 feet long, with a maximum hight of 25 feet. The water is about 110 feet deep over the surface of the old Kensico reservoir, which was developed in 1885, and is 54 feet deep over the surface of the Rye ponds, which were auxiliary to the old Kensico reservoir and are included in the new.

For the purpose of the new Kensico reservoir, 3,200 acres of land were acquired; which, in addition to the 1,300 acres acquired for the old reservoir and Rye ponds, make a total of 4,500 acres, providing a marginal protective strip around the entire flow line in but few places less than 500 feet wide.

Catskill water is delivered into Kensico reservoir at the upper end of the Bronx valley where the normal surface of the reservoir, elevation 355, is at the hydraulic grade line of Catskill aqueduct. At this place there is a covered influent weir and a gate-house. The water is drawn from the reservoir through a short tunnel at a point on the west side of the reservoir about one mile above the Kensico dam. At the reservoir end of this tunnel is the Upper Effluent gate-house containing sluice-gates for controlling the flow from the reservoir into the aqueduct. At the lower end of the outlet tunnel is a large gate-chamber in which the flow of the water is regulated by valves and either diverted through the Kensico aerator or sent directly to the aqueduct. Near the Lower gate-house is the Screen chamber in which all the water is passed through fine mesh screens before it flows on toward Hill View reservoir. A reinforced concrete by-pass conduit, 11 feet in diameter and 11,000 feet long, from the Influent gate-house at the upper end of the reservoir, connects with the Upper Effluent gate-house so that water may be delivered direct through the aqueduct alone without sojourning in the reservoir.

Although the Kensico reservoir is within 15 miles of the City line, it lies in a practically undeveloped region, consisting principally of farms and woodland, with no important industry. New highways were required, the most important of which is the county road leading from White Plains to Mount Kisco. This crosses an arm of the reservoir on a reinforced-concrete arch bridge consisting of five spans of about 127 feet each, known as the Rye Outlet bridge.

Two sites for the Kensico dam were explored by borings and test-pits: One immediately below, and the selected site, about 400 feet above, the old dam. The old dam was a rolled-earth embankment with a masonry core-wall, only a portion of which was founded on the rock. The adoption of the upper location required drawing off the old reservoir. In order to maintain the supply which serves a portion of The Bronx, two substitute reservoirs were built farther up the valley within the basin of the new reservoir. These substitute reservoirs were formed by two rolled-earth dikes with timber core-walls, one across the Bronx valley, and the other across the valley of the Rye outlet. These two temporary reservoirs are inter-connected by a small tunnel and supplied the Bronx conduit through a 36-inch riveted steel pipe. In order to secure a good quality of water in the substitute reservoirs, about 186 acres of swamp were cleared and covered with a layer of earth averaging a foot in depth, and the water before being drawn into the pipe line was passed through a temporary aerator just below Rye dike, discontinued December 8, 1915. A conduit through the dam serves permanently to maintain this supply from Kensico reservoir.

The Kensico dam is a gravity masonry structure of cyclopean concrete. The up-stream face is of concrete blocks. The concealed portion of the down-stream face below the final grading was molded against forms, above which the remainder of this face is of cut-stone masonry. The entire dam is divided into sections by transverse expansion-joints about 79 feet apart longitudinally. These expansion-joints are faced on one side with concrete blocks forming a series of vertical tongues and grooves against which the masonry of the other side was built. Near the upstream face a copper strip has been placed across each expansion-joint continuous from bottom to top to act as a water-stop. The contraction and expansion are caused by changes of temperature and result in slight opening and closing of the joints from season to season.

Drainage wells 15 feet apart, longtitudinally, formed of porous concrete blocks, extend from an inspection gallery below the top of the dam near the upstream face to an inspection gallery near the level of the reservoir bottom, which in turn connects with a transverse drainage gallery leading to the downstream face of the dam.

The downstream face of the dam was given a dignified architectural treatment in harmony with engineering fundamentals. For the profile of the downstream face a true hyperbola was adopted. Since the dam is divided for structural reasons by 22 expansion-joints, its downstream face has 21 panels and 2 terminal structures. At each expansion-joint there is a massive band of rusticated stone, 15 feet wide, projecting boldly from the general surface. These bands separate the panels the fields of which are of roughly-squared stone masonry, surrounded by borders 3 feet 6 inches in width of dimension stone cut to relatively flat surfaces. To add interest to the panels, dimension-stone headers about 1½ feet square are spaced throughout the fields to a diamond pattern and set to project slightly. A large proportion of the hight of the dam in the central part of the valley is below the level to which the earth has been graded against the dam. From this it results that 13 of the panels are of uniform hight, while at each end 4 panels on the hill slope make a triangular wing. At the foot of each slope, where the inclined portion of the visible bottom of the dam joins the horizontal portion, the panel forming the end of the main part of the dam is advanced beyond the other panels to form a pylon. The whole length of the dam is crowned by a massive entablature, including a crudely-carved frieze and a heavy torus surmounted by a simple parapet. All this stonework is of coarse texture and bold relief, in harmony with the massiveness and strength of the dam.

