Spring 5-11-2022

Controlling the Contamination: Preventing Environmental Impacts of Combined Sewage Overflows in NYC

Samiur R. Turjja

Controlling the Contamination:

Preventing Environmental Impacts of Combined Sewage Overflows in NYC

Samiur Turjja

Abstract

This paper examines the role and effectiveness of Water Pollution Control Plants (WPCPs) in remediating the negative environmental impacts caused by the release of raw sewage in NYC waterways. As global climate patterns shift and storms become more prevalent in coastal cities, the probability of flooding and consequently combined sewage overflows (CSOs) increases. This paper investigates the long-term environmental impacts of untreated wastewater caused by CSOs on two NYC water bodies with similar ecological and historical functions. Chapter 1 utilizes ecological and quantitative data from various sources such as the findings of the NYC Department of Environmental Protection (NYC DEP) on the health of local waterways, studies conducted by the United States Environmental Protection Agency (U.S. EPA) on the Gowanus canal, and various private and public research studies which look at the origin, nature, and impacts of raw, untreated sewage in aquatic environments. Chapter 2 examines, compares, and contrasts the similar environmental histories and functions of the East River and the Gowanus Canal within the last two hundred years. Chapter 3 then discusses the many ecological implications of wastewater in marine ecosystems and how these changes impact human health. Chapter 4 analyzes the different federal and local environmental policies implemented for the East River and the Gowanus Canal. This chapter also looks at the effectiveness of these policies and assess whether there are environmental injustices caused by them by comparing water quality data with public health and community wealth data. Chapter 4 also discusses the ten proposed infrastructure initiatives under *PlaNYC* for water quality improvement of NYC waterways. Finally, based on the environmental history, ecological implications, cost-benefit analysis, and sociological implications examined in chapters 2-4, chapter 5 presents comprehensive policy recommendations to mitigate the social and environmental impacts of combined sewage overflows and presents an argument for the implementation of more wastewater treatment facilities across the city to combat the negative impacts of CSOs.

Keywords: Combined Sewer Overflow, East River, ecological implication, environmental justice, Gowanus Canal, NYC, sewer system, wastewater, Water Pollution Control Plants

Table of Contents

Introduction: Understanding the Implications of CSOs

The one thing that most New Yorkers hate more than slow walkers during rush hour must be those constant flash-flood alerts during spring showers, summer storms, and unusually warm winter days after large snowstorms. Flash floods are floods caused by heavy or excessive rainfall in a short period (National Weather Service n.d.). The repercussions of these overwhelming amounts of water reach far beyond simple disruption of vehicular traffic; they give rise to a larger issue of CSOs, which can significantly impact the health and functionality of aquatic systems.

CSO stands for “Combined Sewer Overflow,” which happens when combined sewer systems discharge their contents into nearby waterways (NYC EP 2019). Upwards of 60 percent of New York City’s sewage infrastructure is the combined sewer system (NYC EP 2019). In this system, a single pipe carries sewage and stormwater from buildings to a designated wastewater treatment plant. During heavy rainfall and snow melts, the combined sewer system receives a higher than usual water flow. The treatment plants cannot handle large amounts of water along the normal sewer system route and thus discharge the mix of stormwater and untreated sewage directly into a city’s waterways through CSO “outfalls” located along many of NYC’s waterfronts and coastlines (NYC EP 2019).

Of the 460 outfall locations along NYC’s coasts, 11 are located along the 1.8-mile length of the Gowanus Canal, and 139 are located along the entire 16-mile length of the East River (Gowanus Canal Conservancy 2019; Kensinger 2020). The main difference between the Canal and the River, besides the length and gallons of sewage-laced water received annually, is that the Canal has no current or system to flush or dilute the toxic waste, unlike the East River. The East River has multiple wastewater treatment plants along its coasts which each treat millions of gallons of wastewater daily (NYC DEP n.d.). Because multiple studies show that wastewater treatment plants are effective at removing solid wastes and pollutants while simultaneously breaking down organic matter and adding oxygen back into the water, the goal of this paper is to examine whether having wastewater treatment plants along a CSO outfall location can effectively flush out toxins in CSOs and prevent their harmful effects of before they occur.

Chapter 1 will briefly explain the four main categories of ecosystem services and how they are relevant to the aquatic ecosystems of waterways such as NYC's Gowanus Canal and the East River. Then by utilizing quantitative data about the components of CSOs and their ill-effects, I will provide an overview of the specific ecosystem services of NYC waterways that CSOs disrupt and degrade. Chapter 1 also provides an overview of how wastewater treatment plants help remediate and prevent the degradation of the associated ecosystem services. Chapter 2 will provide in-depth historical data on the Gowanus Canal and East River and elaborate on their relationship with sewage/waste disposal, ecosystem, and public health. Chapter 2, noting the historical similarities in the functions of the Gowanus Canal and East River, will elaborate on the turning point of water quality of these two waterways after the creation of NYC's first wastewater treatment plants [WPCPs]. Chapter 3 will focus on the public and environmental health concerns caused by unregulated CSO effluents into the Gowanus Canal and discuss these health concerns in environmental justice issues. Chapter 4 will also explore the importance of the Federal Clean Water Act in NYC policymaking and understand the different components of the law. This chapter will discuss some existing policies concerning CSOs, public health, and infrastructure that the city adheres to for the protection of the people and environment from the harmful effects of CSOs. Finally, in chapter 5, by utilizing data on the effectiveness and shortcomings of current NYC policies along with data on the specific benefits of wastewater treatment facilities, I will propose policy recommendations, based on successful global policies, that can be utilized to reduce harmful CSOs in NYC waterways and improve the public health issues and environmental justice concerns caused by the impacts of CSOs.

Chapter 1. NYC's Water Quality and Quality of Living

New York City's current sewer network involves over 6,000 miles of sewer pipes; 135,000 catch basins, 494 permitted outfalls, 93 wastewater pumping stations, and 14 wastewater treatment plants (NYC DEP n.d., 4). Wastewater treatment began in New York City between the 1890s and the early 1900s in Brooklyn and Queens near the two popular beaches in those boroughs (NYC DEP n.d., 5). The early focus was to keep the beaches clean and protect the beachgoer's health rather than the maintenance of water quality (NYC DEP n.d., 5). However, as the population grew exponentially, the two wastewater treatment plants became overburdened and gave way to waterborne bacteria and diseases. This event led to creating a citywide master plan which included the construction of treatment plants to keep up with wastewater from growing populations and put focus on water quality. By 1968, 12 wastewater treatment plants were operating in NYC. They treated over one billion gallons of water a day and removed 65 percent of waste from the wastewater (NYC DEP n.d., 6). After the Clean Water Act was passed in 1972, treatment plants needed to have secondary treatment, and this process brought up the effectiveness of treatment plants from 65% to 85% (NYC DEP n.d., 7). All 14 of the city's wastewater treatment plants undergo five major treatment processes: preliminary treatment, primary treatment, secondary treatment, disinfection, and sludge treatment (NYC DEP n.d., 7). These treatment processes, further elaborated in detail in the following chapters, remove between 85 to 95 percent of pollutants before the treated water is released into local waterways.

Combined Sewage Overflow discharges contain polluted stormwater and untreated wastewater that have not gone through the treatment processes, which remove upwards of 95% of physical and chemical pollutants. The release of CSOs into NYC's waterways heavily disrupts natural aquatic ecosystems and their ecosystem services.

The Millennium Ecosystem Assessment, an international work program containing scientific information concerning the relationship between ecosystem change and human well-being, explains what ecosystem services are, the different types of services, and how they are related to human well-being (Millennium Ecosystem Assessment 2005, v). According to the assessment, ecosystem services are the benefits people obtain from ecosystems (Millennium Ecosystem Assessment 2005, viii). The four types of ecosystem services are support services, provisioning services, regulating services, and cultural services (TEEB 2011, 3).

Supporting services are needed as a basis for all the other services; ecosystems provide the necessary living spaces for plants and animals and support their maintenance (Böck, Polt, and Schülting 2018, 415). The supporting services in freshwater environments include nutrient cycling and maintaining the fertility of coastal plains and primary production. Provisioning services describe the material outputs from ecosystems, including food, water, and other resources (Böck, Polt, and Schülting 2018, 415). The provisioning services in freshwater environments include water for consumptive uses and non-consumptive uses and aquatic organisms which can be used for food and medicine. Regulating services are services that ecosystems provide based on their regulating capacity. In a freshwater environment, these services would include the maintenance of water quality which is natural filtration and water treatment, and the buffering of flood flows, which is erosion control. Lastly, cultural services are non-material benefits such as the aesthetic, spiritual, and psychological benefits people get from ecosystems (Böck, Polt, and Schülting 2018, 415). This type of service in freshwater ecosystems includes recreational services, tourism, and existence values.

Changes in ecosystem services influence human well-being, which is the basic material for a good life and tied to equity and fairness (Millennium Ecosystem Assessment 2005, vii). The untreated toxic substances, organic pollutants/nutrients dispersed through CSOs, by negatively impacting freshwater ecosystems in NYC, are threatening human well-being. While CSOs are not the only methods for these harmful pollutants to enter local waterways, they allow them to enter the waterways in unregulated and uncontrollable amounts. If the wastewater had gone through treatment or partial treatment, the pollutants could have been reduced to manageable levels. Below, some of the most common CSO pollutants and their characteristics are described.

