GREENING THE GRAY AT 34TH STREET AND FDR DRIVE

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ABSTRACT

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Green stormwater infrastructure (GSI) is multifaceted, and its benefits are multitudinous. The main design objective for GSI is reducing the amount of rainwater that enters storm drains to reduce combined sewer overflows by capturing the water in soil. GSI can also reduce the urban heat island effect, reduce air pollution, reduce noise pollution, create habitats for animals, and provide health benefits for the community. GSI provides ecological pockets within urbanized areas which benefits community members and urban scavengers. This report will design a GSI project between 34^{th} Street and FDR Drive in Manhattan. Many GSI designs have lacked consideration for people with disabilities, specifically for visual disabilities, and this report will fill in this gap. This project will design a sensory garden and vertical GSI underneath the FDR bridge. The objective is to reduce the amount of stormwater runoff, create a sensory experience, make the area look nicer, and increase the amount of green infrastructure in Manhattan. Eventually, through many green infrastructure projects like this one, New York City can make itself more resilient to changing climate, natural disasters, and extreme weather events.

INTRODUCTION

Climate change is expected to increase precipitation in New York City, which will cause more nuisance flooding and flash flooding (*New York's Climate Threats*, n.d.). The first "flash flood emergency" in the history of NYC was issued during Hurricane Ida in September 2021, the affects seen in figure 1 (Levenson & Barnard, 2021). Since flooding and rainfall will continue to increase in scale and frequency, it is imperative for New York to properly adapt to these effects of climate change.

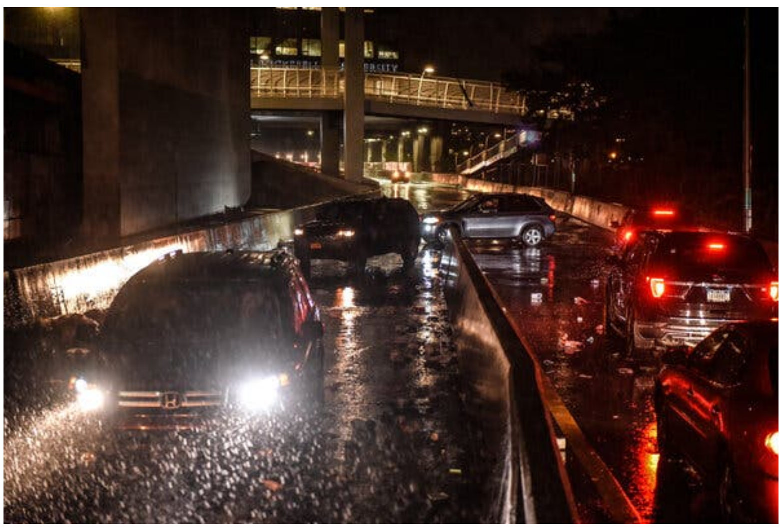


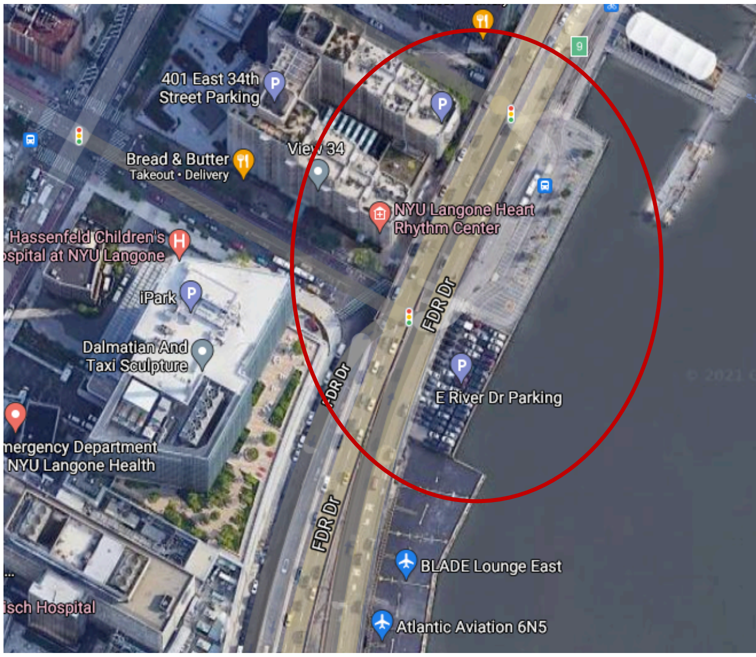
Figure 1. Image taken from New York Times, "Scenes from New York City as Ida paralyzes region." Image shows how flooding can obstruct the cities functions. (Levenson & Barnard, 2021).

Flooding is not the only deleterious effect of rainfall events. Rainfall events also cause pollution from combined sewer overflows (CSOs) and runoff from roadways. CSOs are a set of drainage pipes which carry sewage, stormwater, and industrial wastewater to a sewage treatment plant. If sewage pipes have too much water, they will overflow into the local water body through CSO outfalls. This flow violates the Clean Water Act, which mandates all runoff be treated. Impervious surfaces prevent rainwater from infiltrating into the ground and directs the water towards storm drains; thus, increasing the chance of overflows occurring. Green stormwater infrastructure (GSI) aims to reduce the amount of stormwater entering storm drains by decreasing the amount of impervious surfaces in the urban space through gardens, permeable concrete, and trees. The higher GSI performs, the better the cities compliance to the Clean Water Act as well. Therefore, by implementing GSI for stormwater capture in Manhattan, the amount of pollution from CSOs and runoff will reduce in the East River. In addition to reducing stormwater runoff, GSI has many other benefits for the urban area. There are many types of motivation for developing green infrastructure: improving water quality in local waterways, increasing property value, creating green jobs, decreasing floods, mitigating urban heat island effect, improving air quality, adapting to climate change, creating aesthetic green spaces, improving public mental health and physical health, and more (Chini et al., 2017).

This GSI project is located at the cross of 34th Street and FDR Drive in Midtown, Manhattan, seen in figures 2, 3, and 4. Notably, FDR Drive is a bridged highway located above the project location. Additionally, the project location crosses a part of the East River Greenway, a bike path that spans from the Lower East Side to East Harlem. The goals of this project will be to reduce the amount of stormwater runoff, create a sensory experience, improve aesthetics, and increase the amount of green infrastructure in Manhattan. The focus of this research is the development of a sensory garden to inspire new GSI projects that consider disabilities. This will be written as a proposal project for NYC Department of Parks.

The project goals are:

1. Reduce stormwater runoff
2. Create a sensory experience
3. Make the area greener
4. Increase the amount of green infrastructure in Manhattan



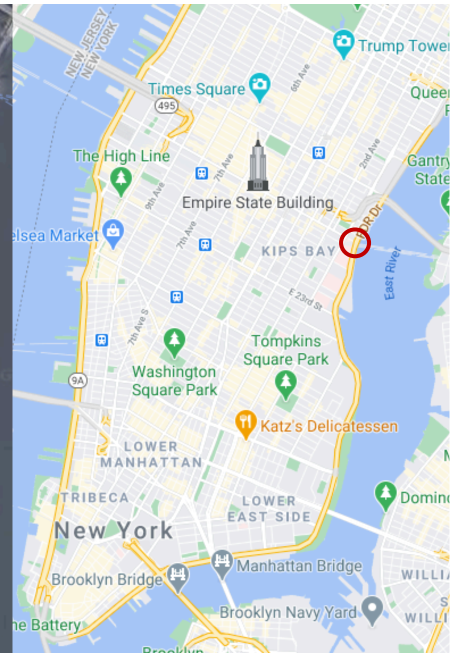


Figure 2. Overhead shot of the intersection of 34th and FDR. The location of this project is within the red circle. Source: Google maps, 2021
Figure 3. The location of this project is within the red circle. Source: Google maps, 2021