A public highway traverses the top of the dam, approaching from the east over a 3-arch masonry bridge across the nearby waste channel of the reservoir. Each terminal of the dam is surmounted by a circular pavilion of granite. Along the level portion of the visible base of the dam extends a masonry terrace 30 feet broad, about 10 feet above the adjacent earth. Beneath the terrace is placed the Lower gate-chamber, controlling blow-off pipes and connections to Bronx conduit, and storage spaces for use of the maintenance force. At each end of the terrace is a pair of small square pavilions surmounting a flight of steps leading down from the terrace to the driveway level. The length of the level part of the visible base of the dam, and of the terrace, is about 1,025 feet. The vertical hight of the exposed face, from the terrace to the top of the parapet, is 133 feet, but the maximum hight from lowest foundation to top of parapet is 310 feet. A shallow rectangular pool, with fountains, parallels the terrace and is separated from it by a strip of parking. The area downstream from the dam was utilized for the disposal of surplus materials from the excavations for the foundation, for the concrete block yard, the labor camp, for storage of cut granite, and for other construction purposes, and is being laid out as a park with which the northern end of the Bronx River parkway, extending from New York City, will connect.

Surveys for the reservoir were begun in May, 1906, and the contract, No. 9, for the dam, reservoir and substitute supply works, was awarded, in December, 1909, to Rodgers, Rodgers and Hagerty. The contract was assigned to H. S. Kerbaugh, Inc., in September, 1910. The amount of the contract, based on the bid prices and the approximate estimate of quantities, was $7,953,050. The amount of the bond required was $1,000,000 and the date set for the completion is February 14, 1920. The contract required that by November 14, 1917, the dam should be sufficiently completed to store water to elevation 315; and that the dam be effectively completed to its full hight (elevation 370) by April, 1919. The unprecedented progress in masonry laying developed through the methods employed brought the dam to its full hight in October, 1915, and water to the amount of 16,000,000,000 gallons and reaching elevation 320 was in storage January 10, 1916. During August, 1914, the record amount of 84,450 cubic yards of masonry was laid.

Camp and Equipment at The Kensico Reservoir

When at its hight the work on the Kensico reservoir gave employment to about 1,500 men, who lived, many of them with their families, in a camp built by the contractor a few hundred feet down-stream from the dam site. The camp was divided into Italian and American sections. There have been provided sewerage and water-supply systems and dwellings which are generally one-story wooden structures, those occupied by families being two stories in hight. All doors and windows of the camp buildings are screened. Electric lights are provided. There are also a hospital, police regulations, fire protection, kindergarten and schools for the children.

An evening school for men is one of the features of the camp. This school was originally operated by the Civic League of North America, but is now in a special public school district supported by The City. The 8-hour day gives plenty of spare time to attend the school, where the elements of the English language and of national, state and city governments are taught; all in an effort toward good citizenship and promoting efficiency in the workmen. The camp schools are encouraged and assisted by the Commissioners personally. They have been supported by private subscriptions, together with the help of the contractors.

Besides the large camp, which had accommodations for 1,200 persons, there were several small camps on outlying parts of the work, and of the men employed there were also quite a number who lived in the surrounding villages, but practically all outside of the limits of the drainage area of the Kensico supply.

For carrying on the work on this reservoir, the machinery, railroads, derricks, etc., in use cost over one and a quarter million dollars. This plant was largely operated by electricity obtained from the power-houses of the Edison Company in New York City. The current is transmitted in underground ducts at a potential of 13,000 volts to the Dunwoodie transformer station where it is stepped up to 44,000 volts for transmission over a steel tower line on the aqueduct right-of-way from Dunwoodie to the site of the work. In the power-house at the easterly end of the dam site the current is stepped down to 2,200 volts for distribution. Field transformers further reduce the voltage to 440, 220 and 110 for the operation of rock drills, hoists, cableways, the rock-crushing plant and the lighting system. In the power-house are also two air-compressors of a capacity of 1,500 cubic feet of free air per minute. The 40 electric hoists on the work were all of 75 horse-power. At the excavations for the dam and at the quarry, besides many rock drills of the usual type, a large number of electric pneumatic drills were employed.

For constructing the main portion of the dam, stiff-leg derricks mounted in pairs on travelers were used. These travelers, as well as the cars bringing materials to them, operated on a system of elevated tracks supported on concrete piers about 20 feet high, which were left embedded in the dam. Two lines of traveler tracks running longitudinally with the dam permitted four travelers to be placed in pairs facing each other over a section of the dam between expansion joints, thus making eight derricks available for each section of the dam. This whole system of tracks and travelers was elevated from time to time as the masonry progressed by means of two movable cableways of 1,860-foot span stretching across the dam site between timber towers 125 feet high. The cables are of lock-bar type, 2½ inches in diameter. For the upper 130 feet the reduced width of the dam permitted the use of only one traveler track.

