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UWSR Eco Letter November/December 2022
COMMENTARY:
New York City Water Supply System

Water – it's a part of every day. You fill your tea kettle or coffee maker, you brush your teeth, flush a toilet, wash dishes, take a shower, maybe water your plants or keep yourself hydrated. For brief moments we may feel grateful to have a readily available supply of clean and safe water, but more often we don't give it much thought.

In fact, New York City has some of the best water in the world, and it's delivered to us from an extraordinary system that began to take form over 150 years ago. That system draws from a nearly 2,000-square-mile watershed that reaches 125 miles northwest of the City and spans portions of the Hudson Valley and Catskill Mountains. It consists of 19 reservoirs and three controlled lakes with a combined storage capacity of 550 billion gallons, enough to supply NYC for over a year and a half. The water from these reservoirs and lakes flows into aqueducts, tunnels and pipes that deliver it directly to our taps, the majority of which arrives by gravity feed alone.

Every day the New York City Water Supply System provides more than one billion gallons of clean and safe water to more than 8.5 million residents and to millions of tourists and commuters who visit the City throughout the year. It also supplies another 110 million gallons a day to about one million people living in outlying counties. This means that the New York City Water Supply System provides nearly half the population of New York State with high-quality water.

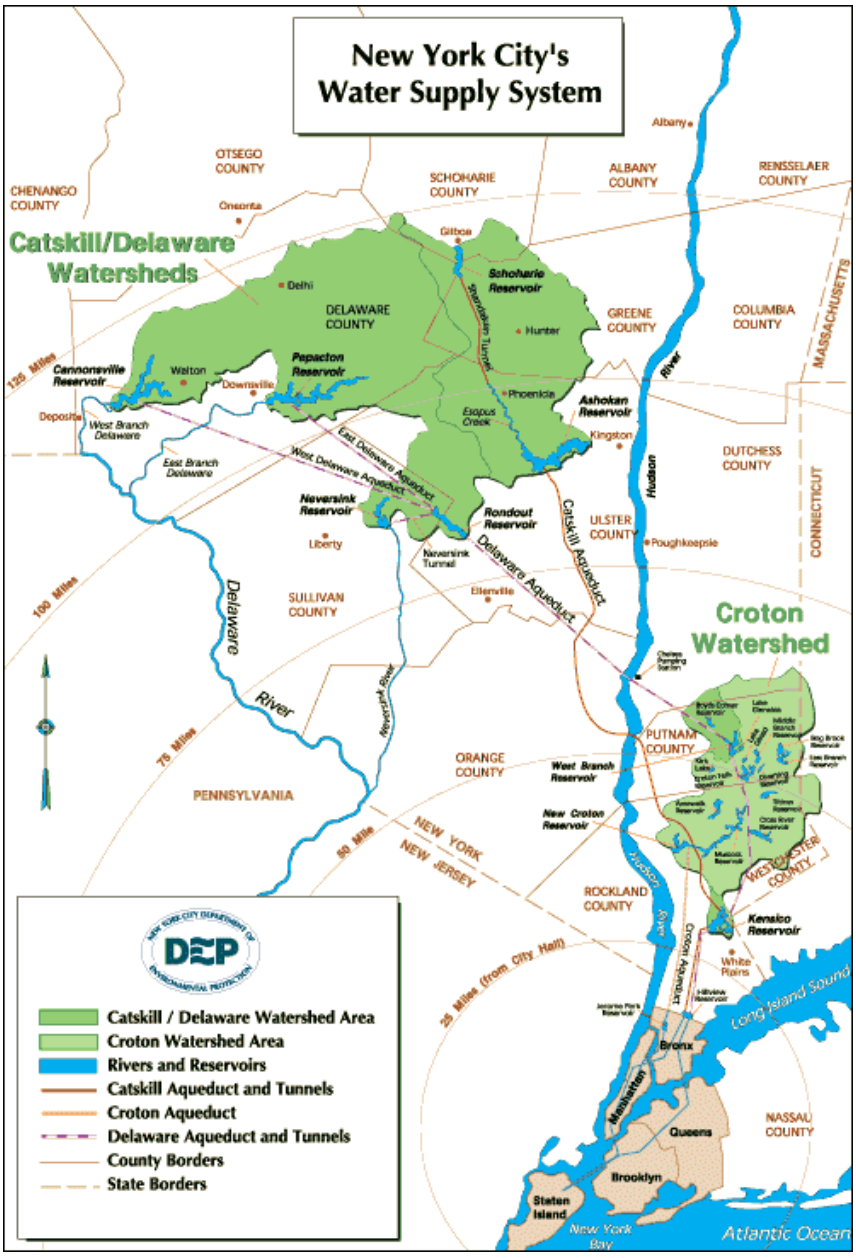
A Brief History of NYC's Water System

The first public well was dug in Bowling Green in 1677. The well used a pump — the first in the City's history — to bring up water from underground. Until the 18th century, New York City depended solely on means such as wells and rainwater ponds to collect water for daily use. However, as the population increased, these methods didn't provide enough water. In the early 1700s, water was hauled from Brooklyn, which had an excellent supply of fresh groundwater, but it still wasn't enough to meet all of the City's needs.