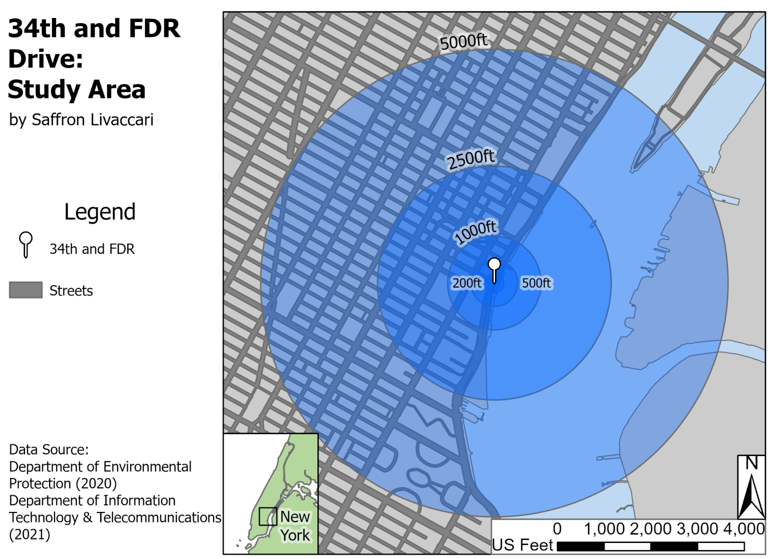


Figure 4. Study Area: The white pin is the location of 34^{th} and FDR Drive. Created in ArcGIS.

BACKGROUND

The East River is a tidal strait that connects Long Island Sound and the Upper New York Bay. The heavy urbanization of New York City caused heavy impacts of the river over the last 150 years. The river has been dredged and filled, and its shorelines have been altered through bulkheading for stabilization (NYC DEP, 2020). Natural tributaries into the river were filled and the flow of the whole river has been altered (NYC DEP, 2020). The river's water quality and ecosystem has been anthropogenically impacted and CSOs continue to negatively impact the East River. Runoff in particular is harmful to waterbodies. According to the EPA, heavy metals, oils, and debris from construction can be present in runoff, absorbing into soil or polluting local water. Even the erosion of streets can create unwanted sediments in local aquatic habitats (US EPA, 2015). In a natural area, only 10% of rain will become runoff. However, if 75% or more of land becomes impervious, 55% of rainfall becomes runoff (US EPA, 2003). Therefore, replacing impermeable surfaces with GSI can reduce the amount of runoff, which can have profound impacts to the river.

New York City has created a Green Infrastructure development plan in 2010 to reduce CSOs and improve water quality and sustainability. The goal of New York City's Department of Environmental Protection (DEP) with this program is "to manage the equivalent of stormwater generated by one inch of precipitation on 10% of impervious surfaces in combined sewer system (CSS) areas in the following five-year increments: 1.5% (December 31, 2015), 4% (December 31, 2020), 7% (December 31, 2025), and 10% (December 31, 2030)" (Licata, 2021). The area of this project is located within a combined sewer overflow area which constitutes about 60% of New York City sewer system (*Combined Sewer Overflows - DEP*, n.d.). Therefore, this project can be a part of this GI Plan and continue to reduce the CSO loads in the East River.

However, New York City's green infrastructure plans have targeted mostly Queens and Brooklyn, as displayed in figure 5 (NYC DEP, 2019). Only about 1-10 green infrastructure projects have been completed in most of the neighborhoods across Manhattan. For the project site, there are five GI projects within 2,500 feet. The location of these projects is shown in figure 6 below. Thus, this design proposal can increase the number of GSI for Manhattan.

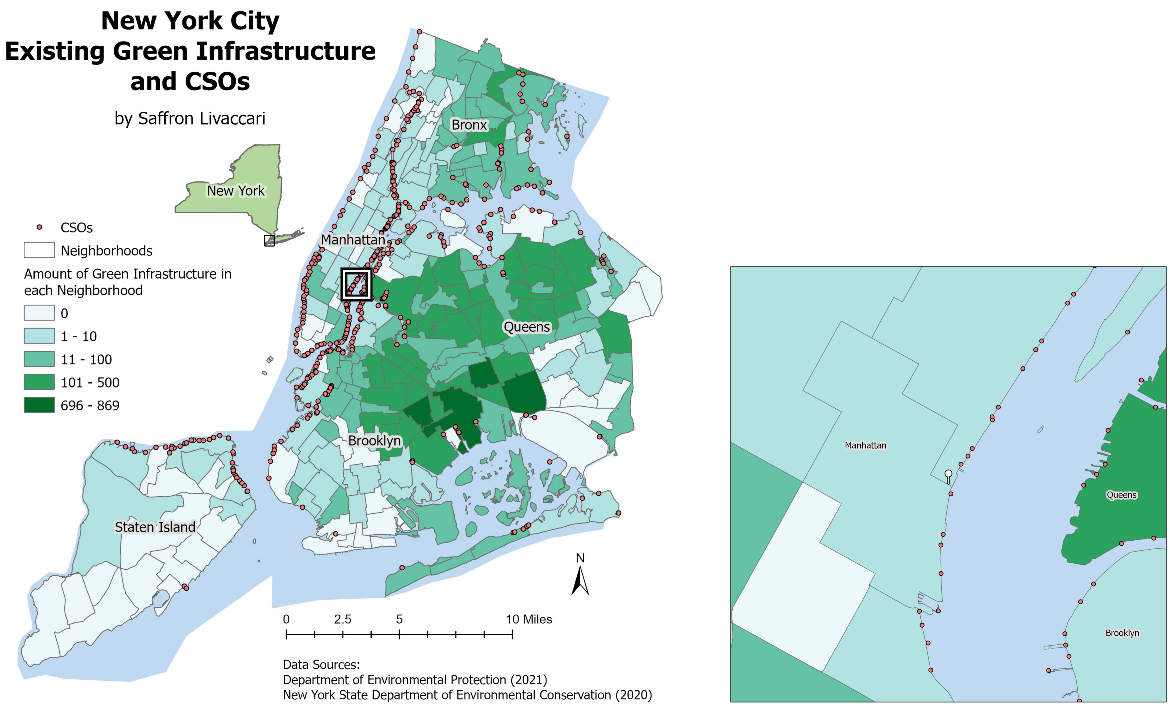


Figure 5. Map of the existing green infrastructure projects throughout the city and the CSO's, created in ArcGIS.

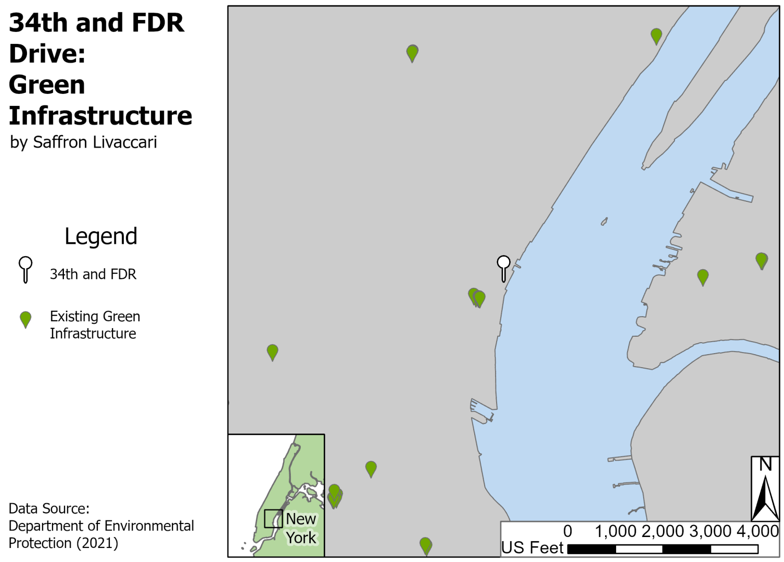


Figure 6. Green infrastructure near the chosen site as defined by the NYC's DEP. Created in ArcGIS.

In New York's Long Term Control Plan for the East River, NYC states their desire to explore long-term opportunities between East 23rd to East 35th street for "maximizing water-dependent and water-enhancing uses along the water from… upgrade esplanade to continuous, consistent design with amenities, study opportunities for additional temporary uses of the 34th St heliport, and construct E. 35th Street ferry landing that provides sheltered waiting area, ticketing, and pedestrian amenities" (NYC DEP, 2020). This project can be incorporated with the design goals in the Long-Term Control Plan for the East River.