Toxic Substances. Heavy metals such as cadmium and mercury, as well as chemical solvents and pesticides, enter the combined sewer system every day to head to the wastewater treatment plants. Many of these substances come from industries and businesses that dispose of their hazardous waste in unauthorized ways. Many other sources come from corroding pipes and air pollutants carried by rain. The department of environmental protection [DEP] tests the treated water from each of the 14 wastewater treatment plants to search for over 130 “priority pollutants,” (NYC DEP n.d., 11).

Nutrients. Carbon, phosphorous, and nitrogen are the primary substances in wastewater. These are also some of the important nutrients that plants need to grow. Excessive nutrients in waterways cause aquatic plants and microorganisms such as algae to bloom and die rapidly. When these plants and algae die, they decompose and reduce dissolved oxygen in the water that many aquatic species depend on for functioning. This phenomenon known as hypoxia directly harms the survival of fish and other species and prevents future reproduction of said species NYC DEP n.d., 14).

A study conducted in 2021 found that emerging contaminants—pharmaceuticals, illicit drugs, and personal care products released untreated through CSOs following storm events- can wreak havoc on global aquatic environments. The researcher notes that emerging contaminants have been the subject of various studies due to the threats they pose to the ecology of their receiving environments in very small concentrations. More than 200 individual compounds were found in various concentrations in different water bodies and had different effects on the native plants and animals. Exposure to synthetic estrogen at 5–6 nanograms per liter led to the collapse of fish populations in Canadian lakes due to the feminization of male fish (Petrie 2021, 4). Likewise, the exposure to antidepressants caused alterations to the behavior and feeding rates of fish (Petrie 2021, 4). Therefore, understanding the different types of pre-existing hazardous waste and patterns of concentrations during dry and wet weather is crucial to understanding the impacts CSOs have on the ecosystem services of an ecosystem.

The GEI technical report documents the investigation methods, findings, results, and evaluation of the ecological conditions of the Gowanus Canal (GEI 2009, 2). The report outlines the techniques, results, and findings of an environmental forensic examination into the source and origin of hydrocarbons detected in Gowanus Canal sediments. The water sampling methods include bulkhead and outfall reconnaissance and mapping, bathymetry survey, surficial sediment sample collection and analysis, sediment coring and sediment sample collection and analysis, sediment coring and age dating of accumulated sediments, surface Water and outfall sample collection and analysis, subsurface soil boring installation, sample collection and analysis, environmental forensic analysis of hydrocarbon impacts in the sediments, and evaluation of the ecological conditions in the canal and assessment of the sources of sediment toxicity (GEI 2009, 2).

The study's findings confirm the notion that the sediments at the canal's bottom are hazardous due to the presence of various chemical stressors. Pesticides, polychlorinated biphenyls (PCBs), metals, polycyclic aromatic hydrocarbons (PAHs), and benzene, toluene, ethylbenzene, and xylene (BTEX) are among the stressors (GEI 2009, 41). Although PAHs had minimal effect on water quality, the magnitude of possible chemical stressor effects in sediments was large, even without taking PAHs into account (GEI 2009, 41). CSO outfalls have been found as a potentially substantial source of metal, pesticide, and PCB pollution in the sediment (GEI 2009, 41). The GEI Ecological Investigation Report (2009) concluded that “the current Gowanus Canal ecology is very limited by a combination of chemical contamination, organic (sewage) pollution, and poor physical habitat, much of which could be artifacts of CSO effluent impacts” (GEI 2009, 42).

In the surface-water screening portion of their environmental investigation of the Gowanus Canal, the New York State Department of Health (DOH) and the Agency for Toxic Substances and Disease Registry (ATSDR) compared the highest levels of contaminants detected in the surface water of the canal in dry and wet weather conditions to New York State public drinking water standards seen in figure 1 (New York State Department of Health 2017, 15). DOH and ATSDR selected the contaminants without a drinking water standard for evaluation if the EPA's list of contaminants of concern included them (New York State Department of Health 2017, 15). Since water from the canal is not used for drinking, the maximum contaminant levels (MCLs) as screening values are conservative to further evaluation (New York State Department of Health 2017, 15). For additional assessment, DOH and ATSDR chose pollutants with surface water levels that exceeded the New York State MCL, as illustrated in figure 1 (New York State Department of Health 2017, 17). They also pointed out that some of the same surface water contaminants, as shown in figure 2, were found in both a 2011 EPA and the 2007 GEI investigations (New York State Department of Health 2017, 15).

Figure 1. Gowanus Canal Surface Water Contaminants in Wet and Dry Weather Conditions (NYS DOH 2017, 16)

Contaminant	Maximum Detection for Dry Conditions (mcg/L)[1]	Maximum Detection for Wet Conditions (mcg/L)[2]	NYS Drinking Water Standard (mcg/L)
Benzene	11	2.9	5
o-xylene	0.53	5.1	5
tetrachloroethene	ND	40	5
toluene	0.95	16	5
benzo(a)pyrene	0.66	0.3	0.2
arsenic	23.4	26.2	10
chromium	99.7	29.3	100
cobalt	ND	3.9	--[3]
iron	ND	1040	300
lead	4.9	26.8	15[4]
selenium	50.9	64.6	50
thallium	2.1	ND	2

Figure 2. Gowanus Canal Surface Water Contaminants Selected for Further Evaluation (NYS DOH 2017, 17)

Contaminant	Maximum Detection in Surface Water (mcg/L)[1]	NYS Drinking Water Standard (mcg/L)
benzene	6.1	5
bromoform	98	5
ethyl benzene	12	5
methyl-*tert*-butyl ether	26	10
toluene	31	5
xylenes (total)	20	5
acenaphthene	56	50
acenapthylene	94	50
anthracene	110	50
benz(a)anthracene	110	50
benzo(a)pyrene	85	0.2
benzo(b)fluoranthene	50	50
benzo(k)fluoranthene	54	50
bis(2-ethylhexyl)phthalate	8	6
chrysene	130	50
fluoranthene	220	50
fluorene	52	50
phenanthrene	450	50
pyrene	320	50
iron	4870	300
nitrate/nitrite (total nitrogen)	16,000	10,000
thallium	57	2
sulfate	2,280,000	250,000

Chapter 2. Urbanization and Outbreaks

The New York City archipelago is in an estuary which is where freshwater meets saltwater. The East River and Hudson River are more an extension of the sea than rivers because they rise and fall with the tides. However, because they are surrounded by land, these rivers are not threatened by the expansion of the Atlantic. Sanderson calls these estuaries "the motor, the connector, the driver, the great winding way, the central place that gathers all the old neighborhoods together and makes the rest possible" (Sanderson 2009, 143). Estuaries and the rivers and streams that carry freshwater to them are vital to the growth and health of the ecosystems that keep the harbor and the people who rely on the harbors safe and protected.

Storm drains and sewers are effectively the streams of the modern city because both their functions are to channel water out into bigger waterways or the ocean. The difference between modern storm drains and historical streams are that storm drains deal with more water after storms than historical streams had to due to NYC's impermeable surfaces such as concrete and asphalt, which act as a hydrophobic barrier. The phenomenon of impermeable surfaces was not the case in Manhattan's early history because of the presence of trees and soil, which would contain stormwater and then slowly release it into streams. Now, however, when it rains the stormwater which combines with raw sewage ends up into the waterways, rendering them unsafe for recreational use and depriving NYC of one of their remaining valuable natural assets, its proximity to water (Sanderson 2009, 222).

Before the arrival of the Dutch explorers—who were seeking a route to China and its oriental riches, the land known as "Mannahatta" or "Island of Many Hills" was occupied by the Lenape Indians (Sanderson 2009, 10). The historical Mannahatta had more ecological communities, native plant species, and bird species than do some of the current American

National Parks (Sanderson 2009, 10). This land and the East River provided all that the Lenape needed to survive. The Dutch came and settled in "New Netherlands" with 30 families in 1624 (Burrows and Wallace 1999, 20). The East River then became essential to the Dutch for both transportation, food, and for their factories.

The physical transformation of lower Manhattan and the East River began with the signing of the Dongan Charter on April 27, 1686, which did two important things. The first is the upholding of the sanctity of private property. The second is the reinforcement of the powers of the merchant elite by conforming to their monopoly over the export of flour (Steinberg 2014, 23). Trade had grown exponentially, and thus there was a need to expand the island. The charter now granted all vacant land on Manhattan Island that extends and reaches the low watermark. A later section also gave the rights to "take and fill in" land along the coast (Steinberg 2014, 26). New Yorkers created "new land" by building retaining structures and depositing materials behind them to fill in the area (Steinberg 2014, 26). It was customary to dump tubs of human waste into the streets or directly into the East River. By the end of the eighteenth century, people were throwing in dead animal carcasses to scraps of ships and unwanted things to the point that the river was filled high with "filth and nastiness" (Steinberg 2014). When city ordinance forbade the processing and storage of animal blood and entrails within city limits, the East River also became a dumping ground for dead carcasses and offal. The "viscous accumulation," impeded navigation through the river and had terrible "olfactory effects," on the residents who lived and worked around the piers (Miller 2000, 42). This act of filling the river gave rise to a tradition of dumping human waste directly into the nearest dock or pier.

During the first half of the nineteenth century, the common belief was that running water purified all effluents and wastes; because of this belief, there was no concern for water pollution.

The city even ordered people to dispose of their waste into the rivers (Goldman 1997, 22). Many people, however, also believed that the vapors coming from still water in front of wharves and along the piers were responsible for diseases. So, they had to be disposed of far into the rivers. The construction of sewers required that the systems extend far into the rivers, which was very costly.