Concrete blocks for facing the dam were cast below the dam in a yard 1,100 feet long. A traveling platform carrying three concrete mixers, each of one cubic yard capacity, spanned the form bed and moved on rails extending longitudinally through the yard. The forms for the blocks were of steel and were set in rows along the tracks, so that as the traveler advanced each mixer discharged concrete into a separate form. The blocks when sufficiently hardened were stacked by traveling cranes for storage until sent to the dam. Blocks were at least three months old before being built into the dam.

Taking advantage of favorable outcrops of rock about one mile east of the dam site, quarries were developed for supplying the stone needed for the various kinds of masonry. Here a rock crushing plant having an output of 150 tons an hour and a cutting shed for dimension-stone masonry with a daily output of 50 cubic yards of dressed stones were established. The crushing plant contains a 60-inch by 84-inch jaw crusher, one of the largest ever built, a 36-inch by 72-inch intermediate jaw crusher, a No. 8 McCully gyratory crusher and a pair of 60-inch rolls for further reducing the size of the crushed product. The product of the crushers is lifted by rubber belt conveyors 36 inches wide carrying steel buckets. The main rotary screen is eight feet in diameter and 30 feet long, equipped with cast manganese steel plates. The crushed stone and dust are carried from the main screen by belt conveyors to the storage bins with hopper bottoms which discharge into cars running on tracks under the bins. The bins have a capacity of 7,280 cubic yards of crushed stone and 740 cubic yards of screenings. The whole is electrically operated by eight motors aggregating 1,120 horsepower.

The stone cutting yard is 225 feet long and 60 feet wide, equipped with a 25-ton Shaw electric crane, nine Oldham surfacing machines, each of which does the work of about 10 hand cutters, and 50 plug drilling machines. All together about 80 stone cutters are employed at this yard.

The Hill View Reservoir

Hill View reservoir is located in the City of Yonkers, just north of the New York City line, and 15 miles south of the Kensico reservoir. Its function is to equalize the difference between the use of water in the city as it varies from hour to hour and the steady flow in the aqueduct. It is an uncovered, artificial reservoir of the earth embankment type. It holds 900,000,000 gallons of water with a depth of 36½ feet, and has a water surface of 90 acres. The contract for its construction was let for $3,270,000, in December, 1909, and it is finished except for some unessential details. It was first filled December 29, 1915.

On the inside of the reservoir, the embankment is protected by six inches of concrete on the bottom and eight inches of concrete on the lower portion of the slope; the upper portion of the slope, above the berm, which is 22 feet above the bottom, is protected by rubble stone paving and riprap. The concrete lining is not intended or constructed for water-tightness. The top and outside slopes of the embankment are covered with top-soil and grassed. Much effort has been made to produce the effect of natural hill slopes in the grading, and with success. The path around the top of the reservoir is 8,600 feet long.

The reservoir is divided into two basins by a wall 2,740 feet long that contains the by-pass aqueduct so that either one or both basins may be used or be by-passed whenever required, or water delivered directly into the City tunnel. The water is controlled by sixteen 5-foot by 15-foot sluice-gates, five in the uptake gate-chamber and eleven in the downtake chamber.

The principal items of work on Hill View reservoir include the following:

Excavation	**2,900,000 cubic yards**
Embankment	**2,900,000 cubic yards**
Soil	**100,000 cubic yards**
Concrete in chambers, dividing wall and lining	**149,000 cubic yards**
Concrete in shafts and tunnels	**13,000 cubic yards**
Portland cement	**218,000 barrels**

The tunnels mentioned in the table are of the pressure type and form the connections between the reservoir and the Yonkers pressure tunnel of the Catskill aqueduct on the northerly end, and the City tunnel at the south.

The Catskill Aqueduct North of the City

There are four distinct types of aqueduct, cut-and-cover, grade tunnel, pressure tunnel and steel-pipe siphon, north of the City line. The entire aqueduct to the City line, aggregating 92 miles, is completed with the exception of some grading, grassing and cleaning up remaining to be done along a few short stretches, the installation of some equipment, completion of a few buildings, and of 1,600 feet of brick lining in Eastview tunnel. In addition there remain the necessary testing of numerous valves and appurtenances and trial operations of the aqueduct as a whole.

The cut-and-cover type forms 55 miles of the aqueduct, is of horseshoe shape in cross-section, 17 feet high by 17 feet 6 inches wide inside and constructed of concrete. As completed it is covered with an earth embankment. This is the least expensive type and so was used wherever the elevation and nature of the land permitted.

