Responding to a Changing Environment: New York City's Green Efforts to Move Towards a More Sustainable, Resilient Climate Change Model

A supervised research project prepared by

Jeff Beaupre

In partial fulfillment for the Masters of Urban Planning

Supervisor: David Brown

McGill University School of Urban Planning

August 2017

Abstract

The effects of urbanization and climate change on today's cities pose unprecedented challenges for planners and decision-makers. Cities have become one of the main contributors to climate change, producing enormous amounts of greenhouse gas emissions and pollution. Urbanization has rendered cities highly vulnerable by altering the natural landform, and replacing natural ecosystems with artificial surfaces. As a result, extreme weather events such as flooding, storm surges and urban heat island (UHI) pose great risks to citizens and infrastructure. Though cities contribute to climate change, they also hold the ability to counteract the effects through proper planning and policy-making. Using the principles of urban ecology, New York City (NYC) has developed forward-thinking plans and strategies to guide resilient and sustainable development through 'green' climate change mitigation and adaptation measures. This paper looks at the changing environment of the NYC borough of Manhattan, and the implications of the city's climate change strategies in shaping land use, biodiversity and well-being. The extent to which urban design and development have been successful in minimizing the negative effects of urbanization and climate change, while increasing ecological resiliency and human well-being, is a main focus.

A history of the landform and present-day case study of Manhattan provide context for the analysis, which centres on a comparison between *PlaNYC,* the city's long-term strategic plan released in 2007; and *OneNYC,* the updated version released in 2015. Other city initiatives, along with email correspondence with actors, researching government and non-profit websites and on-site field observations also help to formulate the analysis, highlighting the implications these plans have on land use, in terms of: green infrastructure, architecture, parks and open spaces. The paper examines the city's efforts towards the promotion and conservation of biodiversity, and the role ecosystem services play in protecting people from extreme events while also providing long-term physical and psychological benefits. The importance of considering equity in the planning process is also stressed. To conclude, recommendations are proposed for NYC, based on the guiding principle of reducing the negative effects of climate change, while maximizing well-being and quality of life (QOL). Lessons are presented for Manhattan and NYC, and for other big cities.

Résumé

Les effets de l'urbanisation et les changements climatiques sur les villes d'aujourd'hui posent des défis sans précédent pour les planificateurs et les décideurs. Villes sont devenus l'un des principaux contributeurs aux changements climatiques, produisant d'énormes quantités d'émissions de gaz à effet de serre et la pollution. L'urbanisation a rendu villes très vulnérable en altérant le relief naturel et en remplaçant les écosystèmes naturels avec des surfaces artificielles. Ainsi, les phénomènes météorologiques extrêmes comme les inondations, les tempêtes et les îlots de chaleur urbains (UHI) posent des grands risques aux citoyens et aux infrastructures. Bien que les villes contribuent au changement climatique, ils détiennent également la capacité à contrecarrer les effets grâce à une bonne planification et d'élaboration des politiques. En utilisant les principes de l'écologie urbaine, New York City (NYC) a élaboré des plans de réflexion prospective et stratégies pour guider le développement résilient et durable par le biais de « vert » climat changent les mesures d'atténuation et d'adaptation. Ce document, on examine l'évolution du milieu de l'île de NYC de Manhattan, et les incidences du climat de la ville changent de stratégies dans le façonnement d'utilisation des sols, la biodiversité et le bien-être. La mesure à laquelle développement et urbanisme ont été permettent d'atténuer les effets négatifs de l'urbanisation et les changements climatiques, tout en augmentant la résilience écologique et bien-être humain, est la préoccupation majeure.

Une histoire du relief et étude de cas actuel de Manhattan fournissent un contexte pour l'analyse, qui se concentre sur une comparaison entre PlaNYC, plan stratégique à long terme de la ville, sorti en 2007 ; et OneNYC, la version mise à jour publiée en 2015. Autres initiatives de la ville, ainsi que de la correspondance électronique avec des acteurs, des recherches sur gouvernement et sites Internet à but non lucratif et sur place observations contribuent également à formuler l'analyse, en soulignant les répercussions de ces plans sur l'utilisation des terres, en termes de : infrastructure verte, architecture, parcs et espaces ouverts. Le document examine les efforts de la ville vers la promotion et la conservation de la biodiversité et les services écosystémiques de rôle jouent dans la protection des gens de phénomènes extrêmes tout en offrant des avantages physiques et psychologiques à long terme. Souligne également l'importance de considérer l'équité dans le processus de planification. Pour conclure, les recommandations sont proposées pour NYC, basé sur le principe de réduire les effets négatifs du changement climatique, tout en maximisant le bien-être et la qualité de vie (QV). Leçons sont présentées pour Manhattan et de New York et d'autres grandes villes.