Another notable point of this area is the hospital, circled in red in figure 7 below. Considering urban greenspace has a substantial impact on health, adding GSI to this area will benefit the hospital patients and employees as well. Greenery, even just gazing at it through a window, can reduce a patients stay at a hospital because of reduced stress (Franklin, 2012). The workers at hospitals can equally benefit from spending time in a green garden (Franklin, 2012).

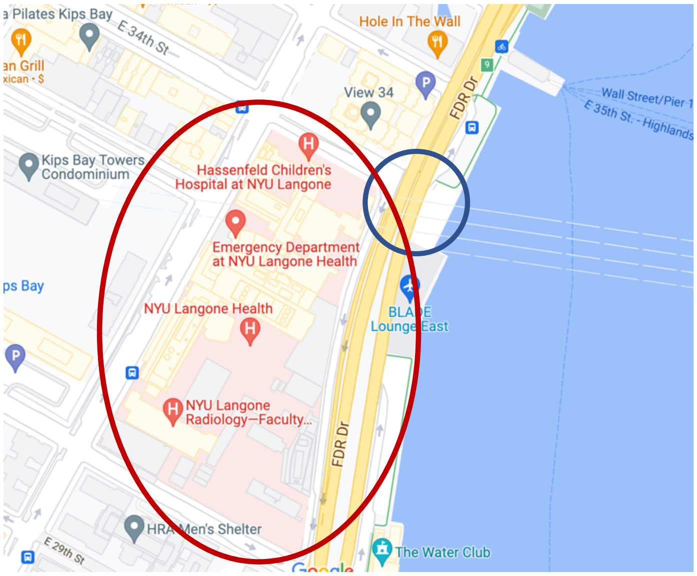


Figure 7. The NYU Langone Hospital is in the red oval and the area of interest is in the blue circle. Source: Google maps, 2021.

METHODS

Benefits of Green Infrastructure

Reducing CSO Pollution and Highway Runoff

GSI is commonly associated with the reduction of CSO discharges in cities. Preventing the amount of water that enters storm drains will subsequently reduce the volume of discharges from a CSO. Figure 8 displays the number of CSOs around the site: one is within 500 feet and four are within 1,000 feet. Both the CSO and the highway pollute the water with sewage and runoff. One aim of GSI is capturing rainwater through soil and plants to reduce the amount of runoff. The volume of runoff will depend on the surface. An area with high vegetation and low slope will generate a small amount of runoff. An area with a high percentage of impervious surface, like the study area, will generate large volumes of runoff. Therefore, building green infrastructure here will reduce the amount of pollution from these CSOs.

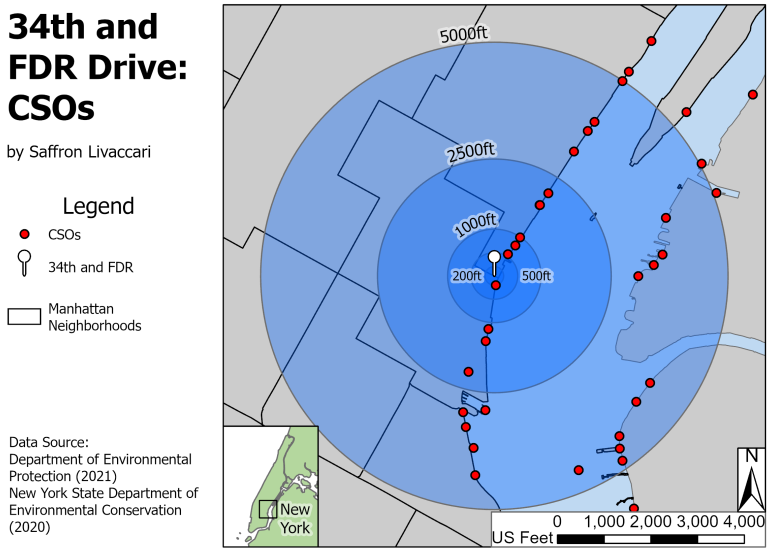


Figure 8. CSOs nearby the study location created in ArcGIS.

Surface water and soils located near highways are contaminated from runoff. Highway runoff typically contains heavy metals (copper, lead, zinc, chromium, cadmium, nickel, and iron), nutrients (nitrogen, phosphorus, and potassium), and polycyclic aromatic hydrocarbons (PAHs) (Luo et al., 2019; Ladislas et al., 2015). The most contamination occurs between 5 to 20 meters from a highway, but can reach 320 meters (Luo et al., 2019). These heavy metals and nutrients impair both the ecosystems and human health. Excessive nitrogen and phosphorous can cause eutrophication in local water bodies and can result in harmful algal blooms (Luo et al., 2019). Heavy metals and PAHs are highly toxic to the ecosystem and people, and are particularly concerning for their persistence in the environment (Ladislas et al., 2015).

Green infrastructure has been studied to reduce the amount of runoff pollution from highways, primarily through filtration and sedimentation (Ladislas et al., 2015). One paper by Hwang and Weng, (2015) studied the amount of pollution next to a highway without a bioswale and one with a bioswale. A bioswale is a shallow, vegetated depression that collects rainwater and allows it to infiltrate into the ground. The effects of the bioswale were obvious; suspended solids, chemical oxygen demand, iron, copper, and zinc, were significantly reduced. Another paper found a bioswale near a highway reduced ammonium nitrogen, total nitrogen, total phosphorus, and soluble phosphate (Shuangcheng et al., 2018). According to a report by the Natural Resource Defence Council, a well designed bioswale can “remote up to 70% of sediment, 30% of phosphorus, 25% of nitrogen, 50% to 90% of trace metals, and 67% to 93% of oil and greass” (*After the Storm: How Green Infrastructure Can Effectively Manage Stormwater Runoff from Roads and Highways*, 2011).

Stormwater Mitigation

Climate change will bring more extreme climate events for New York City. According to a report from the New York State Attorney General, NYC is expected to experience greater rainfall events and has already experienced an increase in precipitation (*Climate Change Impacts in the United States,* 2014). The heaviest 1% of all rainfall events have increased by 71% from 1958 to 2012 in the Northeast US. The number of rainfall events greater than one inch has increased from 1960 and is predicted to continue increasing. To summarize, rainfall is trending towards increased frequency and intensity. This trend is shown in figure 9 below, which was taken from a report on Climate Change Impacts to New York State from the State Attorney General (*Climate Change Impacts in the United States*, 2014).

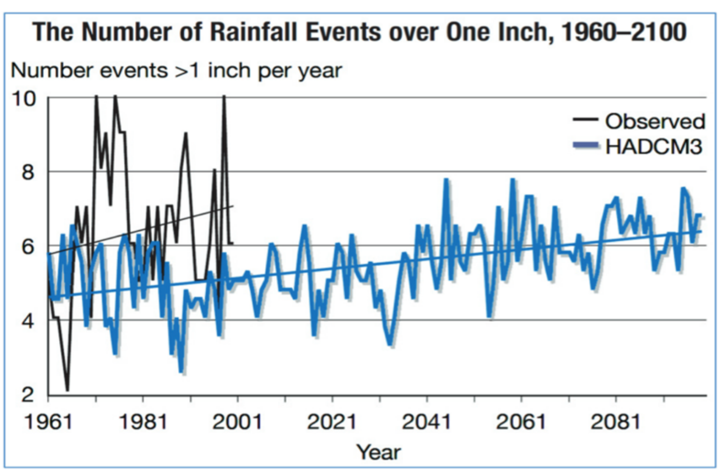


Figure 9. Taken from *Climate Change Impacts in the United States*, (2014). The Number of Rainfall Evens over One Inch from 1960 to 2100 for New York State. Created by New York State Energy Research and Development Agency (NYSERDA). This figure illustrates an increasing trend in rainfall for New York, even more than predicted.

