

Spring 5-8-2014

# Green Infrastructure: A New Way of Addressing Water Quality Issues Within a Growing Population.

Marlin Martes

Fordham University, [mmartes@fordham.edu](mailto:mmartes@fordham.edu)

Follow this and additional works at: [https://fordham.bepress.com/environ\\_2014](https://fordham.bepress.com/environ_2014)

Part of the [Environmental Sciences Commons](#)

---

## Recommended Citation

Martes, Marlin, "Green Infrastructure: A New Way of Addressing Water Quality Issues Within a Growing Population." (2014). *2014 Student Theses*. 21.

[https://fordham.bepress.com/environ\\_2014/21](https://fordham.bepress.com/environ_2014/21)

This is brought to you for free and open access by the Environmental Studies at DigitalResearch@Fordham. It has been accepted for inclusion in 2014 Student Theses by an authorized administrator of DigitalResearch@Fordham. For more information, please contact [considine@fordham.edu](mailto:considine@fordham.edu).

**Green Infrastructure: A New Way of Addressing Water Quality  
Issues Within a Growing Population.**

Marlin Martes

Professor John van Buren PhD.

Fordham University – Environmental Policy

Spring 2014

### **Abstract**

Beneath the great metropolis known as New York City, underlies an intricate system of water networks linking all of New York City's five boroughs. In the same manner that veins function as vessels for the transportation of blood in the circulatory system, NYC's water system interconnects all of the diverse communities found at multiple levels of society within the city. Regardless of origin or background, today all NYC residents and visitors share NYC's tap water as a natural resource without fearing water scarcity tomorrow. However, as the estimated population in New York City is expected to rise above 9 million residents within the next 30 years, the city needs to address water quality and availability in order to meet the demands of its growing population. The use of "green infrastructure" to improve water quality is an applicable solution for city agencies such as the Department of Environmental Protection, responsible for the management of the city's precious resource. Green infrastructure simply refers to "storm water management systems that mimic nature by soaking up and storing water;"<sup>1</sup> green infrastructure systems manage storm water through infiltration, evapotranspiration, reuse, and detention. Types of green infrastructure including vegetated swales, green roofs, rain gardens, pervious surfaces, and pocket wetlands can be effective in the capture of storm water and the reduction of runoff found in urban environments like NYC.

---

<sup>1</sup> "What Is Green Infrastructure?" *Home*. N.p., n.d. Web. 19 Jan. 2014. <[http://water.epa.gov/infrastructure/greeninfrastructure/gi\\_what.cfm](http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm)>.

In order to address this topic I will draw upon the disciplines of public health, environmental architecture, environmental economics, and environmental policy. First, I will highlight some of the challenges NYC neighborhoods face due to surface runoff of storm water. I will use examples of sites within the five boroughs of the city such as the Hudson River, or the “Greenstreets Program” to evaluate the effectiveness of using green infrastructure to improve water quality standards within New York City. I will then draft a cost benefit analysis of the installation of green infrastructure within the city; here I will explain the costs of implementing green infrastructure techniques and the short and long-term benefits of the above mentioned. I will compare and contrast the cost effectiveness between green vs. gray infrastructure. I also intend to touch upon the advantages of using green infrastructure in terms of landscape architecture. With this I hope to highlight how using green infrastructure can beautify neighborhoods and sites all the while improving air quality and even reducing traffic. Finally, I will discuss the types of local policy and laws that have been addressed in order to successfully apply green infrastructure within New York City.

**Introduction:**

*“Based on years of study and our experience with new technologies, we know that green infrastructure—advanced street-tree pits, porous pavements and streets, green and blue roofs, and many other stormwater controls—can improve water and air quality, help to cool the City, reduce energy bills and greenhouse gas emissions, increase property values, and beautify our communities. And we can achieve all of these benefits for billions of dollars less than the cost of the traditional tanks and tunnels that are useful only when it rains.”<sup>2</sup>*

*- Mayor Michal R. Bloomberg*

The introductory lines of this paper is a quote from New York City’s Mayor Michal R. Bloomberg; though his multiple terms within NYC have surely ended he left New York City with a very precious gift. Mayor Bloomberg set in to motion and set goals that would steer the metropolis we know as New York City in to a bright future of sustainability and conservation. “PlaNYC” set the framework NYC to not only reduce carbon emissions yet it brought to light issues that New York City faced in the past and new ones that could arrive in the future. However, do not be fooled in to thinking that this paper is solely about plaNYC and about glorifying Mayor Bloomberg. This paper is designated to tell a story, one that is made available to all New York City residents yet occult behind the veils of ignorance for many. Through plaNYC, New York City has been able to launch projects that incorporate green infrastructure in the City. This paper intends to shed light on the history of stormwater management within New York City. It will outline the ways in which innovative techniques adopted through green infrastructure have improved water quality standards for New York City throughout the years and the possibilities of the years to come. So, how is green infrastructure defined and what is green infrastructure exactly?

---

<sup>2</sup> New York. *PlaNYC: A Greener, Greater New York*. By Michael Bloomberg. New York: City of New York, 2007. Print.

## **Chapter 1: Introduction to Green Infrastructure & Storm Water ( The Problem)**

Green infrastructure can be broadly defined as the integration of networks of natural ecosystems in to land use systems. However, amidst experts the term green infrastructure is most likely coined as “storm water management systems that mimic nature by soaking up and storing water.”<sup>3</sup> Contrary to other readily visible types of infrastructure like roads or bridges, green infrastructure cannot be exclusively singled out in one particular shape or size; it cannot be categorized as a building or a road. Recognizing green infrastructure is easier than it sounds and most importantly it can be found within city blocks, on the tops of buildings, or even parking lots for example. Before dwelling in to different types of green infrastructure or “storm water management systems” it is necessary to understand what is storm water and why it’s management is important to NYC. *Storm water* is generated when rain or snow runs off of land surfaces like impervious surfaces (non-porous) and heavily compacted soils. Impervious surfaces include any areas that are covered by material(s) that obstruct the infiltration of water in to soil.

Impervious surfaces in urban locations can alter the natural hydrology cycle in watersheds by increasing the amount of storm water runoff and by decreasing the amount of ground water recharge. In NYC alone impervious surfaces cover “approximately 72% of New York City’s 305 square miles in land area.”<sup>4</sup> Due to the large percentage of impermeable surfaces in NYC much of the storm water that falls during rain or melting snow cover flows in to roof drains or catch basins on streets. The amount of storm water runoff produced by individual rain events depend on a number of factors including “surface slope, and the texture, density, and

---

<sup>3</sup> "What Is Green Infrastructure?" *Home*. N.p., n.d. Web. 19 Jan. 2014. <[http://water.epa.gov/infrastructure/greeninfrastructure/gi\\_what.cfm](http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm)>.

<sup>4</sup> "Stormwater." *In New York City*. N.p., n.d. Web. 06 May 2014. <<http://www.nyc.gov/html/dep/html/stormwater/index.shtml>>.

permeability of the surface and subsurface soils.”<sup>5</sup> Other factors that affect storm water runoff may also include “the thickness and quality of the surface cover.”<sup>6</sup> During a heavy storm many of the catch basins placed under the streets of the City overflow with accumulated storm water and eventually the storm water will infiltrate in to combined NYC sewers. The problem here is not that the storm water makes its way in to the sewers the problem is that there is no control of the water after it enters the sewer. Impermeable surfaces allow the storm water to pick up all sorts of materials. Pollutants and contaminants including metals, oils, bacteria, and viruses are among the invisible culprits traveling through the veins of the city through stormwater. Like the villain of a romantic novel, impermeable surfaces are a major threat to water quality because they speed up the transfer of pollutants from the sewers in to the surrounding rivers, lakes, and even reservoirs. As a result of the higher volumes of storm water flowing above and under surface the chances of flooding because there really is no soil or basin to catch the water. In order to understand this concept and many of the reasons why green infrastructure is a great alternative to managing stormwater, it is necessary to understand the hydrologic cycle.

### **1.1 The Hydrologic Cycle**

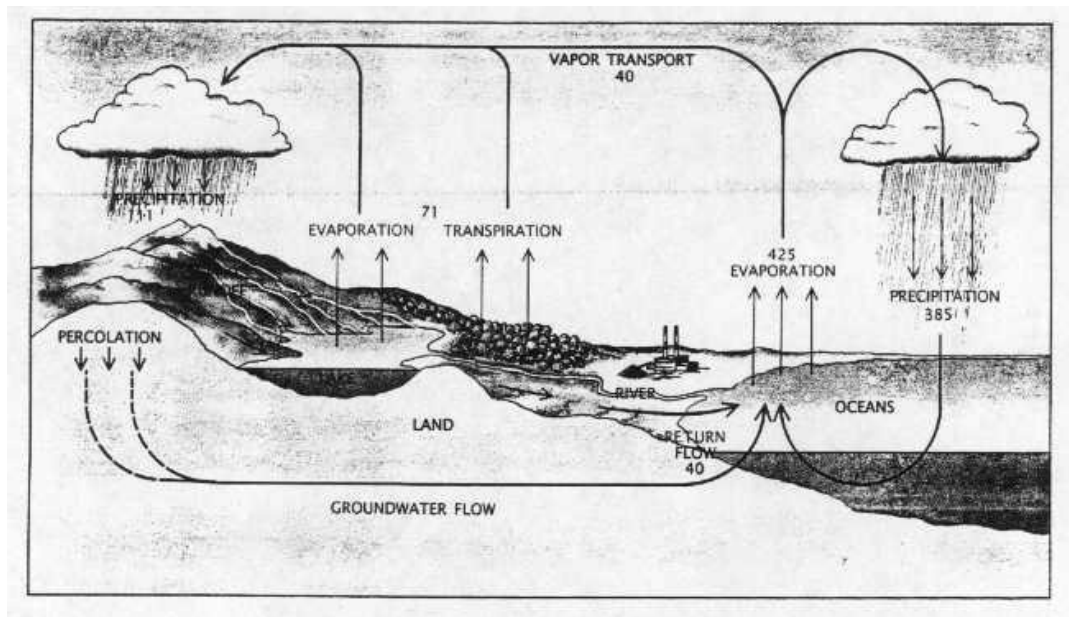
Simply put the hydrologic cycle explains how water moves around earth. Water moves in an endless loop from the atmosphere to earth and inevitably in to the ocean. Temporarily water remains stored in places like soil, streams, groundwater, and ice. At these points, water is available for use. Solar energy causes water to evaporate from the oceans and with enough wind the water is taken above land. When a suitable condition arrives the water will precipitate (rain

---

<sup>5</sup> Horner, Richard R., Earl Shaver, Joseph Skupien, Chris May, and Graeme Ridley. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*. 2nd ed. (Washington, DC: Terrene Institute, 2007), 17.