Acknowledgements

First and foremost, I would like to express my gratitude to my advisor Prof. David Brown for your enthusiastic support. Your motivation, guidance and immense knowledge helped me throughout the research and writing of this project. I would also like to thank Prof. David Wachsmuth for your valuable and detailed comments as second reader.

I would like to thank Mary Lu, my wonderful mother, who took the time to help me proofread this report. Even in retirement, you will always be an English teacher.

Lastly, I would like to thank everyone I had the pleasure of meeting and befriending in the MUP Program. The past two years have been some of the most memorable of my life!

Table of Contents

List of Acronyms

CBD	Central Business District
CEQR	City Environmental Quality Review
CIDI	New York City Center for Innovation through Data Intelligence
CPC	City Planning Commission
DCP	Department of City Planning
CSO	Combined Sewer Outflow
DEP	Department of Environmental Protection
DOT	Department of Transportation
DPR	Department of Parks and Recreation
EIS	Environmental Impact Statement
FAR	Floor Area Ratio
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GHG	Greenhouse Gases
GIP	Green Infrastructure Plan
ICLEI	International Council for Local Environmental Initiatives
IPCC	International Panel on Climate Change
LEED	Leadership in Energy and Environmental Design
MOEC	Mayor's Office of Environmental Coordination
NAC	Natural Areas Conservancy
NFIP	National Flood Insurance Program
NPCC	New York City Panel on Climate Change
NYC	New York City
NYRP	New York Restoration Program
OEC	Office of Environmental Coordination
OLTPS	Mayor's Office of Long Term Planning and Sustainability
ORR	Mayor's Office of Recovery and Resiliency
QOL	Quality of Life
ROWB	Right of Way Bioswale
SGS	Stormwater Greenstreet
SIPA	Columbia University's School of International and Public Affairs
SIRR	Special Initiative of Rebuilding and Resilience
UHI	Urban Heat Island
ULURP	Uniform Land Use Review Procedure
USGS	United States Geological Survey

List of Tables

List of Figures

List of Boxes

Introduction

Planning for the future of today's modern cities poses enormous challenges. Urbanization is occurring at an unprecedented rate, causing large-scale land alterations to the natural environment. The resulting loss of biodiversity and natural ecosystems, along with increasing GHG emissions, has intensified the effects of climate change, making cities more vulnerable in the process. With the increased threat of climate change towards cities, planners must be able to quickly adapt policy to address the ever-changing environment. In the past decade, New York City has been at the forefront of climate change policy, as it has recognized the threats climate change poses to the safety and well-being of the population and to the built environment.

Using the principles of urban ecology, NYC has developed bold plans and implemented creative strategies to help guide resilient and sustainable development, particularly through greening efforts as a form of climate change mitigation and adaptation. As the city has demonstrated, policy-making is a dynamic process that must respond to the changing physical, social and political environment, and to the increasing body of scientific and academic evidence. This paper will look specifically at the changing environment of the NYC borough of Manhattan, and will ask the following questions:

- What are the implications that the city's climate strategies have had in shaping land use, biodiversity and well-being?
- To what extent has urban design and development been successful in minimizing the urban effects of climate change, while increasing ecological resiliency and human well-being?

Recommendations will then be made regarding what NYC needs to do to continue to meet the challenges of climate change.

