Developing a Sustainable Water Management Plan for Central Park, New York using ArcGIS

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Developing a Sustainable Water Management Plan for Central Park, New York using ArcGIS

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A Thesis in the Field of Sustainability and Environmental Management

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Abstract

This research examined how 20th century changes to the design of Central Park, and New York's water management systems, turned an iconic 19th century "naturalistic" urban park into a 21st century "ornamental" city park. Central Park's past water management practices throughout its 160+ year history form the basis of this study to explore the park's potential as a sustainable 21st century urban wetland. Unlike other historical national landmark parks such as Hyde Park in London (on which it was modelled), Central Park, NYC, underwent a number of drastic modernization changes to the design of its original waterways and park drainage systems in the 20th century. These changes greatly affected Central Park's ability to independently manage its own waterbodies, to retain the stormwater runoff from its own watersheds, and to control its municipal potable water consumption. Central Park is a wonderful recreational facility for the city that surrounds it, but it does not contribute its fair share of its resources to the city's green infrastructure. Central Park today is an "artificial" urban park that depends on millions of gallons of municipal potable water per day to feed its man-made concrete-lined water bodies and to irrigate its landscapes, and relies on the city's overwhelmed 19th century combined sewer system to carry off its stormwater.

My research focused on creating a sustainability plan using ArcGIS mapping analysis that recognizes Central Park's potential as a major green infrastructure resource for the City of New York, and reduces the park's burden on the city's gray infrastructure. The main objective of my thesis was to bring the issues from my research of Central

Park's water intake and discharge management practices to light, to trace their origins in the design, construction and management decisions of the past, and run analyses to test my findings using the latest geological mapping and data analysis tools available from global information systems (GIS) analysis program: ArcGIS.

This study identified the historical factors that arrest Central Park's development and keep the park functioning more like an ornamental garden, rather than as a sustainable stormwater retention resource and urban wetland. This analysis explored the hypotheses that: 1) Central Park's decommissioned reservoir with a carrying capacity of one billion gallons of water could be retrofitted to act as a stormwater retention lake for the entire park's watershed; 2) Central Park's artificial concrete-lined waterbodies could be returned to a more natural state and adapted to retain stormwater from their own watershed instead of draining to the city's overloaded combined sewer systems; and 3) Many of Central Park's historical streams underlying its present waterways that were diverted underground during the park's 20th century renovations could be brought to the surface and daylighted as an additional source of freshwater to the park's waterbodies.

I used ArcGIS geodatabase data management applications to analyze both historical and present-day topography data for Central Park to create comparison maps that represent past, present and future water management conditions. My research results supported my hypotheses that Central Park has the potential to convert its decommissioned potable water reservoir to a stormwater retention lake, to return its concrete-lined waterbodies to a more natural state, and to reclaim the historical freshwater streams and waterbodies that pre-date the park and underlie its major waterways.

Dedication

My thesis is dedicated to my family: my late parents Charles and Annie Duffy, my husband Derek Muldowney and our daughters Alanna and Carolyn. You are my clan, my love, and my life. I am so grateful that you choose to travel along this path with me, in body and in spirit on this wonderful life journey. Your loyalty and fierce determination keep our crew strong and keep our boat rowing through challenging and stormy waters. You inspire me to keep striving to be a better person, to keep forging my own path, to never be afraid to speak up and rock the boat of status quo, and to keep shining a light on ways we can take better care of our beautiful environment.

Acknowledgments

My sincere thanks and gratitude are extended to my research advisor, Dr. Mark Leighton, my thesis director, Dr. Andrew Tirrell, and Harvard University Extension School's Department of Sustainability and Environmental Management (SEM). Thank you for keeping the light on for me and for continuing to shine it brightly when I needed structure and guidance. I am very grateful for your wise words, your support and your patience to get me to the last lap of the race. I am hoping that I may get the privilege to finally cross over the finishing line, and that my thesis research will be of some use to our future environment.

I have learned so much from the experience of my professors, from my class TAs and from collaborating with fellow SEM students in my years of study at Harvard University Extension School. My intention is to go forth in the world and pass on this knowledge of the three major cornerstones of sustainability: environment, social-ecology and economic systems management, and the importance of understanding their complex inter-relationships. In combination with studies in GIS-based mapping and spatial analysis technology, I hope to put my SEM studies to good use to help make the environment a little better than I found it.

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Definition of Terms

ArcGIS	Geographic Information Systems (GIS) software developed by the Environmental Systems Research Institute, Inc. (Esri), to create, display and analyze geospatial data
CSS	Combined Sewer Systems: A network of pipes that carry a combination of domestic sewage, industrial wastewater and stormwater runoff to a municipal treatment facility. In wet weather the system may become overloaded and untreated commingled wastewater may be diverted to drain directly into a waterway or ocean.
CSO	Combined Sewer Overflow: The discharges from a CSS are called “combined sewer overflows,” and the point where the wastewater enters a waterway is called a “combined sewer outfall.”
Daylighting	A term used to describe restoration projects that redirect waterways that have been previously buried into an above ground channel
ESRI	Environmental Systems Research Institute, Inc
Naturalistic	Man-made, but derived from real life or nature, or imitating it very closely
TMDL	Total Maximum Daily Load or carrying capacity - The calculation of the maximum amount of a pollutant that can occur in a waterbody and the waterbody can still meet water quality standards
Watershed	A drainage basin or catchment area of land that drains to a common outlet - such as a lake, stream segment or bay
Watershed Delineation	Determining the boundary lines of a watershed drainage basin

Chapter I

Introduction

Central Park is a historical urban landmark park located in the center of the island of Manhattan in New York City. With an area of 843 acres, encompassing 153 city blocks, Central Park is surrounded by some of the most densely populated and high-priced real estate in the world. The park is located north of Times Square and Midtown Manhattan, where an estimated 94% of the land is covered with an impervious surface (Figures 1 & 2). In addition to holding the title of “America’s first public park”, Central Park is also the most visited urban landscape in the United States, receiving an estimated 42 million visitors per year (NYC Department of Parks & Recreation, 2020).

Figure 1. Satellite image of the island of Manhattan, New York City.
(by author using ArcGIS, 2020). Data source: NASA - International Space Station Program: Expedition 39: Astronaut photograph ISS039-E-18538.

Built in 1857, during the Victorian “City Beautiful” era, Central Park’s expansive 2.5 miles long by 0.5 miles wide footprint covers approximately 6.5% of the island of Manhattan’s total acreage. Unlike other historical parks like Hyde Park in London (on which Central Park is modelled), Central Park is hydrologically separated from the city that it serves. It is landlocked without riparian access, centered on an island surrounded by brackish tidal waters. Central Park’s topography is made up of a thin layer of imported topsoil supported by a shallow layer of glacial till with protruding rock outcrops of Manhattan Mica-Schist in many locations throughout the park (Columbia University & Central Park Conservancy Institute, 2013).

Figure 2. Aerial view of Central Park South (Aerial Archives, 2020).

Compared to other major metropolitan urban landscapes, Central Park has a number of very unique and complex challenges regarding its age, location, design, layout, topography, geology, visitor access, thru-park road traffic, and management practices that affect the park's ability to sustainably manage its water intake and stormwater discharge (Figure 3) (Central Park Conservancy, 2020).

Central Park is an entirely man-made "naturalistic" urban landscape infrastructure. The Park's 250 acres of managed lawns, 150 acres of lakes and ponds and 136 acres of woodlands are maintained using city drinking water: an estimated 400 million gallons per year (1.1 million gallons per day). The park contains eight waterbodies, including a 106 acre 1-billion-gallon reservoir that covers approximately 15% of the total area of the park (Figure 4). The reservoir is inaccessible to the public, despite being decommissioned as a source of city potable water in 1993. Central Park does not provide stormwater retention to the city that surrounds it, nor does it retain the stormwater runoff from its own 843 acres. All the park's waterbodies (lakes, streams, ponds and the reservoir) have concrete lined bases with artificial shorelines constructed of masonry set at a steep angle to the water's edge (Figure 5). This impermeable hardscape lining prevents groundwater input and storm-water runoff from the surrounding watershed from entering the park's waterbodies. This greatly affects the park's ecology, with particularly negative consequences for its wetland's habitation. The park's existing natural streams such as the Harlem Creek and Montayne's Rivulet, are prevented from feeding into the park's waterbodies by this hardscape covering, and instead are diverted to drain into the city's overburdened 19th century combined sewer system (City University (CUNY), 2016).

Figure 3. Aerial view of Midtown Manhattan & Central Park South (Google Earth, 2020).

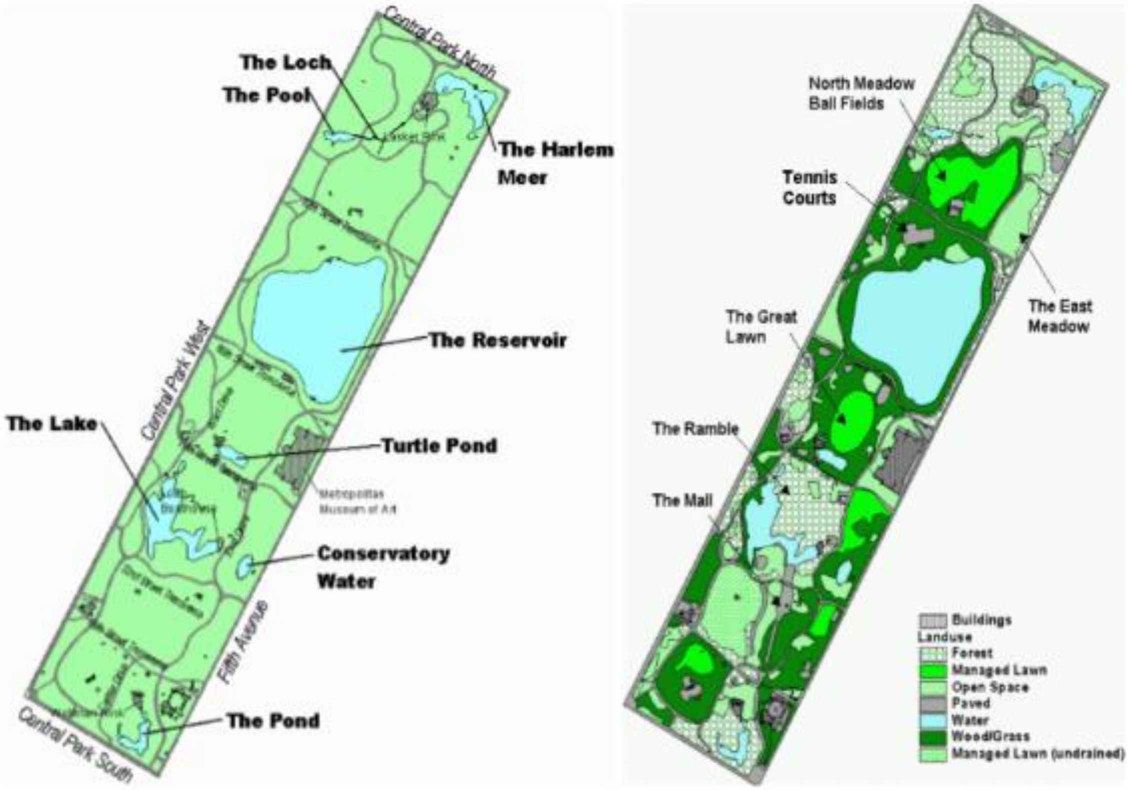


Figure 4. Central Park – eight water bodies (left) and land use (right) (Lenz, 2002).

Figure 5. Central Park Reservoir (left) and Harlem Meer (right) hardscape edges (photos by author, 2020).

Central Park's construction began in 1857 as a "naturalistic" urban landscape, incorporating many of the natural steams and rivulets of the existing topography into its clay lined waterbodies. The park's stormwater run-off drained to a highly engineered system of sub-surface clay tiles which funneled the water into the park's lakes, streams and ponds. However, Central Park's water management processes were drastically changed at the turn of the century, when the City of New York's population quadrupled in size to 5+ million residents in 1910, and expanded north taking up residence on all four sides of the park. Central Park's connection to the City's combined sewer system in 1905, and its connection to the City's second municipal potable water source, the Catskill Aqueduct, which came on line in 1915, brought a faster man-made solution to storm-water runoff. This increased the availability of scarce water resources to flush the lakes and maintain water levels in the park's waterbodies. Beginning in 1915, Central Park's lakes, streams, ponds and reservoir were lined and edged in concrete and masonry. Using the new asphalt material that had been recently invented, the park's clay and gravel circulatory systems that drained stormwater to the park's waterbodies were replaced with asphalt paths and curbs that drained directly to the city's combined sewer system. By the 1930s the access to municipal water and sewage systems and the availability of man-made materials, coupled with increased park visitation resulted in greater trampling and erosion of its landscape. This led to the design of hard regulated style shorelines and concrete lined basins for all of Central Park's lakes, ponds and streams (Rogers, 1987; Central Park Conservancy, 2020).

Research Significance and Objectives

My research focused on creating a sustainability plan that recognizes Central Park's potential as a major green infrastructure resource for the City of New York. My goal was to develop a sustainable 21st Century "Green City" urban wetlands management plan for this historical 19th century city park.

The main areas of my research concentrated on identifying the historical factors and past restoration methods that arrest the park's development and keep this iconic urban landscape functioning more like an ornamental garden, rather than a sustainable contemporary city greenspace. Many of Central Park's unsustainable park management practices regarding potable water intake and stormwater discharge are related to the park's unique heritage, its location, its past design practices and its present historical preservation style management structure. My research focus concentrated on Central Park's present negative effect on the City of New York's municipal drinking water supply and its storm water drainage control systems.

My thesis explored the major challenges faced when a city is home to one of the world's oldest and largest sewage systems and must operate under the confines of a storm-water control system designed in the nineteenth century (Figure 6). The island of Manhattan has operated under a combined storm water drainage system since 1855 (NYC EPA, 2020). This study examined both the geographical and environmental constraints that a legacy park constructed in a high-density urban environment in the Victorian era (1850's) places on present storm-water management practices.

My main research objectives outlined the ways that Central Park can help ease the heavy burden on the city's potable water and storm water control management systems by:

- Developing a sustainable long-term plan to turn the park's eight concrete-lined artificial water bodies into more natural stormwater and groundwater fed lakes, ponds and streams. This would maximize Central Park's potential as a storm-water retention resource by removing the hardscape bases and edges and replacing them with softscape natural clay bases and soft landscaped embankments.
- Decreasing municipal potable water usage to maintain the park's water-levels in its man-made concrete-lined "Naturalistic" lakes, streams, ponds and irrigation systems. This could be achieved by the development of a long-term plan to daylight the park's own natural streams and rivulets and by accessing the park's own groundwater in a similar fashion to Hyde Park, London (A vision of Britain, 2020).
- Reducing discharge from the park to both the city's combined sewer system (CSS) and its combined sewer outfalls (CSO) during wet weather and storm events by creating the necessary green infrastructure within the park to retain the stormwater.

- Developing a sustainable water resource management plan for the park’s 1-billion-gallon 106-acre reservoir that was decommissioned in 1993 and signed over to the Department of Parks and Recreation in 1999, but remains inaccessible to the public and off-limits for use as a stormwater retention lake or recreational facility.
- Mitigating the water bodies limiting nutrient: nitrogen which causes algal blooms during warm weather months by limiting the use of municipal potable water and the presence of orthophosphate, and by removing the concrete lining of the waterways and allowing for a more natural purification of the water.
- Removing the park’s extensive man-made drainage pipe systems in woodlands and along tree-lined avenues that are restricting root growth and increasing old-growth trees vulnerability to root rot, invasive diseases and collapse.

Background

In this section, I first review the elements of Central Park’s water management system that render it unsustainable, and its negative consequences. I then review the history of the park and its water management, then finish reviewing the current context.

Central Park’s Unsustainable Water Management System

Several main factors that play a key role in the park’s water management sustainability are listed as follows:

- Central Park’s reliance on city drinking water; an estimated 400 million gallons per year or 1.1 million gallons per day are used to maintain the water-levels of its lakes, ponds, streams, waterfalls, and fountains, and to irrigate its lawns, ballfields, woodlands and general landscaping.

- All the park’s waterbodies are lined in concrete with artificial shorelines constructed of concrete masonry or boulders set at a steep angle to the water edge.
- The historic watercourse of the Stream (formerly known as Montague’s Rivulet) that originally flowed freely through Central Park’s northern section, connecting the Pool and the Loch with the Harlem Meer has been disrupted since 1966, when the Lasker Pool and Ice-Skating Rink was built directly over the mouth of the stream where it connected the Loch with the Meer (Figure 6). The flow of water was diverted into a five-foot concrete culvert running under the swimming pool/ice rink facility leading to chronic flooding problems for the site and obstructing the drainage corridor of the park’s northern watersheds.
- Central Park does not utilize the natural storm-water retention and absorption capabilities of its own water bodies or its lawn or woodland cover to reduce storm water runoff (Figure 7). The park’s total area of 843 acres is almost entirely drained directly into the City of New York’s combined sewer systems (CSS) (Figure 8), through a series of park-wide drainage system pipes and catch basins - an estimated 250 million gallons of storm-water per year (Columbia University & Central Park Conservancy Institute, 2013).
- Central Park’s challenging site with its underlying bedrock base of Manhattan schist and shallow layers of imported topsoil are not sustainable conditions for its old growth deciduous forests or tree-lined avenues that are characteristic of the Royal Parks of London, on which its design was based. The park’s man-made drainage pipe systems in woodlands and along tree-lined avenues are restricting root growth and increasing old-growth trees vulnerability to root rot, invasive diseases and collapse.

Figure 6. Aerial view of Central Park North - the Harlem Meer and Lasker Pool/ Rink (Aerial Archives, 2020).

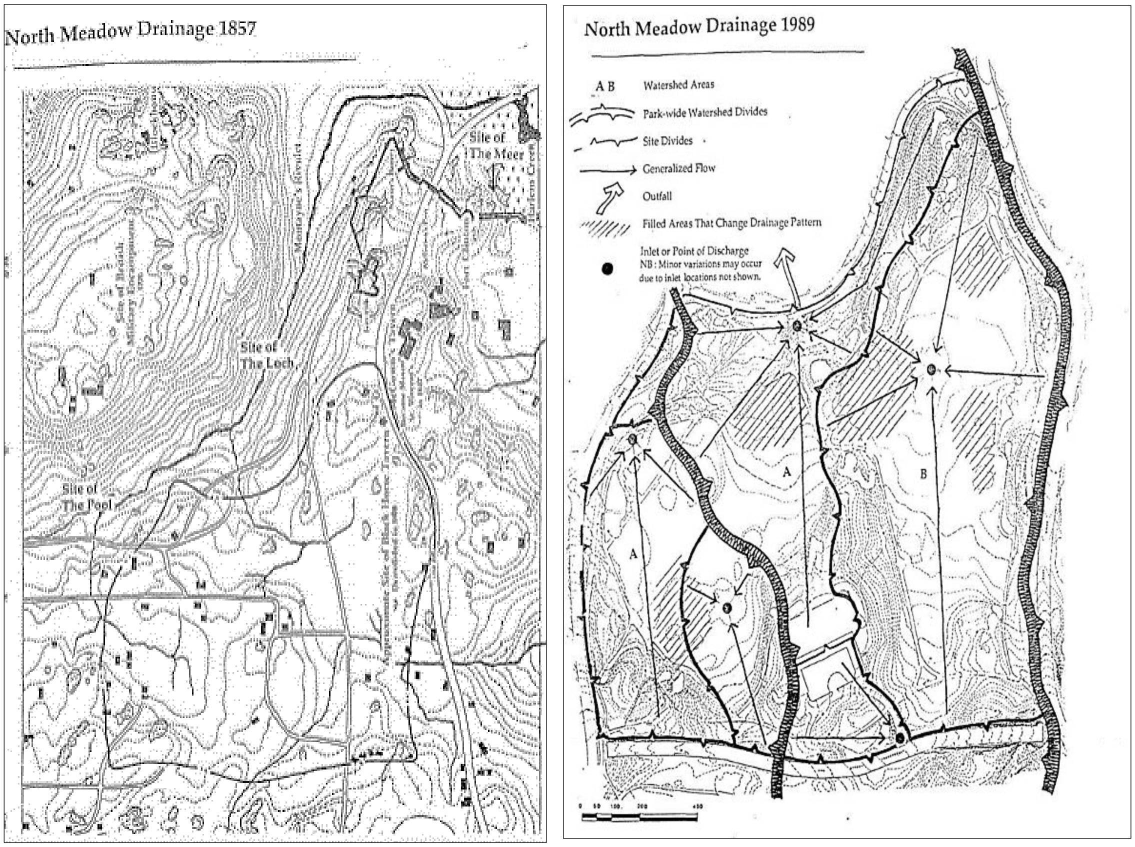


Figure 7. Central Park – North meadow drainage to city sewer outfall 1857 vs 1989 North Meadow drainage 1857 (left) and North Meadow drainage 1989 (right)

(Andropogon Associates, Ltd, 1989).