<sup>6</sup> Horner, Shaver, Skupien, May, and Ridley, *Fundamentals of Urban Runoff Management*, 17.

or snow) on to land. Some of the water that falls with precipitation will be soaked up by vegetation and some of the water that manages to reach the ground is absorbed by the soil. Infiltration is the absorption of water in to the soil. Water that manages to stay above ground and does not seep in to soil will eventually become surface runoff. The water that is not absorbed by vegetation and never manages to touch ground gets evaporated back in to the atmosphere.



**Figure 1: The Hydrologic Cycle (This diagram illustrates the movement of water)<sup>7</sup>**

As water moves through the hydrologic cycle it interchanges heat with the environment. In most cases this process should occur naturally however water is used as a coolant in industrial entities and the release of waste heat can completely alter the water bodies in which the water is being released. Aquatic organisms can feed off of the heat released or can be completely destroyed from the alteration in the water. A healthy water body will have an abundance of species living

<sup>7</sup> "Municipal Water Issues in Canada (BP-333E)." *Municipal Water Issues in Canada (BP-333E)*. N.p., n.d. Web. 06 May 2014. <<http://publications.gc.ca/Collection-R/LoPBdP/BP/bp333-e.htm>>.



and growing within the aquatic system. Aquatic organisms can be used as an indicator to see if how the environmental conditions of a lake for example have been altered. The hydrologic cycle provides us with the appropriate means of analyzing the degree to which man has impacted water resources through the manipulation of land and water bodies. Initially it might seem as a stretch to say that people can influence the way the hydrologic cycle works but taking in to account the changes seen in places like New York City over the years this seems quite feasible. Looking at the history behind bodies of water like the Henry Hudson River or the Bronx River it is quite clear that NYC has allowed its surrounding water bodies to become severely polluted and therefore making some of the water unusable and making aquatic environments unlivable for flora and fauna.

## **1.2 Wastewater**

Sanitary sewage or “waste water” is flushed down toilets in homes, schools, businesses, and even factories on a daily basis. Whether attending school or going to work New York City residents all produce waste water and this waste water flows from our homes or workplaces in to New York City’s sewer system. Before wastewater is released in to local waterways, the water must be treated. Waste water treatment plants are in charge of removing the pollutants found in waste water. In the same manner that wetlands and streams naturally purify water, waste water treatment plants use a combination of physical and biological processes to remove pollutants from the waste water. At the plant it can take over 6 hours to remove pollutants from waste water. The following quote describes the sewage system that NYC uses in order to process the waste water:

*“consists of: over 6,000 miles of sewer pipes; 140,000 sewer catch basins; 426 permitted outfalls for the discharge of combined sewer overflows (CSOs); 95 wastewater pumping stations*

*that transport wastewater to 14 wastewater treatment plants located throughout the 5 boroughs.*"<sup>8</sup>

Most of New York City's sewer system is combined, in other words NYC's sewer system is used to manage both wastewater flow and stormwater flow. The problem that occurs with the management of stormwater and waste water is that during heavy rain, the combined sewers in NYC may receive higher than usual flows of water. Thus, water treatment plants are not equipped to handle the amount of excess water flow. At times there may be up to twice as much water flow than the treatment center is designed to manage. When treatment plants are not able to handle the waste water and storm water, there will be a mix of "excess stormwater and untreated waste water"<sup>9</sup> that will discharge directly in to NYC's water ways at designated outfalls to prevent flooding upstream. Combined Sewer Overflows (CSO's) is therefore the discharges from the mix of excess stormwater and untreated waste water.

---

<sup>8</sup> "Reducing Combined Sewer Overflows in NYC – DEP's Long Term Control Plan." *Reducing Combined Sewer Overflows in NYC – DEP's Long Term Control Plan*. N.p., n.d. Web. 06 May 2014. <[http://www.nyc.gov/html/dep/html/cso\\_long\\_term\\_control\\_plan/index.shtml](http://www.nyc.gov/html/dep/html/cso_long_term_control_plan/index.shtml)>.

<sup>9</sup> Reducing Combined Sewer Overflows in NYC – DEP's Long Term Control Plan.

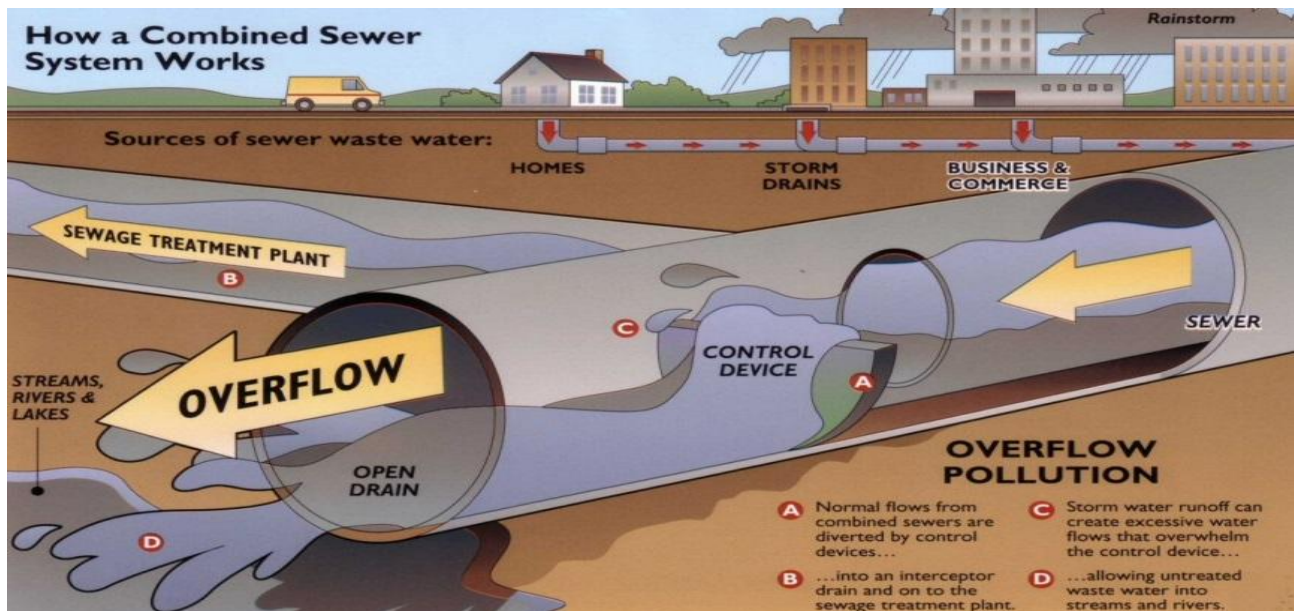
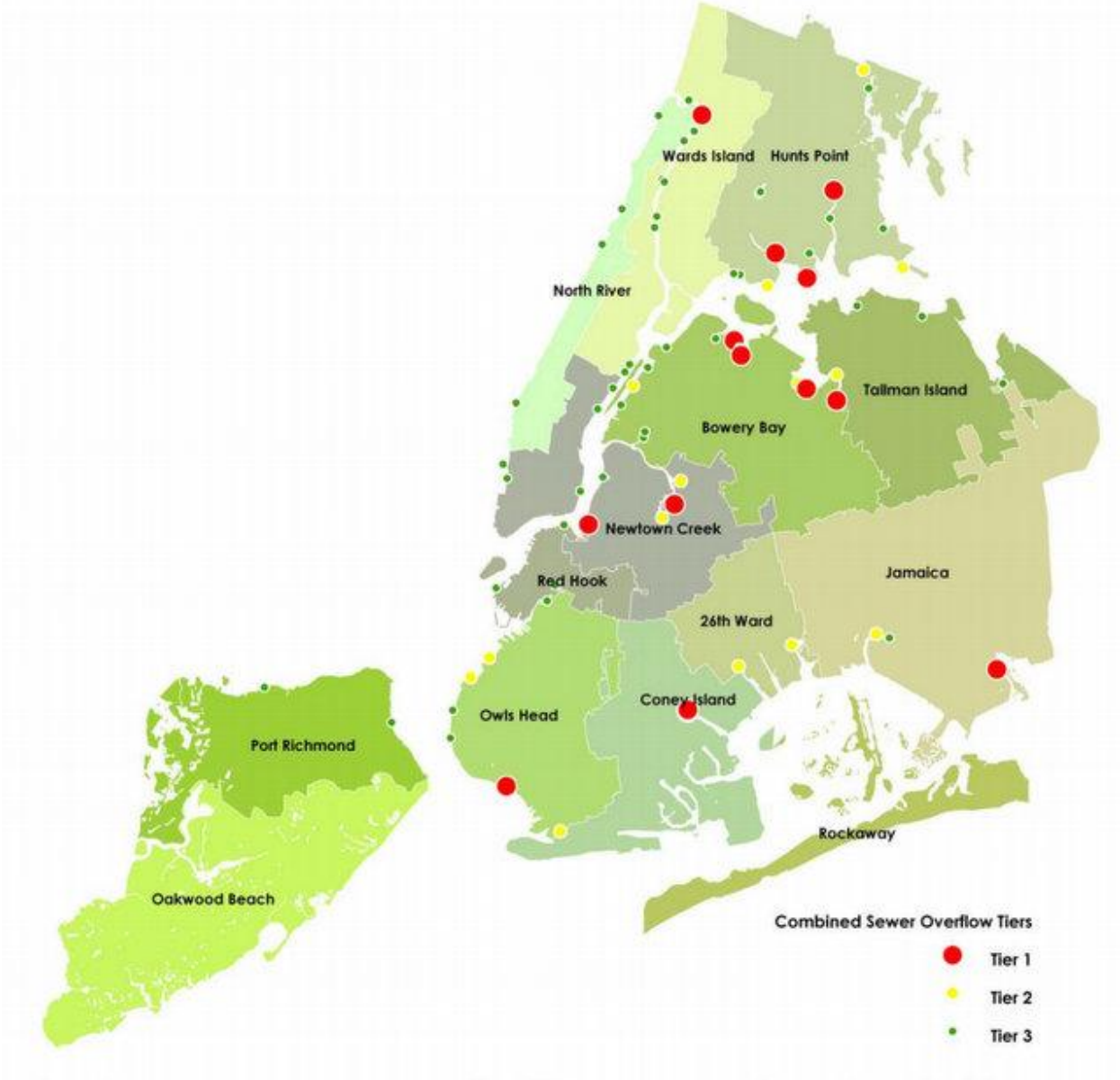