To move forward with this report, it is first necessary to define some key terms that will be used throughout **[Box 1]**

Box 1 – Definitions

Sustainable Development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations,1987)

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. (International Panel on Climate Change, 2014a, p. 5)

Mitigation: Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Mitigation, together with adaptation to climate change, contributes to the objective expressed in Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC):

> *… stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.* (IPCC, 2014b, p. 4)

Resilience: The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation. (IPCC, 2014a, p.5)

It is apparent that climate change is a worldwide phenomenon, and that urbanization is one of the major catalysts. Almost seventy percent of the world's greenhouse gases are produced in cities, making them one of the main contributors of climate change (World Bank, 2010). Urbanization has made cities vulnerable to extreme weather events, due to the destruction of natural surfaces (such as trees and vegetation) being replaced with artificial surfaces (such as concrete, dark roofs, and asphalt roads and lots).

Manhattan is a prime example of an extensively altered landscape over the past 400 years. Once an island teeming with multiple ecosystems, biodiversity, rivers and mountains, it is now an environment of flat, artificial surfaces. The dramatic alteration of the land, combined with the intense development that has occurred has rendered the small island extremely susceptible to the negative effects of climate change. Pollution and GHGs are negative by-products of development, and have become an issue primarily due to the millions of buildings and automobiles, along with out-dated infrastructure present in Manhattan. The hundreds of miles of concrete used for streets combined with rooftops of buildings has created a vast amount of impermeable, low-albedo (low or non-reflective) surfaces. As a result, heat waves, UHI, storm intensity, flooding and storm surges have become severe risks to the population. Modern-day Manhattan now faces environmental issues once naturally controlled by the land. Though it is not possible to return the land to its natural state, past ecological processes should be examined, and attempts should be made to replicate them into modern city plans.

In the 1970s, the United States first began noticing climate change as an issue and began to incorporate it into federal policy; however, it was not until 2007 that the city of New York addressed climate change at the local level by adopting an environmental strategic plan that mapped out sustainable initiatives for the city. *PlaNYC: A Greener, Greater New York* was the first of its kind in the city, and gained much international attention and recognition for its ambitious sustainability and climate change goals and initiatives (McPhearson, Maddox, Gunther & Bragdon, 2013). The plan has undergone a number of dramatic changes over the past decade, due in part to the new scientific knowledge that has emerged, along with significant political and environmental events.

This report traces the evolution of the strategic plans, and how climate change measures became integrated into the physical process of urbanization. The focus will remain primarily on 'green' efforts as means of climate mitigation and adaptation since, as the report argues, there is a significant link between climate change and biodiversity. The importance of providing engineered greenspaces (such as green roofs and bioswales) in the city that work to help mitigate the negative effects of climate change, while at the same time providing peaceful refuses for humans and non-humans, is stressed. 'Grey' mitigation and adaptation efforts (such as zoning, building codes, density and transportation policy) are also discussed, as they too play a very significant role in climate change policy.

Chapter 1 introduces the literature, and how it relates to the major themes presented in this report. Urban Ecology will be defined and presented as to why it is important for sustainable growth and development. How climate change is affecting cities, and what that means for land use, biodiversity and well-being will also be explored. Finally, 'green' climate change mitigation and adaptation strategies are discussed. Chapter 2 explains the methodology, which consists mainly of a review of the strategic plans, along with other regulations and complementary reports. Chapter 3 introduces the history of the landform for Manhattan, and how urbanization and dramatic land alterations have lead to the island's current vulnerabilities to climate change. The second part of this chapter will introduce the current social, physical, political and environmental contexts and how they relate to climate change. Chapter 4 focuses on an analysis of the environmental strategic plans set out by the City of New York, and how the different initiatives have influenced land use, biodiversity and well-being. Finally, Chapter 5 presents recommendations for how NYC can move forward, along with lessons for NYC and other big cities to consider.

Chapter 1 – Literature Review

Introduction

The literature review will provide the necessary background for my analysis of the environmental strategic plans put out by the Mayor's Office of New York City along with other complementary plans and reports released by various agencies and actors. In addition, it will help with the formulation of recommendations for the borough of Manhattan, New York. The literature review is divided into three sections:

- **Section 1** introduces the term "Urban Ecology" and the concept that the city must be regarded as an ecosystem in order to plan for its sustainable urban growth and development.
- **Section 2** discusses the effects of anthropogenic climate change on the urban ecosystem. It draws conclusions about the importance of promoting and conserving biodiversity as a means to enhance human well-being.
- **Section 3** discusses mitigation and adaptation measures being made by planners and decision-makers to address the threats of climate change, along with the importance of social equity in applying these measures.