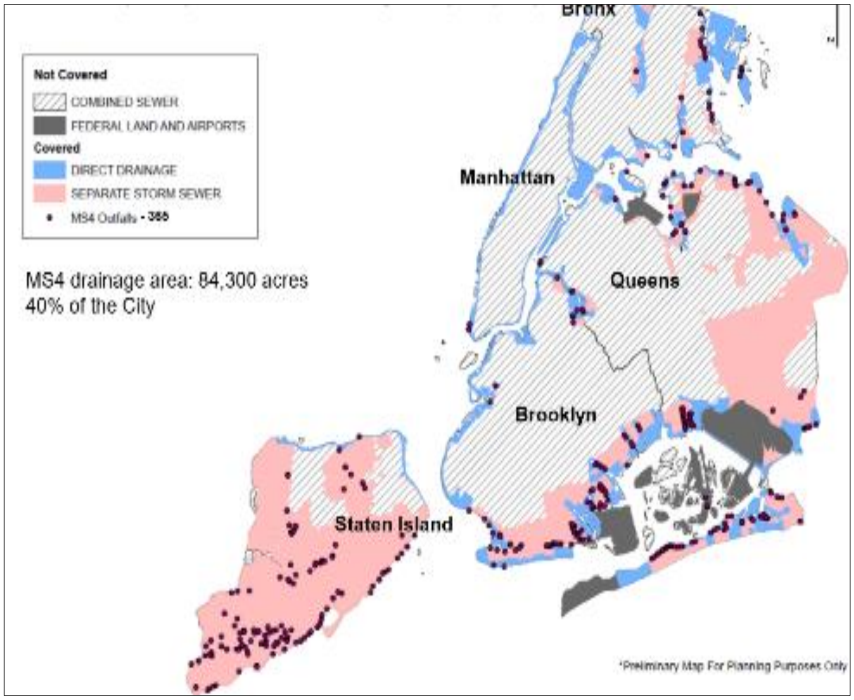


Figure 8. NYC Municipal sewer system (MSS) map. Central Park acerage is included in the City's combined sewer drainage areas (NYC Environmental Protection Agency (NYC EPA), 2020).

Unsustainable Stormwater Management

Drainage from Central Park's Reservoir and Central Park's northern half ,including the Harlem Meer (11 acres), is directed to Sewer-shed 491 – Combined Sewer Outfall WI-024, one of the largest combined sewer-sheds in Manhattan. WI-024 covers 460 acres of northern Manhattan which includes overflow from the Harlem Creek, Harlem Meer, Central Park Reservoir and the northern half of Central Park (Figures 9 & 10), along with millions of gallons of groundwater that is pumped out of Lenox Avenue Subway Station per day by the MTA (Figure 11). During storm events when the capacity of the CSS is exceeded due to a precipitation rate greater than approximately ¼" per hour, storm-water runoff is diverted to the city's combined sewer overflow (CSO) systems, where it is combined with untreated municipal sewage and then discharged into the East River at WI-024 outfall (Figures 12, 13 & 14).

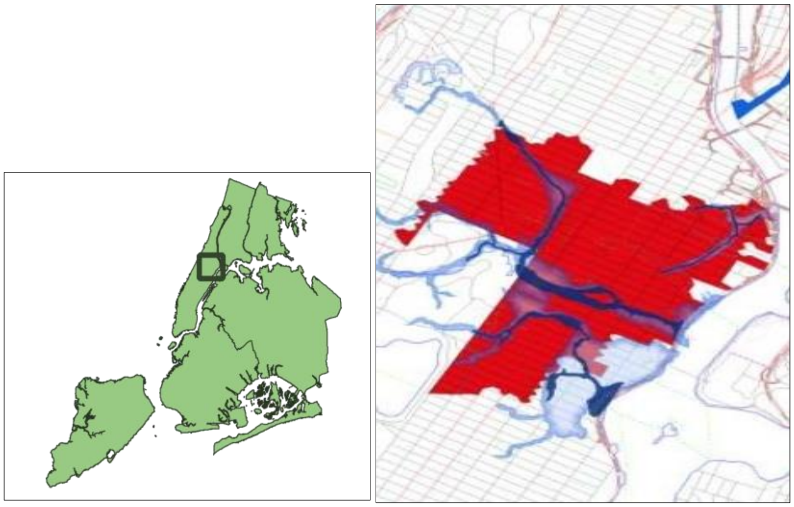


Figure 9. The historic flow of Harlem Creek and Central Park's Harlem Meer in the sewer-shed WI-024 (CUNY Institute for Sustainable Cities (CISC), 2016).

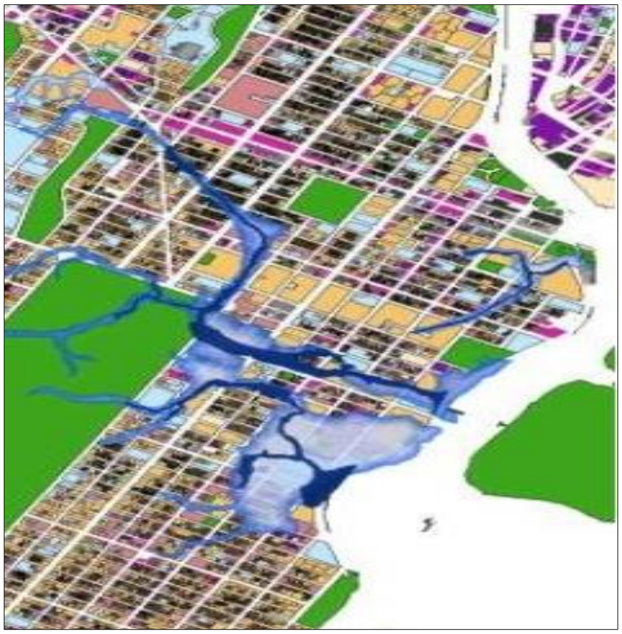


Figure 10. The historic flow of Harlem Creek and Central Park's Harlem Meer over different land-use types in the Upper East Side of Manhattan and Harlem (CISC, 2016).

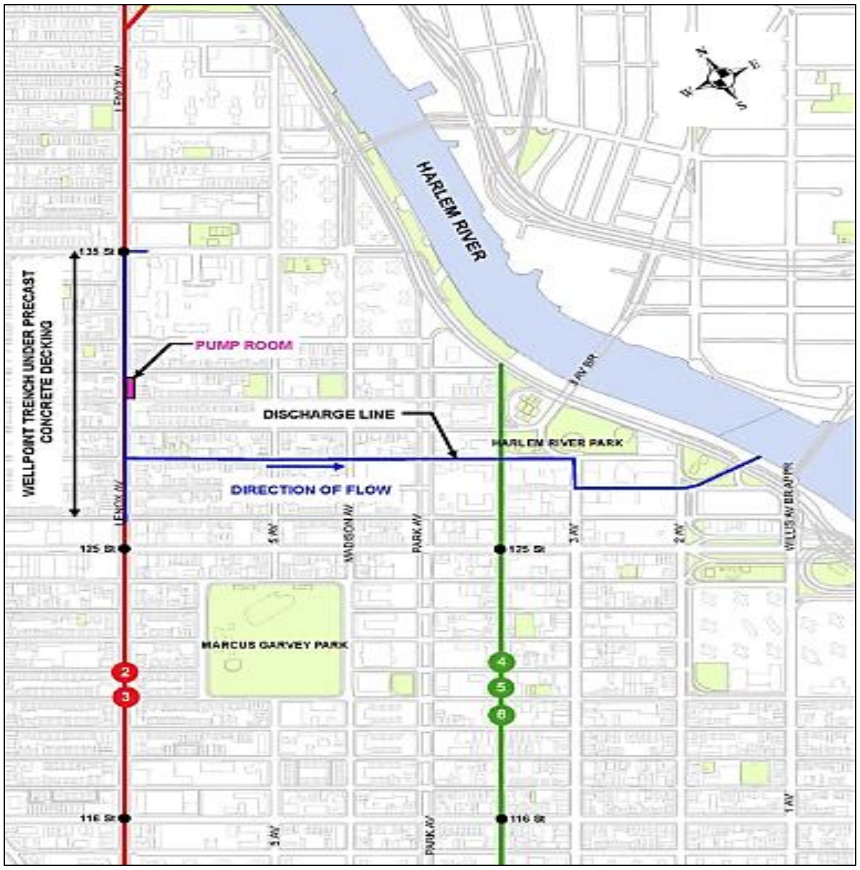


Figure 11. Discharge line from Lenox Avenue subway station to Harlem River (CISC, 2016).

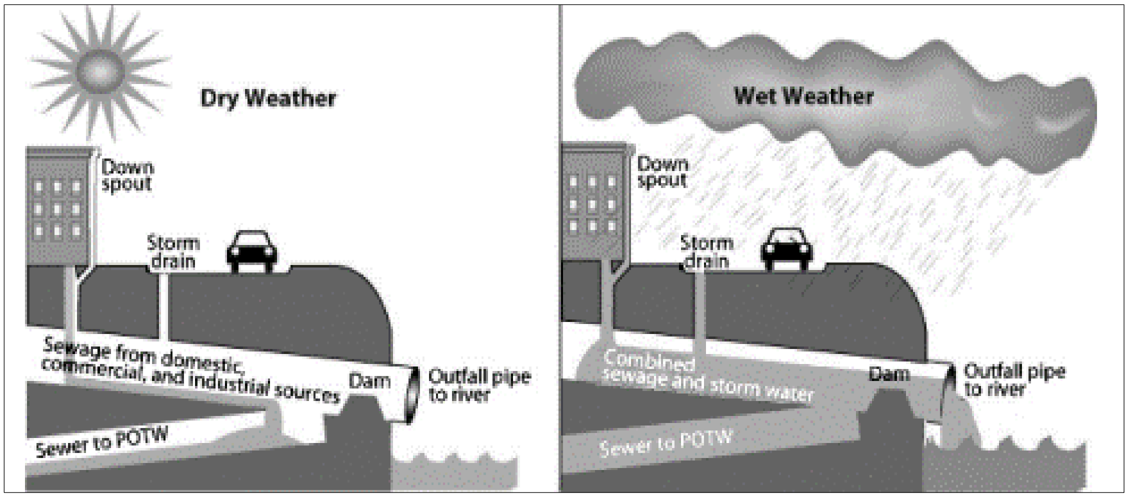


Figure 12. Municipal combined sewer overflow (CSO). Dry weather vs wet weather (EPA, 2020).

Figure 13. NYC Municipal combined sewer overflow (CSO) in wet weather (NYC EPA, 2020).

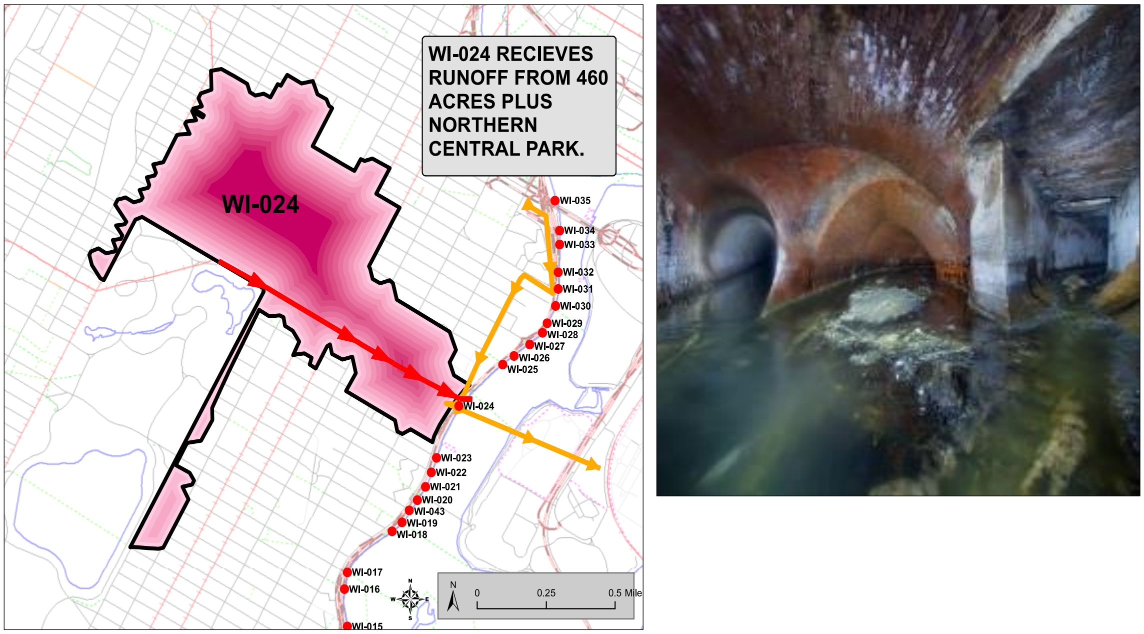


Figure 14. Combined sewer outfall WI-024 area and Central Park North drainage (left) and Harlem Creek buried underground and diverted to the sewer (right) (City University of New York (CUNY) Institute for Sustainable Cities, 2013).

The Effects of an Unsustainable Park Drainage System

Central Park's challenging site with its underlying bedrock base of Manhattan schist, shallow layers of imported topsoil, and man-made underground stormwater drainage systems are not sustainable conditions for its old growth deciduous forests or tree-lined avenues (Figure 15). The Park's design drastically changed in the 1930's from its original "naturalistic" rural landscape setting, where trees were planted in composed groups of several varieties creating a picturesque scene in the park pastoral land (Reed and Duckworth, 1967). In their place was a new urban boulevard style, where trees were planted in homogenous rows along the park's pathways and roads. With little understudy, or access to groundwater, restricted root growth and heavy compaction from park traffic; Central Park's old growth boulevard trees develop top-heavy thicker canopies than their woodland neighbors, increasing their vulnerability to root rot, invasive diseases and collapse (Figure 16).

Figure 15. Central Park: Highly stressed American Elms vulnerable to restricted root growth and heavy compaction from park traffic (by author, 2020).

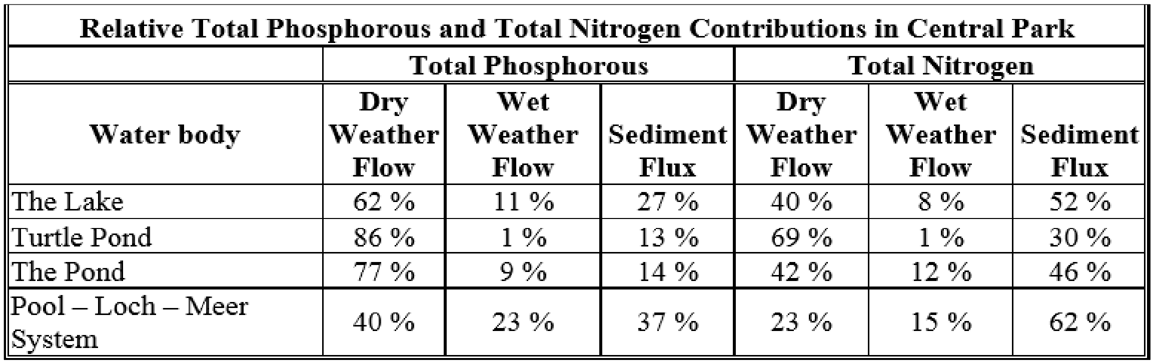
Figure 16. Central Park, NYC: Collapse of an 80+year-old American Elm
due to root rot – seriously injuring a family of four (New York Times, August 15th 2017).

The Effects of Potable Water Usage in the Park's Waterbodies

Central Park's groundwater input and storm-water runoff from the surrounding watershed is prevented by its waterbodies' concrete lined bottom/bases and artificial shorelines constructed of masonry set at a steep angle to the water's edge (Figure 5). The municipal drinking water contains high levels of orthophosphate, which is added to the water by the city to prevent corrosion in its aging supply pipes. Although the Central Parks Reservoir is estimated to be 40' deep at its center, the park's seven other artificial lakes and ponds and streams are shallow with a range of 4 - 7 feet deep. These shallow impermeable water bodies have much higher turnover rates due to the high levels of orthophosphate, combined with the shallow depth of water that retains summer heat. Purification of the water cannot take place due to the hard-concrete base. The park's water bodies are then subject to eutrophication with frequent toxic algae blooms of cyanobacteria (blue-green algae) outbreaks in the warmer summer months (Figure 17).

This is due to the excess amounts of phosphate entering the system and limiting the waterbody's ability to maintain proper oxygen circulation. Typically, freshwater waterways are phosphorus limited with a higher ratio of nitrogen to phosphorus controlling chlorophyll production. However, Central Park's waterbodies are nitrogen-limited due to excess phosphorus creating a lower nitrogen to phosphorus ratio (Table 1). Central Park's continued use of municipal potable water at such a large scale as both an irrigation source and as a waterbody recharge has resulted in seasonal closures of the park's waterbodies due to algae blooms (Columbia University, 2013).

Table 1. Central Park water bodies - phosphorus vs nitrogen levels (Lenz, 2002).



Relative Total Phosphorous and Total Nitrogen Contributions in Central Park

	Total Phosphorous			**Total Nitrogen**		
Water body	**Dry Weather Flow**	**Wet Weather Flow**	**Sediment Flux**	**Dry Weather Flow**	**Wet Weather Flow**	**Sediment Flux**
The Lake	62 %	11 %	27 %	40 %	8 %	52 %
Turtle Pond	86 %	1 %	13 %	69 %	1 %	30 %
The Pond	77 %	9 %	14 %	42 %	12 %	46 %
Pool – Loch – Meer System	40 %	23 %	37 %	23 %	15 %	62 %

Figure 17. The Pond under algae bloom warning (left) and The Lake – algae bloom clearing with algal harvester (right) (Central Park Conservatory, 2020).

Historical Background

Central Park is a national historical landmark park comprising 843 acres (153 city blocks, designed in the "naturalistic" style of the King's Parks in London: Regent's Park and Hyde Park. This legacy park was the first urban landscape design project of the father of American landscape architecture, Frederick Law Olmstead, and his partner Calvert Vaux, a renowned British architect and landscape designer (Charles River Editors, 2017). Olmsted's vision of the urban park was as a place for all citizens regardless of age, sex, ethnicity and socioeconomic class to find respite from the labor of the day in the natural setting of the park (Rogers & Berendt, 1987). Olmstead based his design of "America's first urban park" on the design of the king of England's former private hunting ground parks – Regent's Park and Hyde Park in London (Figure 18).

Figure 18. London's Royal Parks: Hyde Park and Regent's Park (1856)
(A Vision of Britain, 2020).

Central Park was constructed in 1857 as a man-made “naturalistic” park that incorporated many features of the natural topography of the land – ponds, steams, rivulets swamps, uplands and lowlands into its carefully curated architecturally designed landscapes (Figures 19 & 20). Cinder and gravel pathways acted as the parks circulatory system, and served a double purpose as part of the parks surface and subsurface drainage system. Stormwater seeped through the gravel to underground drainage tile pipes, where it was collected in catch basins before it was emptied into the park’s waterbodies. The park’s engineered lakes, ponds and streams were lined with clay, and natural shorelines with excavated boulders placed along their embankments were incorporated into the design for erosion control, park drainage and to provide a natural wetland habitation for wildlife. However, fifty years later, in 1905, Central Park’s landscape began to take on a more man-made engineered look as the city sewer system was connected to the interior of the park. This was followed by the opening of the Catskill Aqueduct in 1915, which provided a steady supply of potable water to flush the lakes and maintain water levels in the park’s water bodies; (US Geological Survey (USGS), 2020). Easier access to municipal water and sewage systems and the availability of man-made materials after the invention of asphalt in 1908, coupled with increased park visitation and greater trampling and erosion of its landscape, led to the design of hard regulated style shorelines and concrete lined basins for Central Park’s lakes, ponds and streams in 1929 (Figure 5) (Rogers & Berendt, 1987).