Figure 2: How a Combined Sewer System Works<sup>10</sup>

Combined Sewer Overflows are of immediate concern for New York City because they are threat to NYC surrounding water bodies. The map illustrated by Figure 2 displays the designated outfalls for CSO around the city. The outfall locations of CSO's for NYC include places like Hunts point in the Bronx. Combined Sewer Overflows can be identified as significant pollutant sources and the runoff from urban places like NYC can be “contaminated with organic matter, sediments, nutrients, heavy metals, pesticides, bacteria, and other toxic substances. [t]hese pollutants will eventually enter the adjacent environment in significant quantities.”<sup>11</sup>

<sup>10</sup> "Greening the ALCOSAN Wet Weather Plan | Reform Pittsburgh Now." *Reform Pittsburgh Now RSS*. Web. 06 May 2014.

<sup>11</sup> Yousef, Yousef A. *Urban Stormwater and Combined Sewer Overflow Impact on Receiving Water Bodies: Proceedings of the National Conference, Orlando, Florida November 26-28, 1979*. Cincinnati, OH: Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, 1980. Print.



**Figure 3: Map of CSO Outfalls along NYC's Waterfront<sup>12</sup>**

Some of the major water bodies that are home to New York City include the East River or the Hudson. Raw sewage is dumped in to these bodies of water solely because the City cannot figure out what to do with such large quantities of water. Figure 3 is a map of CSO outfall points

<sup>12</sup> "Combined Sewer Overflows (CSOs)." *Combined Sewer Overflows (CSOs)*. Department of Environmental Protection, Web. 06 May 2014.

along New York City's waterfront. This map is made available through the Department of Environmental Protection's website. The tiers color coded as green, red, and yellow dots represent different things. The green dots represent water treatment facilities and both the red and yellow dots represent CSO outfalls, the intensity in which the outfall is used for the discharge of CSO in to water bodies is represented by the difference in sizes of the dots. The red dot represents an outfall that is used frequently with a lot of potential for flooding and the yellow dot represents an outfall that is used but not in risk of flooding. In different parts of the city, residents might run in to signs that look like the one below in Figure 4.

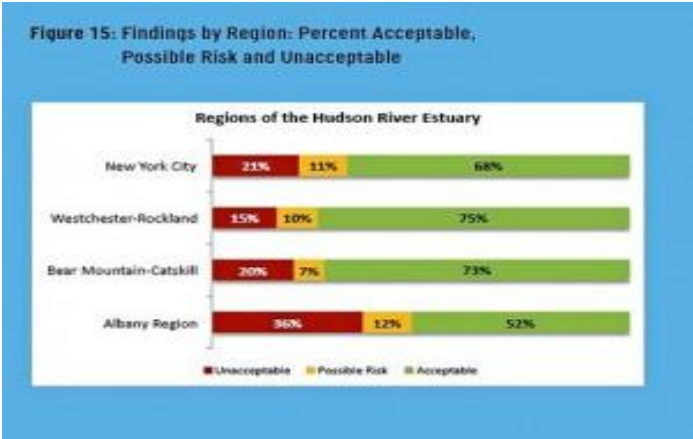


Figure 4: Caution Sign of Discharge Point<sup>13</sup>

<sup>13</sup> "Day 25." *Im Just Walkin*. Web. 06 May 2014.

**1.3 Victims of CSO's**

Though New York City may have some of the best quality water coming in from the Catskill/Delaware reservoirs, local waters are being infested with raw sewage. In fact according to “Riverkeeper’s” water quality report for the Hudson River “the majority of beach closings and advisories in the United States are due to high levels of sewage contamination.”<sup>14</sup> Upon sampling of the Hudson River’s water Riverkeeper’s found that 24% of their water quality samples from the Hudson River failed the Environmental Protection Agency’s guidelines for safe swimming. In contrast to the Hudson River’s results, water quality samples obtained from beaches nationwide only failed the EPA’s requirements by 7%. These numbers reflect some of the problems of water quality within New York City water bodies. Additionally, Riverkeeper’s data reflects that sewage contamination remains “localized near the source;” communities that are known to have frequent water contamination problems are advised to assess water quality before engaging in recreational activities such as swimming or fishing.



**Figure 5: Riverkeeper's Findings by Region<sup>15</sup>**

<sup>14</sup> "Hudson River Data." *Riverkeeper RSS*. Web. 06 May 2014. <<http://www.riverkeeper.org/water-quality/hudson-river/#table>>.

<sup>15</sup> "Hudson River Data." *Riverkeeper RSS*.

The Bronx River is another victim of combined sewage overflow and throughout history its waters have been polluted with contaminants from Yonkers, White Plains, Scarsdale, and Greenburgh. Bronx Borough President Ruben Diaz, Jr. said "the Bronx River is a jewel of our borough and for too long it was literally treated like a sewer."<sup>16</sup>

Like many of the water bodies in NYC, the Bronx River was used almost as a sewer for the disposal of waste from places outside of the City. Many New York City residents are unaware of

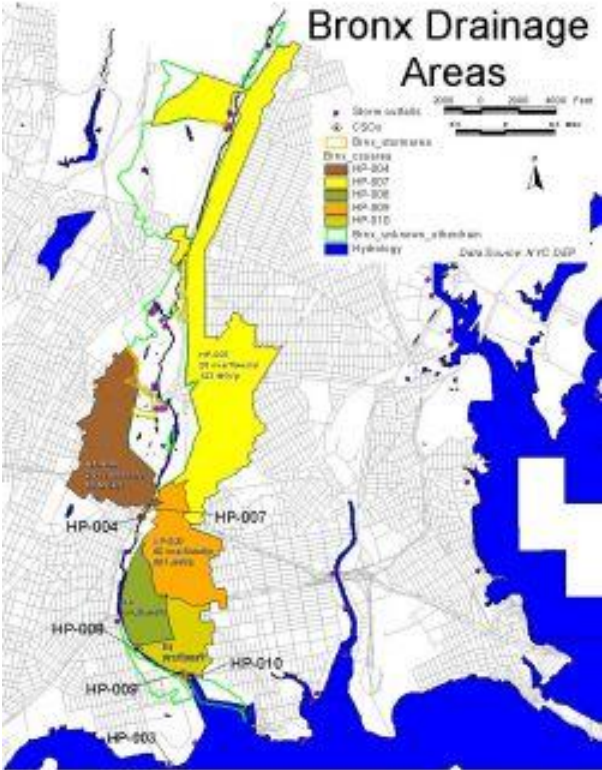


Figure 6: Map of Bronx Drainage Areas

all the problems the city has because of the disregard and lack of funding for projects that protect water bodies like the Bronx River. In 2009, Andrew Cuomo contributed \$1.8 million dollars in order to improve water quality and reduce pollution of the Bronx River. The funds were used to pay for 9 green infrastructure programs that would help reduce the amount of stormwater surging in to the Bronx River. Some of these projects focused on green roofs, storm water capture, storm water management, rainwater harvesting, riverbank stabilization and wetland restoration, pollution control, and etc. The *South Bronx Community Green Roof* project for example is administered by the "POINT" a non- profit organization and it features:

<sup>16</sup> "New York AG Pours \$1.8M into Bronx River Stormwater Upgrades." *New York AG Pours \$1.8M into Bronx River Stormwater Upgrades*. N.p., n.d. Web. 06 May 2014. <<http://www.ens-newswire.com/ens/aug2009/2009-08-28-092.asp>>.