At the same time, there were other significant challenges. Because there was no system for disposing of sewage and garbage, human waste and trash polluted waterways, which ultimately contributed to cholera outbreaks that killed thousands of people. And the stone-lined wells originally dug to tap groundwater became contaminated by salt water from the tidal Hudson and East Rivers. Then there was the issue of fighting fires in an increasingly densely populated

city where most buildings were made of wood – a fire in 1776 destroyed a quarter of Manhattan's buildings. The City built its first reservoir on the East Side in 1831 and a new water supply and distribution system became available for fighting fires. It included a well and cistern on 13th Street between Bowery (4th Avenue today) and Third Avenue.

It became increasingly clear to City leaders that they needed to develop cleaner and more abundant sources of water for a constantly expanding population. After exploring alternatives, the City decided to take water from the Croton River, in what is now Westchester County. By the 1880s, the City opted to enlarge the Croton system with a new dam and aqueduct pulling from a larger watershed. As the population grew, the following decades saw development of the Catskill and Delaware reservoir systems. Now, about 90% of the City's water comes from the Catskill and Delaware Watersheds and the remainder is via the Croton Watershed.



The Croton Water Supply System

Spreading over Westchester, Putnam, and Dutchess Counties, the Croton water supply system consists of *12 reservoirs* and *three controlled lakes*. While this system normally supplies 10% of the City's drinking water, it can produce more if needed.

Between 1837 and 1842 about 4,000 immigrants built the Old Croton Aqueduct, with a capacity of 90 million gallons per day and which included the Old Croton Dam above the junction of the Croton and Hudson Rivers. The Old Croton Aqueduct ran from the Croton Reservoir in Westchester County, south to the Yorkville Receiving Reservoir between 79th and 86th Streets in Manhattan (now the Great Lawn in Central Park), then down to a 20-million gallon distributing reservoir (now occupied by the New York Public Library). Starting in 1848, water ran across the East River on the High Bridge (prior to that, it had flowed through pipes laid under the High Bridge). In 1862 the construction of Lake Manahatta to the north of the Yorkville Reservoir increased storage capacity (now called the Central Park Reservoir, it is no longer part of the NYC water supply system.)

To meet the ever-growing need for water, the City began construction of the New Croton Aqueduct in 1885. The Old Croton Dam was submerged in the reservoir created by the New Croton Dam. The new aqueduct opened for operation in 1890 with a capacity of 300 million gallons per day —almost three times the size of the old aqueduct—and ran from the Croton Reservoir to the Bronx, then over the High Bridge to the Central Park reservoirs in Manhattan. Today, if you look just west of the back side of the New Jewish Home, you'll see a building that slants back from West 105th Street; the slanted alleyway to the east of that building marks the former path of the New Croton Aqueduct.

By the turn of the century, City leaders were yet again forced to expand the water supply. New York State passed legislation that created the New York City Board of Water Supply, which allowed the City to purchase watershed land in the Catskill Mountains and to create new reservoirs by damming streams and rivers. In addition, the City built the Chelsea Pumping Station (just north of the upstate town of Beacon), which can extract water from the Hudson River during droughts; so far it's been used only twice.

The Catskill Water Supply System

Construction of the Catskill system, which began in 1907, includes the *Ashokan* and *Schoharie Reservoirs*, with an operational capacity of approximately 850 million gallons per day, of which less than half is normally used. It currently supplies 35-40% of the City's overall water supply.

Men and mules (and lots of dynamite) built the *Ashokan Reservoir*, as it pre-dated the era of diesel-powered equipment. It consists of two basins separated by a concrete dividing weir and roadway. The reservoir holds 123 billion gallons at full capacity and was the largest man-made reservoir in the world when it was put into service in 1915.

In 1926 the *Schoharie Reservoir* in Gilboa began operation, increasing overall capacity by 18 billion gallons. This reservoir is connected to the Catskill System by the 18-mile-long Shandaken

Tunnel, which flows south under the Catskill Mountains into Esopus Creek and subsequently into the Ashokan Reservoir. Gilboa Dam, at the north end of Schoharie Reservoir, marks the furthest point of the water supply system, approximately 125 miles from NYC. It was recently found to have structural defects and underwent significant repairs.