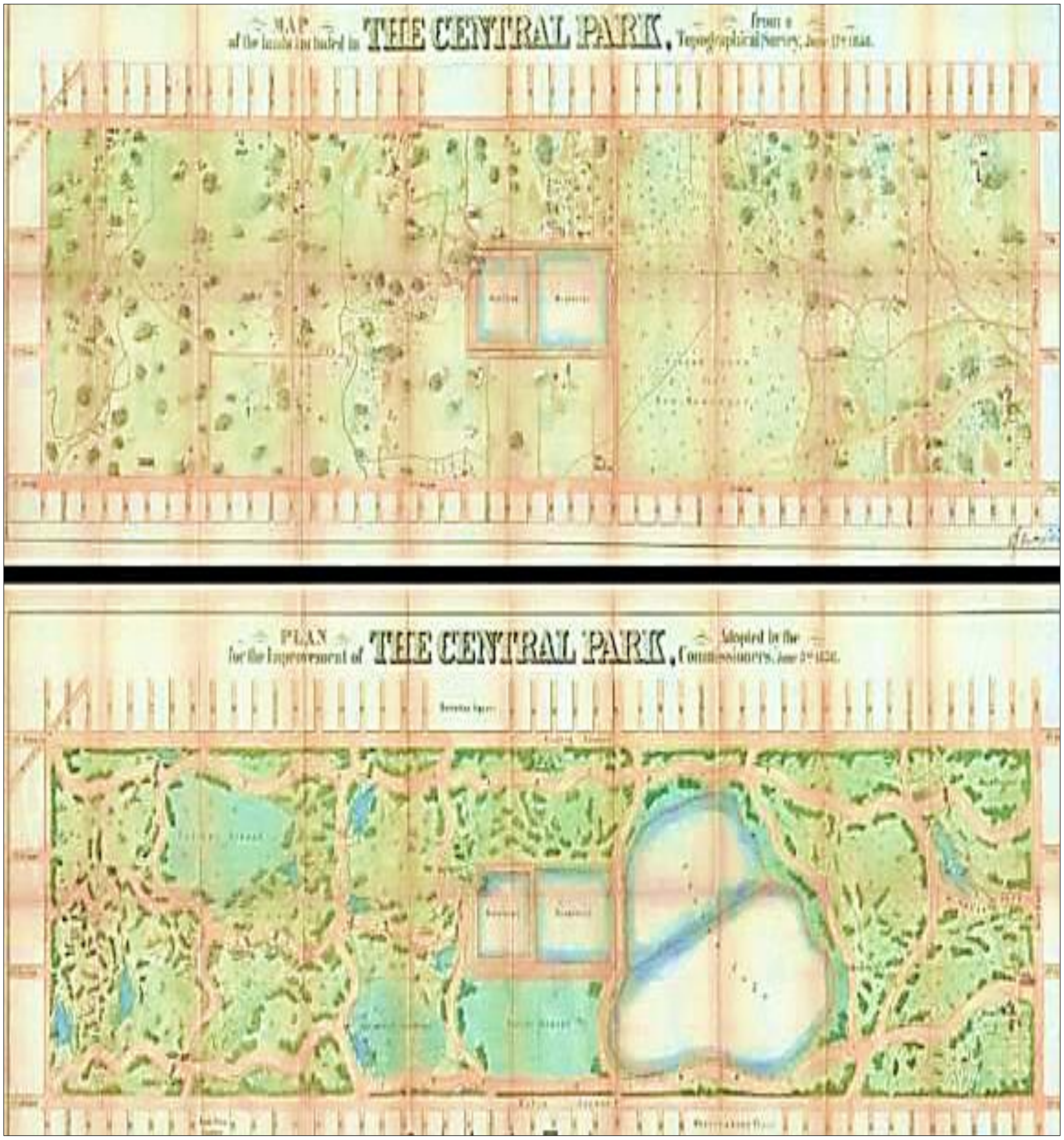
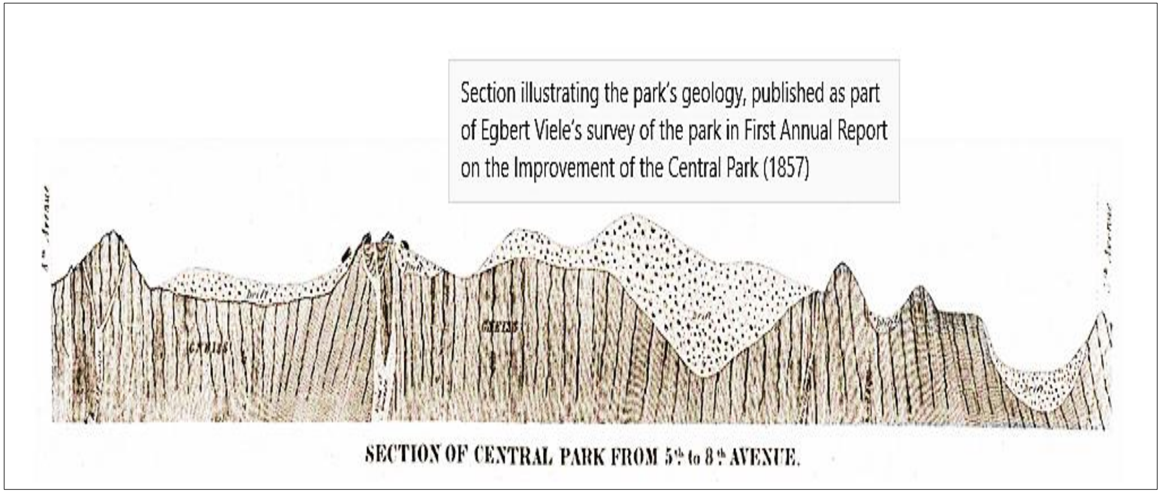


Figure 19. Map of the lands included in Central Park, from a topographical survey on June 17th 1856 (top) and Plan for the Improvement of Central Park, adopted by the commissioners, 1856 (bottom).
(Central Park Conservancy, 2020). Compiled by Egbert Ludovicus Vielé, Civil engineer.



Section illustrating the park's geology, published as part of Egbert Viele's survey of the park in First Annual Report on the Improvement of the Central Park (1857)

Figure 20. Section through Central Park from 5th to 8th Avenue (1857) (Rogers & Berendt, 1987). Compiled by Egbert Ludovicus Vielé, civil engineer.

Central Park was designed with an elaborate drainage system to remove surface water runoff to a drainage network system (62 miles) of underground clay pipes buried 3-4 feet below the surface. The tree branch drainage systems (Figures 21 & 22), were initially designed to direct runoff away from areas such as lawns and walkways where it might oversaturate the soil and perhaps lead to erosion problems. A gravity-based drainage system and clay bottomed water bodies with natural water edges were initially constructed in Central Park, however due to problems with standing water, erosion due to trampling, algae build-up and slow turnover rates of the water-bodies, Central Park drainage was replaced with one that drained directly to the city's combined sewer system (Columbia University & Central Park Conservancy Institute, 2013).

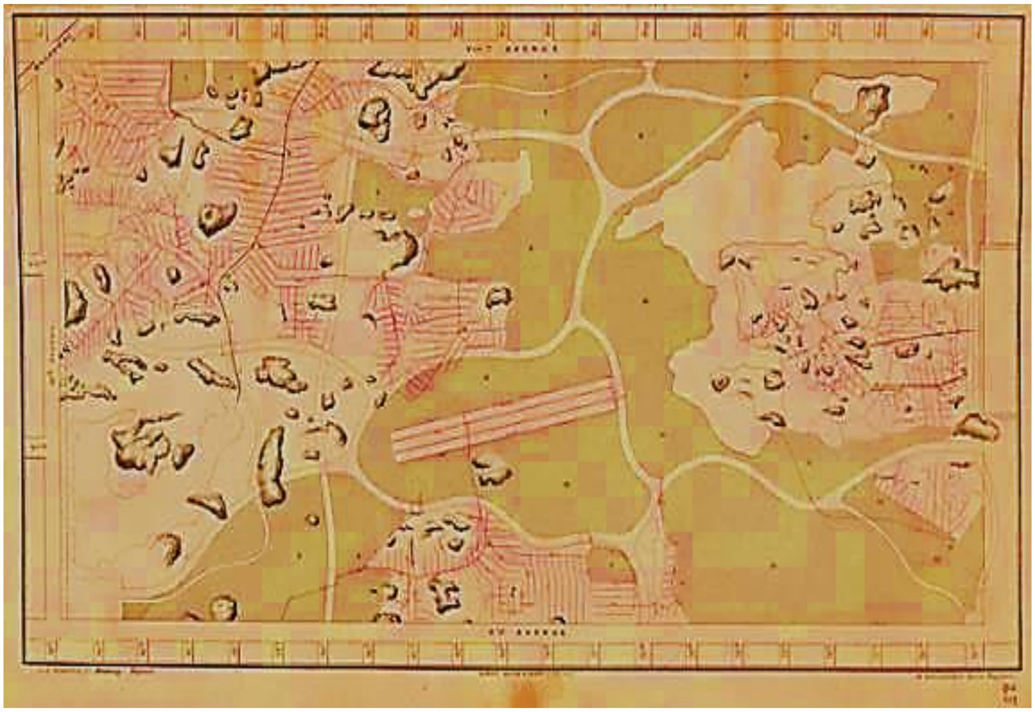


Figure 21. Drainage system on lower part of Central Park as completed up to December 31st, 1858. Compiled by George E. Waring Jr., drainage engineer (Central Park Conservancy, 2020).

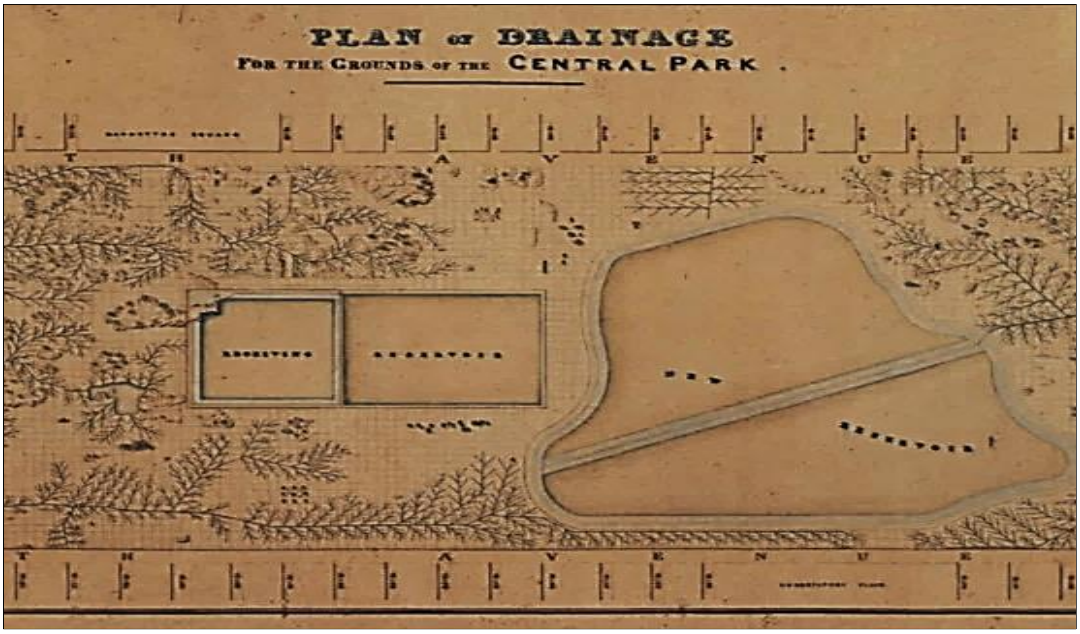


Figure 22. Plan of Drainage for the grounds of Central Park 1856 – 1857.
Source: New York Municipal Archives. Compiled by Egbert L. Vielé, Chief Engineer

Central Park was constructed approximately 2 miles north of the population center of the City of New York. The park was built around the old Croton Reservoir (1842) and the “New” Manhattan Lake Reservoir (designed in 1858 to hold 1 billion gallons of municipal drinking water), in marshy wasteland filled with glacial outcrops of Manhattan schist (Figure 23). Central Park is a legacy park, designed as an open-air oasis for a burgeoning metropolitan city by Olmstead and Vaux. The park was built over a period of twenty years (1857-1877) during the Victorian “City Beautiful” era (Central Park Conservancy, 2020). The Manhattan City grid plan of 1811 was changed to accommodate the building of Central Park. By the time the park was opened to the public in 1859, the Upper East Side was beginning to expand North but the Upper West Side and Northern Manhattan was still un-populated (Figure 24).

Figure 23. Island of Manhattan’s first drinking water system: The Croton Aqueduct. Detail from the “Sanitary & Topographical Map of the City and Island of New York,” created by Egbert L. Vielé in 1856, showing the natural pre-urban streams, ponds, springs, and drainage routes mapped to the contemporary (19th – 20th century) street grid (CUNY, 2013).

Figure 24. The construction of Central Park. William I. Taylor (1879), Lithograph. published by Galt & Hoy, New York. Library of Congress (Heckscher, 2008).

Central Park Today

By the turn of the 20th century, Central Park had deteriorated greatly due to a lack of government funding. The park was revived by New York Parks Commissioner Robert Moses in the 1930s through the 1960’s, but was overrun by crime and neglect again in the 1970s. In the early 80’s, two park advocacy groups combined to become the Central Park Conservatory, with an aim to restore the park to its former glory and continue the legacy of its original designers: Olmsted and Vaux. The present-day $85 million cost of operating and maintaining the park is now handled by the semi-private-public partnership of the Central Park Conservatory (Figures 25, 26 & 27).

Figure 25. Central Park Lake - 1980's (left) and present day (right) (Central Park Conservatory, 2020).

Figure 26. Central Park –The Great Lawn - 1980's (left) and present day (right) (Central Park Conservatory, 2020).

Figure 27. Central Park West 72nd St. entrance - 1980's (left) and present day (right) (Central Park Conservatory, 2020).

Central Park Reservoir

Central Park stores approximately 1 billion gallons of municipal drinking water in a 40-foot-deep, 106-acre reservoir. The Central Park Reservoir, built in 1862 as a receiving pool for the city's water supply was decommissioned as a city potable water source in 1993 when a new main under 5th Avenue and 79th Street connected to NYC's Water Tunnel No. 3, a backup tunnel to the city's upstate water supply (Figure 28). Central Park's Reservoir was deemed obsolete when it was transferred from the Department of Environmental Protection to the Department of Parks and Recreation in 1999 (Figure 29). The entire water body remains enclosed by a 4-foot-high steel fence that runs along its 1.6-mile perimeter (Figure 5, left). For the past 27 years, the reservoir's main function is to serve as a receiving pool to distribute municipal water to the remaining seven artificial water bodies in the park (Lenz, 2002). The reservoir is supplied with water from the NYC municipal drinking water system. Groundwater input and storm-water runoff from the surrounding watershed is prevented by the Reservoir's concrete lined bottom/base and artificial shoreline constructed of masonry that is set at such a steep angle to the water's edge that it prevents all-natural wetland habitat development (Figure 5, left). Although the Reservoir has been under the control of the NYC Department of Parks and Recreation for over the past twenty-one years, it remains inaccessible to the public and off-limits for use as a stormwater retention lake or recreational facility.

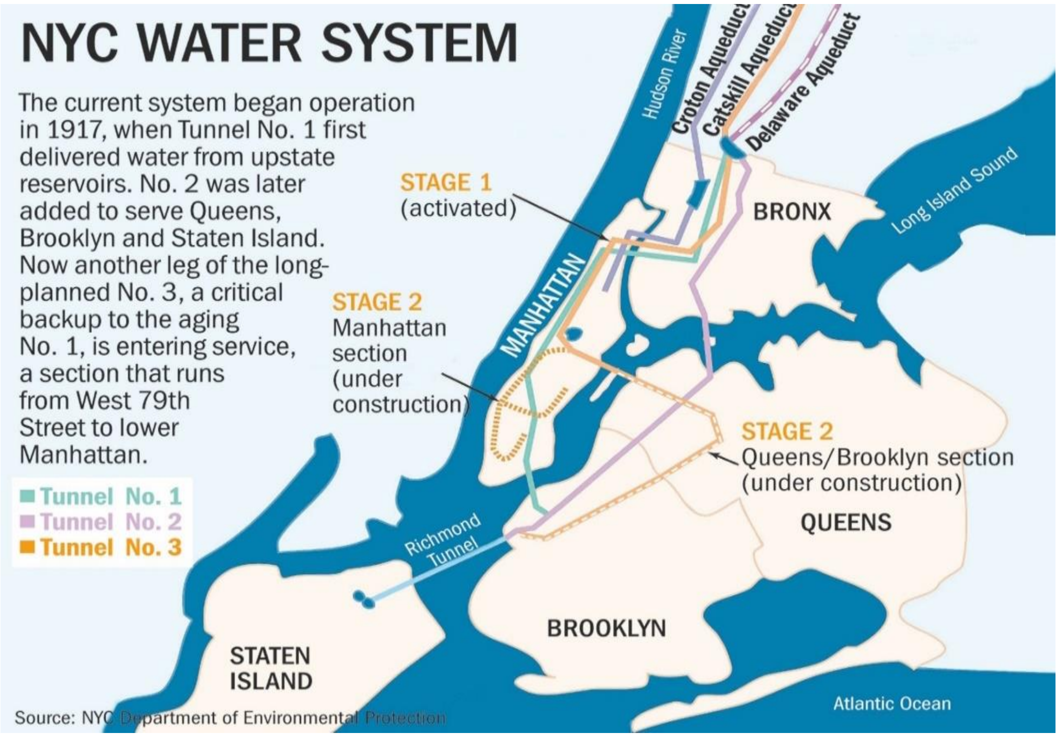


Figure 28. Location of NYC water system tunnels 1-3 and Central Park's reservoir (NYC DEP, 2020).

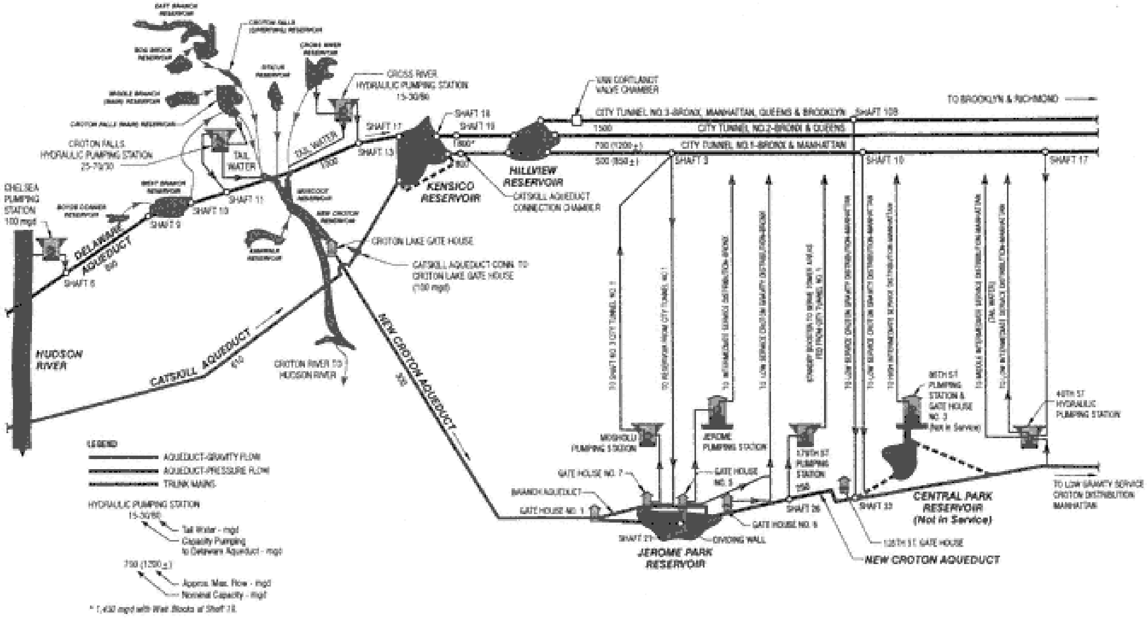


Figure 29. NYC water system: schematic showing reservoirs, aqueducts, tunnels and Central Park's decommissioned reservoir
(NYC DEP, 2020)

Central Park’s Proposed Reengineering of the Lasker Pool/Rink Area Waterways

In the fall of 2019, the Central Park Conservancy and NYC Parks Department unveiled plans to redesign the Lasker Pool and Ice-Skating Rink located in the south-west corner of the Harlem Meer. This project would reconnect the Harlem Meer with the water courses of the Loch and the Pool that have been disrupted since the construction of the Lasker Pool/Rink in 1966 (Figure 30). The plan would involve removing the barriers that had obstructed the flow of water from the Pool through the Loch and into the Harlem Meer (Figures 31 & 32). The historic watercourse of the stream that flowed through the Ravine (a 90-acre deciduous woodland) connecting the Loch with the Harlem Meer had been diverted into a five-foot culvert running under the facility during the Robert Moses era renovation of Central Park in the 1960’s. This decision to locate the Lasker rink/swimming pool directly over the mouth of the stream leading from the Loch to the Meer lead to chronic flooding problems for the site and obstruction of the drainage corridor of the park’s northern watersheds. The Harlem Meer had already undergone major alterations to its naturalistic shoreline of coves and grassy peninsulas in the early 1940’s, when its lake bottom was concreted (like all the other water-bodies in the park), in response to malaria outbreak scares, and its edges were smoothed out and hardscaped with concrete masonry (Rogers, 1987). The proposed plan will take the recreational facility out of the direct path of the stream allowing for a less disrupted flow of water between the three waterbodies of Northern Central Park: The Pond, the Loch and the Harlem Meer. If implemented, this re-construction will be more in keeping with the vision of the park’s original designers, Olmsted and Vaux, who incorporated historic water courses such as Montayne’s Rivulet stream and the marshes of the Harlem Meer into the design of their idealized urban landscape (Central Park Conservancy, 2020).