The overall aim of this literature review is to focus on green strategies that not only integrate greenspace into the urban environment as a means for climate mitigation and adaptation, but that also help to promote biodiversity and human well-being. Though there are a number of other important mitigation and adaptation efforts that could be discussed, the scope of this review will centre specifically on greening efforts as climate strategies.

Section 1- Urban Ecology and the City as an Ecosystem

Urban ecology is a relatively new discipline in the field of Urban Planning, though its origins can be traced back almost 2000 years when Hippocrates first discussed the effects of the environment on the health of people and communities (Spirn, 2012). It was not until the 1920s when urban ecology was developed as a true area of study in the field of sociology at the Chicago school, and was deemed to be "the study of the relationship between people and their urban environment" (Wu, 2014). This was a first step towards studying the city as an ecosystem, yet was limited to the study of humans and their built environment and excluded the natural environment that existed within the city. In fact, the Chicago school had named it "Human Ecology". However, with the increase of scientific literature examining the urban natural environment of cities, urban ecology evolved into its own discipline by the 1970s (Spirn, 2012). The field of urban ecology thus began to integrate traditional ecology, which focused on the biological and physical sciences in its study of ecosystems, with the social sciences (McDonnell, 2015).

Over the last thirty years, the field has evolved from studying the ecology 'within the city', to studying the ecology 'of the city' (McDonnell, 2015; Burkholder, 2012). With this new approach, urban ecology not only changed the way it looked at cities, but how it defined cities. In this view, the city is seen as an ecosystem that contains all living things human and non-human interacting with each other and their physical environment. The built environment (buildings, infrastructure) and the natural environment (water, soil and plants) act in tandem to comprise the ecosystem. Both cultural flows (people, capital, goods) and natural flows (water, air, nutrients, pollutants) run through the urban

ecosystem (Spirn, 2012). These processes act as the fundamental drivers of the ecosystem, while at the same time posing its greatest threats**.** In particular, human activities have manifested into some of the greatest environmental challenges towards the city as an ecosystem.

The prevailing pattern of urbanization has led to increased climate stress, as cities are growing in more suburban, land and resource-intensive ways that are excessive. This has caused a wealth of problems, including greenhouse gas emissions, pollution and land alterations; all of which have been linked to greater issues such as climate change, urban heat island, health issues, flooding, storm surges and other extreme weather events (Wu, 2014). If not monitored properly**,** the urban ecosystem can easily become vulnerable to shocks and stresses, wherein human activities can become too much for it to handle. The city must therefore be managed as an interconnected network of ecological and social patterns and processes (Hostetler, Allan & Meurk, 2011). A comprehensive, multidisciplinary approach is vital for the proper planning of resilient, sustainable cities. As Sprin (2012) says:

> Ecological urbanism is critical to the future of the city and its design: it provides a framework for addressing challenges that threaten humanity, such as global warming, rising sea level, declining oil reserves, rising energy demands, and environmental justice, while fulfilling human needs for health, safety, and welfare, meaning and delight (p.1).

Urban design should follow the principles of urban ecology as closely as possible to help guide land use in a way that will be beneficial, and not detrimental, for present and

future generations. The following sections will discuss the challenges that planners and decision-makers face as a result of climate change, and the different methods that are essential to help decrease vulnerability and build resiliency in a city. Using the urban ecological approach, three main concepts essential for a healthy urban ecosystem will be discussed**:** land use, biodiversity and human well-being. How these concepts act to shape plans and influence city policy development will be the guiding principle for the remainder of this paper.

Section 2 - Threats to the Urban Ecosystem

Climate Change

Anthropogenic climate change is arguably the greatest threat to human society, as the temperature of the earth is rapidly increasing. Evidence has shown that since the beginning of the industrial period, the earth's temperature has increased by almost 1 degree C (World Bank, 2010). It is very likely that humans are altering the earth's climate system, and that this increase in temperature is largely influenced by rapid economic and population growth. The deleterious byproducts of that growth come in the form of unprecedented levels of greenhouse gases (GHG's) in the atmosphere that include carbon dioxide, methane and nitrous oxide (IPCC, 2014c). Cities have a great potential for wealth generation as they are tied to urbanization and economic growth. However, this growth poses great risks to the environment, as well as to the health of citizens. For example, in the United States nearly seventy-five percent of energy consumed comes from the construction and maintenance of buildings and transportation within cities (Steiner, 2009).