Water from both the Ashokan and Schoharie Reservoirs is transported via the Catskill Aqueduct by gravity feed. The system is designed with a gentle grade to take advantage of the descending elevation, and it employs inverted siphons to maintain the flow under the valleys it crosses. From the Ashokan Reservoir (elevation 611 feet above sea level), the aqueduct leads in a southeasterly direction through Ulster, Orange, and Putnam Counties, then runs through a larger inverted siphon 1,100 feet below the Hudson River from Storm King Mountain on the west to Breakneck Mountain on the east. The siphon was bored from both sides and, amazingly, the two sides were less than an inch off perfect alignment when they met in the middle! After going under the river the water travels to the Kensico Reservoir in Valhalla (elevation 355 feet) and on to the Hillview Reservoir in Yonkers (elevation 295 feet), where it connects to the NYC water distribution system.

The Delaware Water Supply System

This system includes four large reservoirs – the *Rondout*, *Neversink* , *Pepacton*, and *Cannonsville* with tunnels and an aqueduct – with a combined capacity of 320 billion US gallons. It supplies about 50-60% of New York City's water.

The *Roundout Reservoir* (in Ulster and Sullivan Counties), which holds 50 billion gallons, was started in 1937 but, because of restrictions on the supply of materials and equipment during World War II, it didn't go into service until 1951.

Next came the nearby *Neversink Reservoir*, put into service in 1954, with a capacity of 35 million gallons, and connected to the Roundout by a 6-mile-long tunnel.

The *Pepacton Reservoir* (also known as Downsville Reservoir) is located in Delaware County on the East Branch of the Delaware River and was added to the system in 1955. Holding 140 billion gallons at full capacity, the Pepacton normally contributes more than 25% of the total daily water flow into New York City. Water withdrawn from the Pepacton Reservoir enters the East Delaware Aqueduct and flows southeast for 25 miles into Rondout Reservoir.

The *Cannonsville Reservoir* (also in Delaware County, on the West Branch of the Delaware River) was placed in service in 1965 with a capacity of 96 billion gallons. It is connected to the Roundout via the 44-mile-long West Delaware Aqueduct.

Water from the Roundout – and from the other three reservoirs that feed into it – enters the Delaware Aqueduct, which was completed in 1945 and, stretching 84 miles to the Hillview Reservoir in Yonkers, is the longest continuous tunnel in the world. The first section of the aqueduct runs from the Roundout to the Hudson River, where it tunnels 600 feet below the river's surface via an inverted siphon from Newburg on the West to Wappingers on the East. It

then runs into the West Branch Reservoir in Carmel, which serves as a supplementary settling basin that removes silt from the water.

Since the early 1990's the NYC Department of Environmental Protection (DEP) has monitored two leaking sections of the Delaware Aqueduct, one in Newburgh and the other in the Ulster County town of Wawarsing. The leaks release an estimated 20 to 30 million gallons per day, most of which is lost in Newburgh. To seal off that leak, the DEP has built a 2.5-mile-long Bypass Tunnel that goes under the Hudson River from Newburgh to Wappingers that will connect to the aqueduct on either side of the leak. In order to make repairs, water from the aqueduct will be shut down and diverted through the Bypass Tunnel; the shutdown is scheduled to begin on October 1, 2023, and end May 31, 2024. In anticipation of this diversion, the DEP plans to take more water than usual from the Delaware System reservoirs, thereby reducing those reservoirs to about 30% of their normal capacity and letting the reservoirs in the Catskills and Croton systems fill up so that water can be drawn from them once the DEP shuts down and empties the Delaware Aqueduct.

In the next section of the Delaware Aqueduct water flows from the West Branch to the Kensico Reservoir in Valhalla, where it joins the Catskill system.

Testing and Purifying the Water Supply

In the Kensico Reservoir robotic buoys transmit information about the water quality. Chlorine, which kills bacteria, and fluoride, for dental health, are added here. Water then travels to a nearby UV disinfection facility located in Greenburgh (the world's largest drinking water UV disinfection system, with a maximum flow of 2.4 billion gallons per day). The last section runs to the Hillview Reservoir in Yonkers where the water receives further disinfection before entering the City's distribution system. In 2019 New York City agreed to build a concrete cover over the Hillview to prevent excrement from seagulls and other birds from contaminating the water with bacteria and viruses.