GSI can reduce flooding by reducing runoff. Floods can result when a substantial amount of rain falls in a short time and builds up on impervious surfaces. This runoff drains into rivers, raising the level of water in the receiving body (NOAA, 2015). Transforming the land from impervious to pervious surfaces can help slow or reduce urban flooding by increasing infiltration, leaving less as runoff. Considering NYC is highly urbanized, the amount of impervious surfaces is exceedingly abundant. Impervious surfaces constitute about 72% of all surfaces in NYC, shown in figures 10 and 11 below (Allegra Miccio, 2018).

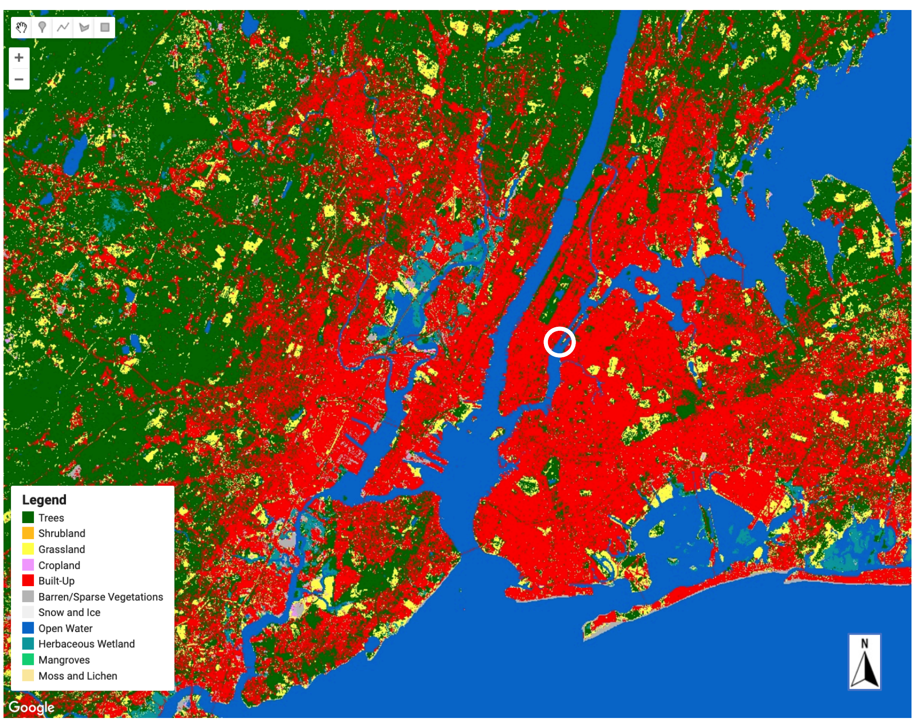


Figure 10. From Google Earth Engine: Land Use map by ESA WorldCover. Notably, the red pixels are the urban areas.

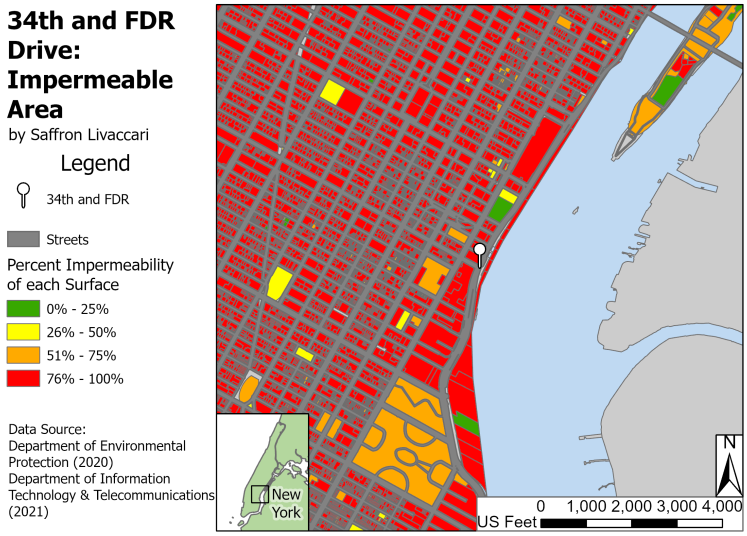


Figure 11. Map of the impermeable surfaces nearby the site created in ArcGIS.

Urban Heat Island Effect

Urban Heat Island (UHI) effect is the phenomenon that occurs when the temperature of a city is higher than the surrounding suburban areas from a lack of greenery (Barron et al., 2018). New York city can get up to 20 degrees Fahrenheit hotter than nearby rural areas and is 2.7 degrees warmer on average in the summer (*New York's Climate Threats*, n.d.). GSI is able to reduce the intensity of the heat island effect primarily through shade, evapotranspiration, and lower surface temperatures because of specific heat capacity (Saaroni et al., 2018). Shaded surfaces can be 25°F cooler than unshaded surfaces (*Landscaping for Shade*, n.d.). The moisture released during evapotranspiration creates ambient cooling, which has the potential to reduce peak summer temperatures by 2–9°F (US EPA, 2014). Additionally, the specific heat capacity of flora is higher than pavement. The amount of heat need to raise the temperature of flora is higher than for pavement; therefore, flora is cooler than pavement during the summer (*Climate - Trees vs. Temperature*, 2007). Conventional pavement can reach temperatures of 120–150°F, while vegetated surfaces reach up to 70°F (Gartland, 2008). NYC heat island effect is shown in figure

12 below and the rising average temperature for NYC is shown in figure 13 below. The impacts of UHI effect range from increased energy usage to severe health issues: heat strokes, exhaustion, or respiratory issues can all occur at high temperatures (US EPA, n.d.). In NYC, there were an average of 10 heat related deaths each year from 2010 to 2019, despite heat related death and injury being consistently undercounted due to the difficulty of diagnosis (*2021 New York City Heat-Related Mortality Report*, 2021).

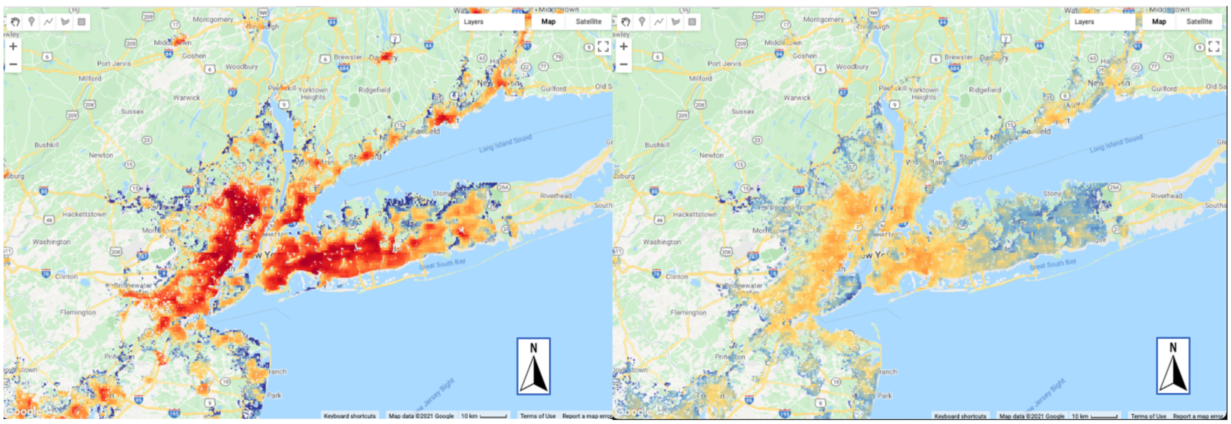


Figure 12. Map of Urban Heat Island Effect around New York City. Map on the left is for the daytime and the map on the right is for the nighttime. Data from Yale Center for Earth Observation (YCEO) available from 2003 to 2018. Maps created from the annual surface heat using multiple different datasets (Chakraborty & Lee, 2019).