Figure 30. Existing aerial view of the Harlem Meer with Lasker Pool and ice-skating rink (left) and rendering of proposed facility with connecting waterways (right) (Central Park Conservancy, 2020).

Figure 31. Existing waterbodies of northern Central Park and their disrupted flow due to the location of the Lasker Pool/Ice Skating Rink (Lenz, 2002).

Figure 32. Topographical plan of the existing waterbodies of northern Central Park and their disrupted flow to the culvert under the Lasker Rink and Pool. The course of the historical stream: Montayne's Rivulet in 1811 is shown running through the waterbody (Greensward Foundation, 2020).

Research Questions, Hypotheses and Specific Aims

Many of Central Park's unsustainable park management practices regarding municipal potable water intake and stormwater management could be resolved if a full picture of the park's past-to-present day control methods and past construction/re-construction practices were integrated into one study. This data could then be analyzed in comparison to the methods employed in other more sustainable historical large-scale urban parks such as Hyde Park in London, on which Central Park was originally designed (Figure 18).

To address this opportunity, the main areas of my research concentrated on identifying the historical factors that arrest Central Park's development and keep this heritage site more like a living museum, rather than a sustainable urban wetland. The central questions I addressed were:

- How can Central Park transition from a historical city landmark park into a sustainable urban wetland for the City of New York?
- How can Central Park reduce its reliance on municipal drinking water to maintain the water-levels in its man-made concrete-lined "Naturalistic" lakes streams and ponds and to irrigate its landscapes?
- Can Central Park restore its own natural waterbodies and access its own groundwater like Hyde Park in London has recently accomplished?
- How can the City of New York mitigate the limitations of legacy systems to maximize the Central Park's potential as a storm-water retention resource?
- How can Central Park reclaim its artificial waterbodies and turn them into a sustainable urban wetland for the City of New York?

The primary hypotheses I examined were:

- Central Park can reclaim its man-made "ornamental" waterbodies and turn them into green infrastructure for the City of New York by changing the park's unsustainable water management practices regarding potable water intake and stormwater discharge. Specifically, this can be achieved by:
    - Retrofitting the park's receiving reservoir to function as a stormwater retention lake for the entire park.

    - Replacing Central Parks eight concrete-lined and masonry-edged artificial water bodies with clay lined softscape beds and landscaped embankments to increase the waterways sustainability.
    - Reducing the park's reliance on municipal potable water by daylighting the park's historical underlying streams, and accessing the park's groundwater (using similar methods adopted by Hyde Park, London drilling 150 m to reach groundwater to maintain water levels in the Serpentine Lake) and by accessing groundwater from the surrounding subway stations which pump excess groundwater into the city's combined sewer system daily.
- The modernization of Central Park beginning at the turn of the 20th century up until the 1960's is responsible for holding Central Park back in developing an integrated sustainable water management plan for the 21st Century.

Specific Aims

To accomplish this research project, my specific aims were to:

1. Create a file geodatabase for the spatial data for Central Park using ArcGIS for Desktop.
2. Use ArcMap to create a base-map using the World imagery map from ArcGIS online and sourced from USGS that is centered on Manhattan.
3. Search for geodatabase data for present-day Central Park's water management and stormwater drainage systems from ESRI, USGS, NASA, NYDEP, SWMM, and CUNY.

4. Gather geodatabase data for historical Central Park's water management and stormwater drainage systems from Central Park Conservancy, NY Department of Parks and Recreation, NYDEP, Columbia University and City University of New York (CUNY).
5. Create a map of water management and stormwater runoff for historical 19th century Central Park with existing streams and rivulets.
6. Create a map of water management and stormwater runoff for present-day Central Park showing the concrete lined waterways draining to the city combined sewer.
7. Create a map of water management and stormwater runoff for the future 21st Century Sustainable Central Park showing the daylighting of the Harlem Creek and Montayne's Rivulet and the original park streams.
8. Run a soil analysis of the park using United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS) – Web Soil Survey
9. Delineate the watershed for Central Park's Reservoir as a stormwater retention lake.

To summarize I aimed to create a series of maps using both historical and present-day data:

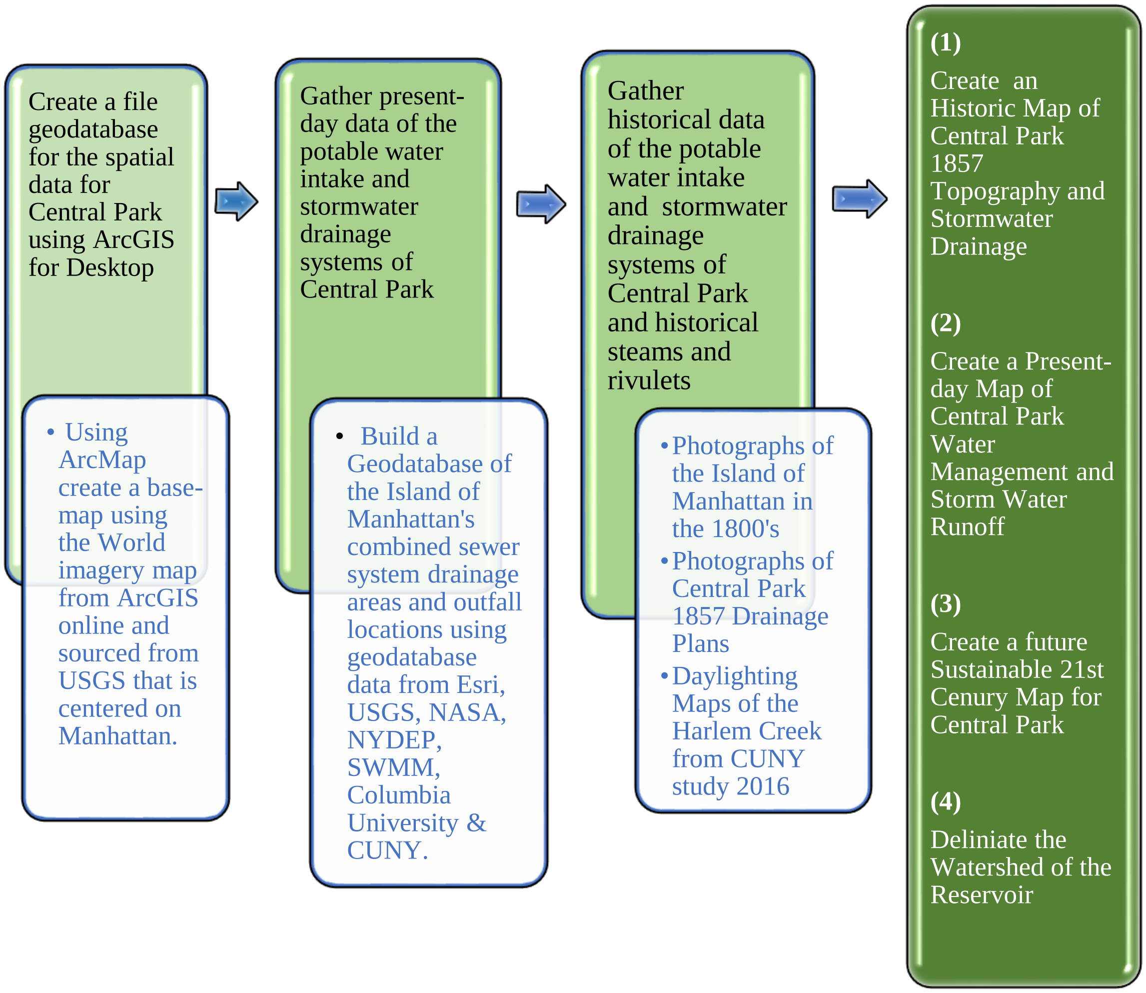
- Map 1: Historical 19th Century Central Park with existing streams and rivulets
- Map 2: Present-day Central Park showing the concrete lined waterways draining to the city combined sewer system.
- Map 3: The future 21st Century Sustainable Central Park showing the park using its own water bodies for stormwater retention and overlaying the parks original

five streams: The Harlem Creek, Montayne’s Rivulet, Saw Kill North and South Branch and DeVoor’s Mill Stream.

Chapter II

Methods

The goal of my thesis was to bring the issues I have found in my research of Central Park's water intake and discharge management practices to light, to trace their origins in the design, construction and management decisions of the past and run analyses to test my findings using the latest geological mapping and data analysis tools available from the global information systems (GIS) analysis program, ArcGIS. I used ArcGIS geodatabase data management applications to analyze both historical and present-day topography data for Central Park and the island of Manhattan (Figure 33). I imported geological data into ArcGIS from the Environmental Systems Research Institute, Inc (ESRI), the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA). I used ArcGIS spatial analysis software to delineate the watershed for Central Park's Reservoir. The project uses USGS Topography Base Maps, NASA satellite images, New York City Department of Environmental Protection's (NYCDEP) and Storm Water Management Model (SWMM) Combined Sewer (CSO) locations and Water Supply Maps to create maps in ArcGIS that represent present storm water management conditions. This information was used to create comparison maps indicating future potential improved water management and storm water control conditions (Figure 33).



Create a file geodatabase for the spatial data for Central Park using ArcGIS for Desktop

- Using ArcMap create a base-map using the World imagery map from ArcGIS online and sourced from USGS that is centered on Manhattan.

Gather present-day data of the potable water intake and stormwater drainage systems of Central Park

- Build a Geodatabase of the Island of Manhattan's combined sewer system drainage areas and outfall locations using geodatabase data from Esri, USGS, NASA, NYDEP, SWMM, Columbia University & CUNY.

Gather historical data of the potable water intake and stormwater drainage systems of Central Park and historical steams and rivulets

- Photographs of the Island of Manhattan in the 1800's
- Photographs of Central Park 1857 Drainage Plans
- Daylighting Maps of the Harlem Creek from CUNY study 2016

(1)
Create an Historic Map of Central Park 1857 Topography and Stormwater Drainage

(2)
Create a Present-day Map of Central Park Water Management and Storm Water Runoff

(3)
Create a future Sustainable 21st Cenury Map for Central Park

(4)
Deliniate the Watershed of the Reservoir

Figure 33. Methodology

Reference Data

To create a file geodatabase for the spatial data for Central Park using ArcGIS for Desktop 2020, I used raster, shapefiles and geodatabase data for present-day Central Park and historical 19th Century Central Park. I imported a historical map of the island of Manhattan into Geoeditor to create a georeferenced map that I could export to ArcGIS. I used the historical georeferenced map as a base map and then overlaid it with modern-day USGS maps to create a series of three maps that highlight Central Park's past, present and future water resources management.

Historical Geographic Data Required for the Project

To create Map 1: historical 19th Century Central Park with five existing streams, marshes and lakes (Figure 49), I referenced historical geographical maps of the park to locate the park's natural waterways that were diverted underground during the park's renovations in the 19th century. I used the Greensward Foundation historical maps of the island of Manhattan to locate Central Park's five original streams: The Harlem Creek, Montayne's Rivulet, Saw Kill North and South Branch and DeVoor's Mill Stream (Figure 34 & 35). To trace the original path of the Saw Mill stream's North branch that underlies the Reservoir, I referenced the Greenward's Foundation 1811/1994 map (Figure 36). I repeated this step to trace the path of the Saw Mill's stream South branch that underlies the Lake (Figure 37).

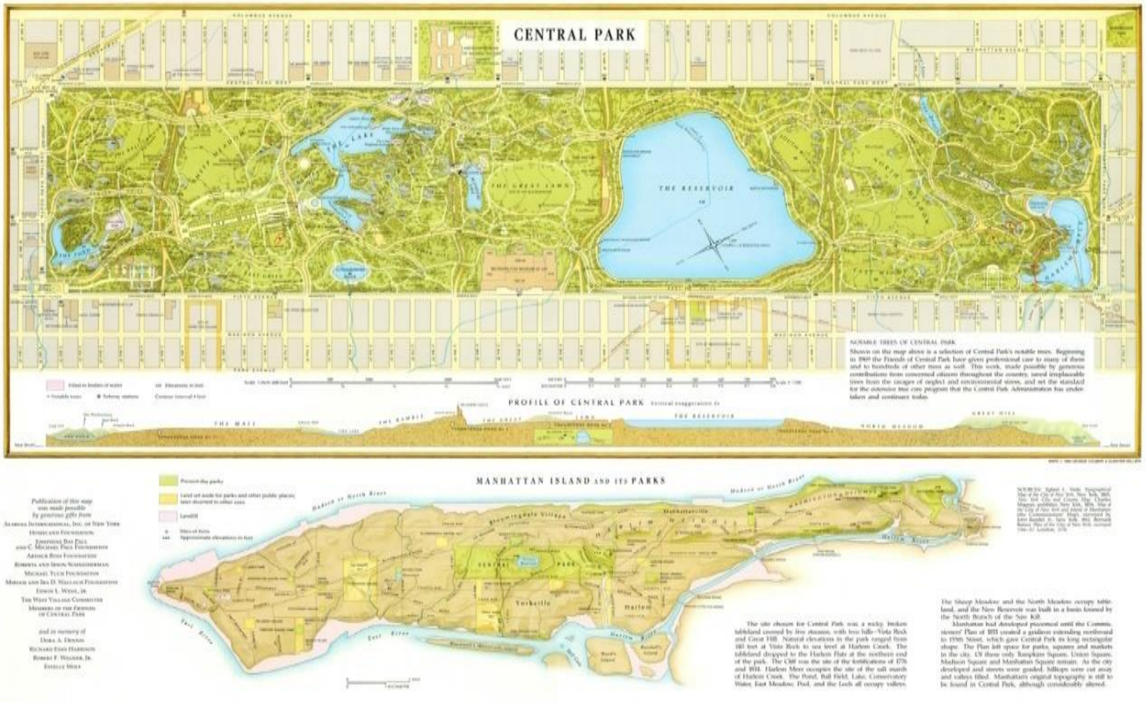


Figure 34. Topographical map of Central Park showing existing water courses in 1994 (top) and historical water courses in 1811 (bottom) (Greensward Foundation, 2020).

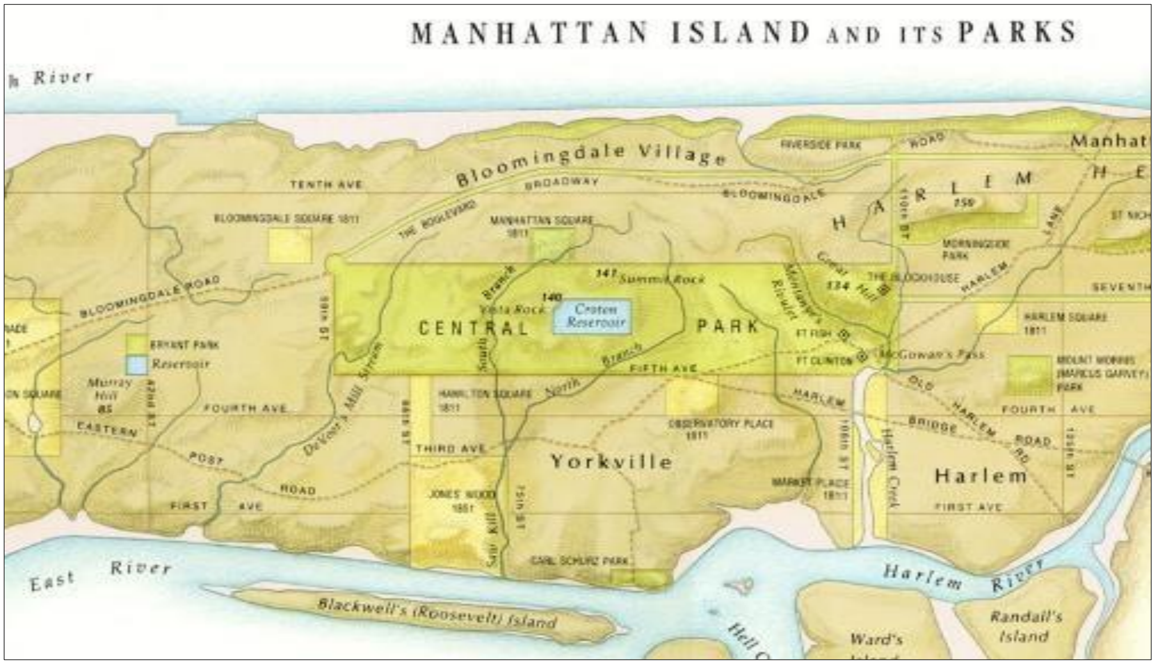


Figure 35. Topographical map of Central Park: showing five historical streams in 1811 (Greensward Foundation, 2020).

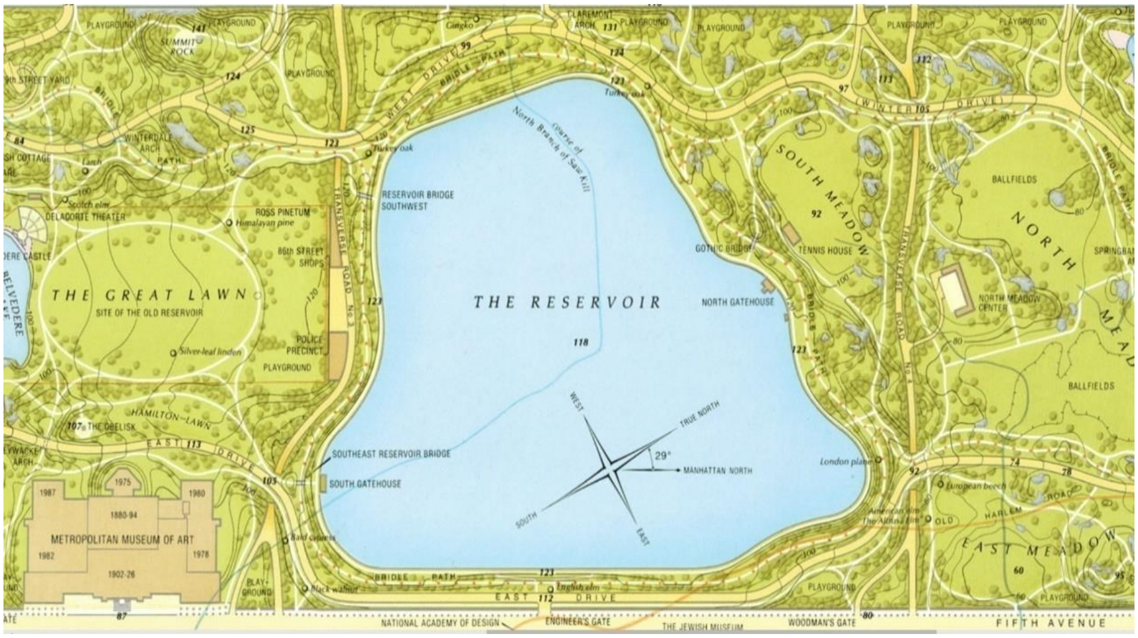


Figure 36. Topographical map of Central Park's reservoir (1994) showing the location of the course of the historical stream: north branch of Saw Mill in 1811 (Greensward Foundation, 2020).