The Collect, a seventy-acre pond in the center of Manhattan, was one of the only freshwater supplies for New York City since the 1700s. By the mid-1780s, however, it became home to tanneries and breweries and gained the reputation as “a very sink and common sewer,” the Collect was soon filled in since it was considered a major nuisance (Stradling 2010, 43). In 1811, a New York State-appointed Street Commissioner began planning an expansion up Manhattan Island (Stradling 2010, 43). The goal was to help create air circulation to promote the city’s health. However, this plan ignored the topography of the Island and the natural watercourses. According to the plan, the natural features would be suppressed, and the landscape would adapt around it over time.

By the 1830s, as the population and commerce grew, New York City exhausted local water supplies (Goldman 1997, 55). Outbreaks of yellow fever in the 1820s and a cholera epidemic in 1832 generated an outcry for sanitary improvements. Limited understanding of how diseases spread led to the development of the miasma theory which linked poorly drained bodies of water and vapors to epidemics. The theory inspired a rush to drain all dry swampy lands, and this did help by reducing contact with human waste and destroying the primary mosquito breeding grounds (Stradling 2010, 41). In the early 1800s, it was generally accepted that all urban environments contributed to the spread of disease and poor human health (Stradling 2010, 41). The 1832 cholera epidemic caused over 100,000 people to flee from Manhattan, bringing the city to a halt. And by the time the epidemic had calmed, over 3,500 people had died citywide (Stradling 2010, 70). The overall devastation was caused by the city's lack of ample fresh water. Politicians were finally forced to create a water commission and tasked it with planning a new water system.

New York State then took on the responsibility of constructing the Croton Aqueduct in the early 1830s (Goldman 1997, 55). The availability of a new freshwater supply then brought up the idea of a waste disposal system by water carriage. Sewers at the time were primarily used for the diversion of stormwater from the filthy streets. Water-carriage of waste disposal offered many advantages to traditional methods of using cesspools; waste could now be mindlessly carried out into rivers without the worry of interruption to service, as long there was an adequate water supply. The water that the Croton aqueduct supplied provided an ample source of water for waste disposal. Moreover, by 1845, sewers became the city's best method of waste disposal, so much so that the demands for sewers increased (Goldman 1997, 77). The methods for building these new sewers, however, became no different from those of the old sewer systems, and the environmental and health issues remained.

Towards the 1850s and 1860s, the call for sewerage reforms grew even louder because the population began to grow, and the environmental problems caused by the sewerage system at the time remained the same. Wastewater could not be properly discharged through the "faulty" sewers, and the stagnant cesspools soon became public nuisances. People were dying of cholera and typhus—both of which are waterborne diseases. Scientific evidence that directly linked the connection between diseases with wastewater gave a valid reason to push for change.

> "I have seen the cart coming from Bellevue hospital carrying the plaster casts from ulcerated sores, the wrappings from cancer operations, with rank and filth of all kinds that you can imagine and beyond any man's imagination except one coming from a hospital. In the same cart, there was

> kitchen garbage, legs of chickens, heads of fish, ends of sausage, all in one cart dumped over there, and those men scrambled for it and picked out the stuff and put it to one side and ate it and took it home" (Miller 2000, 78).

This quote introduces two different causes of the outbreak of diseases caused by garbage. One of the causes is poverty, and the other is the improper disposal of medical and domestic waste. The improper disposal of medical waste, which ended up in landfills and in waterways and allowed to stagnate, gave rise to malarial and diphtheritic diseases across New York City (Miller 2000, 79). Even after pinpointing diseases and diphtheritic outbreaks to specific dumps across the city, with the limited knowledge of microbes and the miasma theory, the city resorted to using various experimental methods such as the 'Woolf's Electrozone Device' to combat these outbreaks (Miller 2000, 79). These testing methods worked only in theory but were not practical on large scales.

Even after the arrival of Croton water in 1842, many buildings were slow to connect to the new freshwater supply, and many of the buildings that did connect had to be fitted with new plumbing systems. Tenement districts and poorer neighborhoods were the ones most affected. The freshwater could not solve the more significant problem of overcrowding and a growing population. Croton Water created more wastewater problems, the increased water supply stimulated increased water use which led to the production of more wastewater.

In 1849, seven years after the arrival of Croton water, there was yet another cholera epidemic in New York City (Stradling 2010). The extreme symptoms and high death rates were attributed to rapid dehydration. In the second half of the 1800s, the threat of cholera and other water-borne illnesses became significantly lower than they were in the first half of the century.

However, the fear of the diseases continued to drive protesters and reformers who demanded cleaner streets and tighter housing regulations (Stradling 2010, 117).

Concerns over wastewater rose as data supported the assumption that inadequate sanitation contributed to disease transmission. In response to this increased knowledge, doctors and engineers revived their advocacy for sanitary change. The Common Council's apparent failure to construct a functioning sewer system bolstered the reform campaign and pushed civil engineers to carve out a niche in managing the city's public works (Goldman 1997, 168).

During the 1850s and 1860s, New York State withdrew the control of public services from city agencies and gave those controls to state agencies and their engineers (Goldman 1997, 77). This new formulation of city government opened greater possibilities for engineers to focus on coordinated infrastructure plans to improve the whole city. Senator William M. [“Boss”] Tweed of New York established new sanitary policy management systems in 1870 (Goldman 1997, 170). He included engineers into the Department of Public Works and granted them policymaking authority. Tweed oversaw the planning, building, and reintegration of new and old sewage lines in a timely and cogent manner (Goldman 1997, 170). However, since these sewer lines had no treatment facilities in the end, the outfalls ended up dumping the wastewater into the nearest waterway (Stradling 2010, 127).

Waterways became the favored dump sites for all variety of waste since disposal in the water was essentially free and simple. In the late nineteenth century, one of the most polluted NYC waterways polluted by heavy industrial waste was the Newtown Creek, a tributary of the East River (Stradling 2010, 127). The garbage from the fertilizer factories and oil refineries along the creek was responsible for fish kills and ecosystem collapse of the tidal stream (Stradling 2010). Later, several other industries, such as fat-rendering plants and glue works, expanded along the creek. Since the “creek” fed into the East River, hundreds of thousands of gallons of the untreated wastewater flowed into Manhattan, destroying ancient oyster beds (Stradling 2010, 127).

At around the same time, the mid-nineteenth century, as the city of Brooklyn expanded into the U.S.’s third largest city, there was a need for a shipping lane which would go into the city center from the New York Harbor. The city gained “great commercial advantages” with digging a canal along the location of the once winding Gowanus creek, from the harbor and 1.8 miles into the center of Brooklyn (Eldredge 2014).

Soon, the canal's banks became crowded with businesses that produced various wastes and effluents. Paint and ink companies, coal yards, tanneries, and different chemical industries, including the first U.S. manufacturer of chemical fertilizers, were among the perpetrators. (Eldredge 2014, 187). In principle, a mechanical system pumped in water from the East River helped flush the dirty canal water. However, by 1910, critics claimed that the canal water was virtually solid with garbage, prompting the installation of the brick-lined Gowanus flushing tunnel and pump in 1911 to flush away the filth. The pumping system was destroyed when a municipal worker allegedly placed a manhole cover on the pump in the 1960s (Eldredge 2014, 187).

The canal has attracted an increasing number of tourists since the Clean Water Act in 1975 and the public's increased awareness of the environment caused by the act. While the local administration still cautions against swimming in waters infected with viruses like E. coli and gonorrhea, the waterways are now home to oysters, white perch, herring, striped bass, crabs, jellyfish, and anchovies; all of which, however, are still considered not safe to eat. A new type of life-form, termed “white stuff,” has been discovered at the bottom of Brooklyn's Gowanus Canal

(Eldredge 2014, 202). The biofilm's components, which include bacteria, protozoa, chemicals, and other detritus, appear to work together to search food, exchange genes, and make secretions that function like antibiotics to fight against toxins in the water. Researchers hope that this discovery will lead to the development of new medications to tackle human illness (Eldredge 2014, 202).

Chapter 3. Wastewater Treatment for Public Health

Brooklyn, New York City, is home to the Gowanus Canal. Park Slope, Cobble Hill, Carroll Gardens, and Red Hook are just a few of its surrounding neighborhoods. The Gowanus Canal is one of the nation's most heavily contaminated water basins due to years of discharges, stormwater runoff, sewage outflows, and industrial contaminants (GEI Consultants Incorporated 2009, 6). Biological organisms, polychlorinated biphenyls (PCBs), coal tar wastes, metals, and volatile organic compounds have been discovered as contaminants (NYS DOH 2017, 7).

The Gowanus Canal, built between 1853 and 1869, was designed as a barge canal (Stone and Webster 1984). The canal made it possible to transport and store coal, petroleum, asphalt, and lumber, which aided Brooklyn's fast industrial boom. The canal remained a key mode of transportation for products and supplies into the area until the Gowanus Expressway was completed in 1951(Stone and Webster 1984). The canal's constricted nature and inadequate tidal exchange caused sedimentation and low water quality. In the late 1800s, sludge and sediment accumulations in the canal became an issue. By 1889, sewage and industrial discharges contaminated the Gowanus Canal to the point that it was deemed a public health danger.