Climate change is also a natural process. As historical records have shown, it is a process that occurs slowly over thousands of years. Many climate change events have

occurred in the earth's history, ranging from ice ages to global warming (Environmental Protection Agency, n.d.). In comparison, anthropogenic climate change caused by urbanization and industrialization is occurring at a much faster rate. The World Bank (2010) reports that: "human-induced climate change is occurring on a one-century time scale, giving societies and ecosystems little time to adapt to the rapid pace" (p. 4). This change has put tremendous strains on cities, making them highly vulnerable to environmental hazards in the process. Pelling (2012) defines vulnerability as: "an exposure to risk and an inability to avoid or absorb potential harm" (p. 5). This is further broken up into physical and social vulnerability, the former being a "vulnerability in the built environment" and the latter a "vulnerability experienced by people and their social, economic and political systems" (p. 5). The more vulnerable the city, the greater the exposure it has to hazards and potential disasters.

The number of extreme weather and climate events associated with anthropogenic climate change has been rising dramatically since the 1950s. The events most affecting cities include: decreasing cold temperatures, increasing warm temperatures, increasing sea-level and an increase in heavy precipitation events (IPCC, 2014c). Cities are particularly vulnerable due to the destruction of natural surfaces, such as trees and vegetation, to allow for artificial surfaces such as concrete, dark roofs, and asphalt roads and lots. The low albedo and permeability of these surfaces can contribute to negative impacts such as flooding and storm surges, and the Urban Heat Island (UHI) effect. This is evident in a city such as New York, where there has been a large-scale alteration of the natural ecosystem due to urbanization.

Most large cities are particularly vulnerable to UHI and flooding. Urban planning must take into account both proper design along with proper integrated strategies, policies and regulations in order for a city to adapt and become sustainable and resilient. Over half the world's population presently lives in cities, and this number is expected to grow to two thirds of the population by 2050 (Pauleit, Fryd, Backhaus & Jensen, 2013; Haase, 2013). Therefore, it is imperative that cities adopt climate change mitigation and adaptation policies. These policies, through proper resilient planning strategies, will focus on sustainable land use implementations, and the protection and restoration of local biodiversity (Mawdsley, O'Malley & Ojima, 2009).

Land Use and Extreme Events

In order to address the climate change mitigation and adaptation strategies for a city, it is first necessary to understand the processes that are affecting the city. This section will discuss how land-use has changed the natural environment to become hazardous to humans, particularly those living in large cities. UHI and flooding will be the focus of this section, as they are two major processes that result from climate change that have serious negative effects on cities.

Urban Heat Island

The UHI effect refers to the increased temperature of an urban area compared to the surrounding rural areas. The dramatic change in land use that occurs during urbanization has a significant impact on the earth's climate (Johnson, 2015). Cities create new, artificial surfaces from concrete and asphalt (in the form of roads and buildings), which take the place of vegetation, are impervious to water and trap the sun's heat (Scott, 2006). The lack

of permeability of these surfaces leads to an increase of volume and rapidity of water runoff, thereby affecting the evaporation of rainwater that would otherwise help cool the air (Snep & Clergeau, 2013). Concrete and asphalt surfaces have a lower albedo compared to vegetative cover, which acts to absorb the sun's energy rather than to reflect it. This energy is absorbed during the day and is slowly released at night, leading to much warmer nighttime temperatures (Greene & Millward, 2016). On average, the UHI in a city will increase temperatures by around 3 or 4 degrees C during the day, and as much as 11 degrees C at night (Heisler & Brazel, 2010).