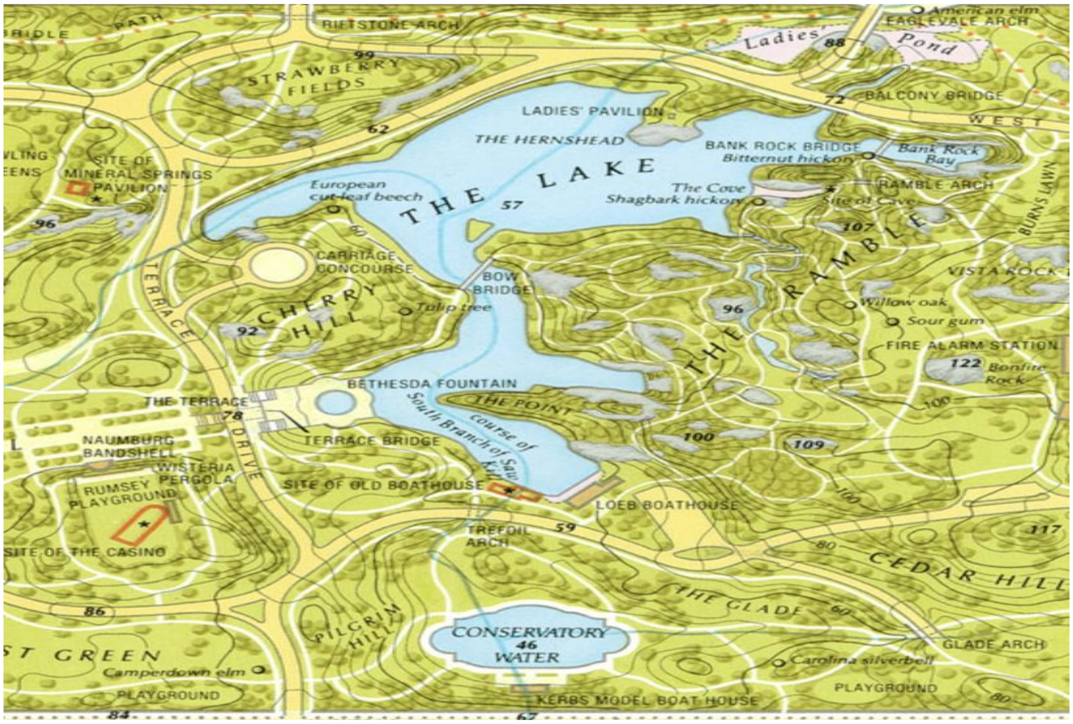


Figure 37. Topographical map of Central Park's lake (1994) showing the location of the course of the historical stream: South Branch of Saw Mill in 1811 (Greensward Foundation, 2020).

I imported civil engineer Egbert Ludovicus Viele's Topographical Atlas of the City of New York: showing original water courses and made land into Geoeditor to create a georeferenced historic map of Central Park's 1874 topography with existing streams and rivulets (Figure 38). I imported the historical map into Geoeditor 2020 and overlaid it onto a present-day map of New York City. I used georeferencing tools to place control points on the perimeter of Central Park in order to rotate and scale the map to create a georeferenced map of the island of Manhattan (Figure 39). I then exported the georeferenced map from Geoeditor into ArcGIS as a .tiff file to create a GIS-based historical/present-day map of New York City (Figure 40).

Figure 38. Topographical Atlas of the City of New York: showing original water courses and made land created by civil engineer Egbert L. Vielé in 1874. (David Rumsey Cartography Associates Map Collection, 2020).

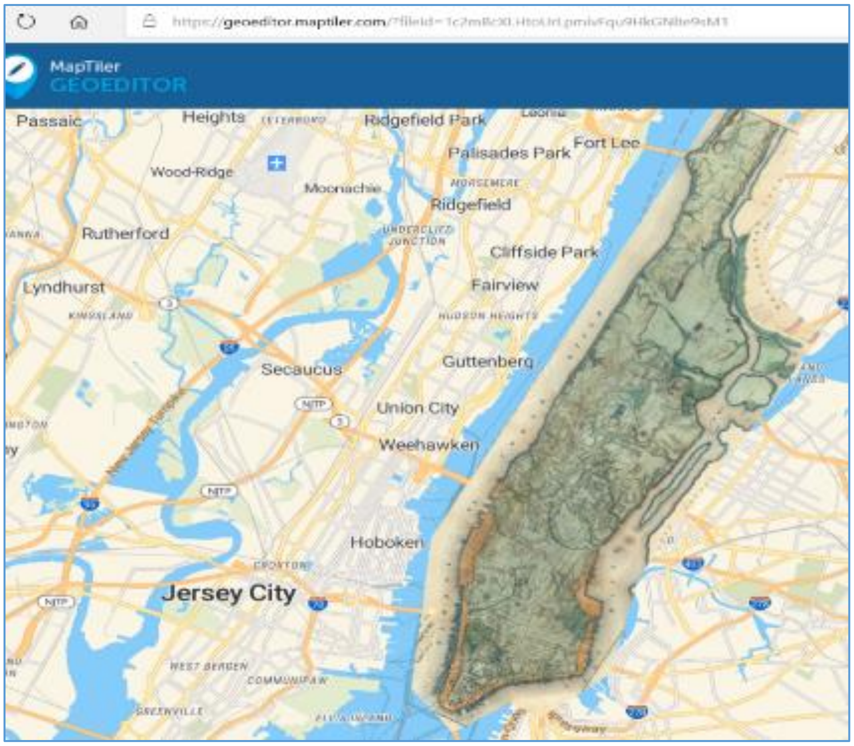
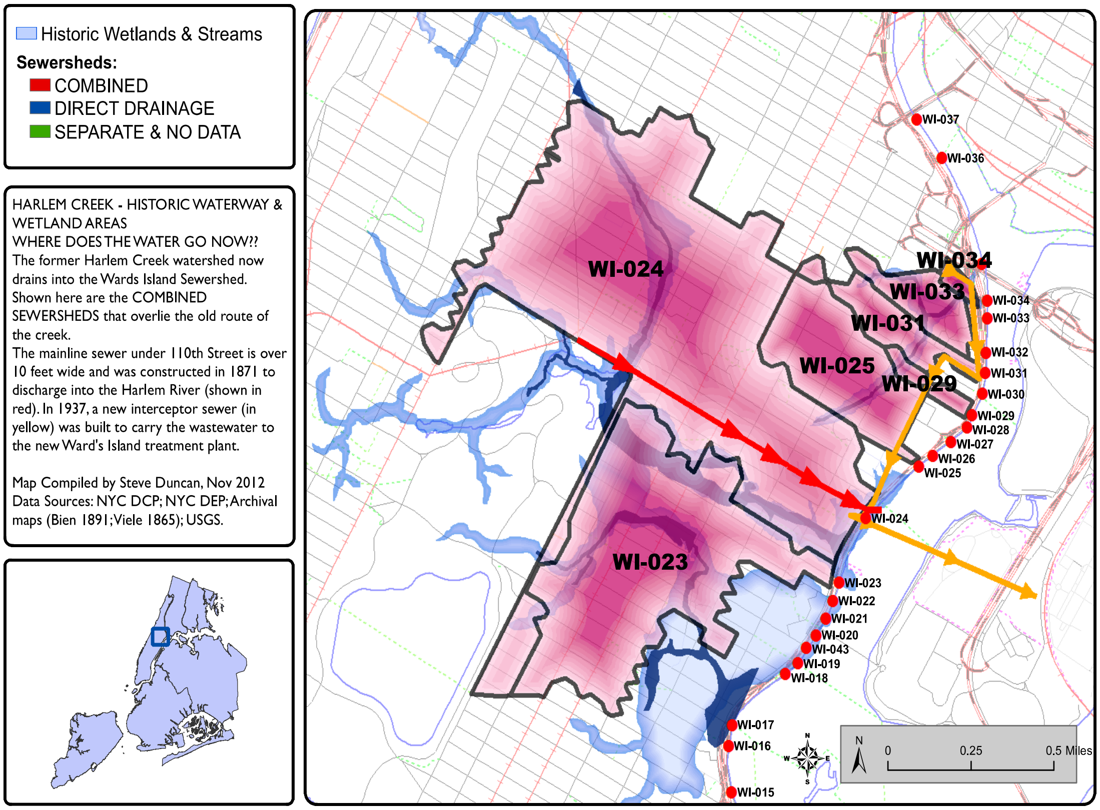


Figure 39. Imported historical map of the City of New York created by Egbert L. Vielé in 1874 overlaid on present-day map of the City of New York (by author using Geoeditor, 2020).

Figure 40. ArcGIS historical map of Manhattan in 1874 overlying present-day map (by author using ArcGIS, 2020).

Present-Day Geographic Data Required for the Project

To create Map 2: present-day Central Park showing the concrete lined waterways draining to the city combined sewer (Figure 50), I referenced geographical data from CUNY (2013), Stream Daylighting in NYC Hydro-Ecology report on the daylighting of the historic urban streams and wetlands of Harlem Creek. I accessed their georeferenced maps of the overflow and drainage from Central Park's Reservoir and the Harlem Meer flows through drainage tunnels into the combined sewer network system, where it is sent to Ward's Island wastewater treatment plant during dry weather or discharged into the Harlem River during wet weather through WI-24 and WI-25 CSO's (Figure 41).



HARLEM CREEK - HISTORIC WATERWAY & WETLAND AREAS
WHERE DOES THE WATER GO NOW??
The former Harlem Creek watershed now drains into the Wards Island Sewershed. Shown here are the COMBINED SEWERSHEDS that overlie the old route of the creek.
The mainline sewer under 110th Street is over 10 feet wide and was constructed in 1871 to discharge into the Harlem River (shown in red). In 1937, a new interceptor sewer (in yellow) was built to carry the wastewater to the new Ward's Island treatment plant.

Map Compiled by Steve Duncan, Nov 2012
Data Sources: NYC DCP; NYC DEP; Archival maps (Bien 1891; Viele 1865); USGS.

Figure 41. The Harlem Creek historical waterway and wetland underlying CSO locations of drainage from Central Park Reservoir and Harlem Meer into the WI-024 watershed (CUNY, 2013).

To create a present-day georeferenced map of Central Park showing the park’s concrete lined waterways draining to the city’s combined sewer system, I needed to gather data of the stormwater drainage systems of the park. I imported georeferenced data from USGS and Open Sewer Atlas NYC drainage data into ArcGIS 2020. I was able to use this data to create a base map of stormwater drainage from Central Park’s reservoir and northern half that is directed to Sewer-shed 491 – Combined Sewer Outfall WI-024 (one of the largest combined sewer-sheds in Manhattan), and drainage from Central Park’s southern half that is directed to Sewer-shed 550 (Figures 42, 43 & 44). Using ArcGIS spatial analysis, I created a map for the whole of Central Park to show the park’s stormwater drainage into the city’s combined sewer systems (Figure 45).

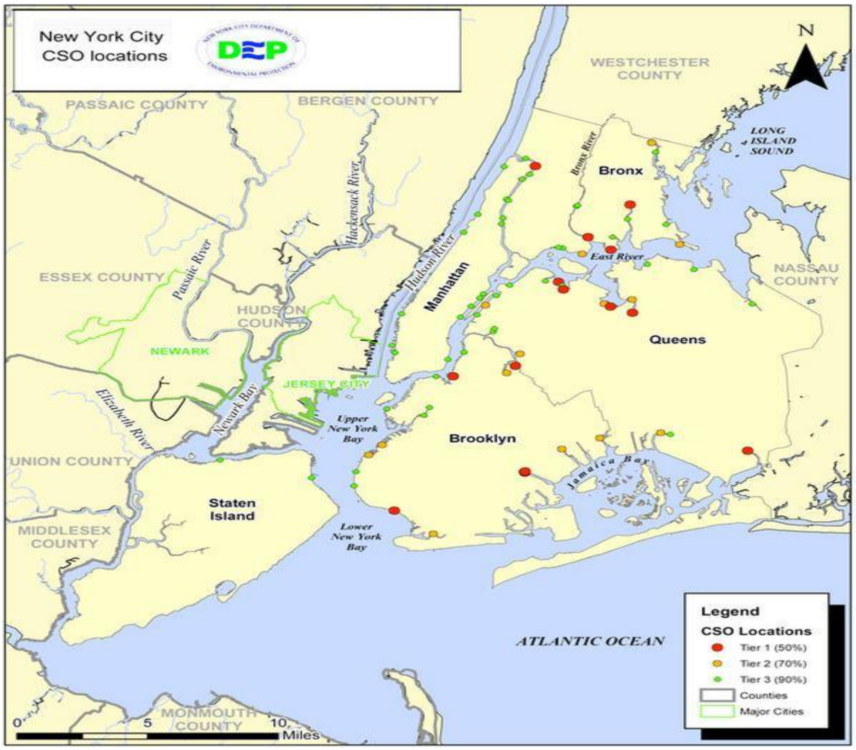


Figure 42. New York City combined sewer outfall (CSO) locations
(NYC Department of Environmental Protection (DEP), 2020

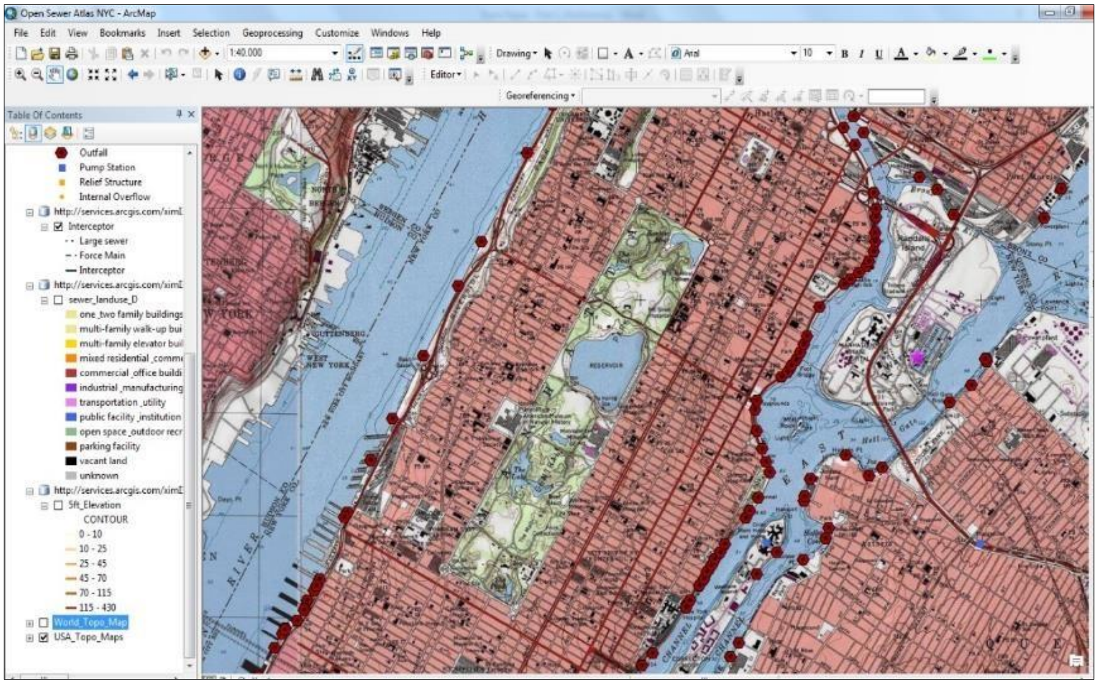


Figure 43. Central Park and northern Manhattan CSO locations (by author using ArcGIS, 2020). Data Source: USGS and Open Sewer Atlas NYC

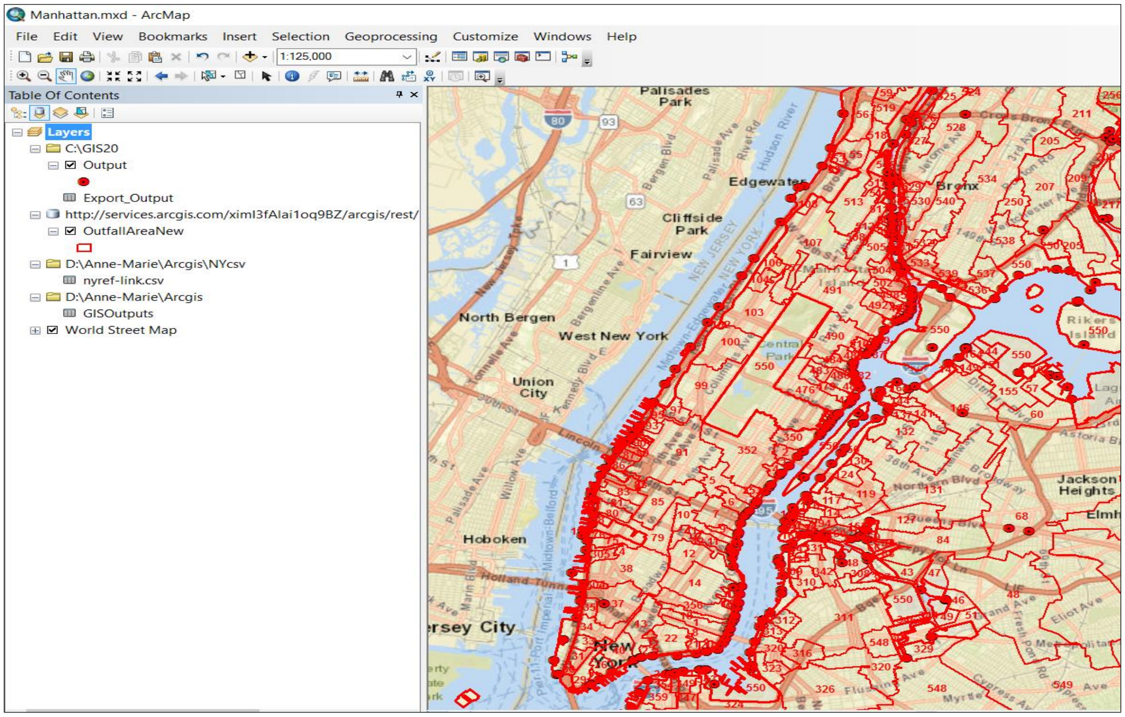


Figure 44. New York City drainage areas and CSO locations (by author using ArcGIS, 2020). Data Source: USGS and Open Sewer Atlas NYC.

Figure 45. CSO drainage areas for Central Park and northern Manhattan (by author using ArcGIS, 2020). Data source: Open Sewer Atlas NYC and USGS.

Future Geographic Data Required for the Project

To create Map 3: The future 21st Century Sustainable Central Park showing the park using its own water bodies for stormwater retention (Figure 51), I used Map 1: Historical 19th Century Central Park with existing streams, marshes and lakes, as a base map in ArcGIS and a USGS map (Figure 46), to create a modern-day layer of the park's 8 waterbodies overlying their historical origins. Map 3 illustrates how Central Park's five historic freshwater streams and marshes that crisscross the park's footprint were originally incorporated into Olmsted and Vaux's design of the park's Pond, Lake, Pool, Loch, Meer and Reservoir.

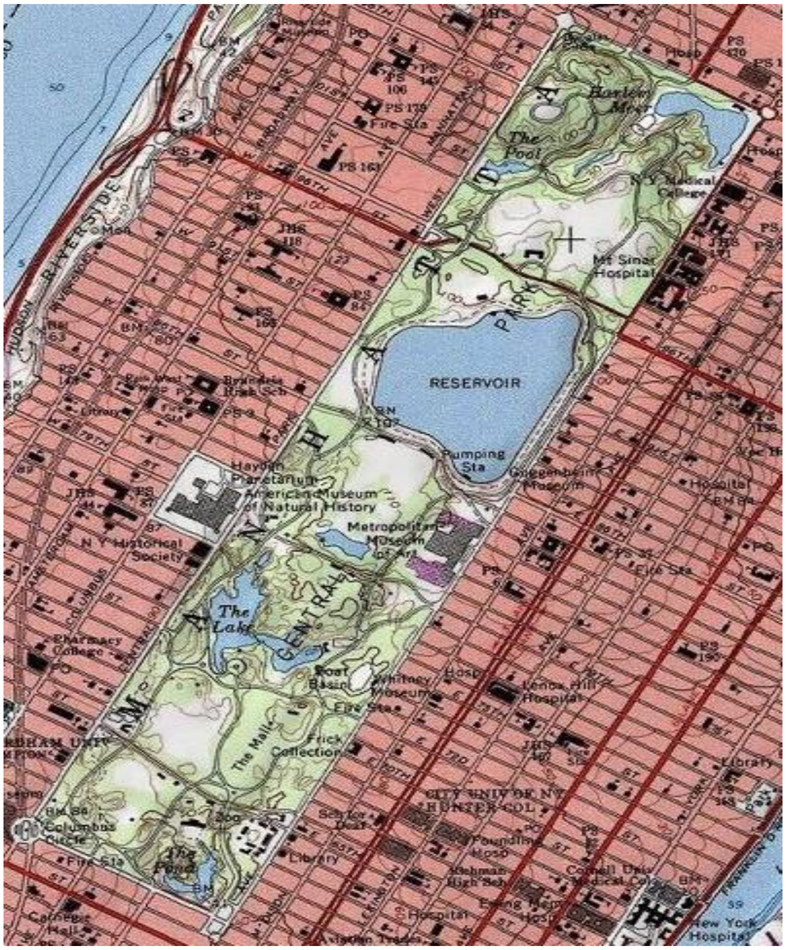


Figure 46. Topographical plan of Central Park, NYC (by author using ArcGIS, 2020). Data source: USGS.