To flush the canal, the City of Brooklyn built storm sewer outfalls that emptied the Fort Greene section of Brooklyn at the canal's crest in 1899. However, this just added to the canal's pollution. To limit sewage discharge to the Gowanus Canal, the City of New York built the Gowanus Canal Pump Station near the canal's head in 1947, followed by the Owl's Head sewage treatment plant in 1952. However, the Gowanus Canal still had thirteen connected outfalls in 1984: nine combined sewer overflow outfalls and four continuous dry weather sewer discharge outfalls (NYS DOH 2017, 8). Daily, they released 16.6 million gallons of raw sewage and four million gallons of combined sewer overflows into the canal (GEI Consultants Incorporated 2009, 7). The CSO discharges to the Gowanus Canal resulted in the accumulation of sludges and sediments not cleared by tidal flushing (NYS DOH 2017, 9). Sewage flow to the Gowanus Canal was reduced but not eliminated after the Red Hook Treatment Plant was built in 1987.

According to the New York State Department of Health (DOH) and Agency for Toxic Substances and Disease Registry (ATSDR), these agencies wish to ensure that the community around the Gowanus Canal has the best information possible about how contaminants in the canal might affect their health. "To evaluate how people's health might be affected, DOH and ATSDR used data from an environmental investigation of the Gowanus Canal conducted by GEI Consultants, Inc. for the KeySpan Corporation in 2007 and from the remedial investigation conducted by the United States Environmental Protection Agency (EPA) in 2010 through 2011," (NYS DOH 2017, 1).

The DOH and ATSDR investigations allowed the DOH to reach four conclusions about the Gowanus Canal. The four conclusions are as follows:

> *Conclusion 1*: Full body immersion recreation (e.g., swimming, scuba diving) in the Gowanus Canal could harm people's health (NYS DOH 2017, 1).
>
> *Conclusion 2*: Recreational boating (for example, canoeing or kayaking) or "catch and release" fishing from a boat in the Gowanus Canal is not expected to harm people's health, although there

may be some physical hazards such as large commercial boat traffic. However, certain precautions are recommended because accidental swallowing and skin contact with the water would lead to increased exposure to chemical and biological contaminants (NYS DOH 2017, 2).

Conclusion 3: If people don't follow DOH's fish consumption advisories and eat more fish and crabs from the Gowanus Canal than recommended in the advisory, their risk for adverse health effects will increase and their health could be harmed (NYS DOH 2017, 3).

Conclusion 4: Breathing contaminants from the Gowanus Canal in outdoor air near the canal is not expected to harm people's health (NYS DOH 2017, 4).

Pollution, ecological changes, and physical alteration of the environment are being worsened by various human activities in coastal habitats (Bhat and Danek 2012, 1924). Fecal coliform bacteria are present in natural waters and human sewage and animal waste. One of the most important factors of water pollution is microbial pollution Although a few types of coliform bacteria can cause serious human illness, their abundance is primarily used to assess the presence of other more virulent pathogens associated with sewage (Bhat and Danek 2012, 1924).

Water quality degradation due to fecal coliform bacteria contamination may provide additional health risks to recreational users. Direct contact with polluted water and intake of infected oysters and mussels can result in sickness and even death. The standard for identifying fecal contamination in surface waters when coliform bacteria surge following a rain event is a density count of fecal coliform bacteria (Bhat and Danek 2012, 1923). These coliform bacteria decline or disappear from the water column due to mortality and sedimentation processes but can be resuspended in shallow waters following the sedimentation (Bhat and Danek 2012, 1924).

The Suwanee case study allows us to understand how big of an impact a wastewater treatment facility can have on fecal coliform bacteria contamination, in a smaller scale. In 1997, Suwannee, a coastal town in southeast USA, constructed a central wastewater treatment facility, eliminating 850 improperly working on-site sewage treatment and disposal facilities (OSTDS) which were close to shellfish harvesting areas (Bhat and Danek 2012, 1925). Because of the OSTDS's closeness to local shellfish harvesting sites in the Suwannee River Sound, the failure of these systems was seen as a potential source of bacteriological contamination observed in oysters gathered from the region between 1989 and 1990. (Bhat and Danek 2012, 1924). Salmonella was found in oyster samples from Louisiana and Florida. Approximately 39% of the oysters tested positive for Salmonella, and of those, about 90% were from Suwannee Sound and surrounding regions (Bhat and Danek 2012, 1924).

The study conducted by Bhat and Danek gives the results of fecal coliform distribution in canals and the main stem of the Suwannee River between 1996 and 2009. To examine the water quality before and after installing the central wastewater treatment facility, Bhat and Danek measured and analyzed fecal coliform levels. Their study found significant changes in fecal coliform counts found in canals near the town of Suwannee between samples collected before and after the construction of the central Wastewater Treatment Facility [WWTF] (Bhat and Danek 2011, 1926).

“Before the installation and operation of the WWTF, the average canal concentration of fecal coliform was 537 MPN/ 100 ml, which decreased after the operation of WWTF to an average of 218 MPN/100 ml showing a 59% reduction.” (Bhat and Danek 2011, 1927). Fecal coliform concentrations were measured and evaluated on four different occasions between 1996 and 2009 in the Suwannee River and its inner canals. Bhat and Danek note that before the installation of the wastewater treatment facility in 1997, high fecal coliform presence was observed in the river's inner canals, which eventually discharged into the river itself. After the installation of the wastewater treatment plant, there was a significant decrease in the fecal coliform concentrations in the canals over 13 years (Bhat and Danek 2011, 1929). The study, however, found no significant decrease in fecal coliform concentrations in the river itself after installing the wastewater treatment plant (Bhat and Danek 2011, 1929). The researchers concluded that river flow, rainfall, groundwater movement, and seasonality must be accounted for when studying fecal coliform concentrations in waterways.

To better understand how wastewater treatment plants, which are also called sewage treatment plants or water pollution control plants, help improve water quality and remove pollutants, we must once again examine the five major processes of treatment and what they do. As mentioned in chapter 1, the five major processes are preliminary treatment, primary treatment, secondary treatment, disinfection, and sludge treatment, respectively. Some of these treatment processes were recently (mentioned in a later chapter of this paper discussing policies) and since then have increased the effectiveness and productivity of wastewater treatment plants. These five processes are described in detail in the New York City Department of Environmental Protection’s informational guide.

Preliminary Treatment. The incoming wastewater or influent from NYC's homes and businesses passes through screens with three-inch holes. The screen removes large pieces of trash, including cloth, sticks, newspaper, cans, bottles, plastic cups, etc. This initial screening protects the main sewage pumps and other equipment. The wastewater from the screening chamber is then brought to the surface level of the plant (NYC DEP n.d., 7).

Primary Treatment. Next, the wastewater enters primary sedimentation tanks for a few hours. The goal is to allow heavier solids to settle to the bottom of the tank and the lighter materials to float to the top. At the end of the process, the floatable trash, such as grease and small plastic material, rises and is skimmed from the top of the tank's surface. The primary sludge is then pumped to the plant's sludge handling facilities for further processing. While the partially treated wastewater from the primary settling tanks then flows to the secondary treatment system (NYC DEP n.d., 7).

Secondary Treatment. Secondary treatment, also known as the "activated sludge process," adds air and "seed" sludge from the plant treatment process to the wastewater to further break it down. Air pumped into massive aeration tanks mixes the wastewater and sludge, promoting the growth of oxygen-using bacteria and other small organisms found in sewage. Most of the residual organic elements are consumed by microbes, and the heavier particles settle during the treatment process. The aerated wastewater is then directed to the final settling tanks, where heavy particles and other materials settle to the bottom as secondary sludge. The sludge contains microorganisms that contribute to the removal of as many contaminants as possible by maintaining the proper balance of bacteria and air in the tank. The residual secondary sludge is collected from the settling tanks and mixed with the primary sludge in the sludge handling facilities for further processing (NYC DEP n.d., 8).

Sludge Treatment. Disease-causing organisms may persist in treated wastewater even after primary and secondary treatment. Sodium hypochlorite, the chemical used in household bleach, is mixed into the wastewater for 20 minutes to disinfect, and kill hazardous organisms. The treated wastewater, known as effluent, is discharged into nearby waterways (NYC DEP n.d., 8-9).

Disinfection. The sludge is further treated after thickening to make it safer for the environment. The sludge is placed in digesters, which are oxygen-free tanks that are heated to at least 95 degrees Fahrenheit for 20 days. This promotes the growth of anaerobic bacteria, which eat organic matter in sludge. Unlike the microorganisms in the aeration tanks, these bacteria live in an oxygen-free or “anaerobic” environment. The digesting process thickens the sludge by turning a large portion of it into the water, carbon dioxide, and methane gas (NYC DEP n.d., 9).

Chapter 4. Policies, Effectiveness, and Inequality

The Federal Clean Water Act of 1972 established strict rules for treatment facilities, requiring that all plant discharges be free of 85 percent of conventional contaminants. As a result, the city of New York had to replace or renovate twelve existing wastewater treatment plants and install two new ones (Protopapas 1999, 135). The Water Pollution Control Act prompted NYC to conduct an area-wide water quality assessment in the 1970s to address the CSO problem. The city was compelled to implement a city-wide CSO abatement program by New York State's State Pollutant Discharge Elimination System (SPDES) in 1985 (Protopapas 1999, 135). Understanding the background and requirements of the Clean Water Act (CWA) is necessary to understand many of the current CSO abatement policies that are implemented.

The Federal Water Pollution Control Act or Clean Water Act was originally implemented in 1948. The most recent and stricter amendments were revised in 1972. The 1972 legislation created ambitious water quality improvement programs that are still being improved and implemented by industries and municipalities (Gatz 2018, 1). The Federal Water Pollution Control Act of 1948 provided local and state governments with technical assistance funding to address water pollution issues. Since water pollution was seen as a state and local governmental problem, there were no federally required standards or guidelines. Thus, when it came to enforcement of the act, federal involvement was limited.