In 1997, due largely to the efforts of DEP Commissioner Marilyn Gelber, the City implemented a comprehensive watershed protection program that targeted potential sources of water contamination upstate. For example, barnyard run-off cannot run into streams that enter the reservoirs, septic systems have to be a certain distance from the reservoirs, and swimming or washing clothes in the reservoirs is prohibited. In addition to 230,000 tests performed in the watershed the Environmental Protection Agency performs more than 330,000 tests annually at about 1,200 sampling locations throughout New York City. (See the September/October 2016 *Eco Letter Commentary* on *Water Quality*; just click on "Archive of Past Commentaries" in the *Eco Letter*, then select "Water Quality" from the list on the first page.)

Impact of NYC's Water System on Local Communities

It's important to note that, in order to provide New York City with this water, construction of its different parts had a huge impact on local upstate communities. About 20 towns and villages were flooded; houses, stores, farms and churches were forced to move or torn down; about 6,000 people were displaced; land was lost; and highways and cemeteries were relocated. Not

surprisingly, the people affected by all this resented it greatly; many households had been there for generations. The City paid for the properties, but only at only half the assessed value. However, on the positive side, these major constructions created local jobs and new businesses. And New York City pays taxes on the land it acquired and in many towns it is the largest taxpayer.

NYC Distribution System

From the Hillview Reservoir in Yonkers, water flows by gravity into three tunnels under New York City.

1. *Water Tunnel No. 1*, completed in 1917, flows under the Central Bronx, Harlem River, West Side, Midtown, and Lower East Side of Manhattan, and then under the East River to Brooklyn, where it connects the Richmond Tunnel to Staten Island.
2. *Water Tunnel No. 2*, completed in 1935, runs under the Central Bronx, East River, and Western Queens to Brooklyn, where it connects to Tunnel 1.
3. *Water Tunnel No. 3* is the largest capital construction project in New York City's history. It was started 1970, and its first and second stages are complete. Stage 1 starts at the Hillview Reservoir, runs through the Bronx into Northern Manhattan, then crosses under Central Park, goes under the East River and Roosevelt Island, into Astoria, Queens. Stage 2, with two sections, continues into Southern Manhattan and also runs further into Queens and Brooklyn and connects with the Richmond Tunnel.

   These tunnels provide the City with a critical third connection to its Upstate New York water supply system so that the City can, for the first time, close Tunnels No. 1 and No. 2 for repair. The third stage, which will start at the Kensico Reservoir, then run parallel to the Delaware and Catskill Aqueducts to the Van Cortlandt Valve Chamber complex in the Bronx (bypassing the Hillview Reservoir), will not be completed until about 2026.

Water flows from the tunnels into a 6,800-mile-long network of water mains, some of which are large enough for a man to easily stand upright inside. There is at least one water main underneath almost every street in New York City. The water is then connected to individual buildings through over 800,000 smaller pipes called service lines. Since the water has flowed by gravity from elevations hundreds of feet above sea level, it has built-up pressure (called a “head”), and this head is sufficient to raise the water to the top of a six-story building.

Buildings taller than six stories need to pump water up their roof where it is often stored in large wooden tanks, each holding up to 10,000 gallons of water. Wood acts as a natural insulator, preventing the water from freezing in the winter. Also, the wood expands with water inside, preventing leaks. These tanks have been built and maintained by three family-run businesses for over 100 years and are an iconic aspect of our city’s skyline.

Only a fraction of the City’s water is actually used for drinking. Most of it ends up in toilets, showers, washing machines, dishwashers, fire hydrants, etc. Water consumption has decreased more than 30% since the late 1980s, when the City made a concerted effort to educate the public about the need for water conservation and required the installation of water conserving

devices in modern toilets, faucets and showerheads. The City has also actively looked for and fixed leaks in water mains and service lines.

In addition to the third water tunnel, the City is spending billions of dollars for dozens of projects to fix decaying infrastructure and improve water quality. One such project is the Croton Underground Water Filtration Plant constructed next to the Mosholu Golf Course in Van Cortlandt Park in the Bronx. With a capacity to filter up to 290 million gallons of water a day, it is the largest facility of its kind in the United States.

Additional information:

- Galusha, Diana (1999) *Liquid Assets: A History of New York City's Water System*, Purple Mountain Press, Fleishmanns, NY, 303 pp.
- How New York Gets Its Water, *New York Times*, March 30, 2016
- History of the NYC Water Supply, Catskill Watershed Corporation
- How Does New York City Get Its Water, Hudson Reed
- New York City's Water Supply System: Past, Present, and Future, National Library of Medicine
- Water Supply, NYC Environmental Protection