*“an extensive green roof and smaller intensive green roof that will function as a demonstration area and outdoor classroom, the project will help reduce stormwater outfalls and improve water quality and river ecology along the Bronx River while helping to educate the community about low impact development strategies”<sup>17</sup>*

Not only can CSO’s affect the water bodies around NYC, they can also affect recreational spaces for the public. In order to address water contamination, New York City will need funding for project focused on green and gray infrastructure. Over the next 20 years, the Department of Environmental Conservation projects “the conservative cost estimate of repairing, replacing, and updating New York's municipal wastewater infrastructure is \$36.2 billion”<sup>18</sup> dollars. To date New York City has allocated approximately 1.8 billion dollars in funds in order to control CSO discharges. New York City has also committed to “spend an additional 1.6 billion dollars on grey infrastructure that is projected to reduce CSO discharges by approximately 8.4 billion gallons a year (from a baseline of 30 billion gallons a year).”<sup>19</sup> In order to further diminish the problem of CSO discharges the DEP has engaged within projects that involves the construction of a number of large combined sewer overflow retention tanks. Over time the DEP has developed infrastructure that “have increased DEP’s standardized CSO capture rate from about 30% in 1980 to over 72% today.”<sup>20</sup>

---

<sup>17</sup> "THE POINT's South Bronx Community Green Roof." *Test*. N.p., n.d. Web. 06 May 2014. <<http://thepoint.org/test.php>>.

<sup>18</sup> "Disclaimer." *Wastewater Infrastructure Needs of New York State Report*. N.p., n.d. Web. 06 May 2014. <<http://www.dec.ny.gov/chemical/42383.html>>.

<sup>19</sup> Reducing Combined Sewer Overflows in NYC – DEP’s Long Term Control Plan.

<sup>20</sup> “ ”



## **Chapter 2: New York City's Water System**

As of July 2013 New York City houses a population of approximately 8,405,837<sup>21</sup> residents. All 8,405,837 of the city's residents and an additional 1 million residents in Putnam, Westchester, Ulster, and Orange counties place demand on NYC agencies to provide immediate access to potable drinking water. In order to supply water to such a dense population, NYC agencies make use of an extensive watershed roughly "2,000 square-miles<sup>22</sup>" in the Catskill Mountains and the Hudson River Valley. New York City's watershed is split in to two reservoir systems "Catskill/Delaware watershed west of the Hudson River and the Croton watershed east of the Hudson."<sup>23</sup> NYC residents and county residents are supplied water from the reservoir systems north of the city; daily these residents are supplied with 1.4 billion gallons of water. One of the advantages of having NYC water supply system upstate is that 95% of water delivered in to the city from the watershed is gravity fed with a mere 5% needed to be pumped to maintain water pressure.

New York City's water network is comprised of 19 reservoirs and three controlled lakes that supply the Bronx, Brooklyn, Queens, Manhattan, and Staten Island boroughs of the city. New York City's Water Supply System (PWSID NY003493)<sup>24</sup> consists of three separate water supply locations which include the Catskill/ Delaware water supply, the Croton water supply and a ground water supply system infrequently used in the Queens borough. NYC agencies like the

---

<sup>21</sup> Population - New York City Department of City Planning." *Population - New York City Department of City Planning*. N.p., n.d. Web. 01 May 2014. <<http://www.nyc.gov/html/dcp/html/census/popcur.shtml>>.

<sup>22</sup> New York City 2013 Drinking Water Supply and Quality Report, 2013, 1.

<sup>23</sup> "New York City Watershed." *EPA*. Environmental Protection Agency, n.d. Web. 06 May 2014. <<http://www.epa.gov/region2/water/nycshed/>>.

<sup>24</sup> New York City's water system ID: *can be used to find out more information on EPA website*

Department of Environmental Protection (DEP) have adopted a series of preventive measures around NYC's watershed in order to protect the water quality of NYC. Most of the city's watershed conservation and green infrastructure emphasis has been to protect water quality because the city does not want to spend billions of dollars on water filtration plants. The Filtration Avoidance Determination given to New York City is perhaps the single most important catalyst in promoting green infrastructure throughout the City. In order to keep the Filtration Avoidance Determination, New York City has made sure to keep up with the demands of the Environmental Protection Agency. This means that New York City has been willing to preserve the water quality of the Catskill/ Delaware water supply by engaging with the communities surrounding the reservoirs and building up programs which do not only control the types of recreational activities surrounding the reservoirs yet they have also restricted farming. In order to continue to provide "unfiltered" water to NYC residents the DEP (lower cost than filtering the water) but have also agreed to construct and ultraviolet disinfection facility. The Hazen and Sawyer firm<sup>25</sup> of environmental engineers stated on their website that the EPA was worried of any potential illness outbreaks.

*"Coupled with increased vigilance over Cryptosporidium- and Giardia-related illness following outbreaks in other parts of the US and EPA's Long Term 2 Enhanced Surface Water Treatment Rule, prompted the New York City Department of Environmental Protection (NYCDEP) to initiate the design and construction of a 2,020-mgd Ultraviolet (UV) Disinfection Facility in Westchester County. Hazen and Sawyer, in joint venture, undertook pilot testing, planning, environmental assessment, design, permitting and construction services for the innovative Catskill-Delaware Ultraviolet Disinfection Facility."*<sup>26</sup>

---

<sup>25</sup> This firm has been contracted to build the Catskill Ultraviolet Disinfection Facility

<sup>26</sup> "Projects." *Catskill-Delaware Ultraviolet Disinfection Facility (2,020 Mgd)*. N.p., n.d. Web. 06 May 2014. <<http://www.hazenandsawyer.com/work/projects/catskill-delaware-uv-disinfection-facility/>>.

The firm concluded that the construction of the UV light disinfection facility coupled with a strong water source protection program would provide increased protection from bacteria and it would cost far less than the construction of a filtration plant.



**Figure 7 Catskill UV Treatment Plant<sup>27</sup>**

---

<sup>27</sup> "Catskill–Delaware Ultraviolet Water Treatment Facility, New York, United States of America." *Unit Three of the Delaware / Catskill UV Treatment Facility*. N.p., n.d. Web. 06 May 2014. <<http://www.water-technology.net/projects/-catskill-delaware-ultraviolet-water-treatment-facility/-catskill-delaware-ultraviolet-water-treatment-facility5.html>>.

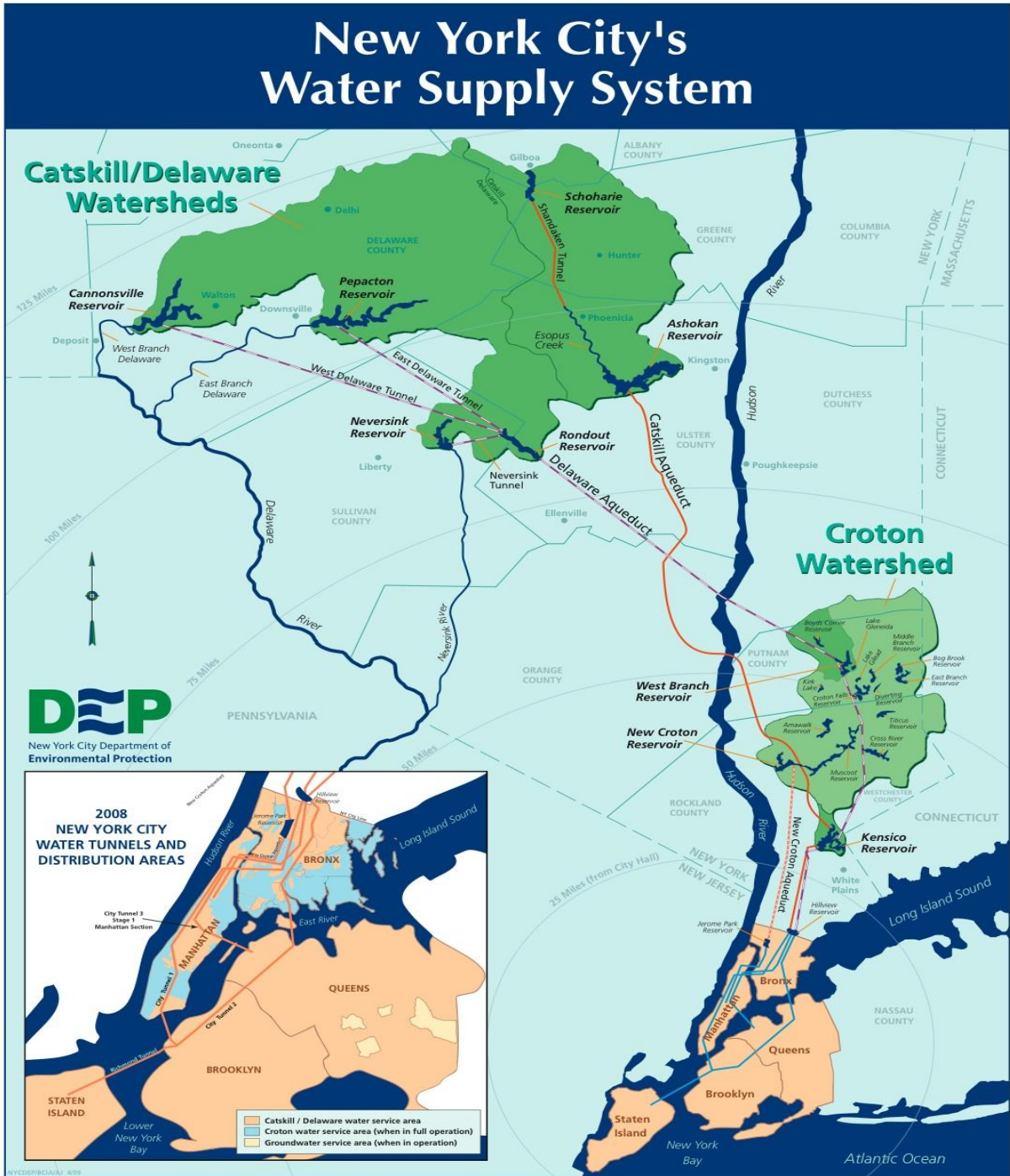


Figure 8: Map of New York City Watershed<sup>28</sup>.