By the late 1960s, there was a general belief that existing enforcement procedures were too time-consuming (Gatz 2018, 2). The water quality standards approach was inadequate since it was difficult to pinpoint a single discharger to water quality issues. Moreover, there was rising concern with the slow pace of pollution cleanup attempts and worries that control technologies were not being implemented to address the issues (Gatz 2018, 2).

The 1972 revisions were triggered by these impressions and frustrations and by a growing public interest in environmental conservation. The objective of the 1972 legislation was to restore and maintain “the chemical, physical, and biological integrity of the nation's waters,” (Gatz 2018, 2). Two additional objectives were to have aero percent pollution discharge by 1985 and national water quality that is both “fishable” and “swimmable” by mid-1983 (Gatz 2018, 3).

Water quality programs have prioritized the reduction of harmful pollution emissions. States must adopt control plans for waterways projected to remain contaminated by harmful chemicals even after industrial dischargers have installed the best available remediation methods required by state law. Prior to the 1987 revisions to the 1978 Clean Water Act programs, the Clean Water Act's programs were largely focused on point source pollution, which consisted of pollutants released from “discrete and identifiable industrial and municipal sources, such as pipelines and other outfalls,” (Gatz 2018, 3). Non-point source pollution, which includes stormwater, agricultural, and construction runoffs, on the other hand, has received little attention, despite accounting for more than half of the nation's remaining water pollution concerns (Gatz 2018, 3).

On August 10, 1989, the EPA's Office of Water released a National Combined Sewer Overflow Control Strategy [54 Federal Register 37370] (Cook 1995, 1-2). The Clean Water Act (CWA) and the National Pollutant Discharge Elimination System (NPDES) permit requirements apply to CSOs, which were reiterated in this Strategy. According to the CSO Strategy, all CSOs should be identified and classified based on their level of compliance with these requirements. It also established three goals: ensure that if CSOs occur, they are only because of wet weather (Cook 1995, 1-2). Bring all wet weather CSO discharge points into compliance with the technology-based and water quality-based requirements of the CWA (Clean Water Act) (Cook 1995, 1-2). Minimize the impacts of CSOs on water quality, aquatic biota, and human health from CSOs (Cook 1995, 1-2).

Figure 3. Agency Roles and Responsibilities for Controlling CSOs (Cook 1995, 1-1)

Permittee	NPDES Permitting Authority	NPDES Enforcement Authority	State WQS Authorities
• Evaluate and implement NMC • Submit documentation of NMC implementation by January 1, 1997 • Develop LTCP and submit for review to NPDES permitting authority • Support the review of WQS in CSO-impacted receiving water bodies • Comply with permit conditions based on narrative WQS • Implement selected CSO controls from LTCP • Perform post-construction compliance monitoring • Reassess overflows to sensitive areas • Coordinate all activities with NPDES permitting authority, State WQS authority, and State watershed personnel	• Reassess/revise CSO permitting strategy • Incorporate into Phase I permits CSO-related conditions (e.g., NMC implementation and documentation and LTCP development) • Review documentation of NMC implementation • Coordinate review of LTCP components throughout the LTCP development process and accept/approve permittee's LTCP • Coordinate the review and revision of WQS as appropriate • Incorporate into Phase II permits CSO-related conditions (e.g., continued NMC implementation and LTCP implementation) • Incorporate implementation schedule into an appropriate enforceable mechanism • Review implementation activity reports (e.g., compliance schedule progress reports)	• Ensure that CSO requirements and schedules for compliance are incorporated into appropriate enforceable mechanisms • Monitor compliance with January 1, 1997, deadline for NMC implementation and documentation • Take appropriate enforcement action against dry weather overflows • Monitor compliance with Phase I, Phase II, and post-Phase II permits and take enforcement action as appropriate	• Review WQS in CSO-impacted receiving water bodies • Coordinate review with LTCP development • Revise WQS as appropriate: Development of site-specific criteria Modification of designated use to - Create partial use reflecting specific situations - Define use more explicitly Temporary variance from WQS

The CSO Strategy charged all States with developing state-wide permitting strategies designed to reduce, eliminate, or control CSOs.

The United States Environmental Protection Agency authorized New York's SPDES program for the control of surface wastewater and stormwater discharges in conformance with the Clean Water Act (NYS DEC, n.d.). The SPDES program, however, has a broader scope than the Clean Water Act, as it monitors point source discharges to both groundwater and surface waters. The SPDES program seeks to remove pollution in New York waters while maintaining the highest possible water quality with focus on: public health, public enjoyment of the resource, protection and propagation of fish and wildlife, and industrial development in the state (NYS DEC, n.d.).

The CSO Control Policy makes it clear what is expected of permit holders (Cook 1995, 1-2). Figure 3 shows what permittees, NPDES permitting and enforcement authorities, and State WQS authorities do and what they are responsible for. In short, the NPDES permitting authorities should consider the financial capability of permittees when reviewing CSO control plans (Cook 1995, 1-2). And permittees should immediately implement the nine minimum controls (NMC) as soon as practicable (Cook 1995, 1-2).

Municipalities must implement best available technology (BAT) or best conventional pollutant management technology, as indicated in the CSO Control Policy. And it should include the nine minimum controls (NMC), which are determined by the NPDES permitting authority exercising best professional judgment (Cook 1995, 1-6). The nine minimum controls, identified in the CSO Control Policy as the minimum technology-based controls that can be used to solve CSO problems before long-term control measures are put in place (Cook 1995, 1-6). These controls can be used without extensive engineering studies or major constructions and are as follows:

1. Proper operation and regular maintenance programs for the sewer system and CSO outfalls (Cook 1995, 1-7).
2. Maximum use of the collection system for storage (Cook 1995, 1-7).
3. Review and modification of pretreatment requirements to ensure that CSO impacts are minimized (Cook 1995, 1-7).
4. Maximization of flow to the POTW for treatment (Cook 1995, 1-7).
5. Elimination of CSOs during dry weather (Cook 1995, 1-7).
6. Control of solid and floatable materials in CSOs (Cook 1995, 1-7).

7. Pollution prevention programs to reduce containments in CSOs (Cook 1995, 1-7).
8. Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts (Cook 1995, 1-7).
9. Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls. (Cook 1995, 1-7).

To demonstrate conscientious effort in the application of the minimum controls, the municipality should consider including the following things in documentation for the NPDES permitting authority:

1. A summary of observed incidents (i.e., the number and location of overflow events. as well as duration, volume, and pollutant loadings, if available) (Cook 1995, 10-5).
2. A summary of existing water quality data for receiving water bodies (Cook 1995, 10-5).
3. A summary of receiving water impacts that are directly related to CSOs (e.g., beach closing, floatable wash-up episodes, fish kills) (Cook 1995, 10-5).
4. An assessment of the effectiveness of any CSO control measures already implemented such as the reduction of floatable and fish kill incidents (Cook 1995, 10-5).
5. Development of a long-term monitoring plan for the LTCP, as appropriate (Cook 1995, 10-5).

Proper Operations and Regular Maintenance Programs. This first minimum control should consist of a program that establishes the operation, maintenance, and inspection procedures to ensure that a treatment plant will function to maximize the treatment of CSOs and still comply with NPDES permit regulations (Cook 1995, 2-1). By enabling existing facilities to work as efficiently as possible, implementing this first minimum control will reduce the magnitude, frequency, and duration of CSOs (Cook 1995, 2-1).

The steps involved in implementing this minimum control are:

1. Assess how well the existing operation and maintenance program is being implemented (Cook 1995, 2-1).
2. Determine whether the O&M program needs to be improved to satisfy the intent of the CSO Control Policy (Cook 1995, 2-1).
3. Develop and implement the improvements to address CSOs (Cook 1995, 2-1).
4. Document any actions and report them to the NPDES permitting authority (Cook 1995, 2-1).

Maximization of Storage in the Collection System. This second minimum control suggests making simple modifications to the combined sewer systems to enable the system to store the wet weather flows just until the treatment facilities can handle them (Cook 1995, 3-1). More complex modifications should be evaluated in the municipality or city's long-term control plan. The steps involved in implementing this minimum control are:

1. Identify possible locations where minor modifications can be made to the combined sewer system to increase in-system storage (Cook 1995, 3-1).
2. Analyze possible modifications to ensure that they will not cause other problems such as street or basement flooding (Cook 1995, 3-1).
3. Implement the modifications and document efforts for the NPDES permitting authority (Cook 1995, 3-1).

Review and Modification of Pretreatment Requirement. The municipality should establish if nondomestic sources contribute to CSO impacts and if so, consider strategies to manage them under the third minimum control. This control aims to reduce the consequences of industrial and commercial discharges into combined sewer systems during wet weather events. As well as to reduce CSO occurrences by changing inspection, reporting, and supervision processes within the authorized pretreatment program (Cook 1995, 4-1).

Maximization of Flow to the POTW for Treatment. The fourth minimal control involves making modest changes to the combined sewer systems and treatment plant to allow as much wet weather flow as practicable to reach the treatment plant. This minimum control aims to once again limit the “magnitude, frequency, and duration” of CSOs that flow untreated into receiving waters (Cook 1995, 5-1).

The EPA suggests these measures be taken to aid in implementing the fourth minimal control:

1. Determine the capacity of the major interceptor(s) and pumping station(s) that deliver flows to the treatment plant (Cook 1995, 5-1).
2. Analyze existing records to compare flows processed by the plant during wet weather events and dry periods and determine the relationships between performance and flows.
3. Compare the current flows with the design capacity of the overall facility, as well as the capacity of individual unit processes (Cook 1995, 5-1).