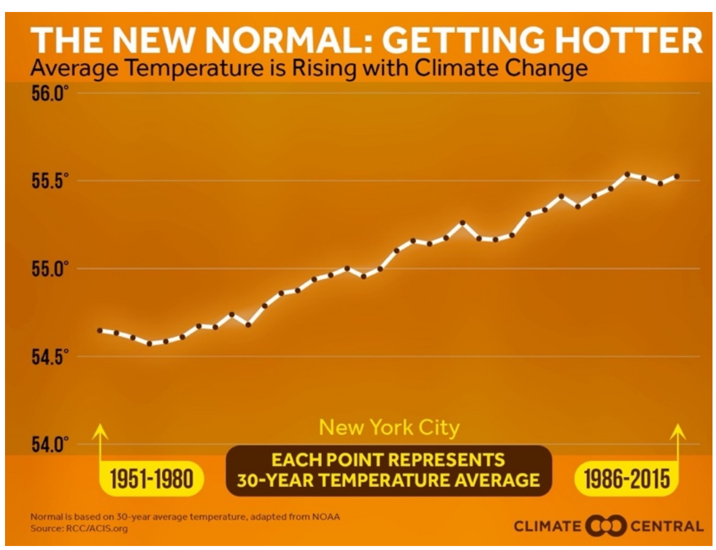


Figure 13. Shows the increasing average temperature in NYC in Fahrenheit. Taken from Climate Central (Climate Central, n.d.).

Air Pollution

With rising temperature also comes ozone air pollution. There is a relationship between summer high temperatures and ground-level ozone pollution, seen in figure 14. Ground-level ozone is an unnatural byproduct of nitrogen oxides and volatile organic compounds that react in heat and sunlight. Ozone can be created from factories and vehicle exhausts (Climate Central, 2014). According to Climate Central (2014), NYC had 10 days of unhealthy ozone levels in 2018. Additionally, air road traffic emits a range of polluters that contribute to poor air quality: particulate matter, ultrafine particles, nitrogen oxide, carbon monoxide, and sulphur dioxide (Abhijith et al., 2017). Higher levels of air pollution is correlated with distance to major roads; even pedestrians near roads are exposed to pollutions from vehicle exhausts (Kaur et al., 2007). Air pollution has substantial human health effects, being correlated with stroke, heart disease, pneumonia, and lung cancer (WHO, n.d.). Ozone is one of the most dangerous air pollutants as well, causing an increased risk of metabolic disorders, an impact on the central nervous system, and an increased risk of reproductive complications (American Lung Association, n.d.).

GSI can mitigate air pollution in several ways. First, plants are able to absorb pollutants through their stomata (Kumar et al., 2019). Second, wind-borne pollutants can adhere to leaves and stems (Currie & Bass, 2008). Third, lower temperatures from shade lessons smog formation by promoting chemical reactions that reduces ozone concentrations (Kumar et al., 2019). A paper by Abhijith et al. (2017), synthesized multiple studies on air pollution and green infrastructure, and discovered that "in open road conditions, vegetation barriers have a positive impact on air quality with thick, dense and tall vegetation."

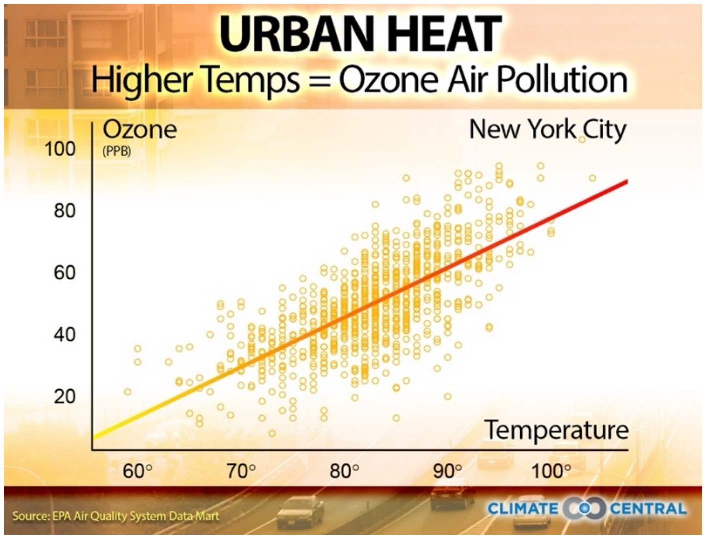


Figure 14. Graph of the relationship between high temperatures and ozone pollution in NYC. Taken from Climate Central (Climate Central, 2014)

Noise Pollution

Noise pollution directly affects human health by reducing cardiovascular health and causes stress, sleep disturbance, and hearing impairment. As seen in figure 15, most of Manhattan has extremely high amounts of noise pollution. The most common source of noise pollution is from traffic. Airport sites, ferry lines, highways, and construction sites all accrue into noise pollution (Slabbekoorn, 2019). Street canyons can reverberate sounds along a street, increasing the volume of noise (Echevarria Sanchez et al., 2016). GSI reduces noise by absorbing a portion of the signal and scattering the sound waves. A thick hedge along a highway can reduce traffic noise by 1000% (Maksymenko et al., 2021). Therefore, GSI is a valuable resource to reduce urban noise pollution and decrease its effects on the surrounding community.

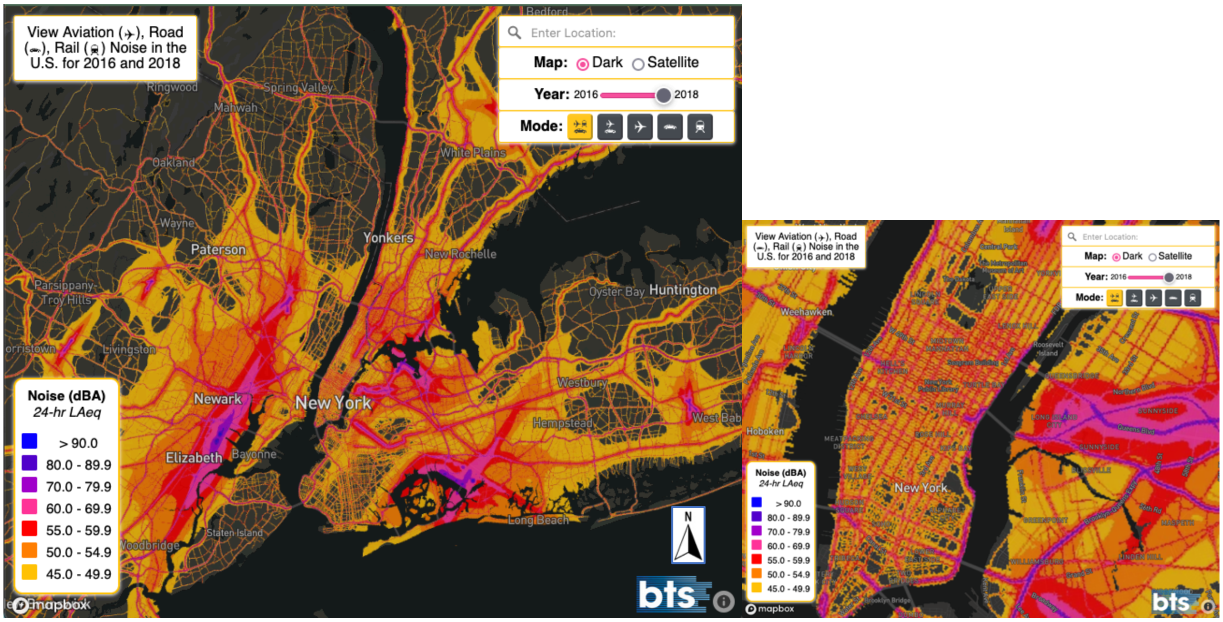


Figure 15. Displays noise pollution in NYC taken from the U.S. Department of Transportation (DOT, n.d.).

Habitat Creation and Restoration

Green infrastructure can also be considered to help mitigate and adapt to climate change by creating corridors or patches for local fauna, whose habitats have reduced from urban development. Native insects and animals can connect habitat areas in urban landscapes via "corridors" (Adams & Dove, 1989). These connections of ecological zones provide safe spaces for animals to breed, raise and feed young (Adams & Dove, 1989). GSI is particularly important for pollinators, as green infrastructure in urban areas act as "pollinator refugee habitats" (Li et al., 2020). Thus, green infrastructure can maintain biological diversity in urban zones.