<sup>28</sup> "New York City's Water Supply System Map." *New York City's Water Supply System*. Web. 06 May 2014. <[http://www.nyc.gov/html/dep/html/drinking\\_water/wsmaps\\_wide.shtml](http://www.nyc.gov/html/dep/html/drinking_water/wsmaps_wide.shtml)>.

## **2.1 The Catskill /Delaware Water Supply**

The Catskill/ Delaware water supply systems are located in “Delaware, Greene, Schoharie, Sullivan, and Ulster counties.”<sup>29</sup> The Catskill Water Supply System was completed in the year 1927 and the Delaware Water Supply system was completed in 1967. Combined the Catskill/ Delaware watersheds cover around 1,600 square miles. The drinking water quality of these reservoir locations is of high quality and as such this water is provided to NYC and county residents unfiltered. Historically, the Catskill and Delaware watersheds have fed up to 90% of all water supplied to NYC however last year the use of the Catskill/ Delaware watershed increased in order to cover the territories the Croton reservoirs supplied. Although the Croton water supply is the oldest source of water for the City the water from the Croton supply very often violates “the aesthetic for color.” The construction of a new water filtration plant in the Croton water supply location will allow the City to use the Croton supply in the future with less interruptions in service due to water quality problems. According to the “New York City 2013 Drinking Water Supply and Quality Report” released by NYC’s Department of Environmental Protection “100% of the City’s drinking water” was fed from the Catskill/ Delaware locations in 2013.

---

<sup>29</sup> New York City 2013 Drinking Water Supply and Quality Report, 2013

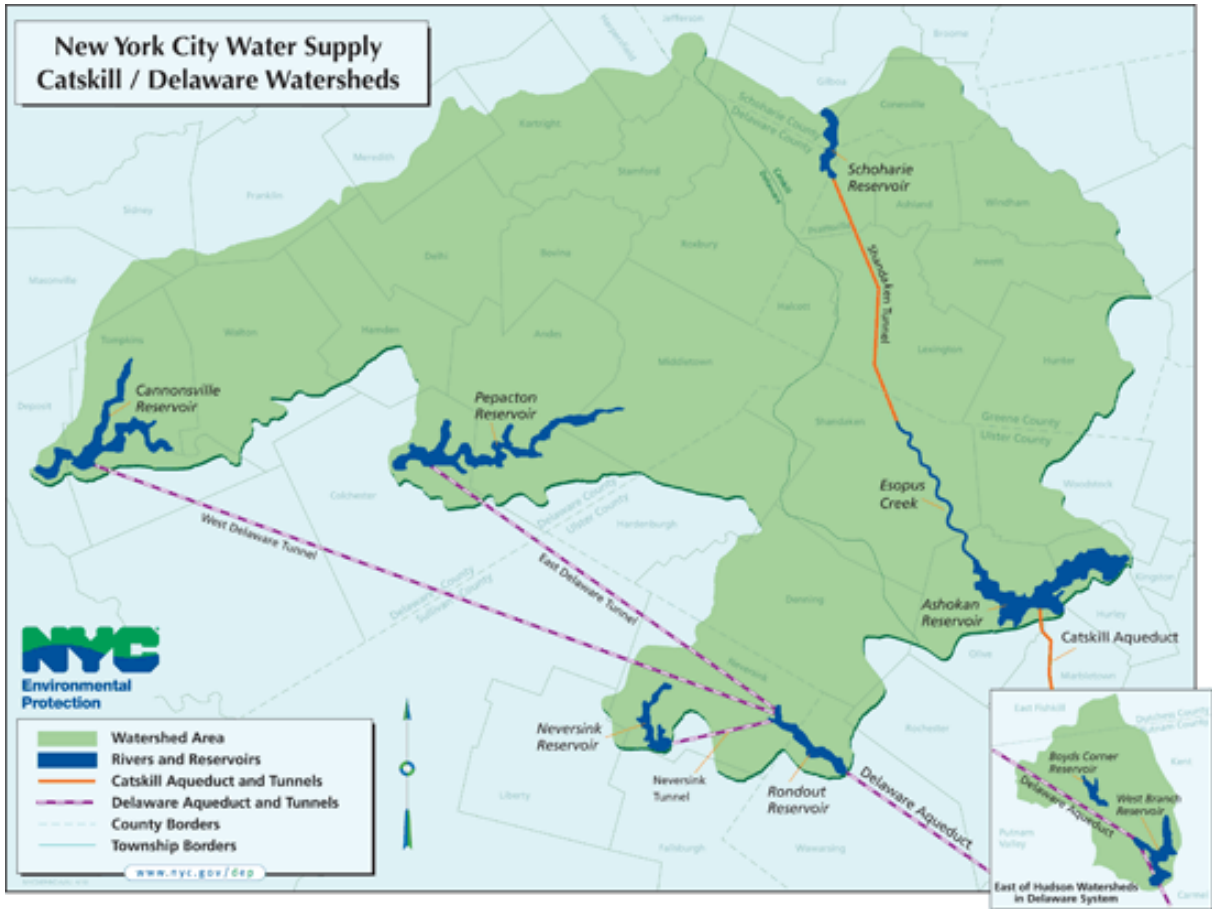


Figure 9: Catskill / Delaware Watershed Map<sup>30</sup>

<sup>30</sup> "New York City's Water Supply System Map." *New York City's Water Supply System*. Web. 06 May 2014. <[http://www.nyc.gov/html/dep/html/drinking\\_water/wsmaps\\_wide.shtml](http://www.nyc.gov/html/dep/html/drinking_water/wsmaps_wide.shtml)>.

## 2.2 The Croton Water Supply

The Croton water supply is the city's original upstate water supply source and this location has over 10 reservoir basins in the counties of Dutchess, Putnam, and Westchester. During the year of 2013 the Croton water supply was not used for the distribution of water in NYC. The "Old Croton Aqueduct" was NYC's first water supply system, it was completed by 1842 and it provided thousands of NYC residents at the time with water. According to the New York State office of Parks, Recreation, and Historic Preservation the Croton Aqueduct was:

*Built to meet the city's needs for 100 years, its capacity was soon exceeded by the spiraling population growth to which is contributed. The New Croton Aqueduct, triple the size, was started in 1885 a few miles to the east and began service in 1890. The Old Aqueduct supplied decreasing amounts of water until 1955. (The northernmost portion reopened in 1989 and continues to supply water to the Town of Ossining.<sup>31</sup>)*

The Croton Water Filtration Plant which will treat Croton water is known to be "the largest single construction project in New York's history"<sup>32</sup> with an estimated cost of 1.6 billion dollars to construct. Despite the many times that the City tried to postpone the construction of the plant, it was forced in to doing it through a lawsuit on behalf of the EPA who required that the Croton water supply source be filtered on account of the many shutdowns the supply system had over the years due to turbidity test failures. Building the plant was a challenge for the City because community residents opposed the building of the water filtration plant and New York State also did not want to allow the City to build the plant.

---

<sup>31</sup> *Old Croton Aqueduct State Historic Park History- NYS Parks, Recreation & Historic Preservation.* N.p., n.d. Web. 06 May 2014. <<http://nysparks.com/parks/96/history.aspx>>.

<sup>32</sup> "Croton Water Filtration Plant, United States of America." *Croton Water Filtration Plant.* N.p., n.d. Web. 06 May 2014. <<http://www.water-technology.net/projects/crotonfiltration/>>.



Figure 10: Map of Croton Watershed<sup>33</sup>

<sup>33</sup> "Croton Watershed Map." *Croton Watershed Map*. N.p., n.d. Web. 06 May 2014. <[http://www.nyc.gov/html/dep/html/dep\\_projects/croton\\_wide.shtml](http://www.nyc.gov/html/dep/html/dep_projects/croton_wide.shtml)>.



### **2.3 Filtration Avoidance Determination & Surface Water Treatment Rule**

As a result of the 1974 Safe Drinking Water Act (SDWA), the Environmental Protection Agency (EPA) was given authorization to regulate drinking water within the United States. The most significant changes brought forth by the SDWA occurred later when the 1986 Amendments required the EPA to set maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs).<sup>34</sup> The EPA was “to establish regulations, require disinfection of all public water supplies, specify filtration requirements for nearly all water systems that draw their water from surface sources, and develop additional programs to protect ground water supplies.”<sup>35</sup> Three years after the 1986 Amendments came in to play the 1989 Surface Water Treatment Rule required that most groundwater and surface water under “direct influence” of Subpart H systems<sup>36</sup> to remove microbial contaminants through filtration. The 1989 Surface Water Treatment Rule set maximum contaminant level goals for contaminants such as *Legionella* and *Giardia lamblia* due to the health risks associated from the exposure of these types of contaminants. The bacterium *Legionella pneumophila* is found in both potable and non-potable water systems. Legionella are “natural inhabitants of water and can be detected in rivers, lakes, and streams.”<sup>37</sup> Upon contact with Legionella hosts can contract a severe and potentially lethal form of pneumonia. *Giardia lamblia* is a parasite that causes “giardiasis” a diarrheal illness. *Giardia* can be found in soil and food and water contaminated with fecal matter from humans and

---

<sup>34</sup> United States. Environmental Protection Agency. Office of Water. *Surface Water Treatment Rules: What Do They Mean to You?*. N.p.: n.p., 2011. Web. 6 May 2014. 1. <<http://water.epa.gov/lawsregs/rulesregs/sdwa/swtr/upload/SWTRPlainEnglishGuideFinal.pdf>>.