Elimination of CSOs During Dry Weather. The fifth minimum control includes the measures to ensure that the combined sewer system does not overflow during dry weather conditions where there are no burdens to be caused by excessive stormwater, as is the case with wet weather conditions (Cook 1995, 6-1).

Control measures that can be implemented to eliminate CSOs during dry weather flow include:

1. Inspection of the system to identify dry weather overflows (Cook 1995, 6-1).
2. Correction of the dry weather overflows (Cook 1995, 6-1).
3. Notification to the NPDES permitting authority when a dry weather overflow has occurred (Cook 1995, 6-1).
4. Submittal of a description of the corrective actions taken (Cook 1995, 6-1).

Control of Solid and Floatable Materials in CSOs. The sixth minimum control is intended to minimize or eliminate the visible floatable and solid materials in combined sewer overflow using simple and inexpensive devices. These simple devices include screens, catch basin modifications, and nets (Cook 1995, 7-1). These screens, catch basin modifications, and nets will remove the floatable and solid materials from the wastewater. In contrast, skimmers and booms will remove floatable and solid materials from the receiving water bodies, which in this case are the East River and the Gowanus Canal.

Pollution Prevention Programs to Reduce Contaminants in CSOs. The objective of the seventh minimum control is to reduce to the greatest extent the number of contaminants that enter the combined sewer system and from the receiving waters. The basis of this minimum control is the Pollution Prevention Act of 1990. The suggested measures involve societal behavioral changes such as street cleaning, public education programs, and product bans rather than the construction of treatment devices (Cook 1995, 8-1).

The Pollution Prevention Act establishes these strategies for management efforts:

1. Pollution should be prevented or reduced at the source whenever feasible (Cook 1995, 8-1).
2. Pollution that cannot be prevented should be recycled in an environmentally safe manner whenever feasible (Cook 1995, 8-1).
3. Pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible (Cook 1995, 8-1).
4. Disposal or release of pollution into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner (Cook 1995, 8-1).

Public Notification. The eighth minimum control is intended to inform the public of the location of CSO outfalls, the actual occurrences of CSOs, the potential health and environmental effects of CSOs, and the recreational or commercial activities which have been impacted by CSOs (Cook 1995, 9-1). The selected measure(s) should be the one(s) most cost-effective and provides the most assurance to the public.

The potential measures for notifying the public include:

1. Posting at Affected Use Areas (Cook 1995, 9-1).
2. Posting at Selected Public Areas (Cook 1995, 9-1).
3. Letter notifications to Affected Residents (Cook 1995, 9-1).

Monitoring to Effectively Characterize CSO Impacts. The ninth and final recommended minimum control involves visual inspection to determine the occurrence and impacts of combined sewer overflows (Cook 1995, 10-1). This minimum control characterized the combined sewer system to record information on CSOs and their impacts on beaches and shellfish beds. Recorded changes will help us better understand whether these nine minimum control techniques are effective at controlling CSOs in the short term.

PlaNYC, an extensive sustainability plan created in 2007 by NYC mayor Michael Bloomberg, seeks to address the threat of climate change on NYC's development. The plan considers the successful development of NYC since the 1970s. It aims to protect the city's sectors associated with land, water, transportation, energy, and air from the threats of global climate change and increasing populations. In terms of water use and water quality maintenance, the plan's end goal is to open 90% of NYC's waterways to recreation by preserving natural areas and reducing pollution (The City of New York 2007, 53). The plan notes the two categories of NYC's waterways that require the most attention. The first group includes significant portions of the harbor estuary, such as the Hudson and East Rivers, periodically closed to swimming due to high rainfall and subsequent CSO occurrences. The second category contains the more difficult challenge, which is a network of man-made canals, such as the Gowanus, built primarily to allow ships to enter the city more effectively.

According to the plan, by 2007, the city captured 70% of CSOs before they entered the surrounding waterways. Still, other cities such as Boston and Chicago were doing better, approaching rates of 90% (The City of New York 2007, 54). The plan emphasized the completion of large capital improvements that will expand the capacity of NYC's treatment plants and sewers. The plan noted that achieving the city's water and water quality sustainability will require a balance between infrastructure solutions and more realistic strategies. The city set goals for upgrading the wastewater treatment facilities while integrating separated storm sewers into new development projects like Hudson Yards (The City of New York 2007, 54). At the same time, they were planning to expand efforts to harness the environment as a natural water filter. That includes expanding NYC's pioneering Bluebelt system, adding nearly one million more trees, and landscaping the streets (The City of New York 2007, 54).

Figure 4. PlaNYC Plan for Water Quality, Ten Initiatives (The City of New York 2007, 55)

Continue implementing infrastructure upgrades

1 Develop and implement Long-Term Control Plans
2 Expand wet weather capacity at treatment plants

Pursue proven solutions to prevent stormwater from entering the system

3 Increase use of High Level Storm Sewers (HLSS)
4 Capture the benefits of our open space plan
5 Expand the Bluebelt program

Expand, track, and analyze new Best Management Practices (BMPs) on a broad scale

6 Form an interagency BMP Task Force
7 Pilot promising BMPs
8 Require greening of parking lots
9 Provide incentives for green roofs
10 Protect wetlands

The 2014 *PlaNYC* progress report provides an update of the progress that has been made on the water control initiatives proposed in the 2007 *PlaNYC* plan (The City of New York 2014, 5). The NYC DEP completed several grey infrastructure projects to safeguard water quality and decrease CSOs, according to the progress report. To minimize contaminants entering local waterways, DEP completed a $237 million upgrade to the Wards Island Wastewater Treatment Plant, which is expected to cut nitrogen emissions by nearly half (The City of New York 2014, 14). And over the span of the year 2014, the city worked with the EPA, community partners, and other stakeholders to assess remediation alternatives for two Superfund sites, the Gowanus Canal and Newtown Creek. The city collaborated with federal, state, and local partners to identify the greatest chances for wetland restoration and conservation using innovative remote-sensing datasets (The City of New York 2014, 15).

Below are brief summaries of each of the ten initiatives shown in figure 4.

Initiative 1, Develop and implement Long-Term Control Plans. The City of New York planned to finish all 14 NYC watershed Long-Term Control Plans required by law (The City of New York 2007, 56). In 2007 the City planned to submit its plans for 18 waterbodies detailing CSO mitigation measures to the State Department of Environmental Conservation (DEC) Waterbody/Watershed (The City of New York 2007, 56). The goal was to build holding tanks and upgrade NYC's sewage infrastructure to improve 14 wastewater treatment plants. The WB/WS plans would be incorporated into the DEC-mandated 14 watershed-specific LTCPs, which would boost CSO capture from 70% to 75% (The City of New York 2007, 56).

Initiative 2, Expand Wet Weather Capacity at Treatment Plants. The initiative notes how in 2007, all treatment facilities were required to treat twice the amount of flows that would have occurred on a normal day without rain (The City of New York 2007, 56). The City of New York planned to reduce CSO discharges by more than 185 mgd during rainstorms and upgrade NYC's treatment facilities to comply with existing and emerging regulatory requirements reliably (The City of New York 2007, 56). The City planned on expanding the wet weather capacity at Newtown Creek, the 26th Ward, and Jamaica Waste Water Treatment Plants to reduce the CSO discharges in those sewer sheds by more than 185 million gallons per day (mgd) during rainstorms (The City of New York 2007, 56).

Initiative 3, Increase Use of High-Level Storm Sewers (HLSS). The City of New York planned to convert combined sewers into HLSS and integrate HLSS into significant new developments, as appropriate (The City of New York 2007, 56). High-Level Storm Sewers (HLSS) are one strategy for alleviating pressure on the combined sewer system and limiting CSO events. The initiative notes that the City could not simply install these separated sewers and would have to analyze each site carefully on a case-by-case basis to determine the appropriateness of the strategy (The City of New York 2007, 56).

Initiative 4, Capture the Benefits of our Open Space Plan. The City of New York planned to expand the amount of green, permeable surfaces to reduce stormwater runoff. Green spaces act as natural stormwater capture and retention devices (The City of New York 2007, 57). The City's Department of Parks and Recreation estimated that city street trees capture 870 million gallons of stormwater each year (The City of New York 2007, 57). Over the next 25 years, the City planned to undertake 40 new Greenstreets projects every planting season, bringing the citywide total to more than 3,000 by 2030 (The City of New York 2007, 57). The existing total acreage of Greenstreet's sites in New York City was almost 164 acres, translating into a nine million gallon capacity citywide (The City of New York 2007, 57). With an additional 40 new Greenstreet projects covering 75 acres, the capacity to hold stormwater would increase by four million gallons (The City of New York 2007, 57). In addition to increasing stormwater storage through Greenstreets, the City would increase the number of trees in NYC by one million (The City of New York 2007, 57).

Initiative 5, Expand the Bluebelt Program. The City of New York planned to expand the Bluebelt in Staten Island and other boroughs (The City of New York 2007, 57). In many areas of Staten Island, development preceded the full build-out of the sewer system. Over the next 25 years, the City would add 4,000 acres in Staten Island, South Beach, New Creek, and Oakwood Beach (The City of New York 2007, 57). The Plan notes that up until 2007, the Bluebelt program had saved the City an estimated $80 million in infrastructure costs and had also saved homeowners money in flood damage (The City of New York 2007, 57).