Reduce Carbon

An incredibly valuable benefit of GSI for climate change mitigation is carbon sequestration. From the United States Geologic Survey: "carbon sequestration is the process of capturing and storing atmospheric carbon dioxide" (*What Is Carbon Sequestration?*, n.d.). Kavehei et al. (2018) conducted an extensive LCA analysis on the carbon impacts of various

GSI. Out of green roofs, rain gardens, bioretention basins, vegetated swales and stormwater ponds; raingardens were determined to provide the highest carbon sequestration potential compared to its carbon footprint as seen in figure 16. The mean carbon sequestration of rain gardens specifically is −75.5 ± 68.4 kg CO^2 eq. m^{-2} over a 30-year life span (Kavehei et al., 2018). Considering the carbon footprint of the materials required to create a rain garden, its net carbon footprint is −12.6 kg CO^2 eq. m^{-2} over a 30-year life span (Kavehei et al., 2018). Overall, raingardens, which this design will focus on developing, are an excellent measure to increase carbon sequestration in urban areas to mitigate climate change. This design will also include trees, which are incredibly powerful at sequestering carbon dioxide. According to the Arbor Day Foundation, a mature tree may potentially sequester 48 pounds of carbon dioxide from the atmosphere (Arbor Day Foundation, 2014).

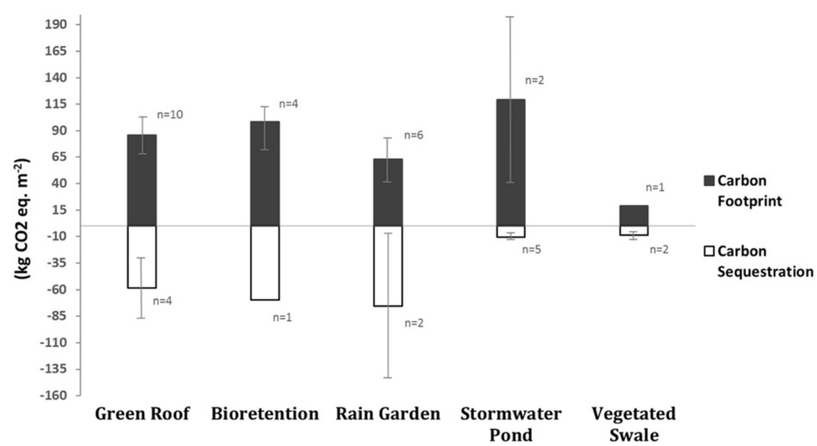


Figure 16. The carbon footprint of various GSI compared to the potential carbon sequestration. Rain Gardens have the highest possibility of offsetting its own carbon footprint. Taken from Kavehei et al. (2018).

Site Analysis

The site chosen for this project is on the cross between 34th Street and FDR Drive. The site also crosses the East River Parkway, a bike route spanning lower Manhattan to upper Manhattan along the East River, shown in figure 17. A section of this parkway in the East

Village/Lower East Side has the John V. Lindsay East River Park, which has tennis courts, baseball fields, soccer fields, fitness parks, bike lanes, and walkways (NYC Parks, n.d.). However, the section of the parkway around 34th Street and FDR Drive is a stark contrast to the East River Park. The area is surrounded by only gray: a bridged highway, streets, cemented docks, and a parking lot. By adding a GSI park to this area, the East River Parkway can be better connected with pockets of greenery for even more community members to enjoy.

Figure 17. Map of the Greenway along the Manhattan waterfront. The blue dot is the area of interest, 34th and FDR Drive. Taken from NYC Gov (NYC GOV, n.d.).

Currently, the whole area is impervious except for the small tree squares, shown in figure 18 below. The trees do not count as green infrastructure, since street trees only count if there is an engineered filtration system underneath. The site is directly next to the East River, where a concrete wall separates the water from the land. FDR Drive is on a bridge running parallel to the river's edge, pointed out by the blue arrow in figure 18. Underneath the bridged highway is another street, the FDR Service Road, which eventually leads onto FDR Drive. The M34 bus is also seen in the picture, as its route along 34th street terminates here for the ferry. The area with the trees and the bus is called the East River Esplanade.

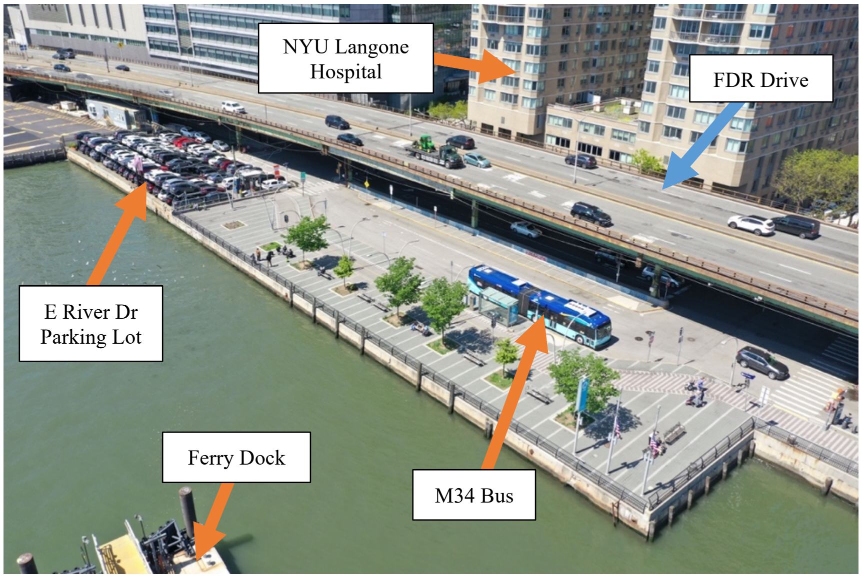


Figure 18. Shows the East River Esplanade and FDR Drive. Arrows with labels point out the features of this area. Taken by Austin Bell, 2021.

There is a parking lot called E River Dr Parking Lot, seen more clearly in figure 19 below. This project will propose the parking lot be moved and the GSI park be created there. There are multiple other parking lots around the area: 577 1st Ave Garage, NYC Parking NYULMC A Garage Corp, 300 E 29th St Garage, East 37th Street Parking Garage, and more. Figure 18 also shows the helicopter landing zone to the left of the parking lot, owned by BLADE Lounge East.

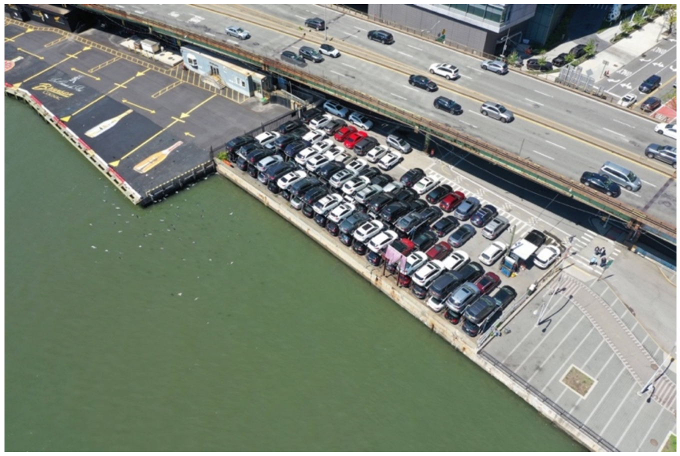


Figure 19. Shows the E River Dr Parking Lot. Taken by Austin Bell, 2021.

Currently, water on the FDR Drive runs directly off the highway, and rust from water damage can be seen on the pillars holding the bridge, seen in figure 20.

Figure 20. Shows the rusting of the pillar from runoff. The bridge has FDR Drive and the road underneath is FDR Service Road.