<sup>35</sup> Environmental Protection Agency. Surface Water Treatment Rules, 2011, 1.

<sup>36</sup> Subpart H systems are public water systems using surface water or ground water under direct influence of surface water as a source that are subject to the requirements of Subpart H of 40 CFR Part 141 (40 CFR 141.3).

<sup>37</sup> "Legionella.org." *Water Sources*. N.p., n.d. Web. 06 May 2014. <<http://legionella.org/about-the-disease/what-is-legionnaires-disease/water-sources/>>.

animals whom already have been infected. Water is the most common form of transmission for the parasite and is therefore needed to be regulated in drinking water. In order to measure the performance of filtration systems, the 1989 Surface Water Treatment rule uses turbidity.

*Turbidity* is simply a measure of the clarity of liquids.

In order to qualify for filtration avoidance under the Surface Water Treatment Rule the water system “must meet source water quality limits for coliform and turbidity,”<sup>38</sup> the water system cannot be the source of waterborne disease outbreak, and it needs to meet “coliform and trihalomethane maximum contaminant levels”<sup>39</sup>. Filtration avoidance also implicates that disinfectant residual levels and disinfection capabilities must also be maintained. A watershed control program has to be implemented in order to minimize the microbial contamination of the source water. The watershed control program must “identify, monitor, and control manmade and naturally occurring activities” that may become a potential harm for water quality. On January 1993 and December 1993, the EPA determined that New York City met the criteria for filtration avoidance. The Filtration Avoidance Determination (FAD) given to NYC in 1993 set a number of 150 conditions that were directly linked to the protection of the city’s watershed and adequate monitoring of the source. Despite the Catskill/ Delaware system qualifying for the FAD New York City faced many challenges in implementing the parameters set by the conditions of the FAD. The Croton water supply system unlike the Catskill/ Delaware system did not meet the conditions for the FAD. The Surface Water Treatment Rule and the New York State Sanitary Code requires New York City to filter water from the Croton system. The New York State Department of Health (NYSDOH) and the City made a stipulation agreement for the filtration of

---

<sup>38</sup> "Filtration Avoidance." *EPA*. Environmental Protection Agency, n.d. Web. 06 May 2014. <<http://www.epa.gov/region2/water/nycshed/filtad.htm>>.

<sup>39</sup> "Filtration Avoidance." *EPA*. Environmental Protection Agency, 06 May 2014.

the water in the Croton supply in 1992. Then in 1993 the EPA and the NYS DOH sought the intervention of court in order to force the City in to building a water filtration facility

The City was not able to obtain the approval of revised watershed regulations from New York State and the land acquisitions needed in order to adequately monitor the activity around the watershed. In addition to not being able to upgrade waste water treatment plants outside of New York City boundaries; updating the waste water treatment plants were necessary in order to protect the watershed from point discharge of contaminants. In 1996 the NYC's FAD was scheduled for evaluation by the EPA and inevitably the EPA determined that critical watershed protection activities set by the Surface Water Treatment Rule were not being satisfied by NYC. Due to the lack of proper regulation the Environmental Protection Agency could not secure that NYC was equipped to handle all of the conditions set by the FAD for the Catskill/ Delaware water systems. In order to resolve the issues related to the Filtration Avoidance Determination, the EPA, the City of New York, New York State, and communities surrounding the watershed met to negotiate. As a resolution to months of negotiations, the above mentioned parties were able to enter the NYC Watershed Memorandum of Agreement. The agreement set forth land acquisition requirements, placed in to motion stricter watershed regulations for the City and it required NYC to upgrade all wastewater treatment plants included within the scope of the watershed. From this agreement there city launched watershed partnership programs.

With the NYC Watershed Memorandum Agreement set in to place the EPA issued New York City a five-year Filtration Avoidance Determination, since then New York City has continued to push for short term and long term watershed protection programs that will allow to keep intact the FAD. In 2006 the Department of Environmental Protection released a "Long-Term Watershed Protection Program" which set up milestone commitments for the City. The

proposed objectives of the 2006 Long-Term Watershed Protection Program include the following 1. Compliance with the SWTR requirements (monthly sampling of source water) 2. Enhance core environmental infrastructure in the west of the Hudson watershed (septic systems, wastewater treatment plants, and storm water controls)<sup>40</sup> and 3. Rehabilitate and replace septic tanks in the watersheds. The EPA agreed to allow New York City to not filter its water from the Catskill/ Delaware water supply as long as the city could set aside around 300 million dollars in order to acquire land around the water supply sources. This would afford the City on spending around 8 billion dollars to construct a water filtration plant in the Catskill/ Delaware system.

---

<sup>40</sup> "New York City's Revised Long-Term Watershed Protection Program in Support of the Filtration Avoidance Determination for the Catskill and Delaware System." *NYC's Revised Long-Term Watershed Protection Program in Support of the FAD for the Catskill and Dela.* N.p., n.d. Web. 06 May 2014.  
<[http://www.nyc.gov/html/dep/html/environmental\\_reviews/watershed\\_prot\\_plan\\_fad\\_update.shtml](http://www.nyc.gov/html/dep/html/environmental_reviews/watershed_prot_plan_fad_update.shtml)>.

### **Chapter 3: plaNYC & The Green Infrastructure Plan**

In 2007 Mayor Michael R. Bloomberg released a comprehensive sustainability plan in order to create a greener New York. The sustainability plan Mayor Bloomberg has enacted is called “plaNYC” and it is a roadmap to fulfill 10 objectives. The objectives of plaNYC are the following 1) create enough housing for a growing population 2) ensure that all New Yorkers have parks within a 10-minute walk 3) clean up contaminated land in New York City 4) develop water network back-up systems 5) Open 90% of our waterways and protect natural areas 6) improve travel times by adding transit capacity for millions 7) achieve “state of good repair” on our transportation system 8) upgrade our energy infrastructure to provide clean energy 9) achieve the cleanest air of any big city in America 10) reduce global warming emissions by 30%. PlaNYC was made as an agenda to address a growing population, aging infrastructure, and a changing climate.



**Figure 11: Mayor Bloomberg Announcing plaNYC**

Within a time span of four years the plaNYC was able to reduce greenhouse gas emissions in the city by 13 percent compared to 2005 levels. Setting up goals like reducing GHG emissions by 30% by 2030 (compared to 2005 levels) will benefit the city and the growing population expected to hit 9 million people. Most importantly what is born out of plaNYC is a new concern for the treatment of storm water in various city agencies besides the DEP. PlaNYC made the city require more green parking lots along with incentivizing New York City residents to build green roofs. The City was also motivated to build more Bluebelts and Greenstreets. From plaNYC

there was born an Inter-agency Best Management Practices Task force which concluded that the implementation of green infrastructure around the city was actually feasible and that it would be more cost effective than having to fund large scale grey infrastructure projects.

### **3.1 The Green Infrastructure Plan**

In 2010 the Green Infrastructure Plan was launched by the cooperation of the Mayor's Office, the DEP, the Department of Transportation (DOT), the Department of Parks and Recreation (DPR), the Department of Design and Construction (DDC), the Department of City Planning (DCP), the Department of Education (DOE), the Department of Sanitation (DSNY), the Department of Citywide Administrative Services (DCAS), the Department of Housing and Preservation and Development (HPD), the New York City Economic Development Corporation (EDC), and the New York City Housing Authority (NYCHA). Though the list of collaborators is extensive, the involvements of all the City agencies mentioned were all necessary for the successful application of green infrastructure methods around NYC. The Green Infrastructure program aims to integrate green infrastructure such as bio-swales and to make investments on a smaller scale for grey infrastructure around NYC.