Along with the actual physical characteristics of the urban form that contribute to UHI, there are also indirect influences (or by-products) that emerge from the artificial surfaces. Cities are big producers of GHGs, primarily created by traffic, industry and the byproducts of running of air conditioners (Ibid., 2010). The release of GHGs further exacerbates the effects of climate change by increasing the occurrences of UHI events, leading to "adverse human health, economic and environmental impacts" (Corburn, 2009, p. 414). UHI is not completely bad, as it has shown to have some positive effects for city-dwellers in the winter. Warmer winters mean less energy used for heating homes. It also means less snow and ice, which also leads to longer growing seasons (Voogt, 2004). However, the negative effects of UHI are still present in the winter. At night, inversion layers can form over the city which trap the ascending warm air, essentially covering the city with a lid. This process can greatly exacerbate the pollution in the air (Yamamoto, 2006). During the summer, UHI can lead to extreme events. In particular, the intensity and duration of heat waves are magnified significantly by UHI, increasing heat stress mortality rates (Sachindra, Ng, Muthukumaran & Perara, 2016). In July, 1995, a heat wave in Chicago

resulted in over 700 people losing their lives (Yamamoto, 2006). In the summer of 2003, a devastating heat wave swept across Europe, resulting in the death of over 70,000 people (Robine et al., 2008).

There is mounting evidence that climate change and UHIs are causing these extreme events to occur and that adaptation and mitigation measures are required, starting at the local level. The IPCC (2014c) reports that it is "very likely that heat waves will occur with a higher frequency and longer duration" (p. 10), based on an emissions scenario for the end of the 21st century.

Flooding and Storm Surges

Sea-level rise is a major concern for coastal cities across the globe. Climate change further exacerbates the vulnerability of the particular city as it has a direct influence on sea-level rise. Extreme events such as storm surges and flooding are more likely to occur, and can be devastating to a city. The level of vulnerability of the city is based upon its adaptive capacity and level of resiliency. The urban form of the city and how planners and decision-makers manage its land use is extremely important. Much like the measures taken for UHI reduction, planners and officials must be aware of the potential impacts of climate change on the urban infrastructure.

Most cities are not built to withstand extreme climate events due to the makeup of the built environment. Urbanization has created artificial surfaces that disrupt the earth's natural ecological processes. Paved surfaces are impervious to rainwater, thereby

increasing the likelihood of flooding (van Bueren, 2012). Proper drainage systems are of the utmost importance as urbanization increases drainage flow demand for both wastewater and rainwater (Lamond, 2013).

Additionally, the ecosystems of coastal cities are much more complex and delicate than non-coastal cities. Development that occurs on coastlines disrupts very sensitive ecosystems such as wetlands, estuaries and coastal strips (Pelling & Blackburn, 2013). This is troublesome, as there are currently twenty-three coastal megacities (a city with 10 million or more inhabitants) (Blackburn & Marques, 2013). These cities are normally constructed in locations that are not ideal for the development of stable physical infrastructure. When cities are built on coastal wetland or peat soil areas, developers remove the original upper soil layer and replace it with constructive-supportive sand layers. This process effectively seals the soil underneath, thereby altering its composition and reducing the permeability (Snep & Clergeau, 2013). As a result, when faced with extreme weather events, coastal cities face a high risk of flooding and storm surges.

A storm surge is defined as "an abnormal rise of water generated by a storm, over and above the predicted astronomical tide" (National Weather Service, n.d., p. 1). New York City is highly vulnerable to storm surges, as witnessed during Hurricane Sandy in 2012 when peak storm-surge tides rose to 9.43 feet (Schubert et al., 2015). In a study conducted through climate modeling, Lin, Emanuel, Oppenheimer and Vanmarcke (2012) predicted that due to climate change, the probability of a 100-year surge flooding in New York City could occur even sooner in the next twenty years. It is evident that storm surges pose a

great risk, and their frequency will increase with the rise in sea level (IPCC, 2014c; Grimmond, 2013)

Threats to Biodiversity and Well-Being

The loss of natural ecosystems in cities has led to more attention being placed on the importance of biodiversity and its relation to climate change. The two are inextricably linked, as climate change is affecting local biodiversity, causing natural habitat loss and death of local species while introducing other invasive species. In turn, the loss of biodiversity magnifies the adverse effects of climate change, which can have significant effects on human well-being and quality of life (ICLEI, 2010). The following sections will discuss the effects of urbanization on biodiversity and the imperative to protect and promote biodiversity as a means to ensure human well-being.