Delineating the Watershed of the Reservoir

To delineate the watershed of Central Park's Reservoir and explore the park's potential as a future stormwater retention lake, I referenced geographical data from previous soil and watershed analysis studies of the park. Lenz (2002), used an integrated analysis of GIS and Storm Water Management Model (SWMM) to delineate the watersheds for each of Central Park's waterbodies. The analysis illustrated the park's reliance on outside drainage systems for the majority of the park acreage. Central Park's Reservoir, Lake and managed lawn areas watersheds are reported to drain directly out of the park and into the City's combined sewer rather than to their own waterbodies. They are therefore designated as "out of park" or "City" watersheds due to their reliance on the City's CSOs to drain stormwater runoff from the park (Figure 47).

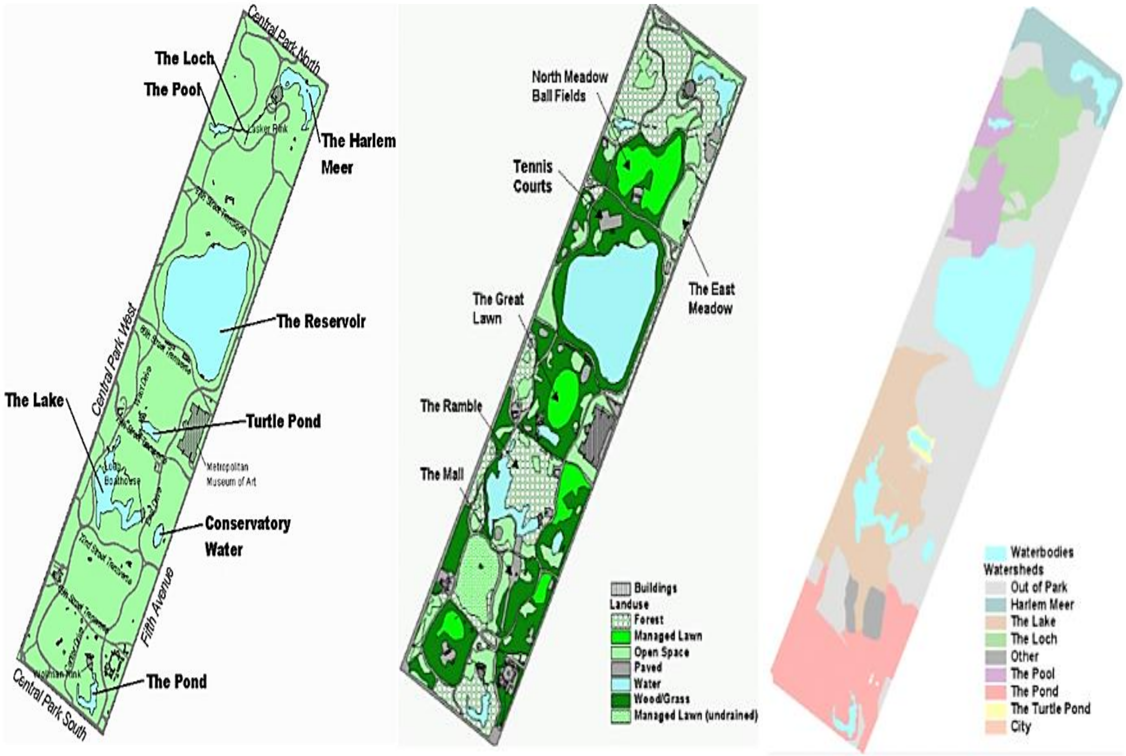


Figure 47. Central Park: waterbodies (left), land use (middle) and watersheds (right) (Lenz, 2002).

Lenz (2002) created a simplified soils map of Central Park and classified the hydrologic soil groups into four main categories from A to D: Urban land till substratum (man-made concrete), Rock, Greenbelt Loam and Water (Figure 48 - right). Central Park's rocky outcrops of Manhattan schist can be seen shaded in yellow, surrounded by the park's greenspaces and its waterbodies in orange. Urban land till substratum (UtA) is shaded in red and is found in the northern section of the park in the man-made waterfalls of the Loch (Figure 46 – left). The soil type data were applied to watershed analysis within the GIS to delineate the watershed for each waterway in the park (Figure 46 – right). Lenz and How (2000) first delineated the watersheds based on topography and then revise their calculations to account for the park's original gravity-based drainage systems, and also to incorporate information from flow patterns collected during their field investigations of the park's drainage systems. Central Park's Reservoir was not included however in the calculations, as unlike the other seven waterbodies, the Reservoir's watershed is considered to drain "out of the park" (Figure 48 – right) to the city's combined sewer drainage system instead of to its own waterbody (Table 2).

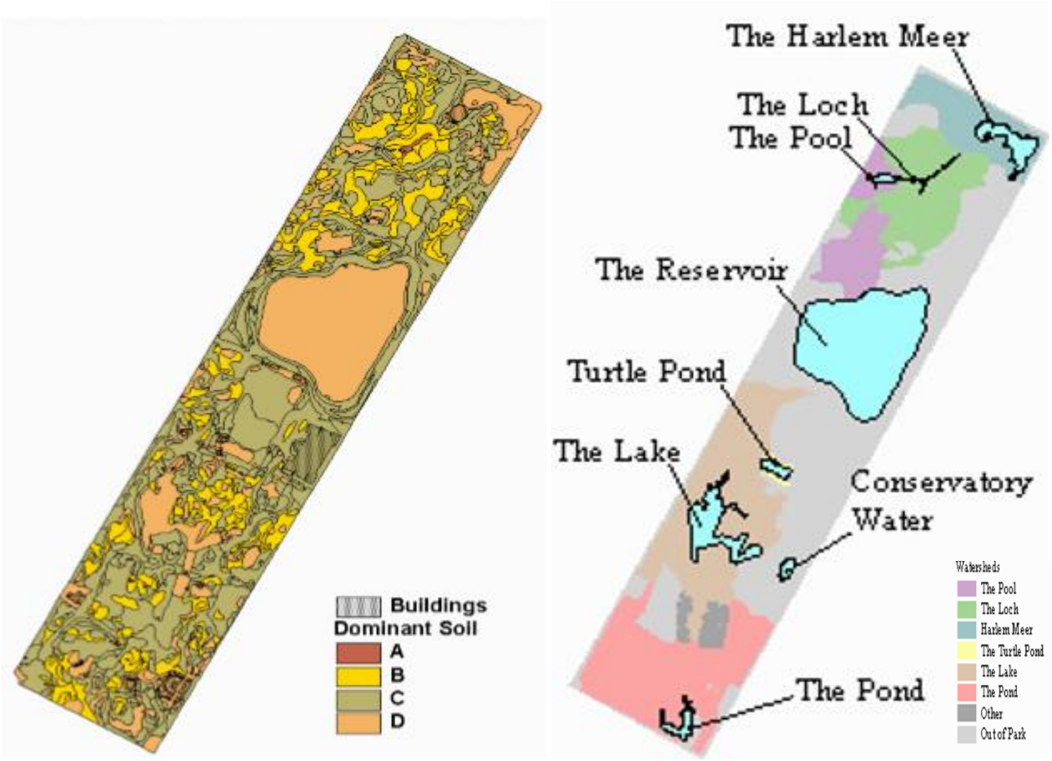


Figure 48. Central Park – Soil survey map: dominant soil types (left) and waterbodies (right) (Lenz, 2002).

Table 2. Central Park watershed areas.

Waterbody	**Watershed Areas excluding waterbodies (acres)**		
	Based on topography	**Updated with drainage mapping**	**Updated with drainage mapping and field investigations**
Pool	38.1	39.6	46.2
Loch	46.9	88.8	81.8
Meer	54.5	44.9	44.9
Turtle Pond	24.3	2.9	2.9
Lake	144.0	95.3	129.7
Pond	152.9	57.2	123.7
Other	0	0	14.7
Out of Park	256.3	388.3	272.9

Watershed areas excluding waterbodies: original and updated watershed areas to account for the gravity-based drainage system and field verification (Lenz & How, 2000).

Chapter III

Results

I created a series of georeferenced maps to highlight Central Park's past, present and future water resources management. I wanted to draw attention to Central Park's original bodies of water before they were encased in concrete or channeled underground during the park's renovations in the 20th century. The three maps I produced were:

Map 1: historical 19th Century Central Park, explores the natural waterways and watershed drainage of Central Park's original site. The five natural streams on which the Central Park's waterways were originally designed are emphasized: The Harlem Creek, Montayne's Rivulet, Saw Kill North and South Branch and DeVoor's Mill Stream (Figure 49).

Map 2: Present-day Central Park showing the concrete lined waterways draining to the City's combined sewer system (CSS) (Figure 50). Map 2 emphasizes Central Park's total reliance on the City's stormwater drainage system to carry its overflow to the combined sewer system. The northern half of Central Park drains to sewer shed #491, while the southern half of the park drains to sewer shed #505.

Map 3: The future 21st Century Sustainable Central Park showing the park using its own water bodies for stormwater retention (Figure 51).

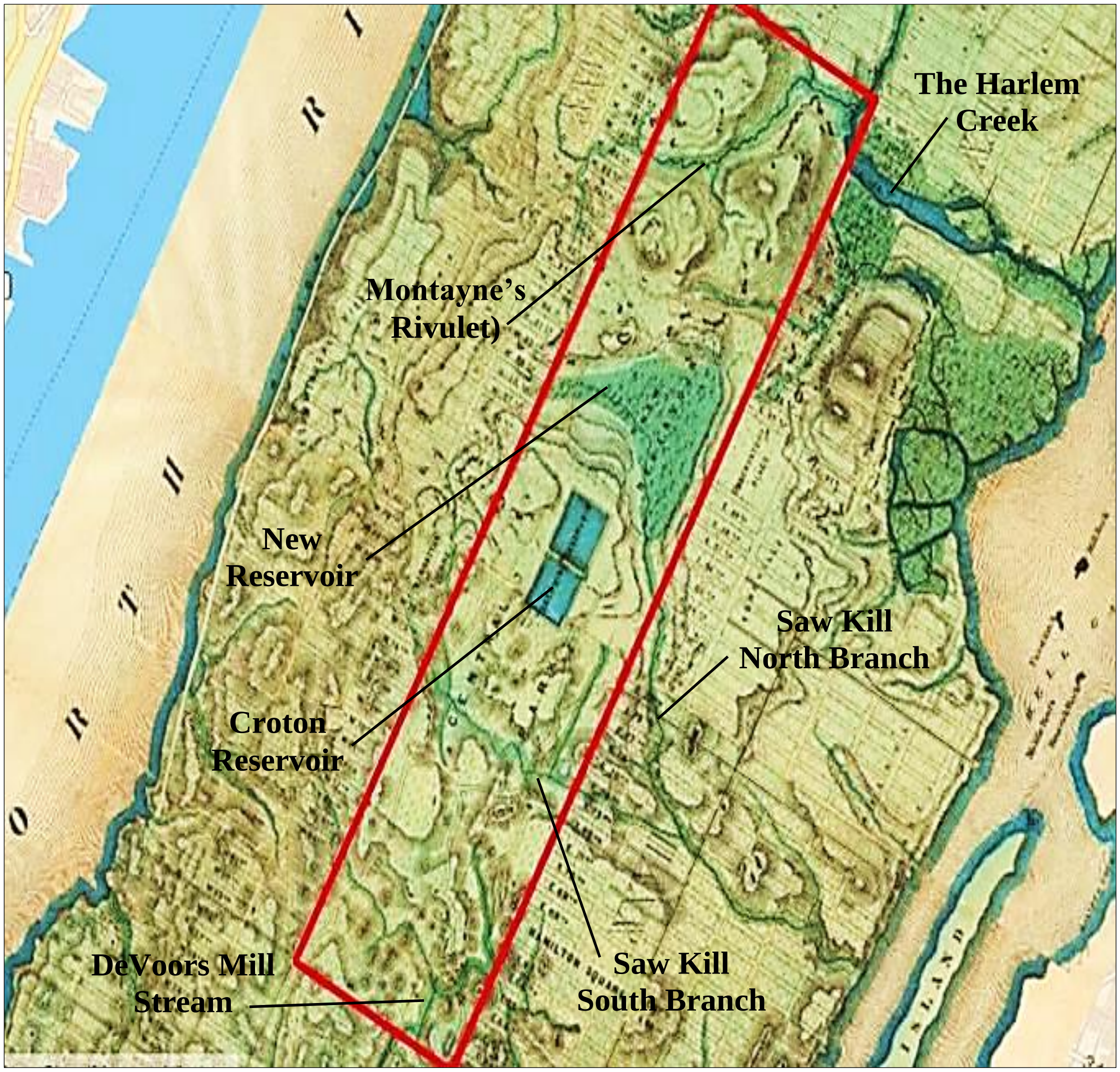


Figure 49. Map 1: Historical 19^{th} Century Central Park with five existing streams (by author using Geoeditor & ArcGIS, 2020). Data Source: Topographical Atlas of the City of New York: showing original water courses and made land created by Civil Engineer Egbert L. Vielé in 1874 (David Rumsey Cartography Associates Map Collection, 2020).

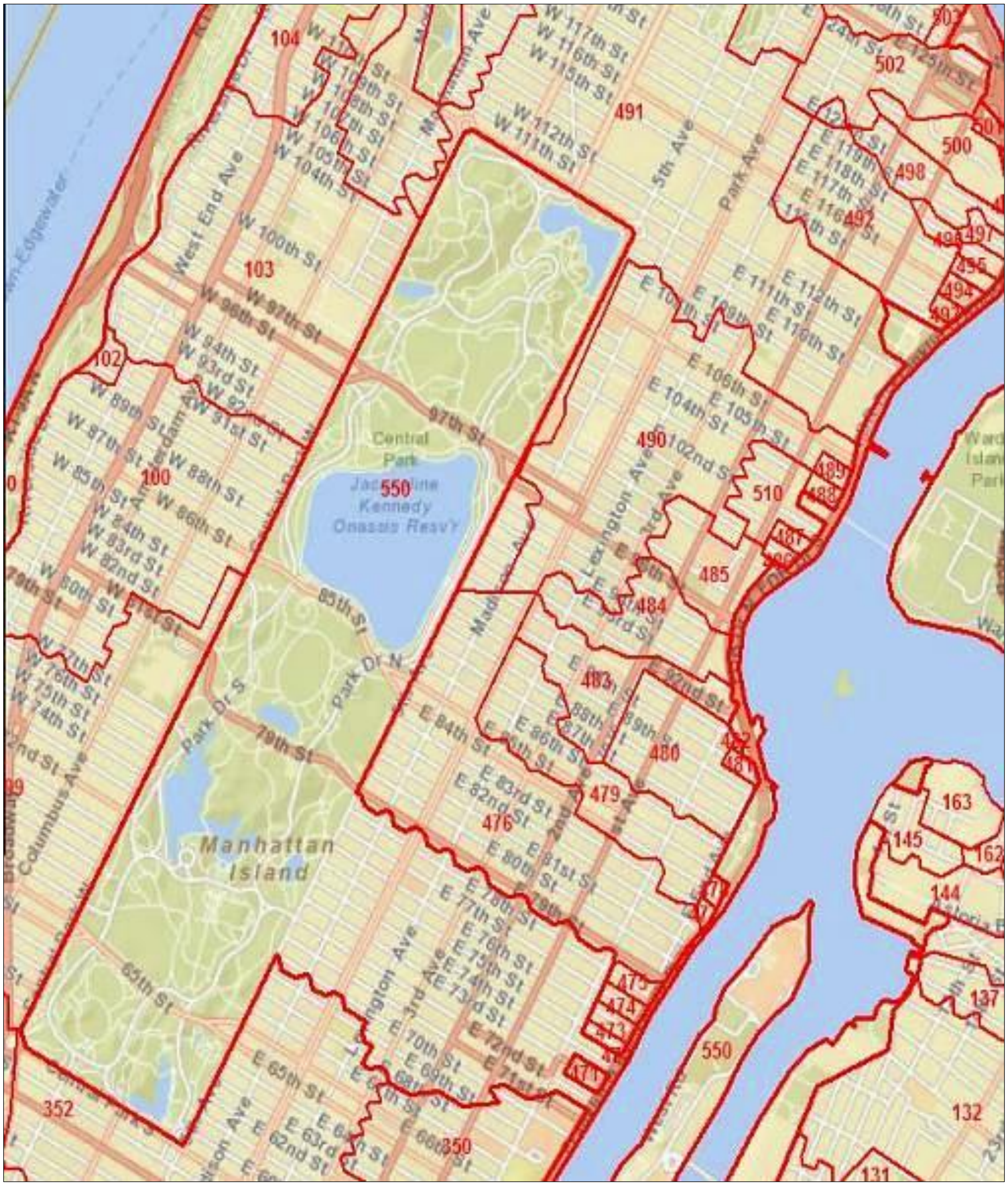


Figure 50. Map 2: Present-day Central Park showing stormwater draining to the City's Combined Sewer System (CSS) (by author using ArcGIS, 2020). Data source: Open Sewer Atlas NYC and USGS.

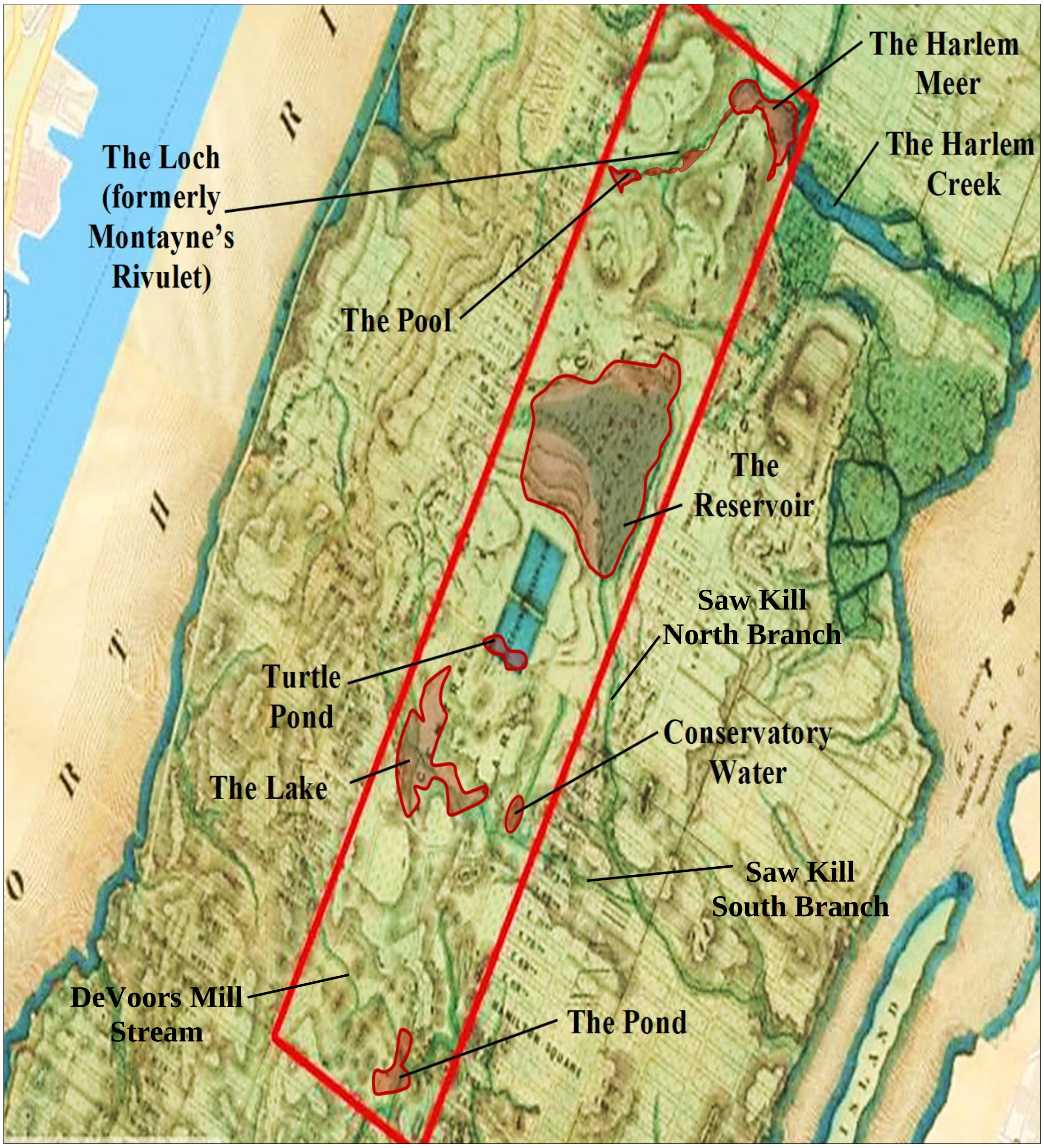


Figure 51. Map 3: The future 21st Century Sustainable Central Park. This shows the park using its own water bodies for stormwater retention and overlaying the parks original five streams: The Harlem Creek, Montayne's Rivulet, Saw Kill North and South Branch and DeVoor's Mill Stream (by author using ArcGIS, 2020). Data Source: USGS and Topographical Atlas of the City of New York: showing original water courses and made land created by Civil Engineer Egbert L. Vielé in 1874 (David Rumsey Cartography Associates Map Collection, 2020).