Where hills or mountains cross the line and it would have been impracticable or uneconomical to circumvent them, tunnels at the natural elevation of the aqueduct were driven through them. There are 24 of these grade tunnels, aggregating 14 miles. They also are horseshoe shape, 17 feet high by 13 feet 4 inches wide, and lined throughout with concrete. They are on a steeper gradient than the cut-and-cover portions.

Where deep and broad valleys were crossed and there was suitable rock beneath them, circular tunnels were driven deep in the rock and lined with concrete. There are seven pressure tunnels, totaling 17 miles, with a diameter of about 14 feet. A shaft at each extremity connects each pressure tunnel with the adjacent portions of the aqueduct, with one exception. This exception is the junction between Bryn Mawr steel-pipe siphon and Yonkers pressure tunnel; the three pipes, each 11 feet in diameter, enter the hill at an elevation 167 feet below hydraulic gradient of the aqueduct and are sealed into the rock in three branch tunnels, which converge into the main tunnel 16 feet, 7 inches in diameter. The City tunnel described later, is also a pressure tunnel 18 miles long.

Drainage shafts were constructed so that each tunnel can be unwatered for inspection, cleaning or repair. Usually a drainage shaft is near a large stream and intermediate between the end shafts. For the pressure tunnel under Croton lake, the downtake shaft is also the drainage shaft and contains the connection to the lake. Yonkers pressure tunnel can be drained by gravity through the Bryn Mawr steel-pipe siphon, with which it is connected. Besides the end and drainage shafts other shafts were sunk to aid in excavating and lining the tunnels. These construction shafts were afterwards sealed and partially refilled.

The Hudson river is crossed by means of a tunnel wholly in granitic rock, at a depth of 1,114 feet below sea-level, between a shaft at Storm King mountain on the west bank and another shaft on the east side of the river at Breakneck mountain. The top of the west shaft is closed by a thick concrete plug, but the east shaft, which is the drainage and access shaft for the Moodna-Hudson-Breakneck pressure tunnel, as well as a waterway, required a removable cover, and for it steel castings and forgings of unusual size and shape had to be manufactured. The drainage shaft is 14 feet in diameter inside the concrete inner lining, which protects the 15-foot-diameter steel interlining, outside of which concrete is solidly packed against the rock. About 10 feet above sea-level, this shaft is covered by a steel casting nearly hemispherical in shape. This dome rests on a cast-steel ring called the curb. To hold the dome in place against the head of the water when the aqueduct is in service, which at this point will be about 410 feet, there are 36 anchor-bolts, each 4½ inches in diameter and 50 feet long, made of nickel-chrome steel. These bolts go through bored holes in the flange of the dome and the curb, and through steel sleeves to a cast-steel anchor-ring 46 feet farther down. The object of these sectional steel sleeves is primarily to insure the application of the anchorage stresses at a suitable depth in the rock, secondarily to permit the removal of the bolts if desired in connection with the removal of the cover or for inspection and also for convenience and necessary adjustments during construction operations. The top and bottom sections of these sleeves are of cast steel each with 47 collars on the outside to afford a good grip on the concrete; the middle sections are commercial pipe.

Steel-pipe siphons were used in valleys where the rock was not sound or where for other reasons pressure tunnels would be impracticable. These steel pipes are made of plates from 7/16 inch to 3/4 inch in thickness riveted together, and are 9 feet and 11 feet in diameter. They are lined with two inches of cement mortar, enveloped with concrete and covered with an earth embankment. There are 14 of these siphons, aggregating six miles. Three pipes are required in each siphon for the full capacity of the aqueduct, but only one is now needed and this one pipe has been completed in all the siphons. These pipes are not true siphons but are given this name because of their approximate resemblance to an inverted siphon.

Aeration and Filtration

In connection with the headworks of the Catskill aqueduct, at the Ashokan reservoir, and also at the Kensico reservoir, an aerator capable of treating all the water which will flow in the aqueduct has been built and is being equipped. These two aerators are substantially alike and are great fountain basins, approximately 500 feet long by 250 feet wide, each containing about 1,600 nozzles through which jets of water will be thrown vertically into the air. The nozzles are so designed that the water will be divided into fine spray, thus permitting thorough admixture of oxygen and removal of undesirable gases and other matters causing tastes and odors. The jets have been so arranged as to be pleasing in appearance, and the fountains will be well worth visiting when in operation.

Provision for a filtration plant was made by the acquisition of 315 acres of land at Eastview, near Tarrytown, close to the line of the aqueduct, and about two miles below the Kensico reservoir. Here a connection chamber was built in the aqueduct, so that water can be diverted to, and received back from, the filter plant. Pending the completion of the filters, for which studies are in progress, a small coagulating plant is being built over the aqueduct, in Pleasantville, about two miles above Kensico reservoir, to aid in removing turbidity from the water whenever the turbidity rises above a satisfactory limit.