The 2010 Green Infrastructure Plan had 5 key goals that it wanted to achieve and these goals are 1) to build cost effective gray infrastructure<sup>41</sup> 2) optimize the existing water system 3) Control runoff from 10% of impervious surfaces through green infrastructure 4) institutionalize adaptive management, model impacts, measure CSO's, and monitor water quality. 5) Engage and enlist stakeholders. In order to achieve the five goals the city needed to take a series of steps which will

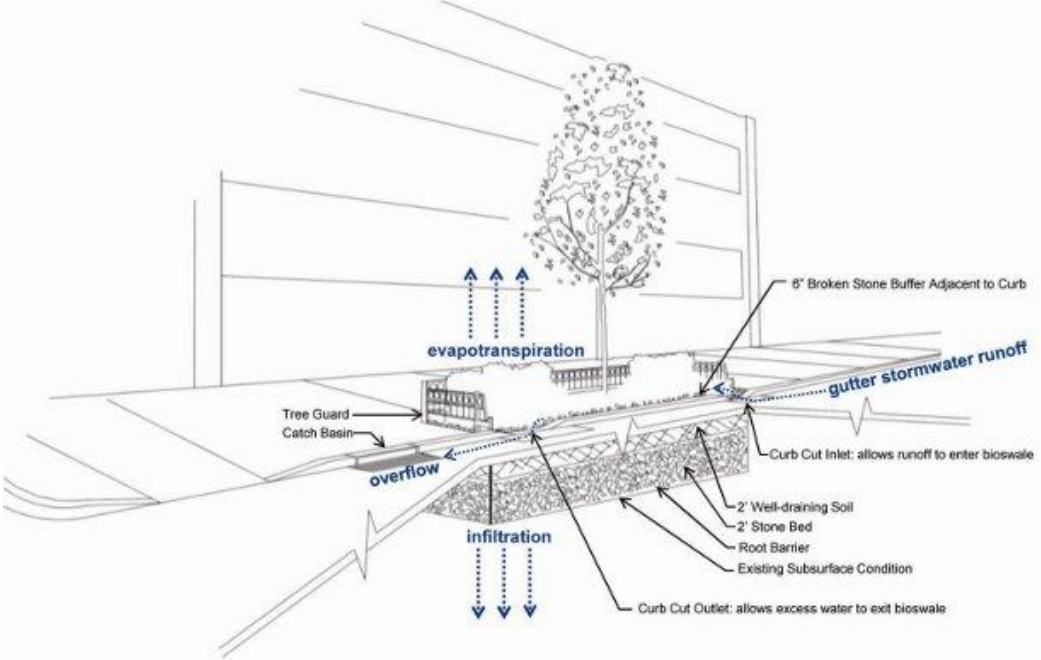
---

<sup>41</sup> Gray infrastructure is the traditional form of storm water and waste water management through sewers and pipes.

be prolonged over a long period of time. The costs for capturing 10% of runoff from impervious surfaces alone would cost the City approximately 1.5 billion dollars however this amount proves to be significantly lower than investing in gray infrastructure to address storm water management at a cost of \$3.9 billion dollars. Green infrastructure costs are can vary depending on the site or the type of green infrastructure installed. But it can go for \$1 dollar to \$2 dollars per gallon of CSO avoided. While it might appear to be quite expensive, the truth is that compared to gray infrastructure the costs are lower. After 20 years the DEP estimates that New Yorkers could receive as much as \$418 million dollars in additional benefits from green infrastructure. Tunnels and tanks stay with little use until there is a storm, but the construction of this type of infrastructure also takes a lot of time; time which can be used to find where to plant the next tree with green infrastructure. So green infrastructure is more time and cost effective than investing in gray infrastructure and NYC is well aware that the investments placed in green infrastructure will not only improve water quality it will also reduce CSO discharge, increase air quality, and beautify NYC neighborhoods on a larger scale.

**3.2 Green Infrastructure & Recognizing the Most Suitable Type**

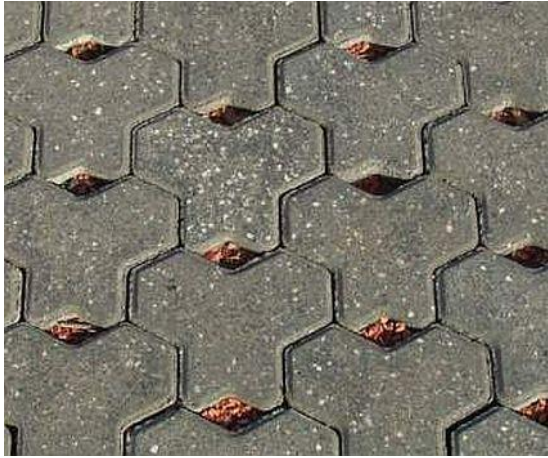
The different types of Green Infrastructure include Pervious surfaces (green space), Permeable pavements, Rain barrels and cisterns, Rain gardens, Vegetated swales, Vegetated sidewalk swales (Bioswales) , Pocket wetlands, Infiltration planters, Trees and tree boxes, Vegetated median strips, Green roofs, and Blue roofs. *Bioswales*, are liner sloped water retention areas which capture water. Plants that are placed in to bioswales slow the flow of water and they allow sediments to settle while the roots of the plants absorb pollutants. Bioswales allow water to infiltrate the ground over a period of atleast 24 hours. They can also be used to prevent soil erosion. These types of retention areas are commonly found in larger sites but they are now being seen all throughout New York City blocks.



**Figure 22: Bioswale NYC design<sup>42</sup>**

<sup>42</sup> "SubscribeGreen Infrastructure." *Green Infrastructure*. N.p., n.d. Web. 06 May 2014.

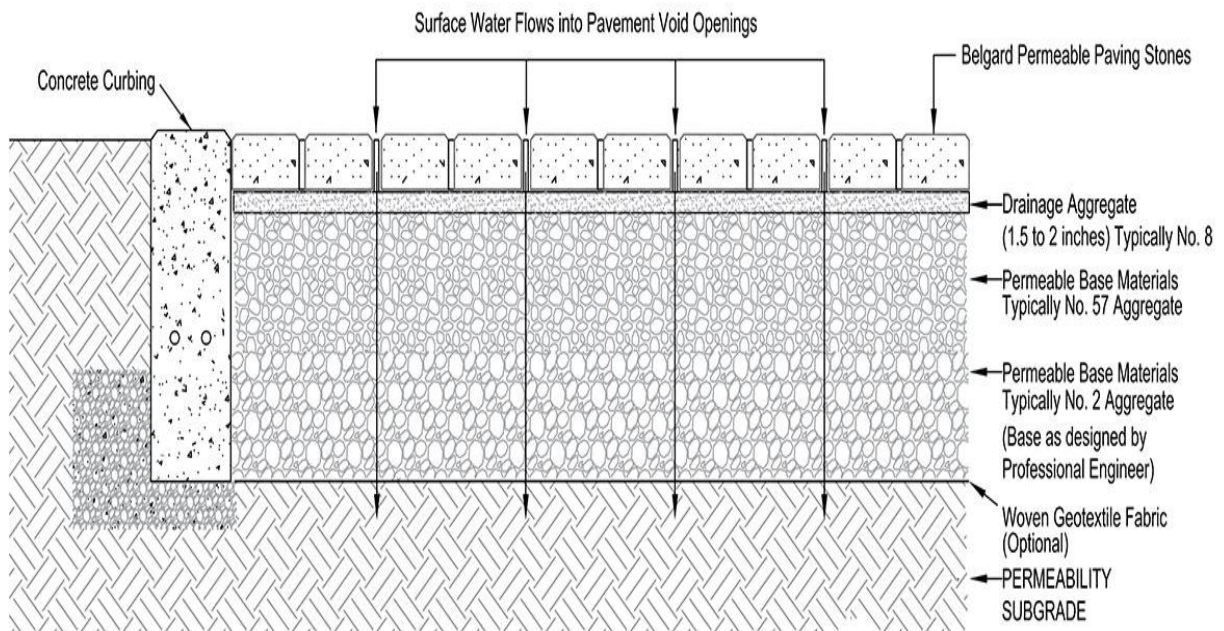




**Figure13: Example of a Permeable Paver**

Permeable Pavers- Permeable pavements are designed to allow the infiltration of stormwater from above the surface and in to soil. The soil naturally filters the stormwater and pollutants are therefore removed. Permeable pavers include permeable asphalt and permeable concrete which naturally reduce the amount of runoff found in urban landscapes. In contrast to impervious surfaces like

regular concrete which does not allow the infiltration of water and actually leads to the collection of pollutants by stormwater above ground; permeable pavements are a nice alternative for places with few foot or automobile traffic.



**Figure14: How Permeable Pavers Work<sup>43</sup>**

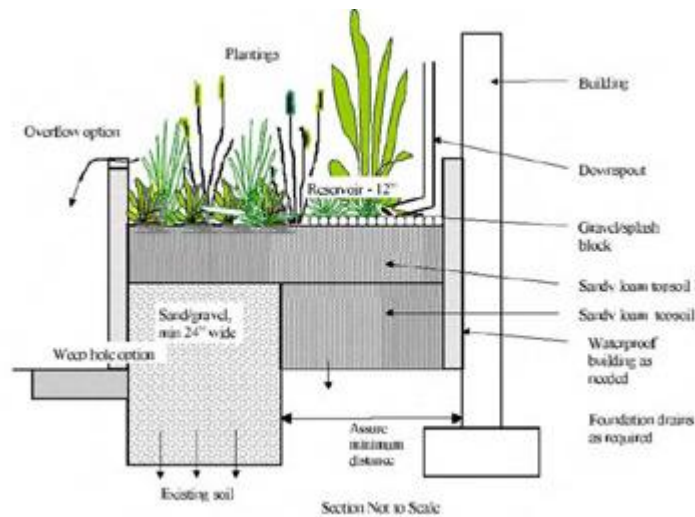
<sup>43</sup> "Drainstone™." *Pavers, Northeast*. Web. 07 May 2014.



Rain gardens are a form of bioretention areas, these are usually basins that receive and hold stormwater runoff. Rain gardens like

**Figure15: Rain garden (Colleen)**

bioswales are designed to hold stormwater runoff then slowly release it in to the groundwater while filtering the water. Plants that are placed in rain gardens are natural filters as they are able to absorb pollutants and become an asset for wildlife habitat. Rain gardens usually have perennials and grasses that can handle extremes in weather such as drought or excessive rainfall. Rain gardens can range in size from as small as 3ft. to as big as 400 ft. and are usually planted in



shallow depressions.