Soil Survey Analysis of Central Park's Watershed Areas

To delineate the watershed boundaries of Central Park's Reservoir, I first ran a soil analysis of the entire park's watershed area. I used the soil analysis program, Web Soil Survey, from the United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS), to create a topographical plan to map the distribution of the different soil types over the park's watershed areas (Figure 52 & 53).

These data were used to generate a table with a detailed description of each soil type and its total acreage in the park's footprint (Table 3). From the results of the soil analysis, Central Park's topography was broken down into five basic categories of land covering: Rocky/Slope (A), Greenbelt loam (B), Rock Outcrop (C), Urban Land (man-made) and Water. Greenbelt loam (B) or vegetation covered approximately 32.7% of the park's footprint, rock outcrop (C) 28.3%, water 15.5%, rocky/slope (A) 12.3% and urban land 11.2% (Table 2). This indicated that the park's watershed area has approximately 52% impermeable surfaces, consisting of rock outcrops, rocky/slopes and urban land (all of which stormwater runs off quickly), and approximately 48% permeable land covering, consisting of vegetation and water that can be used to retain stormwater. From the results of the soil analysis, Central Park's land covering is approximately half permeable and half impermeable.

Figure 52. Central Park soil survey analysis map -soil types (by author, 2020). Data Source: US Department of Agriculture - Natural Resources Conservation Service (USGS NRCS).

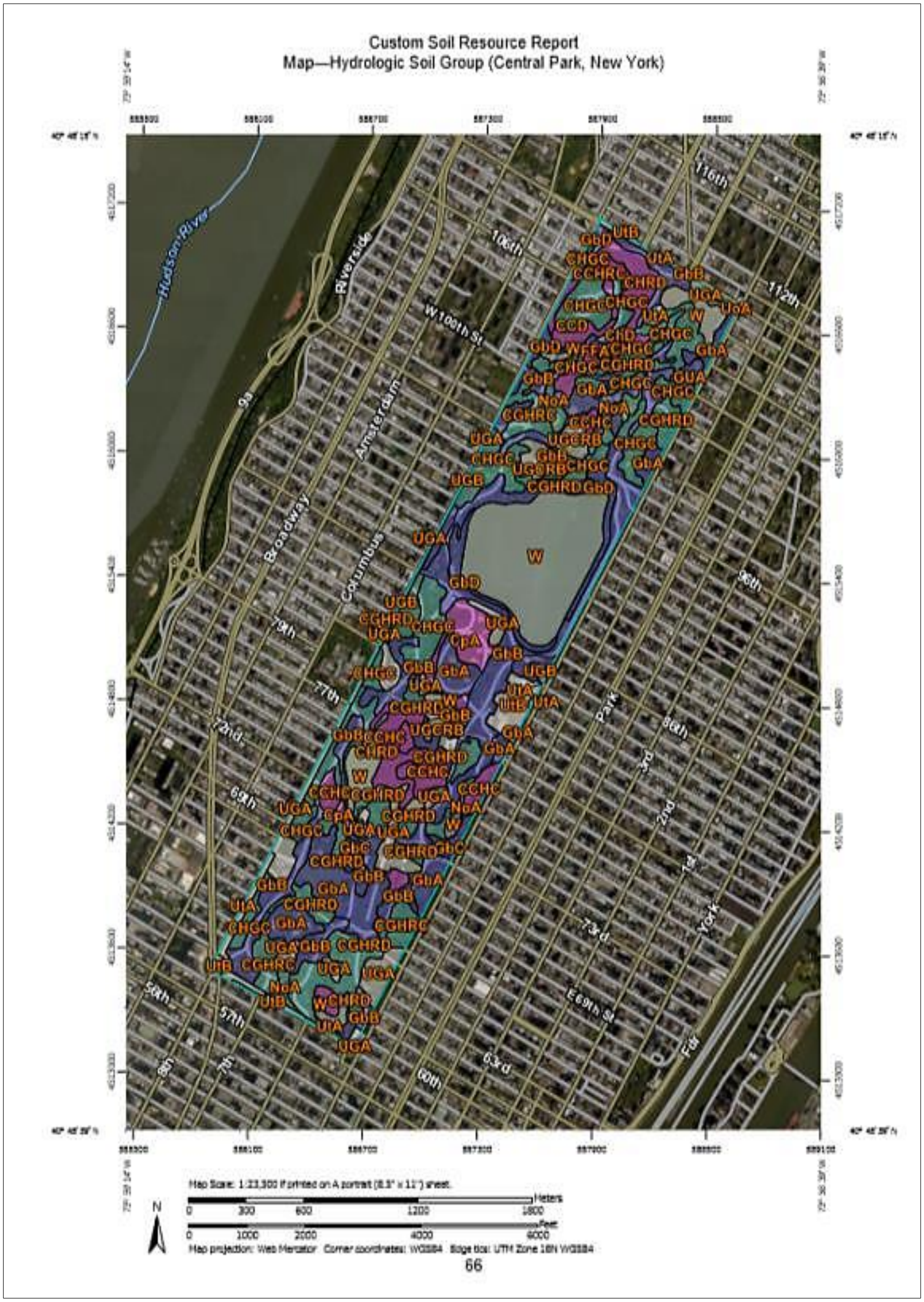
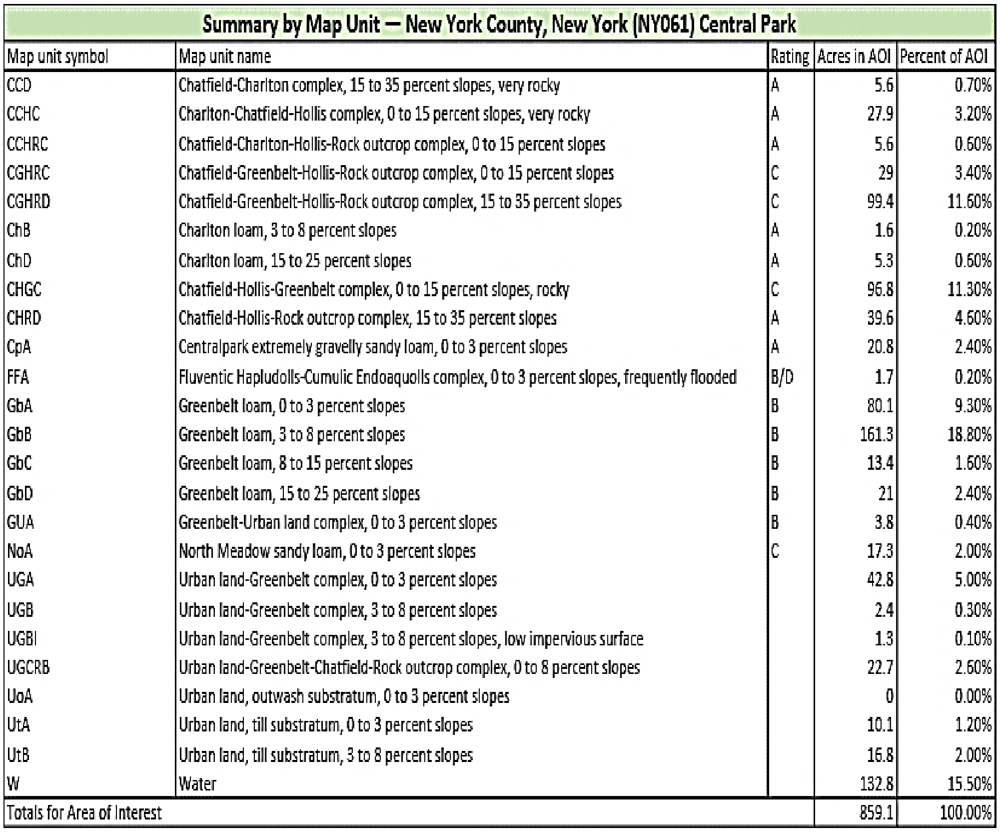
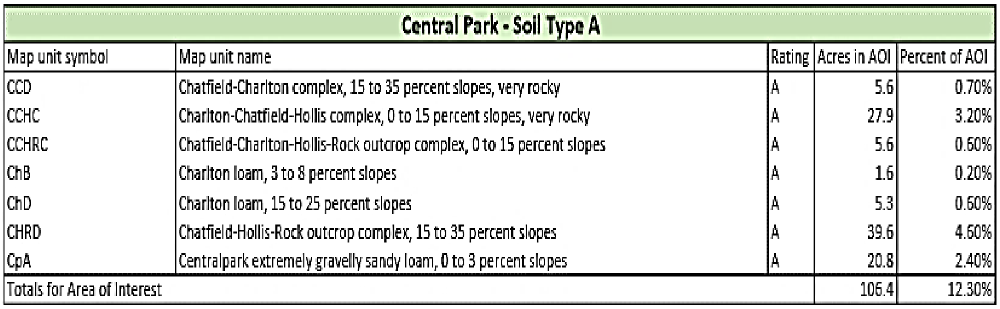


Figure 53. Central Park soil survey analysis map - soil types illustrated (by author, 2020). Data Source: USGS NRCS.

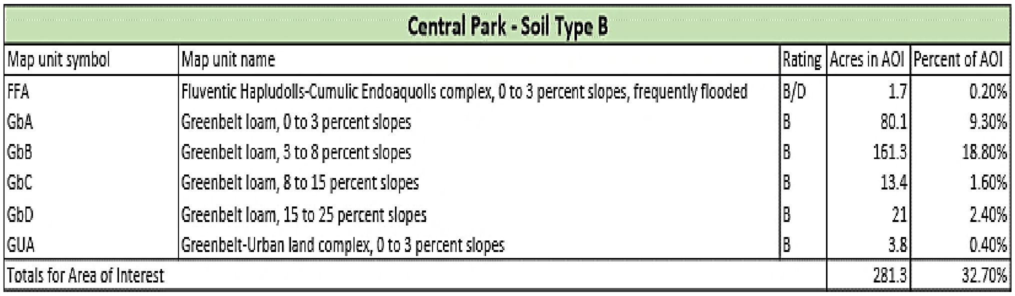
Table 3. Central Park soil survey map data. (by author, 2020). Data Source: USGS NRCS.



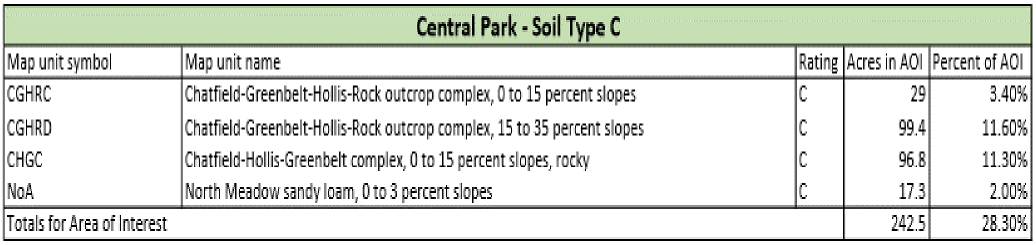
Summary by Map Unit — New York County, New York (NY061) Central Park				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
CCD	Chatfield-Charlton complex, 15 to 35 percent slopes, very rocky	A	5.6	0.70%
CCHC	Charlton-Chatfield-Hollis complex, 0 to 15 percent slopes, very rocky	A	27.9	3.20%
CCHRC	Chatfield-Charlton-Hollis-Rock outcrop complex, 0 to 15 percent slopes	A	5.6	0.60%
CGHRC	Chatfield-Greenbelt-Hollis-Rock outcrop complex, 0 to 15 percent slopes	C	29	3.40%
CGHRD	Chatfield-Greenbelt-Hollis-Rock outcrop complex, 15 to 35 percent slopes	C	99.4	11.60%
ChB	Charlton loam, 3 to 8 percent slopes	A	1.6	0.20%
ChD	Charlton loam, 15 to 25 percent slopes	A	5.3	0.60%
CHGC	Chatfield-Hollis-Greenbelt complex, 0 to 15 percent slopes, rocky	C	96.8	11.30%
CHRD	Chatfield-Hollis-Rock outcrop complex, 15 to 35 percent slopes	A	39.6	4.60%
CpA	Centralpark extremely gravelly sandy loam, 0 to 3 percent slopes	A	20.8	2.40%
FFA	Fluventic Hapludolls-Cumulic Endoaquolls complex, 0 to 3 percent slopes, frequently flooded	B/D	1.7	0.20%
GbA	Greenbelt loam, 0 to 3 percent slopes	B	80.1	9.30%
GbB	Greenbelt loam, 3 to 8 percent slopes	B	161.3	18.80%
GbC	Greenbelt loam, 8 to 15 percent slopes	B	13.4	1.60%
GbD	Greenbelt loam, 15 to 25 percent slopes	B	21	2.40%
GUA	Greenbelt-Urban land complex, 0 to 3 percent slopes	B	3.8	0.40%
NoA	North Meadow sandy loam, 0 to 3 percent slopes	C	17.3	2.00%
UGA	Urban land-Greenbelt complex, 0 to 3 percent slopes		42.8	5.00%
UGB	Urban land-Greenbelt complex, 3 to 8 percent slopes		2.4	0.30%
UGBI	Urban land-Greenbelt complex, 3 to 8 percent slopes, low impervious surface		1.3	0.10%
UGCRB	Urban land-Greenbelt-Chatfield-Rock outcrop complex, 0 to 8 percent slopes		22.7	2.60%
UoA	Urban land, outwash substratum, 0 to 3 percent slopes		0	0.00%
UtA	Urban land, till substratum, 0 to 3 percent slopes		10.1	1.20%
UtB	Urban land, till substratum, 3 to 8 percent slopes		16.8	2.00%
W	Water		132.8	15.50%
Totals for Area of Interest			859.1	100.00%



Central Park - Soil Type A				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
CCD	Chatfield-Charlton complex, 15 to 35 percent slopes, very rocky	A	5.6	0.70%
CCHC	Charlton-Chatfield-Hollis complex, 0 to 15 percent slopes, very rocky	A	27.9	3.20%
CCHRC	Chatfield-Charlton-Hollis-Rock outcrop complex, 0 to 15 percent slopes	A	5.6	0.60%
ChB	Charlton loam, 3 to 8 percent slopes	A	1.6	0.20%
ChD	Charlton loam, 15 to 25 percent slopes	A	5.3	0.60%
CHRD	Chatfield-Hollis-Rock outcrop complex, 15 to 35 percent slopes	A	39.6	4.60%
CpA	Centralpark extremely gravelly sandy loam, 0 to 3 percent slopes	A	20.8	2.40%
Totals for Area of Interest			106.4	12.30%

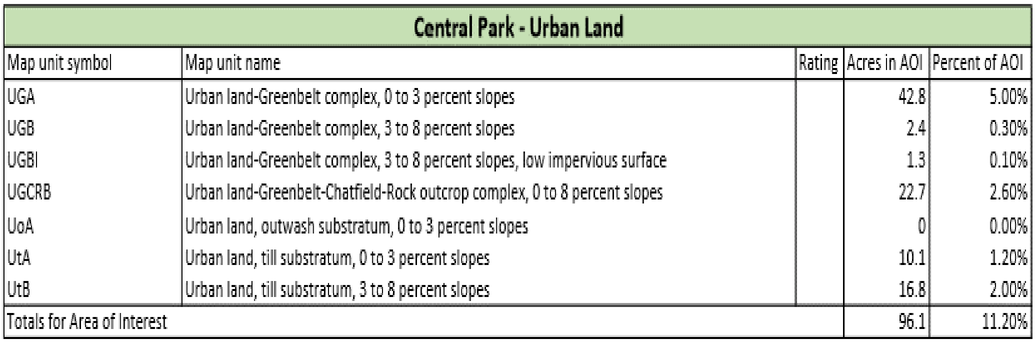


Central Park - Soil Type B				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
FFA	Fluventic Hapludolls-Cumulic Endoaquolls complex, 0 to 3 percent slopes, frequently flooded	B/D	1.7	0.20%
GbA	Greenbelt loam, 0 to 3 percent slopes	B	80.1	9.30%
GbB	Greenbelt loam, 3 to 8 percent slopes	B	161.3	18.80%
GbC	Greenbelt loam, 8 to 15 percent slopes	B	13.4	1.60%
GbD	Greenbelt loam, 15 to 25 percent slopes	B	21	2.40%
GUA	Greenbelt-Urban land complex, 0 to 3 percent slopes	B	3.8	0.40%
Totals for Area of Interest			281.3	32.70%



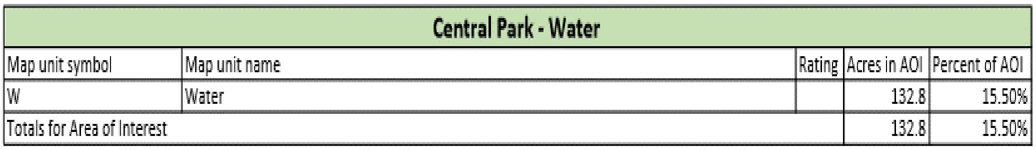
Central Park - Soil Type C

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
CGHRC	Chatfield-Greenbelt-Hollis-Rock outcrop complex, 0 to 15 percent slopes	C	29	3.40%
CGHRD	Chatfield-Greenbelt-Hollis-Rock outcrop complex, 15 to 35 percent slopes	C	99.4	11.60%
CHGC	Chatfield-Hollis-Greenbelt complex, 0 to 15 percent slopes, rocky	C	96.8	11.30%
NoA	North Meadow sandy loam, 0 to 3 percent slopes	C	17.3	2.00%
Totals for Area of Interest			242.5	28.30%



Central Park - Urban Land

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
UGA	Urban land-Greenbelt complex, 0 to 3 percent slopes		42.8	5.00%
UGB	Urban land-Greenbelt complex, 3 to 8 percent slopes		2.4	0.30%
UGBI	Urban land-Greenbelt complex, 3 to 8 percent slopes, low impervious surface		1.3	0.10%
UGCRB	Urban land-Greenbelt-Chatfield-Rock outcrop complex, 0 to 8 percent slopes		22.7	2.60%
UoA	Urban land, outwash substratum, 0 to 3 percent slopes		0	0.00%
UtA	Urban land, till substratum, 0 to 3 percent slopes		10.1	1.20%
UtB	Urban land, till substratum, 3 to 8 percent slopes		16.8	2.00%
Totals for Area of Interest			96.1	11.20%