The City Tunnel

From the Hill View reservoir, Catskill water is delivered to the five boroughs by a circular tunnel in solid rock reducing in diameter from 15 feet to 14, 13, 12 and 11 feet. The total length of the tunnel is 18 miles. From two terminal shafts in Brooklyn, steel and iron pipe-lines extend into Queens and Richmond. A

36-inch flexible-jointed, cast-iron pipe, buried in a trench in the harbor bottom, has been laid across The Narrows to the Staten Island shore, whence a 48-inch cast-iron pipe extends to the Silver Lake reservoir, holding 435,000,000 gallons. The total length of this delivery system is over 34 miles. The tunnel is at depths of 200 to 750 feet below the street surface, thus avoiding interference with streets, buildings, subways, sewers and pipes. These depths are necessary also to secure a substantial rock covering to withstand the bursting pressure of the water inside.

The City tunnel, which is the longest tunnel in the world for carrying water under pressure, or any other purpose, was constructed from 25 shafts, including the downtake shaft at Hill View reservoir, about 4,000 feet apart, located in parks and other places where they interfered very little with traffic. Through 22 of these shafts the water will be delivered into existing and additional mains. Provision is made at Shafts 11 and 21 for unwatering the tunnel whenever necessary for inspection, cleaning or repairs. Shaft 1 was sunk for construction purposes only and was sealed and refilled. At the top of each of the twenty-four other shafts a chamber has been constructed to contain the valves and other appliances for controlling the admission of water from Hill View reservoir, the flow and pressure of the water from the tunnel into the street mains and for the unwatering apparatus. Unusual features in connection with the operation of the tunnel are the bronze riser valves in the shafts, 48 inches and 72 inches in diameter, and the section valves, 66 inches in diameter, also of bronze. The former are located about 100 feet below the top of sound rock and are designed to close automatically in case of a break in the valve-chamber or in the street mains, causing an abnormally large flow of water. The section valves, two in number, are located across the main tunnel, at the foot of Shafts 13 and 18, and will permit the tunnel to be divided into parts and drained in sections without putting it entirely out of commission. Next to each section valve on either side are bronze reducing pipes which are connected to steel castings embedded in the concrete tunnel lining. Approaching the valve on either side, the tunnel is of conical shape, reducing gradually from the standard tunnel diameter, which is 14 feet at Shaft 13, and 13 and 12 feet adjacent to Shaft 18. Each valve will be operated by a hydraulic cylinder in the shaft-head chamber.

At Shafts 3 and 10 connections were made to the Jerome Park reservoir and the Croton aqueducts respectively. Below 24th street connections are being made at each of the shafts except Shaft 24, to the present high-pressure fire service, with electrically operated valves at the shafts controlled from the fire pumping-stations.

The waterway of the City tunnel is completed. All but two of the shaft chambers are completed. In these chambers the valves to control the volume and pressure of flow to the street mains have all been set. The making of connections from the chambers to the mains is under the jurisdiction of the Department of Water Supply, Gas and Electrcity, which has awarded contracts for some of this work. This department also is utilizing over 13 miles of 66-inch steel and 48-inch cast-iron mains in Brooklyn, extending from Shafts 23 and 24 towards the Boroughs of Queens and The Narrows.

The estimated cost, including the tunnel, pipe-lines, appurtenances and Silver Lake reservoir, is $23,000,000.

Shafts of the City Tunnel

Shaft	Location	Depth (Feet)
Downtake, Hill View reservoir		281
1	241st street and Jerome avenue, Van Cortlandt Park	245
2	Mosholu and Jerome avenues, Van Cortlandt Park	228
3	Sedgwick avenue and Mosholu parkway, Jerome Park reservoir	218
4	196th street and Jerome avenue, Jerome Park reservoir	242
5	183rd street and Aqueduct avenue	226
6	176th street and Aqueduct avenue	278
7	167th street and Sedgwick avenue	352
8	165th street and High Bridge Park	478
9	150th street and St. Nicholas avenue	441
10	135th street and St. Nicholas Park	405
11	121st street and Morningside Park	449
12	106th street and Central Park	262
13	93rd street and Central Park	253
14	79th street in Central Park	240
15	65th street in Central Park	221
16	50th street and Sixth avenue	218
17	Sixth avenue in Bryant Park	223
18	24th street and Broadway, Madison Square	205
19	Sixth street and Fourth avenue, Cooper Square	710
20	Delancey and Eldridge streets	749
21	Clinton and South streets	752
22	Sands and Bridge streets, Brooklyn	717
23	Flatbush avenue and Schermerhorn streets, Brooklyn	318
24	Ft. Greene Park at Myrtle avenue, Brooklyn	329

In the total 50 miles of tunnels, in the whole Catskill aqueduct, some geological uncertainties were naturally encountered. To have developed them fully in advance would have been impossible, and an attempt to do so would have been extravagant in time and in money expended upon borings and other subsurface explorations. Likewise, to have constructed all those parts of the tunnels in which some slight doubt as to the strength or character of the rock arose during the progress of excavation, so strongly as to have been beyond question in case an unsuspected weakness should develop at any of the doubtful places, would have been extremely costly. Instead, the common-sense, businesslike policy was adopted of making the structure at the few such places of abundant strength for the apparent condition of the rock and developing the weakness, if any existed, by subsequent thorough tests of the structure.