Design Solutions

Redesigning the Parking Lot – Sensory Garden

Considering outdoor green spaces has numerous benefits, people with visual disabilities equally enjoy green spaces. A "sensory garden" is the term for a garden created for all senses (taste, touch, smell, hear, and sight) to experience as a form of natural therapy (Zajadacz & Lubarska, 2020). For the visually disabled, native plants to New York that have the sensory experience of taste, scent, and touch were chosen for this design. A park made for visually disabled people will need to have the following features (Zajadacz & Lubarska, 2020):

1. Clear path layout
2. Paths with rounded corners
3. Tactile walking surface indicators
4. Various types of path surface
5. Audible information
6. Scent, touch, and taste
7. Mobile phone applications
8. Site plans
9. Curbs along the sidewalks as guides
10. Railings
11. Elevated flowerbeds

To create a peaceful park next to a highway and helicopter pad, a sound barrier should be created to block out as much noise as possible. Trees will line the sides of the park closest to the highway and helicopter pad. The trees chosen for this is sweetgum and sassafras for their aroma. The shrubs lining the bottom of the trees will be coastal pepperbush. Additionally, bicycles and rollerblades should be prohibited from entering the area for the safety of the people in the park. A clearly textured walkway will lead into the garden, and the walkway should have a wall a few inches high along the edges as a guiding path for those who use canes.

Raingardens for this park serves multiple function, as the area will unify the management of stormwater and engaging, unique experiences. Stormwater is managed through a raingarden by layers of soil and rock to allow water to infiltrate slowly and reduce the runoff into water bodies and storm drains. This is a remarkable solution to runoff because raingardens will also be able to include sensory specific plants to create an immersive sensory experience. The water collected from the raingardens will be reused for a fountain in the middle of the garden. The basic design of these raingardens is in figure 21 below.

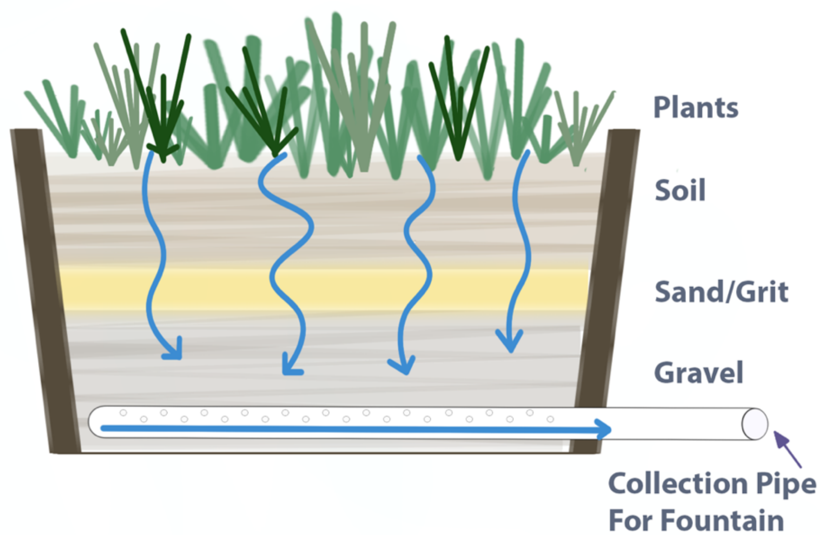


Figure 21. Basic design of a raingarden in this park. Between each layer will be a geotextile fabric to keep each layer intact. Created in Photoshop.

The raingardens will be separated into three categories: scent, touch, and taste. Each plant chosen in this design is native to New York. The scent garden will include fragrant plants: such as Joe Pye Weed, Hyssop, Creeping Lemon Thyme, Lavender, Spicebush, Sunny Woodmint, and Honeysuckle. The full list of plants is in table 1. The taste garden will include all edible plants, tomato, blueberries, and herbs as seen on table 2. The touch garden will include the fuzzy, soft Lamb's Ear, grasses, ferns, and stonecrops as seen on table 3.

Table 1. Table of scented plants for the 'scent' specific raingarden.

SCENT RAINGARDEN			
Plant	Scientific Name	Ecological Value	Citation
Joe Pye Weed	*Eutrochium purpureum*		(*Eutrochium Purpureum Var. Purpureum (Sweet Joepyeweed)*, n.d.)
Blue Giant Hyssop	*Agastache foeniculum*	Native Bees, Bumble Bees, Honey Bees	(*Agastache Foeniculum (Blue Giant Hyssop)*, n.d.)
Yellow Giant Hyssop	*Agastache nepetoides*	Native Bees, Bumble Bees, Supports Conservation Biological Control	(*Agastache Nepetoides (Yellow Giant Hyssop)*, n.d.)
Purple Giant Hyssop	*Agastache scrophulariifolia*	Native Bees, Bumble Bees, Honey Bees	(*Agastache Scrophulariifolia (Purple Giant Hyssop)*, n.d.)
"Tiny Rubies" Dianthus	*Dianthus gratianopolitanus*	Butterflies, Hummingbirds	(*Dianthus Gratianopolitanus 'Tiny Rubies,'* n.d.)
Creeping Lemon Thyme	*Thymus serpyllum*		(*Creeping Lemon Thyme (Thymus Serpyllum)*, n.d.)
Lavender	*Limonium carolinianum*		(*Limonium Carolinianum (Carolina Sealavender)*, n.d.)
Carolina Geranium	*Geranium carolinianum*		(*Geranium Carolinianum (Carolina Geranium)*, n.d.)
Spotted Geranium	*Geranium maculatum*	Native Bees, Bumble Bees, Birds	(*Geranium Carolinianum (Carolina Geranium)*, n.d.)
New York Aster	*Symphyotrichum novi-belgii*	Native Bees	(*Symphyotrichum Novi-Belgii (New York Aster)*, n.d.)
Spicebush	*Lindera benzoin*	Birds, Butterflies	(*Lindera Benzoin (Northern Spicebush)*, n.d.)
Bayberry	*Morella pensylvanica*	Birds, Butterflies	(*Morella Pensylvanica (Northern Bayberry)*, n.d.)
Elderberry	*Sambucus nigra*	Birds, Provides Nesting Materials/Structure for Native Bees, Supports Conservation Biological Control	(*Sambucus Nigra Ssp. Canadensis (Common Elderberry)*, n.d.)
New York Ironweed	*Vernonia noveboracensis*	Birds, Butterflies, Native Bees	(*Vernonia Noveboracensis (New York Ironweed)*, n.d.)
Southern Arrowwood	*Caprifoliaceae*	Birds, Butterflies, Native Bees, Bumble Bees, Supports Conservation Biological Control	(*Viburnum Dentatum (Southern Arrowwood)*, n.d.)
Sunny Woodmint	*Blephilia ciliata*	Native Bees, Bumble Bees, Supports Conservation Biological Control	(*Blephilia Ciliata (Downy Pagoda-Plant)*, n.d.)
Northern Bush Honeysuckle	*Diervilla lonicera*	Bumble Bees	(*Diervilla Lonicera (Northern Bush Honeysuckle)*, n.d.)
Limber Honeysuckle	*Lonicera dioica*	Hummingbirds, Bumble Bees	(*Diervilla Lonicera (Northern Bush Honeysuckle)*, n.d.)
American Fly Honeysuckle	*Lonicera canadensis*	Hummingbirds, Butterflies, Bumble Bees	(*Diervilla Lonicera (Northern Bush Honeysuckle)*, n.d.)

Rose	*Rosa setigera*		(*Rosa Setigera Var. Setigera (Climbing Prairie Rose)*, n.d.)

Table 2. Table of plants with edible parts for the 'taste' raingarden.

TASTE RAINGARDEN			
Plant	Scientific Name	Ecological Value	Citation
Tomato			
Dill			
Mint			
Parsley			
English Thyme			
Rosemary			
Sage			
Chive			
French Tarragon			
Winter Savory			
Salad Burnet			
Oregano			
Basil			
Highbush Blueberry	*Vaccinium corymbosum*	Birds and Mammals, Native Bees, Bumble Bees	(*Vaccinium Corymbosum (Highbush Blueberry)*, n.d.)
Mapleleaf Viburnum	*Viburnum acerifolium*	Birds , Butterflies, Larval Host of the Springe Azure Moth	(*Viburnum Acerifolium (Mapleleaf Viburnum)*, n.d.)