**Figure 16 : The (DEC)'s Mini-Rain garden diagram<sup>44</sup>**

<sup>44</sup> "Disclaimer." *Create a Rain Garden*. Web. 06 May 2014.

A Green roof is simply a layer of vegetation that is grown on the roof of a building. Green roofs hold rain water and they also help to control the temperature of buildings by removing heat from the air through evapotranspiration. In order, for a green roof to work it requires a flat surface and usually it is composed of grasses. PlaNYC really encouraged NYC residents to build green roofs by providing tax abatement for those who chose to build green roofs:

*The NYC Green Roof Tax Abatement Offers building owners a property tax abatement equal to \$4.50 / square foot up to \$100,000 for green roof installations that cover at least 50% of a roof. Applications must be submitted by March 15th for a tax abatement to be applied to the current fiscal year's property taxes.*

The incentives given on behalf of the city for green roofs represented a great opportunity for displaced farmers living in the City to generate some income without all the costs of the City.

The implementation of any of the mentioned green infrastructure developments around the city is not difficult. The problem is that in order to install any type of green infrastructure in to an area, there must be extensive site analysis done to see which system is more effective.



**Figure 17: Green Roof NYC parks**

### 3.3 Greenstreets Program NYC



**Figure 18: Greenstreets**

One of the greatest things about living within a city like NYC is being able to witness to all the diverse communities found at the end of each city block. Walking around the five boroughs of the city there is an observable difference in landscape, buildings, and even people inhabiting the different parts of the City. Usually what is forgotten by NYC residents is that street trees and other types of vegetation in NYC are also part of the communities that compose New York City's culture. Trees and plants are living and breathing components of NYC and over the years this fact has been ignored by many. Street trees serve as supplement to open space by working as windbreaks; in the summer trees provide cooling shade and during the winter trees provide protection from cold temperatures. Trees also help beautify neighborhoods; they can completely change the ways people feel about their communities and they are natural buffers for water. Under the right conditions vegetation can be used as forms of microclimate control and most importantly vegetation can hold storm water and prevent flooding. When Mayor Bloomberg proposed plaNYC for a more sustainable New York he committed NYC to building 80 new Greenstreets every year.

The Greenstreets program was first launched in 1996 and it was used as a way to convert islands of unused road beds in to micro parks. Traffic triangles and medians are usually the site used to implant these small scale parks. Other sites used for the Greenstreets program include sidewalks that are larger enough to make space for curbside plantings. Though the program has been held in place since before the year 2000, it was not until the release of plaNYC in 2007 and the funding of \$15 million dollars that the program that it has really gained any traction. By March 2010 the Greenstreets program grew to have around 2,470 sites around the city. Greenstreets “enrich city streets by adding lushness and color to the concrete and asphalt hardscape. [t]hese roadside gardens add natural beauty to otherwise barren spaces.”<sup>45</sup>

A single Greenstreet site can hold as much as 55,000 gallons of water. By 2010 the Greenstreets program could therefore hold around 135 million gallons of storm water a year. By replacing the paved roadbeds found around NYC with vegetation or pervious ground cover, Greenstreets increase the amount of permeable surface area around the city that captures stormwater.



**Figure 19: Street view of Greenstreets**

<sup>45</sup> *Best Practice: Greenstreets: Greening Roadways*. Rep. New York City Global Partners, Mar. 2010. Web. 06 May 2014.

In order to make the Greenstreets program a success, the Department of Parks and Recreation (DPR) needs the continuous cooperation of the New York City Department of Transportation (DOT) since most of the roadbeds used for the green streets belong to the DOT. The types of vegetation chosen to be implanted in New York City must be able to survive all of the extremes in climate of NYC. New York City is a cool-temperate region and this means that there are varying temperatures that range from very hot in the summer to cold in the winter. During the spring and the fall seasons, there is expected to be moderate weather. In 2014 the weather has gone from one extreme to the next within a day. With such varying temperature, the plants and trees that are found within NYC streets need to resist all types of conditions. The vegetation selected by landscape architects in the DPR are specifically chosen to be able to withstand the extremes in temperature as well as other factors including vandalism, pollution, and human foot traffic. In an urban area like New York City a multitude of people can present a potential risk to vegetation because people will trample and step over the plants found in greenstreets. The designs of the greenstreets will usually have some form of a barrier to protect the plants from human contact. In Figure 19 there is a noticeable “tree guard” placed to create a barrier between the people walking on the sidewalk. A great example of the benefits from installing green infrastructure through the Greenstreets program is the change seen on Church Ave in Brooklyn, NY. Where there once was a vast asphalt triangle there is now an active storm water capture site which has been converted in to an ornamental planting bed and bioretention planting bed. The site now disconnects 6,825 square feet of impervious area from the combined sewer system.

Another site located in the Bronx between Pelham Parkway and Stillwell Avenue has been transformed to a Greenstreet site now able to capture runoff from 12,320 square feet of catchment area.

## **Conclusion**

The sustainable future of New York City relies on the further development of green infrastructure within its five boroughs. PlaNYC helped initiate the conversion of New York City into a greener city. Though within the next 15 years there is an expected rise in population if New York City manages to continue to motivate private shareholders to install green infrastructure like green roofs, rain gardens, and bioswales all throughout NYC people will be able to enjoy better water quality and enjoy more spaces for recreational activity. Water bodies like the Bronx River or the Hudson River shouldn't be so greatly damaged by CSO's. The communities surrounding these places will enjoy the sight of more vegetation and be less afraid of flooding. New York City residents will be able to go to beaches around the city more frequently knowing that the water is frequently being tested for quality. The Filtration Avoidance Determination provided to NYC's tap water (from the Catskill/ Delaware water supply) is the most significant event in NYC's recent history to first spark interest in the development of green infrastructure for the city. Without the EPA regulations that aggressively target pollution sources the Department of Environmental Protection would not care much for the water quality problems in New York City. The damage of urban runoff and the mismanagement of stormwater are a large threat to New York City Residents and if it weren't for all the added costs of investing in gray infrastructure many of the city agencies would not have bothered with using green infrastructure to manage storm water. The Filtration Avoidance Determination in other words required that New York City take an interest in green infrastructure unless they were willing to pay the costs of installing more gray infrastructure such as the 8 billion dollar water filtration plant or new sewer systems to replace the existing ones.

## **Bibliography**

1. "Croton Water Filtration Plant, United States of America." *Croton Water Filtration Plant*. N.p., n.d. Web. 06 May 2014.  
<<http://www.water-technology.net/projects/crotonfiltration/>>.
2. "Filtration Avoidance." *EPA*. Environmental Protection Agency, n.d. Web. 06 May 2014.
3. Horner, Richard R., Earl Shaver, Joseph Skupien, Chris May, and Graeme Ridley. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*. 2nd ed. (Washington, DC: Terrene Institute, 2007)
4. "Hudson River Data." *Riverkeeper RSS*. Web. 06 May 2014.  
<<http://www.riverkeeper.org/water-quality/hudson-river/#table>>.
5. "Legionella.org." *Water Sources*. N.p., n.d. Web. 06 May 2014. <<http://legionella.org/about-the-disease/what-is-legionnaires-disease/water-sources/>>.
6. New York. *PlaNYC: A Greener, Greater New York*. By Michael Bloomberg. New York: City of New York, 2007. Print.
7. "New York AG Pours \$1.8M into Bronx River Stormwater Upgrades." *New York AG Pours \$1.8M into Bronx River Stormwater Upgrades*. N.p., n.d. Web. 06 May 2014.  
<<http://www.ens-newswire.com/ens/aug2009/2009-08-28-092.asp>>.
8. "New York City's Revised Long-Term Watershed Protection Program in Support of the Filtration Avoidance Determination for the Catskill and Delaware System." *NYC's Revised Long-Term Watershed Protection Program in Support of the FAD for the Catskill and Dela*. N.p., n.d. Web. 06 May 2014.
9. *New York City Drinking Water Quality Control: 2013 Annual Report*. Valhalla, NY: New York City Dept. of Environmental Protection, Bureau of Water Supply & Wastewater Collection, 2013. Print.
10. *Old Croton Aqueduct State Historic Park History- NYS Parks, Recreation & Historic Preservation*. N.p., n.d. Web. 06 May 2014.  
<<http://nysparks.com/parks/96/history.aspx>>.



11. "Projects." *Catskill-Delaware Ultraviolet Disinfection Facility (2,020 Mgd)*. N.p., n.d. Web. 06 May 2014.

<<http://www.hazenandsawyer.com/work/projects/catskill-delaware-uv-disinfection-facility/>>.

12. "Reducing Combined Sewer Overflows in NYC – DEP's Long Term Control Plan." *Reducing Combined Sewer Overflows in NYC – DEP's Long Term Control Plan*. N.p., n.d. Web. 06

13. "Stormwater." *In New York City*. N.p., n.d. Web. 06 May 2014.

<<http://www.nyc.gov/html/dep/html/stormwater/index.shtml>>.

14. *Wastewater Infrastructure Needs of New York State Report*. N.p., n.d. Web. 06 May 2014.

<<http://www.dec.ny.gov/chemical/42383.html>>.

15. "What Is Green Infrastructure?" *Home*. N.p., n.d. Web. 19 Jan. 2014.

<[http://water.epa.gov/infrastructure/greeninfrastructure/gi\\_what.cfm](http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm)>.

16. Yousef, Yousef A. *Urban Stormwater and Combined Sewer Overflow Impact on Receiving Water Bodies: Proceedings of the National Conference, Orlando, Florida November 26-28, 1979*. Cincinnati, OH: Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, 1980.