At four places such weaknesses were developed. In the Rondout pressure tunnel a short stretch of the lining was subsequently reinforced by an interlining made up of steel channel rings, welded and riveted together, and lined with concrete. At the easterly end of the Moodna tunnel, where it joins the Hudson siphon, a short supplementary tunnel was driven at a depth 400 feet below the original tunnel approaching the shaft on the west side of the river. Here a seemingly very slight chance had been taken, in rock of unusual apparent soundness, in order to utilize in the permanent structure the test shaft, 1,200 feet deep, sunk in order to determine the level at which the tunnel could safely be driven beneath the river. In this one case alone a few hundred thousand dollars were saved. In a portion of Eastview tunnel the rock penetrated was found, after construction, to contain an acid-forming mineral. The acidulous water percolating through this rock attacked the concrete tunnel lining. To overcome this trouble an inner lining of vitrified brick is to be built inside this portion of the tunnel. In the City tunnel, near Madison square, a few slight cracks caused by compression of the rock under the water pressure in the tunnel are to be made tight by sheet copper lining, at a relatively small expense. Here the yielding of the rock with the consequent cracking of the tunnel lining and its resultant outward leakage was so slight that if it had occurred out in the country, no remedy would have been called for.

The economy of this policy has proved to be many hundreds of thousands of dollars. Furthermore, the alternative for the deep pressure tunnels in rock was metal pipe construction. Difficulties would have been increased a thousandfold, especially within the City, by the use of pipes. The pipes would have been of relatively short life. North of the City line at least three very large steel pipes would have been required for each pressure tunnel. Within the City much smaller pipes would have been demanded by street conditions; 16 steel pipes 66 inches in diameter or 30 cast-iron pipes 48 inches in diameter would have been needed. Pressure tunnels as a substitute for pipes within the City alone saved at least $15,000,000 in present-day expenditures, not to mention the avoidance of great expense for renewals at a later day and the intolerable annoyance of such extensive pipe-laying in the busy City thoroughfares.

Silver Lake Reservoir

The terminal reservoir for the Catskill water system, located on Staten Island, is about 2,400 feet long and 1,500 feet wide. It will hold about 435,000,000 gallons. Earth embankments close natural depressions in the ground and a dividing dike lined with concrete forms two basins. From a gate-chamber built in this dike, reinforced concrete conduits extend to the boundary of the reservoir, and cast-iron pipes prolonged from them connect with the Narrows siphon and with the Staten Island service mains. The contract for the construction of the reservoir and appurtenances was let in August, 1913.

Area of water surface	54	acres
Area of land	111	acres
Length of shore line	1.6	miles
Available depth	35	feet
Length of North basin	1,100	feet
Width of North basin	1,200	feet
Length of South basin	1,200	feet
Width of South basin	1,700	feet
Elevation above tide	228	feet

Summary of Expenditures

To January, 1917, 160 contracts, aggregating $101,155,000 in value, and more than 110 agreements, totaling $1,808,000 in value, have been entered into, amounting to a total of $103,035,000. On this liability $96,850,000 have been earned, and of this amount $82,950,000 cover contracts which have been entirely completed and for which final payment certificates have been issued. The expenditures and obligations of the Board to date for all purposes aggregate nearly $138,000,000.

During the past few years the value of construction work accomplished in each of the most active months has exceeded $2,000,000. Construction work expenditures totaled, approximately $15,600,000 in 1910, $19,100,000 in 1911, $19,500,000 in 1912, $15,000,000 in 1913, $11,000,000 in 1914, $4,000,000 in 1915, and $2,500,000 in 1916.

Contractor's Forces

During the nine years of active construction thus far the contractor's forces have ranged from a minimum of 500 to a maximum of 17,243, counting only the men actually and directly at work on the City's structures. To these must be added men engaged upon incidental work for the contractors, the men in camp but for one reason or another idle on any given day, and the large number of men in cement, metal and other manufacturing establishments, widely scattered over the country, engaged in the production of materials, equipment and supplies for the work. Hence, it is no exaggeration to say that in addition to the numbers given above, thousands of persons have been indirectly employed upon this great undertaking of the City of New York, bringing the maximum total to approximately 25,000.