Table 3. Table of plants with interesting textures for the 'touch' raingarden.

TOUCH RAINGARDEN			
Plant	*Scientific Name*	Ecological Value	Citation
Fox Sedge	*Carex vulpinoidea*	Birds	(*Carex Vulpinoidea (Fox Sedge)*, n.d.)
Ditch Stonecrop	*Penthorum sedoides*		(*Penthorum Sedoides (Ditch Stonecrop)*, n.d.)
Roseroot Stonecrop	*Rhodiola rosea*		(*Rhodiola Rosea (Roseroot Stonecrop)*, n.d.)
Lambs' Ears	*Stachys byzantina*		(*Growing Lamb's Ear*, n.d.)
Soft Rush	*Juncus effusus*	Birds	(*Juncus Effusus (Common Rush)*, n.d.)
Sensitive Fern	*Onoclea sensibilis*	Birds, Shelters salamanders and frogs	(*Onoclea Sensibilis (Sensitive Fern)*, n.d.)
Cinnamon Fern	*Osmunda cinnamomea*	Birds	(*Osmunda Cinnamomea (Cinnamon Fern)*, n.d.)
Pennsylvania Sedge	*Carex pensylvanica*	Birds	(*Carex Vulpinoidea (Fox Sedge)*, n.d.)
Little Bluestem	*Schizachyrium scoparium*	Birds, Butterflies, Provides Nesting Materials/Structure for Native Bees	(*Schizachyrium Scoparium (Little Bluestem)*, n.d.)
Tall Goldenrod	*Solidago altissima*	Birds, Butterflies, Native Bees, Honey Bees, Supports Conservation Biological	(*Solidago Altissima (Tall Goldenrod)*, n.d.)

		Control; Larval host for Dusted Skipper, Indian Skipper, Crossline Skipper, Ottoe Skipper	
Flattop Goldenrod	*Euthamia graminifolia*	Native Bees, Supports Conservation Biological Control	(*Euthamia Graminifolia (Flat-Top Goldentop)*, n.d.)
Marsh Milkweed	*Asclepias incarnata*	Butterflies, Hummingbirds	(*Asclepias Incarnata (Swamp Milkweed)*, n.d.)

The fountain in the middle of the garden will use water collected from the raingardens. The fountain will be simple, water running down a stack of a few rocks. This will provide a calming sound of water and remind visitors the importance of the natural resource. Surrounding the fountain will be a bioswale: a shallow, vegetated depression that collects rainwater and allows it to infiltrate into the ground. The bioswale will have grey birch trees and coastal pepperbush. Grey birch will block noises while providing a pleasant rustling sound in the wind, whose leaves ruffle in the breeze. Grey birch is also important plant for the Eastern Tiger Swallowtail butterfly (*Betula Populifolia (Gray Birch)*, n.d.). Coastal pepperbush will provide noise suppression around the bottom of the tree baren of leaves, while providing a gorgeous fragrant scent. This bush smells very sweet and is important for bees, butterflies, and hummingbirds (*Clethra Alnifolia (Coastal Pepperbush)*, n.d.).

Furthermore, there will be two seating areas to provide areas for people to relax and engage with nature. There will be two circular seating areas, to the left and right of the fountain. Lastly, permeable pavements will be used for the walkways in the garden area. Permeable pavements are porous surfaces which allow water to permeate through the walkway into the soil. These materials are also useful for the visually disabled because of the texture they can provide. The rendered design can be seen below in figure 22.

Figure 22. Rendering of the Design. Next to the river are the three rain gardens. From left to right is the touch, taste, and scent gardens. There are two seating areas next to the fountain area in the middle of the park. Entrance to the park is on the right.

Highway Gutters and Rain Gardens

To remediate the water damage on the pillars of FDR Drive and to reduce polluted runoff from entering the East River, a gutter can be added to the side of the highway, and spiral down the pillar, ending in a rain garden. Figure 23 has a rendering of this design and table 4 has the plants to be included in the raingarden. This design is inspired from a report by the Weitzman School of Design called "Greening the Elevated." The report includes a design for vertical green infrastructure around a gutter similar to the one below, used as an art installation to educate viewers on the impacts of stormwater (Ben-Amos et al., 2016). Realistically, this gutter will not be able to hold much stormwater, but rather can educate the public about stormwater in an artistic method. This artistic piece is also a good introduction to the green sensory garden park.

Figure 23. Rain gutter spiraling down a pillar leading to a raingarden.

PLANTS FOR RAINGARDEN UNDER HIGHWAY		
Plant	Scientific Name	Citation
Autumn Fern	*Dryopteris erythrosora*	(*Autumn Fern*, n.d.)
Eastern Hay-scented Fern	*Dennstaedtia punctilobula*	(*Dennstaedtia Punctilobula (Eastern Hay-Scented Fern)*, n.d.)
Northern Maidenhair Fern	*Adiantum pedatum*	(*Adiantum Pedatum (Northern Maidenhair Fern)*, n.d.)
Virginia Bluebells	*Mertensia virginica*	(*Mertensia Virginica (Virginia Bluebells)*, n.d.)
Turk's Cap Lily	*Lilium michiganense*	(*Lilium Michiganense (Michigan Lily)*, n.d.)
Blue Flag Iris	*Iris virginica*	(*Lilium Michiganense (Michigan Lily)*, n.d.)
Great Blue Lobelia	*Lobelia siphilitica*	(*Lobelia Siphilitica Var. Ludoviciana (Great Blue Lobelia)*, n.d.)
Pennsylvania Sedge	*Carex pensylvanica*	(*Carex Vulpinoidea (Fox Sedge)*, n.d.)
New York Ironweed	*Vernonia noveboracensis*	(*Vernonia Noveboracensis (New York Ironweed)*, n.d.)
Cardinal Flower	*Lobelia cardinalis*	(*Lobelia Cardinalis (Cardinal Flower)*, n.d.)
Soft Rush	*Juncus effusus*	(*Juncus Effusus (Common Rush)*, n.d.)
Hibiscus	*Hibiscus laevis*	(*Hibiscus Laevis (Halberdleaf Rosemallow)*, n.d.)
Speckled Alder	*Alnus incana ssp. rugosa*	(*Alnus Incana Ssp. Rugosa (Speckled Alder)*, n.d.)
Butterfly Milkweed	*Asclepias tuberosa*	(*Asclepias Tuberosa (Butterflyweed)*, n.d.)
Seacoast Angelica	*Angelica lucida*	(*Angelica Lucida (Seacoast Angelica)*, n.d.)
Blue Boneset	*Conoclinium coelestinum*	(*Conoclinium Coelestinum (Blue Mistflower)*, n.d.)
Nannyberry	*Viburnum lentago*	(*Viburnum Lentago (Nannyberry)*, n.d.)

Table 4. Native plants that can live in shade were chosen for this raingarden. Since the area for the raingarden is not very spacious, the number of plants does not need to be too long. Many plants from this list came from Plants for Stormwater Design by Shaw & Schmidt (2003).

CONCLUSION

Considering New York City is extremely vulnerable to climate change and will experience more intense and more frequent rainfall events, actions will need to be taken to make the city more resilient. It is uncommon for one project to provide such a myriad of benefits which building resiliency: reducing runoff, preventing CSO overflows, increasing air quality and water quality, lessening the UHI effect, reducing noise pollution, and sequestering carbon dioxide. The objective of this GSI design is to reduce the amount of stormwater runoff, create a sensory experience, make the area look nicer, and increase the amount of green infrastructure in Manhattan. By focusing the types of plants within the design on ones that people can touch, smell, and hear, people with visual disabilities can also enjoy this garden. Eventually, through many green infrastructure projects like this one, New York City can make itself more resilient to the changing climate while also creating spaces for disenfranchised residents.

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