Initiative 6, Form an Interagency BMP Task Force. The City of New York planned to reduce CSO volumes and other environmental issues as a priority for all relevant City agencies, including but not limited to the Departments of Transportation, Parks & Recreation, Buildings, and City Planning (The City of New York 2007, 58). The establishment of the New York City Interagency BMP Task Force would bring together all relevant City agencies to analyze ways to incorporate BMPs into the design and construction of projects (The City of New York 2007, 58). The focus would be on greening the public right-of-way, developing BMPs on City-owned land, improving environmental performance of open space, and creating strategies to promote BMPs on private development (The City of New York 2007, 58).

Initiative 7, Pilot Promising BMPs. The City of New York planned to immediately pilot various BMPs to monitor and assess its performance in neighborhoods (The City of New York 2007, 59). The Task Force would pilot the following three BMPs, selected for their feasibility and proven effectiveness in other programs across the United States: creating a mollusk habitat pilot program, planting trees with improved pit design, and creating vegetated ditches (swales) along highways (The City of New York 2007, 59).

Initiative 8, Require Greening of Parking Lots. The City of New York planned to modify the zoning resolution to include design guidelines for off-street parking lots for commercial and community facilities (The City of New York 2007, 60). The City would modify the zoning resolution to require perimeter landscaping of commercial and community facility parking lots over 6,000 square feet and street tree planting on the adjacent sidewalks (The City of New York 2007, 60). In addition to the zoning modification, the City would analyze the costs and benefits of integrating additional BMP's into parking lots (The City of New York 2007, 60). The initiative notes that increased landscaping, along with storm water detention and retention, could slow down the rate at which water enters the sewer system; that it would enable New York's combined sewer system to treat a higher percentage of storm water (The City of New York 2007, 60).

Initiative 9, Provide Incentives for Green Roofs. The City of New York planned to encourage the installation of green roofs through a new incentive program (The City of New York 2007, 60). This initiative notes how a 40-square-foot green roof could result in 810 gallons of storm water captured per year (The City of New York 2007, 60). The City also planned to develop four residential and two commercial pilots to analyze the potential cumulative benefits of green roofs on the City's combined sewer system (The City of New York 2007, 60). The expected cost for each was $100,000 for design and $1.3 million for construction and equipment. Because incentives were necessary to off-set some of these costs, the City planned to begin providing incentives for green roofs (The City of New York 2007, 60). New York City would support the installation of extensive green roofs by having enacted a property tax abatement to off-set 35% of the installation cost of a green roof (The City of New York 2007, 60).

Initiative 10, Protect Wetlands. The initiative notes how wetlands play an important role in maintaining and even improving water quality, and how NYC had lost 86% of its wetlands in the last century (The City of New York 2007, 61). The City of New York planned to assess the vulnerability of existing wetlands and identify additional policies to protect and manage them. In 2005 the City Council sponsored, and Mayor Bloomberg signed Local Law 83 which formed the Wetlands Transfer Task Force to assess available City-owned properties that contain wetlands

(The City of New York 2007, 61). In 2007, the City planned to launch a study to identify gaps, or areas not effectively addressed under existing Federal and State laws to assess where existing regulations fall short of protecting New York City's remaining wetlands (The City of New York 2007, 61).

Chapter 5. Policy Recommendations for Prevention and Sustainability [Word Count: 1568]

Julie Sze, a leader in the field of environmental justice, suggests a relationship between physical waste, stratification based on race or social class, and public health. That it bears emphasizing that the identification of people of color and low-income communities with garbage and the ascription of value to that metaphor has a heinous history. Indeed, that was the case when we discussed “The Collect” in chapter 3; what was once the source of fresh water for thousands of New Yorkers became a foul, rancid cesspool of waste, and on the spot where it once stood originated, one of the nation's first slums (Stradling 2010). Buildings constructed in the neighborhood called 'Five Points' had basements that stayed wet and always had a foul smell in the air. Five Points became home to immigrants and African Americans and became plagued by crime and prostitution (Stradling 2010). It provided evidence of how degraded environments encouraged immoral behavior and crime. But the people of Five Points, just as the people in neighborhoods impacted by the negative impacts of CSOs, are victims of “Social Pollution” (Sze 2007). Radicalized communities in New York City are the most recent additions to a long history that links garbage with social stigma and pollution. Economic decline and environmental pollution are inextricably linked, and the stigmatization of geographical areas is linked to their industrial nature, air pollution, and populations' bad health (Sze 2007). Policy recommendations for the management of CSOs must keep the stigmatization of geographical areas such as the

Gowanus Canal residential areas in mind and find a policy which would benefit the people impacted.

Protopapas, from NYC's Department of Civil and Environmental Engineering, suggests that the ultimate solution to CSO abatement involves:

1. Construction of storage tanks near the discharge point of large CSOs); stored overflows will be treated later by treatment at nearby treatment plans (Protopapas 1999, 150).
2. For storm flows exceeding the capacity of the storage facilities, the facilities themselves will operate as primary treatment plants, with solid and floatable removal and disinfection where necessary; for smaller CSOs floatable removal seems necessary at most locations with disinfection added in certain cases; the abatement of smaller CSOs presents great technological and regulatory challenges due to higher costs and diminished benefits; innovative technologies are needed to address this challenge (Protopapas 1999, 150).
3. The optimal use of sewer capacity by controlling the quantity and direction of flows (Protopapas 1999, 150).

It is necessary to construct storage tanks near the discharge point of large CSOs and utilize the storage facilities themselves as primary treatment plants instead of only for stormwater storage. NYCDEP studies have concluded that "there is no single solution to the CSO abatement problem for all areas within the New York-New Jersey Harbor estuary… it is recognized that there can only be a long-term solution to the CSOs problem over a time horizon of 10 to 20 years," (Protopapas 1999, 151). The City of New York continues to monitor and characterize the quality in the New York Harbor waterways and sediments, as well as improve operations in the fourteen water pollution control plants (Protopapas 1999, 151).

The Gowanus Canal gets about 363 million gallons of CSO discharge per year through eleven separate CSO outfalls. Overflows occur as frequently as 59 times each year, with as little as 0.37 inches of rain per occasion (Gowanus Canal Conservancy 2019). Grey and green infrastructure initiatives are being planned to limit the amount of combined sewage overflow into the Gowanus Canal. After these initiatives are implemented, around 115 million gallons of yearly CSO discharge to the Canal will stay unregulated (Gowanus Canal Conservancy 2019). Separate stormwater pipes are being built to direct rainwater falling on streets straight to the Canal. This will lower the load on the combined sewer and help to alleviate some street flooding. Two big holding tanks will be constructed in the two CSO sheds with the highest overflows. Combined, the tanks will prevent 12 million gallons of sewage and rainwater from entering the Canal during storms. Curbside rain gardens, also known as bioswales, may absorb up to 2,500 gallons of rainfall that falls on the street per bioswale per rainfall. In the Gowanus Watershed, the City has constructed 103 rain gardens that manage approximately 14.4 million gallons of rainwater annually (Gowanus Canal Conservancy 2019).

The Department of City Planning (DCP) published a Draft Scope of Work for a Proposed Rezoning of the Gowanus area in 2019 (Gowanus Canal Conservancy 2019). According to the City, rezoning might result in 20,000 extra residents and an increase in wastewater generation of 1 billion gallons per year, on top of the 115 million gallons of yearly CSO that will remain unmanaged (Gowanus Canal Conservancy 2019). Because the rezoning will result in increased wastewater generation, it will require more infrastructure investment to manage more stormwater and wastewater. An integrated system that incorporates in-building storage and reuse, as well as site-specific green infrastructure in parks, streets, and along the coastline, can assure a net-zero rise in yearly CSO (Gowanus Canal Conservancy 2019).

CSO last has been an issue for cities and areas that rely on the Combined sewer system for some time now. Taking into consideration that CSOs occur because of higher than usual flows of water and that the rise in global temperature facilitates higher than usual events of rain and precipitation along with coastal cities, it is not hard to see how CSOs will be a huge issue for the health of both New Yorkers and of the few remaining environmental services we have left. Implementing green and grey infrastructure such as CSO storage tanks and bioswales is necessary to prevent both excess stormwater and excess sewage—the two main components of CSO discharges–from entering the combined sewage system and consequently the CSO outfalls during heavy rain events. Green Infrastructure like bioswales helps to reduce physical pollutants such as floatable from entering the storm drains and help retain stormwater to prevent overburdening the system (Gowanus Canal Conservancy 2019). While the grey infrastructure, such as the storage tanks, tunnels, and pipes, also contains excess sewage water and prevents overburdening the system (Gowanus Canal Conservancy 2019). However, as we see with the pattern of urbanization, population booms, and increased waste production in chapter 2, will these types of infrastructure implementation be enough to prevent CSOs?

The EPA and water quality guidelines discussed in chapter 4 show how city agencies take precautionary steps to prevent toxins and metals from industries and old infrastructure from getting into the waterways. By looking at current policy plans and guidelines the SPDES, we can determine whether these policies are keeping the nine minimum controls in mind. The Gowanus Canal public health report shows how there are still chemical pollutants in the canal's waters that can harm people's health. What can we do about that?

Chapters 1 and 2 discuss many environmental and ecological risks posed by fecal coliform and excess nutrients. Chapter 3 then examines the case studies of the Suwannee wastewater treatment plant and its role in improving water quality and removing fecal coliform bacteria and related pathogens from the Suwannee sewer shed. Using this information, we can argue for the construction of more wastewater treatment plants in NYC to increase the effectiveness of wastewater treatment and serve more communities and prepare for an increase in population.