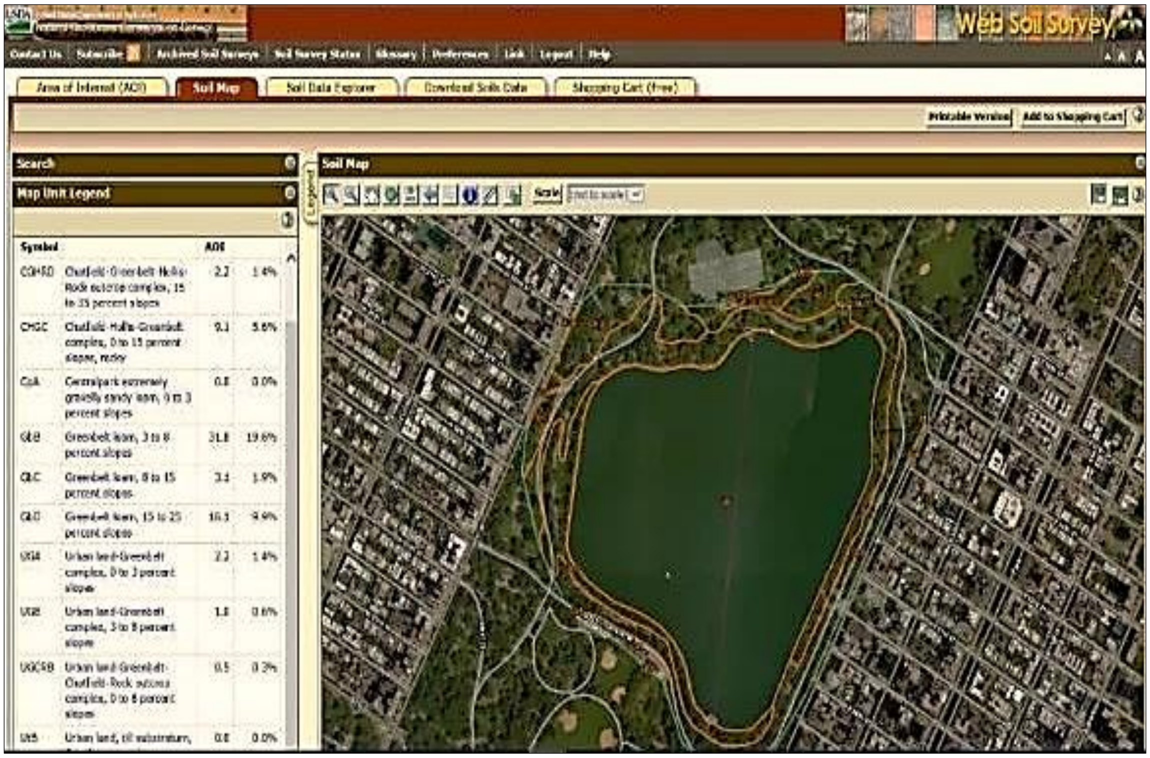


Central Park - Water

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
W	Water		132.8	15.50%
Totals for Area of Interest			132.8	15.50%

Reservoir Soil Analysis and Watershed Delineation

I ran a soil analysis of the Reservoir watershed using the USDA-NRCS Soil Survey to create a topographical plan of the distribution of the different soil types in the delineated watershed area (Figures 54 & 55). These data were used to create a table with a detailed description of each soil type and its total acreage in the watershed (Table 4). From the results of the soil analysis of the Reservoir's watershed, the topography is broken down into four basic categories of land covering: Greenbelt (B), Rocky/Slope (C), Urban Land (man-made) and Water. Greenbelt loam or vegetation (B) covered approximately 31.4%, of the Reservoir’s watershed area, rocky slope (C) 11.3%, urban land 3.7% and water 59.3%. The soil analysis data were used to calculate the Total Maximum Daily Load (TMDL) of phosphorus for the Reservoir’s watershed area (Table 5). The total area of the Reservoir’s watershed that would drain to its waterbody if the park was re-designed as a freshwater retention lake instead of a potable water receiving reservoir, was calculated as 258.3 acres (approximately a third of the park’s total area). The watershed was analyzed using the EPA’s standards for drinking water quality of 20 micrograms of phosphorus per liter of water. The TMDL was calculated using an annual precipitation rate of 45 inches per year and a fifty percent evaporation rate for precipitation. The Reservoir’s watershed area was found to generate 14.1 million cubic feet (105.5 million US gallons) of discharge per year which could be retained in the park’s Reservoir/future “retention lake” for irrigation purposes instead of being released to the city’s combined sewer system.



Symbol		AOI	
CGHRD	Chatfield-Greenbelt-Hollis-Rock outcrop complex, 15 to 35 percent slopes	2.2	1.4%
CHGC	Chatfield-Hollis-Greenbelt complex, 0 to 15 percent slopes, rocky	9.1	5.6%
CpA	Centralpark extremely gravelly sandy loam, 0 to 3 percent slopes	0.0	0.0%
GbB	Greenbelt loam, 3 to 8 percent slopes	31.8	19.6%
GbC	Greenbelt loam, 8 to 15 percent slopes	3.1	1.9%
GbD	Greenbelt loam, 15 to 25 percent slopes	16.1	9.9%
UGA	Urban land-Greenbelt complex, 0 to 3 percent slopes	2.2	1.4%
UGB	Urban land-Greenbelt complex, 3 to 8 percent slopes	1.0	0.6%
UGCRB	Urban land-Greenbelt-Chatfield-Rock outcrop complex, 0 to 8 percent slopes	0.5	0.3%
UtS	Urban land, till substratum,	0.0	0.0%

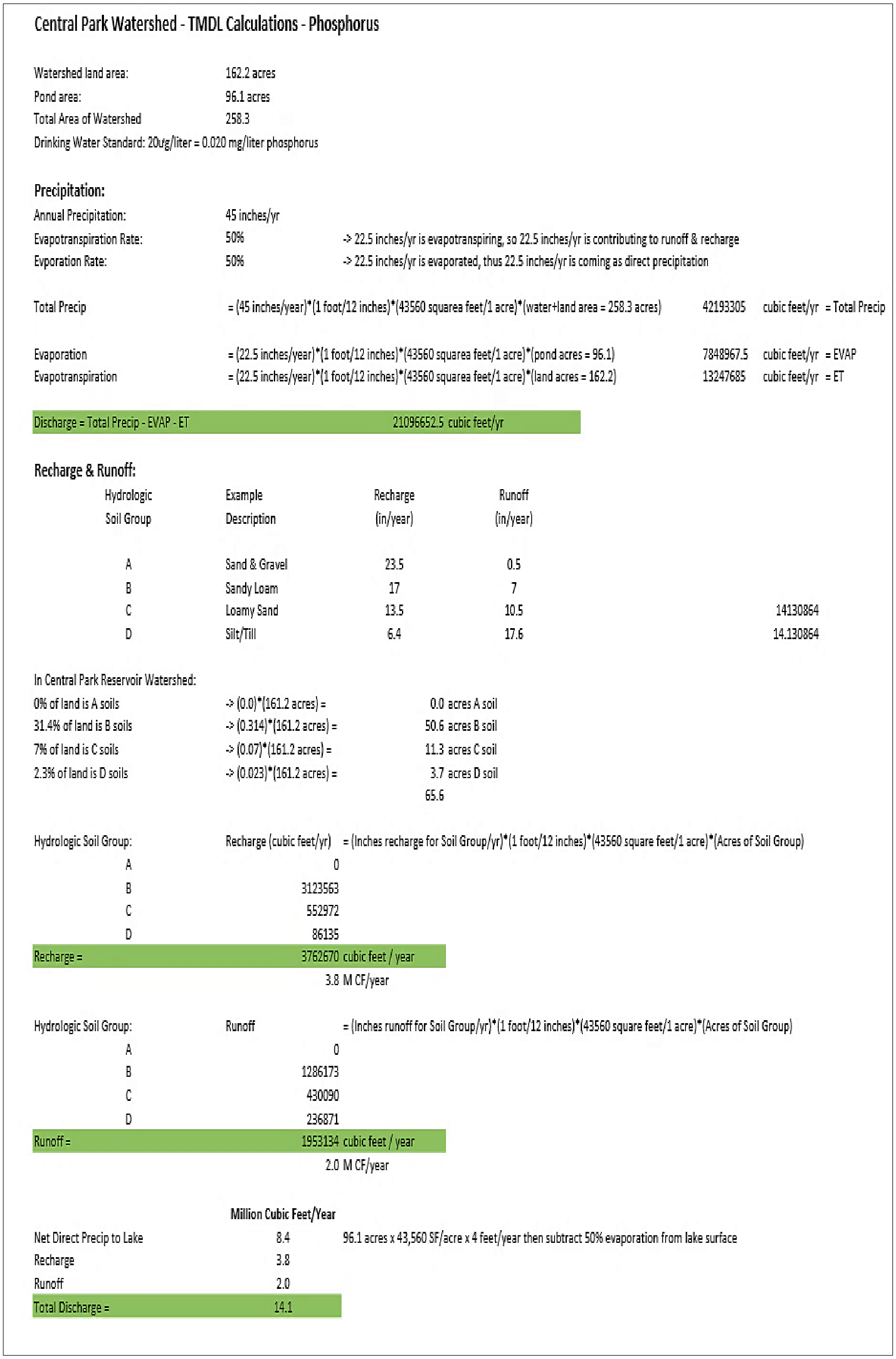
Figure 54. Central Park Reservoir soil survey analysis (by author, 2020). Data Source: USDA NRCS.

Figure 55. Central Park Reservoir soil analysis (left) and watershed delineation (right) (by author, 2020). Data Source: USGS NRCS.

Table 4. Central Park Reservoir soil analysis (by author, 2020). Data Source: USGS NRCS.

Summary by Map Unit — New York County, New York (NY061)				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
CGHRD	Chatfield-Greenbelt-Hollis-Rock outcrop complex, 15 to 35 percent slopes	C	2.2	1.40%
CHGC	Chatfield-Hollis-Greenbelt complex, 0 to 15 percent slopes, rocky	C	9.1	5.60%
CpA	Central park extremely gravelly sandy loam, 0 to 3 percent slopes	A	0	0.00%
GbB	Greenbelt loam, 3 to 8 percent slopes	B	31.8	19.60%
GbC	Greenbelt loam, 8 to 15 percent slopes	B	3.1	1.90%
GbD	Greenbelt loam, 15 to 25 percent slopes	B	16.1	9.90%
UGA	Urban land-Greenbelt complex, 0 to 3 percent slopes		2.2	1.40%
UGB	Urban land-Greenbelt complex, 3 to 8 percent slopes		1	0.60%
UGCRB	Urban land-Greenbelt-Chatfield-Rock outcrop complex, 0 to 8 percent slopes		0.5	0.30%
UtB	Urban land, till substratum, 3 to 8 percent slopes		0	0.00%
W	Water		96.1	59.30%
Totals for Area of Interest			162.2	100.00%

Table 5. Central Park Reservoir total maximum daily load (TMDL) calculation (by author, 2020). Data Source: USGS NRCS.



Central Park Watershed - TMDL Calculations - Phosphorus

Watershed land area:	162.2 acres
Pond area:	96.1 acres
Total Area of Watershed	258.3

Drinking Water Standard: 20ug/liter = 0.020 mg/liter phosphorus

Precipitation:

Annual Precipitation:	45 inches/yr	
Evapotranspiration Rate:	50%	-> 22.5 inches/yr is evapotranspiring, so 22.5 inches/yr is contributing to runoff & recharge
Evporation Rate:	50%	-> 22.5 inches/yr is evaporated, thus 22.5 inches/yr is coming as direct precipitation

Total Precip	= (45 inches/year)*(1 foot/12 inches)*(43560 squarea feet/1 acre)*(water+land area = 258.3 acres)	42193305	cubic feet/yr	= Total Precip
Evaporation	= (22.5 inches/year)*(1 foot/12 inches)*(43560 squarea feet/1 acre)*(pond acres = 96.1)	7848967.5	cubic feet/yr	= EVAP
Evapotranspiration	= (22.5 inches/year)*(1 foot/12 inches)*(43560 squarea feet/1 acre)*(land acres = 162.2)	13247685	cubic feet/yr	= ET

Discharge = Total Precip - EVAP - ET 21096652.5 cubic feet/yr

Recharge & Runoff:

Hydrologic Soil Group	Example Description	Recharge (in/year)	Runoff (in/year)	
A	Sand & Gravel	23.5	0.5	
B	Sandy Loam	17	7	
C	Loamy Sand	13.5	10.5	14130864
D	Silt/Till	6.4	17.6	14.130864

In Central Park Reservoir Watershed:

0% of land is A soils	-> (0.0)*(161.2 acres) =	0.0 acres A soil
31.4% of land is B soils	-> (0.314)*(161.2 acres) =	50.6 acres B soil
7% of land is C soils	-> (0.07)*(161.2 acres) =	11.3 acres C soil
2.3% of land is D soils	-> (0.023)*(161.2 acres) =	3.7 acres D soil
		65.6

Hydrologic Soil Group:	Recharge (cubic feet/yr)	= (Inches recharge for Soil Group/yr)*(1 foot/12 inches)*(43560 square feet/1 acre)*(Acres of Soil Group)
A	0	
B	3123563	
C	552972	
D	86135	
Recharge =	3762670	cubic feet / year
	3.8	M CF/year

Hydrologic Soil Group:	Runoff	= (Inches runoff for Soil Group/yr)*(1 foot/12 inches)*(43560 square feet/1 acre)*(Acres of Soil Group)
A	0	
B	1286173	
C	430090	
D	236871	
Runoff =	1953134	cubic feet / year
	2.0	M CF/year

	Million Cubic Feet/Year	
Net Direct Precip to Lake	8.4	96.1 acres x 43,560 SF/acre x 4 feet/year then subtract 50% evaporation from lake surface
Recharge	3.8	
Runoff	2.0	
Total Discharge =	14.1	

Chapter IV

Discussion

On reviewing the results of my analysis of the present-day water management practices of Central Park, NYC, I found that the data broadly supports my initial hypotheses that Central Park has the potential to: limit its use of municipal potable water, retain its own stormwater in its waterbodies by retrofitting its reservoir to turn it into a stormwater retention lake that the entire park's watersheds can drain into, and remove the hard surfaces of its waterbodies and tap into its freshwater sources that were diverted to drain into the city's combined sewers.

Interpretation of Maps

The historical, present day and future maps of Central Park's are interpreted below to review research findings.

Map 1: Historical 1874 Central Park with Five Existing Streams

In previous studies of Central Park's pre-construction topographical maps, the footprint of the park is not clearly defined, the streams, marshes and lakes are not labeled or highlighted, and their sources and drainage paths were not visible. Map 1 (Figure 49), references a historical geographical map created by civil engineer Vielé (1874), and the Greensward Foundation's (1811) topographical maps of the island of Manhattan. These maps were imported into Geoeditor to create a georeferenced map of Central Park's historical natural waterways: its five original freshwater streams that crisscrossed the park's site supplying drinking water to the island of Manhattan are located and clearly presented within the footprint of the park. The waterbody is traced from its source on the west side of the park to its drainage path to the East River. This map supports the hypothesis that Central Park was built on natural waterbodies that were diverted underground during the park's renovations in the 19th century.

Map 2: Present-Day Central Park Stormwater Drainage into the City Sewer System

Map 2 (Figure 50), was created to highlight the drastic changes in stormwater drainage that occurred in the 20th century when Central Park's waterbodies were lined in concrete and converted from "naturalistic" to artificial, and their stormwater was drained to the city's combined sewer system's outfalls in the Harlem River and the East River. Map 2 clearly defines the island of Manhattan's sewer sheds, Central Park's Harlem Meer and Harlem Creek stormwater drains to sewer-shed 491 where it is mixed with city sewage and sent to Ward's Island wastewater treatment plant on dry days or discharged into the Harlem River on wet days through the outfall WI-24. Central Park south of the Meer drains to sewer-shed 550 where stormwater is combined with city sewage and sent to Newton Creek wastewater treatment plant on dry days or discharged into the East River on wet days. This map supports the hypothesis that Central Park has the potential to retain the stormwater within its own watersheds and not have to burden the city's overworked sewage systems or pollute its rivers.

Map 3: The Future 21st Century Sustainable Central Park

Map 3 (Figure 51), takes a modern-day map of Central Park's waterways and overlays it onto Map 1: a historical geographical map of Central Park's five original freshwater streams. Map 3 illustrates that all of Central Park’s five historical streams that cross the park lie directly under the park’s present-day waterbodies. The historical waterbodies, diverted underground during park renovations in the early 1900’s up until the 1960’s, formed the original paths of Central Park’s waterways. The Harlem Meer flows above the Harlem Creek, the Loch above Montayne’s Rivulet, the Reservoir above the Saw Kill North stream, the Lake above the Saw Kill South stream, and the Pond above DeVoors Mill stream. Map 3 indicates that all of Central Park’s main waterbodies lie above a potential source of additional freshwater. This map supports the hypothesis that Central Park can reduce its reliance on municipal potable water by daylighting the park’s underlying streams.

Research Limitations

The results and conclusions presented in this study are subject to a number of conditions and limitations. The span of this research dates back to a period of over 160 years, since construction began on Central Park. Historical maps of the potable water management and stormwater drainage of Central Park and the island of Manhattan are extremely limited; all but a few 19th Century design drawings of the park’s original site and post construction remain. The Central Park Conservancy stated that when they took over the management of the park in the early eighties, they discovered that most of the historical maps and data had been lost. Nineteenth century maps of Manhattan are also very scarce, especially georeferenced maps that can be imported into GIS software. I was able to purchase one such map (Figure 38) from a reputable cartography company named David Rumsey Cartography Associates Map Collection.

The City of New York's release of information regarding underground water, sewer or drainage pipes locations is restricted for security reasons (Figure 8, 28, 29 & 42). I therefore had to rely on NYC Open Sewer data to locate Combined Sewer Outfall exact georeferenced positions and their drainage sheds. CUNY uses Open Sewer georeferenced data to create base maps for their analysis, so I followed their lead in regards to the collection of limited present-day GIS information regarding stormwater drainage for the island of Manhattan.

Conclusions

The City of New York has a very valuable environmental resource that sits at its center in the form of a beautiful historical ornamental garden with lawns, playing fields, forests, boating lakes, fountains, ponds and streams. Probably very few of Central Park's 42 million visitors a year are aware of the park's reliance on city potable water to feed its waterbodies and maintain its landscapes, and the park's use of an extensive underground drainage system to carry away stormwater from the site to the city's combined sewer system. Central Park, however, has the potential to be so much more than a man-made artificial park. It has a history that blended its natural environment with the latest technologies of the time to create a "naturalistic" park setting that added to the city's green infrastructure. Central Park today only adds to the city's overburdened gray infrastructure by consuming its drinking water and by treating the park's stormwater as a waste product and sending it off-site to be combined with the city's sewage.

This project proposed a way that Central Park can become a key component of the City of New York's green architecture. It focused on Central Park's most underused environmental resource: its Reservoir. I conducted analysis to determine its potential as a retrofitted stormwater retention lake and wetland that stores the park's watershed stormwater on site, and perhaps additional stormwater from the city that surrounds it, in order to irrigate the park's landscapes, feed and maintain its seven other waterbodies, and act as a water storage vessel that can be used during times of drought. Included in this study was an analysis of Central Park's historical waterways that are traced through a series of maps to highlight the park's water management and stormwater runoff history from past to present. A future sustainable 21st century Central Park map was created from this analysis to illustrate the park's potential to increase its freshwater input by daylighting the park's historical natural streams that lie under the park's main waterbodies and were diverted underground during the park's extensive 20th century renovations.

This assessment of Central Park's current sustainability issues is presented in an effort to give stakeholders and park management a clearer picture of the measures that could be taken to turn this "ornamental" historical landmark park into a sustainable "Smart Green City" urban wetland. The Central Park Conservancy has invested more than $1 billion since they took over the management of the park in 1980. In the forty years of the Conservancy's tenure, Central Park's operating costs have constantly risen to their current rate of over $85 million per year. Those costs will now have to expand to include future planned restorative projects such as the daylighting of the historical stream Montayne's Rivulet and the reconnection of the Harlem Meer with the water courses of the Loch and the Pool. The next step in the process would be to fund future research to investigate the financial feasibly of retrofitting the Central Park Reservoir as a stormwater retention lake and urban wetland. The study could include the social and economic benefits of restoring the park to a more natural state and the long-term benefits for the City of New York, along with the city dwellers who consider Central Park as their backyard, and the many visitors to the city who frequent the park.

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