Items of Interest in Connection with the Catskill Aqueduct

MAXIMUM MONTHLY CONSTRUCTION PROGRESS

Grade tunnel excavation (Contract 12, Bonticou tunnel; Hudson River shale; excavation 19 feet high, 16 1/3 feet wide; 10.5 cubic yards per linear foot)	425	linear feet
Pressure tunnel excavation (Contract 47, Wallkill pressure tunnel; Hudson River shale; excavation circular, 18 1/3 feet in diameter; 10 cubic yards per linear foot)	530½	linear feet
Shaft excavation (Contract 80, Breakneck Pressure Tunnel shaft; Storm King granite, excavation circular, 17½ feet in diameter; 8.9 cubic yards per linear foot)	183	linear feet

Concreting cut-and-cover aqueduct (Contract 15; approximately 8,800 cubic yards of concrete were placed from one plant; about 5 cubic yards per linear foot)	1,740	linear feet
Concreting grade tunnel (Contract 2, Garrison tunnel; approximately 6,900 cubic yards of concrete were placed in two directions from one central mixing plant at foot of shaft; 2.8 cubic yards per linear foot, excluding invert of 0.18 cubic yard per linear foot, placed subsequently)	2,453	linear feet
Concreting pressure tunnel (Contract 67, City tunnel; diameter of finished tunnel, 12 feet; 9,470 cubic yards of concrete were placed; 3.34 cubic yards per linear foot, excluding invert of 0.61 cubic yard per linear foot, placed previously)	2,834	linear feet
Concreting shaft (Contract 80, Breakneck Pressure Tunnel shaft; diameter of finished shaft, 14 feet; the concrete placed averaged 3.6 cubic yards per linear foot; the 310 feet were lined in 22 days, elapsed time)	310	linear feet
Placing masonry in Kensico dam, Contract 9	84,450	cubic yards
Laying 66-inch steel pipe, week	1,409	linear feet
Laying 66-inch steel pipe, day	360	linear feet
(Contract 86, part of Queens conduit,; one 8-hour shift per day; pipe length, 30 feet)		
Laying 48-inch cast-iron pipe, week	1,748	linear feet
Laying 48-inch cast-iron pipe, day	312	linear feet
(Contract 86, part of Queens conduit; one 8-hour shift; pipe length, 12 feet)		
Laying 36-inch submerged pipe, week	984	linear feet
Laying 36-inch submerged pipe, day	228	linear feet
(Contract 99, Narrows siphon; three 8-hour shifts; pipe length, 12 feet)		

Weights of Large Valves and Fittings

Cast-steel dome on top of Drainage shaft, Hudson tunnel	46.25 tons
Bronze section valve, City tunnel, 66-inch	20.5 tons
Bronze riser valve, City tunnel, 72-inch	21.4 tons
Bronze riser valve, City tunnel, 48-inch	9.4 tons
Bronze shaft cap, City tunnel, 72-inch by 48-inch by 48-inch	11.8 tons
Bronze shaft cap, City tunnel, 48-inch by 30-inch by 30-inch	4.8 tons

Elevations of Water at Various Points, Above Tide in New York Harbor

Ashokan reservoir, East basin	587 feet
Ashokan reservoir, West basin	590 feet
Aqueduct at headworks (flow line)	511 feet
Kensico reservoir	355 feet

Aqueduct at Kensico Lower gate-chamber	330 feet
Water level, Eastview filters	322 feet
Aqueduct at filter effluent (flow line)	312 feet
Hill View reservoir	295 feet
Silver Lake reservoir	228 feet

Water can be delivered in lower Manhattan at an elevation of 260 feet above tide level and in Brooklyn about 240 feet above tide level.

Distances from Ashokan Reservoir

To Hudson River crossing	45 miles
To Croton lake	64 miles
To Kensico reservoir	75 miles
To Hill View reservoir (New York City line)	92 miles
To Silver Lake reservoir	119 miles

Principal Total Quantities

Earth excavation in open cut	16,000,000 cubic yards
Earth excavation in tunnel	50,000 cubic yards
Rock excavation in open cut	1,000,000 cubic yards
Rock excavation in tunnel	2,700,000 cubic yards
Masonry in open cut	4,200,000 cubic yards
Masonry in tunnel	1,100,000 cubic yards
Cement	6,700,000 barrels
Cast Iron	27,000 tons
Steel	32,000 tons
Bronze and brass	3,000,000 pounds