As seen in figure 4, the ten initiatives that the City of New York plans on implementing for water quality improvement under *PlaNYC* offer the most robust and thorough policies that will benefit NYC waterways in the long run. The first two initiatives to develop and implement Long-Term Control Plans and to expand wet weather capacity at treatment plants, correlate directly to the disciplines discussed in chapter 3 (The City of New York 2007, 56). The next three initiatives which pursue proven solutions to prevent storm water from entering the system also correlate directly to the disciplines discussed in chapters 4 and 5 which call for increased utilization of green and grey infrastructures. The last five initiatives which call for the expansion, recording, and analysis of Best Management Practices, help to understand how the city agencies are working to meet the federal standards under the Clean Water Act.

The third initiative in particular which plans for an increased use of High-Level Storm Sewers (HLSS) and the conversion of combined sewers into HLSS and integration HLSS into major new developments, raises the concern about cost effectiveness in our policy recommendations. The recommended policies should be feasible, sustainable, and cost effective. High-Level Storm Sewers (HLSS) are one strategy for reducing combined sewer system pressure and minimizing CSO events. HLSS is meant to catch 50% of the rainwater before it enters pipes and channels it directly into waterways via allowed outlets, lowering the volume of flows that run through the treatment facilities and combined sewage system (The City of New York 2007, 56). However, the city is unable to construct these separate sewers at every location. This strategy is only cost-effective for developments near the water's edge because it requires a separate pipe and outlet to a waterbody (The City of New York 2007, 56).

The nine minimum technology-based controls that do not require extensive engineering studies and significant construction must be implemented as best as possible in all CSS systems until the *PlaNYC* and NYC Long Term Control Plans are implemented. Previous evidence shows that in several instances of New York City’s history, population, demands, and waste quickly outgrew the revolutionary technology of its time. Cost-effective and feasible improvement plans are more likely to be supported by the city government. It can be implemented at a larger scale rather than be limited to specific neighborhoods and not others. Building new wastewater treatment facilities and upgrading older ones along with implementing HLSS for new building projects is a more cost-effective and feasible initiative rather than replacing all or most of the existing 6000-mile combined sewer system with HLSS. *OneNYC*, the successor to NYC’s *PlaNYC* sustainability goals, still addresses growth, sustainability, and resiliency as *PlaNYC* did, but with an increased focus on addressing inequality, equity, and regional development (The City of New York 2015, 14). While we try to find different ways to fight CSOs and improve the ecosystems of waterways like the East River and the Gowanus Canal that are affected by CSOs, we must think about how our proposed solutions might be affected by growing inequality gaps and rapid climate change.

Bibliography

Bhat, Shirish, and Larry Danek. 2012. "Comparison of Fecal Coliform Before and After Wastewater Treatment Facility: A Case Study near a Coastal Town in the Southeastern USA." *Water, Air & Soil Pollution* 223 (5): 1923–30. doi:10.1007/s11270-011-0991-6.

Böck K., Polt R., Schülting L. (2018) Ecosystem Services in River Landscapes. In: Schmutz S., Sendzimir J. (eds) Riverine Ecosystem Management. Aquatic Ecology Series, vol 8. Springer, Cham. https://doi.org/10.1007/978-3-319-73250-3_21

Brosnan, Thomas M., Thomas L. Stokes Jr., and Angelika B. Forndran. 2021. "Water Quality Monitoring and Trends in New York Harbor." *Oceans Conference Record (IEEE)*, 1598–1603. Accessed November 15. doi:10.1109/oceans.1987.1160593.

Burrows, Edwin G., and Mike Wallace. 1999. *Gotham : A History of New York City to 1898*. Oxford University Press.

Cook, Michael. 1995. *Combined Sewer Overflows [Microform] : Guidance for Nine Minimum Controls*. Washington, D.C. : U.S. Environmental Protection Agency, Office of Water, 1995.

Eldredge, Niles, and Sidney S. Horenstein. 2014. *Concrete Jungle : New York City and Our Last Best Hope for a Sustainable Future*. University of California Press.

Environmental Protection Agency. 1994. "Combined Sewer Overflow (CSO) Control Policy: Notice." Accessed November 15, 2021. https://www.epa.gov/sites/default/files/2015-10/documents/owm0111.pdf

Gatz, Laura. 2018. *Clean Water Act. [Electronic Resource]: A Summary of the Law*. [Library of Congress public edition]. Report / Congressional Research Service: RL30030. Congressional Research Service.

GEI Consultants Incorporated. 2009. *Gowanus Canal Investigation Executive Summary Report AOC Index No. A2-0523-0705* Glastonbury, CT. Retrieved September 13, 2021.

Ghodsi, Seyed Hamed, Zhenduo Zhu, Hazem Gheith, Alan J. Rabideau, María Nariné Torres, and Kevin Meindl. 2021. "Modeling the Effectiveness of Rain Barrels, Cisterns, and Downspout Disconnections for Reducing Combined Sewer Overflows in a City-Scale Watershed." *Water Resources Management* 35 (9): 2895–2908. doi:10.1007/s11269-021-02875-7.

Goldman, Joanne Abel. 1997. *Building New York's Sewers : Developing Mechanisms of Urban Management*. History of Technology Series. Purdue University Press.

Gowanus Canal Conservancy. 2019. "Open Sewer Atlas." Accessed November 15, 2021. https://gowanuscanalconservancy.org/wpcontent/uploads/2018/01/GowanusCanal_OpenSewerAtlas_Aug2019_Final_v2.pdf

Kensinger, Nathan. 2020. "NYC has a plan to clean its sewage-filled waterways. Does it go far enough?" *Curbed NY*. February 20, 2020. https://ny.curbed.com/2020/2/20/21144943/new-york-water-combined-sewer-overflow-dep-plan

Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-being: Synthesis.* Washington, D.C. Island Press.

Miller, Benjamin. 2000. *Fat of the Land : Garbage in New York : The Last Two Hundred Years*. Four Walls Eight Windows.

National Weather Service. n.d. "Flood and flash flood definitions." Accessed November 15, 2021. https://www.weather.gov/mrx/flood_and_flash

New York City Department of City Planning. 1985. Gowanus: A Strategy for Industrial Retention.

New York State Department of Health. 2017. "Public Health Assessment, Final Release, Gowanus Canal." Accessed November 15, 2021. https://www.health.ny.gov/environmental/investigations/gowanus/docs/pha_final.pdf

NYC DEP. n.d. "New York City's Wastewater Treatment System." Accessed September 13, 2021. https://semspub.epa.gov/work/02/206372.pdf

NYC Environmental Protection. 2019. "Combined Sewer Overflows." Accessed November 15, 2021. https://www1.nyc.gov/site/dep/water/combined-sewer-overflows.page

NYC EP. 2020. "Combined Sewer Overflow Long Term Control Plan For Citywide/Open Waters." Accessed September 13, 2021. https://www1.nyc.gov/assets/dep/downloads/pdf/water/nyc-waterways/citywide-east-river-open-water/citywide-open-waters-ltcp-executive-summary.pdf

NYS DEC. n.d. https://www.dec.ny.gov/permits/6054.html. Accessed November 21, 2021.

O'Connor, Donald J. 1966. "An Analysis of the Dissolved Oxygen Distribution in the East River." *Journal (Water Pollution Control Federation)* 38 (11): 1813–30.

Petrie, Bruce. 2021. "A Review of Combined Sewer Overflows as a Source of Wastewater-Derived Emerging Contaminants in the Environment and Their Management." *Environmental Science & Pollution Research* 28 (25): 32095–110. doi:10.1007/s11356-021-14103-1.

Protopapas, Angelos L. 1999. "Combined sewer overflow abatement: The East River project." *Water Resources Management* 13, no. 2: 133-151.

Sanderson, Eric W. 2009. *Mannahatta : A Natural History of New York City*. Abrams.

Steinberg, Ted. 2014. *Gotham Unbound : The Ecological History of Greater New York*. Riverside: Simon & Schuster.

Stone and Webster Engineering Corporation. 1984. Environmental and Engineering Study, Assessing the Suitability of the Gowanus Canal Site for Public Housing and Recreational Use. Accessed November 21, 2021.

Stradling, David. 2010. *The Nature of New York : An Environmental History of the Empire State*. Cornell University Press.

Sze, Julie. 2007. *Noxious New York : The Racial Politics of Urban Health and Environmental Justice*. Urban and Industrial Environments. Cambridge, Mass: The MIT Press.

TEEB (2011). TEEB Manual for Cities: Ecosystem Services in Urban Management. The Economics of Ecosystems and Biodiversity (TEEB): Geneva.

The City of New York. 2007. "A Greener, Greater New York". *PlaNYC*. https://www.nyc.gov/html/planyc/downloads/pdf/publications/full_report_2007.pdf

The City of New York. 2014. "Progress Report 2014: A Greener, Greater New York, A Stronger, More Resilient New York". *PlaNYC*. https://www.nyc.gov/html/planyc/downloads/pdf/140422_PlaNYCP-Report_FINAL_Web.pdf

The City of New York. 2015. "One New York: The Plan for a Strong and Just City". *OneNYC* Strategic Plan. April 2019. https://onenyc.cityofnewyork.us/wp-content/uploads/2019/04/OneNYC-Strategic-Plan-2015.pdf

United States Environmental Protection Agency. 2013. "Record of Decision, Gowanus Canal Superfund Site Brooklyn, Kings County, New York." Accessed September 13, 2021. https://semspub.epa.gov/work/02/692106.pdf

Zimring, Carl A. and Steven H. Corey. 2021. *Coastal Metropolis : Environmental Histories of Modern New York City*. History of the Urban Environment. Pittsburgh, Pa: University of Pittsburgh Press.