Brief Chronology of Catskill Aqueduct

March	15, 1897	Report to Manufacturers' Association; sources west of Hudson river considered for Brooklyn
March	23, 1900	John R. Freeman's report submitted to Comptroller Coler
November	30, 1903	Burr-Hering-Freeman Commission's report rendered to Mayor Low
June	9, 1905	Board of Water Supply Commissioners appointed by Mayor McClellan
August	1, 1905	Chief Engineer began his duties
October	9, 1905	Report to Board of Estimate and Apportionment, recommending development of Catskill Mountain watersheds submitted
October	27, 1905	Plan for this development adopted by Board of Estimate and Apportionment
November	3, 1905	Plan filed with State authorities for approval
November	7, 1905	Constitutional amendment passed exempting water-supply bonds from debt limit
May	14, 1906	Development of watersheds of Esopus, Rondout and Catskill creeks approved by State authorities
February	23, 1907	Experimental shaft, now West shaft of Hudson pressure tunnel begun

March	27, 1907	Contract 2, the first for aqueduct construction, embracing 11 miles between Cold Spring and Hunters brook, awarded
June	20, 1907	First sod turned, with appropriate ceremonies, by Mayor McClellan
August	26, 1907	Contract 3, for the Main dams of Ashokan reservoir, awarded
February	28, 1908	Police bureau established
April	28, 1908	First concrete placed for aqueduct structure, near Peekskill
September	19, 1908	First masonry laid for Olive Bridge dam, Ashokan reservoir
December	10, 1909	Contract 30, for Hill View reservoir, awarded
December	24, 1909	Contract 9, for Kensico reservoir, awarded
May	26, 1911	Contracts 63, 65, 66 and 67, for the City tunnel awarded
June	5, 1911	
August	23, 1911	Maximum contractors' forces, 17,243 men, at active field work
November,	1911	Maximum contractors' earnings, $2,214,000 for month
January	30, 1912	Headings of Hudson pressure tunnel met, and "holing through" shot fired by Mayor Gaynor
September	9, 1913	Storage of water in Ashokan reservoir begun
January	12, 1914	Last heading in City tunnel between Shafts 8 and 9, "holed through" by Mayor Mitchel
October	21, 1914	Authority to develop Schoharie watershed obtained from State Authorities
November	22, 1915	Began filling Kensico reservoir with Catskill water
November	30, 1915	Began filling Hill View reservoir with Catskill water
December	22, 1915	Board of Water Supply approved amended plan to develop Schoharie water shed
December	27, 1915	Bronx Borough supplied with Catskill water for first time, the first delivery of Catskill water into distribution pipes of New York city
December	29, 1915	Hill View reservoir filled to full flow line for first time
January	7, 1916	Report of Merchants Association to Board of Estimate and Apportionment urging development of Schoharie creek without delay
January	31, 1916	Board of Estimate and Apportionment adopted amended plan to develop Schoharie watershed
February	29, 1916	Schoharie plan filed with State authorities for approval
May	23, 1916	Kensico reservoir filled to full flow line for first time
June	6, 1916	Schoharie plan approved by State authorities
November	29, 1916	Manhattan borough supplied with Catskill water for first time
December	12, 1916	Water from Ashokan reservoir wasted over spillway for first time
January	22, 1917	Brooklyn and Queens boroughs supplied with Catskill water for first time
January	27, 1917	Began filling Silver Lake reservoir with Catskill water
February	20, 1917	Silver Lake reservoir filled to full flow line for first time

Organization

The Board of Water Supply consists of three Commissioners appointed by the Mayor. Its forces are divided into Administration, Real Estate, Police, Claims and Engineering Bureaus. In the first four bureaus are the Secretary, the Auditor, the Chief Clerk, the Examiner of Real Estate, Taxes and Legislation, the Superintendent of Board of Water Supply Police and the Chief of Bureau of Claims. The Engineering bureau is composed of five departments, namely: Headquarters, Reservoir, Northern Aqueduct, Southern Aqueduct and City Aqueduct. The Board and the various bureaus are at present made up of the following men, with the necessary assistants:

COMMISSIONERS

Charles Strauss, President, Charles N. Chadwick, John F. Galvin

ADMINISTRATION, REAL ESTATE, POLICE AND CLAIMS BUREAUS

George Featherstone, Secretary
Ralph T. Stanton, Assistant Secretary
Henry C. Buncke, Auditor
A. F. Britton, Examiner of Real Estate, Taxes and Legislation
William S. Haupt, Chief Clerk
Geo. F. Shrady, Superintendent of Board of Water Supply Police
Walter Le C. Boyer, Chief of Bureau of Claims

ENGINEERING BUREAU

J. Waldo Smith, Chief Engineer
Alfred D. Flinn, Deputy Chief Engineer
John R. Freeman, Consulting Engineer
William H. Burr, Consulting Engineer
Frederick P. Stearns, Consulting Engineer
Thaddeus Merriman, Department Engineer
George G. Honness, Department Engineer
Ralph N. Wheeler, Department Engineer
***Frank E. Winsor, Department Engineer**
Walter E. Spear, Department Engineer

*** Resigned August 31, 1915.**