Urbanization and Biodiversity

The United Nations defines biodiversity as: "the variability among living organisms from all sources, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems" (United Nations, 1992, p.3). Anthropocentric climate change due to rapid urbanization has had a significant impact on biodiversity in the past century. The rapidity of urbanization and alteration of ecosystems has been so drastic that the rate of loss of biodiversity is the fastest that has occurred in the last 65 million years (ICLEI, 2010). Extreme climate events such as heat waves and flooding have caused extensive

damage to not only to humans, but to the various ecosystems that exist in and around cities (IPCC, 2014c).

It is said that the earth is in the midst of its sixth mass extinction. The first five extinctions occurred over the last 500 million years, whereas the sixth is occurring over a matter of decades. The resulting destruction includes habitat loss and fragmentation, over-exploitation of species, pollution and contamination, and global warming (Grifo & Rosenthal (Eds.), 1997). In a study conducted by Wiens (2016), 976 different species were studied from across the globe and across different habitats. The author found that forty-seven percent of the species studied had already succumbed to climate-related local extinctions. He concluded that only slight climate changes were enough to kill off certain local species, and that "local populations in many species cannot shift their climatic niches rapidly enough to prevent extinction" (p. 9).

A study by McPhearson et al. (2013) described the threat towards native species in New York City, and concluded that in the last 100 years, ninety-three percent of the species were in decline due to habitat loss, climate change, habitat fragmentation, decreased pollinator availability, UHI, invasive species and pollution. It is evident that urbanization is contributing to rapid biodiversity loss, and is therefore vital that planners and policy-makers alike adopt the right approach to steer the future of development in cities. It may not be possible to protect all biodiversity from the pressures of urbanization, but it is important for a city such as New York to attempt to conserve a sufficient and meaningful amount. Biodiversity plays a key role in land-use planning, and can play a key role in climate change mitigation and adaptation. A healthy, resilient ecosystem rich in biodiversity can help provide cities with natural buffers against extreme weather events,

and can provide for a number of environmental, economic and social benefits (ICLEI, 2010).

Biodiversity and Well-Being

Biodiversity protection in cities is an important topic for planners and decision-makers, though it is often trumped by more immediate goals such as economic development, transportation, land use and recreation (Ahern, 2013). Research is showing that the interaction between biodiversity and humans in the city can have positive impacts on human well-being and quality of life (Carrus et al., 2017; Fuller, Irvine, Devine-Wright, Warren & Gaston, 2007; Palliwoda, Kowarik & Lippe, 2017; Adjei & Agyei, 2015). It is important for people to realize the long-term physical and psychological benefits of living in a healthy, safe and livable city, and that climate change poses a veritable threat to biodiversity and well-being.

Diaz, Fargione, Chapin and Tilman (2006) define well-being as including: "basic materials for a good life, freedom of choice and action, health, good social relationships, a sense of cultural identity and security" (p. 1301). This definition falls in line with that of the Millenium Ecosystem Assessment (2005), however, Diaz et al. (2006) say that the state of well-being can differ culturally, geographically and historically depending on the context. The authors therefore provide a broader definition that meets the basic needs for a larger majority of different human societies where: "well-being...is based more or less directly on the sustained delivery of fundamental ecosystem services, such as the production of food, fuel, and shelter, the regulation of the quality and quantity of water supply, the control of natural hazards, etc." (Ibid., 2006, p. 1301). It should be noted, however, that well-being is

also achieved on a more personal level through the enjoyment of interacting with a rich biological environment. The psychological and spiritual benefits of biodiversity are very important to consider when measuring the effects of ecosystem services on human well-being (Sandifer, Sutton-Grier & Ward, 2015).

Ecosystem services are the key to linking biodiversity and human well-being, as they provide direct benefits and value to humans in the form of provisioning services (i.e. food, water, natural resources) and regulating services (i.e. climate regulation, pest/ control) (Cardinale et al., 2012). Though it is difficult to establish what well-being means to any individual or culture, as Ahern (2007) explains: "The ecosystem services concept helps to place value on ecological functions, often to the direct benefit of human populations in physical health, economic or social terms"(p. 268). On an individual level, ecosystem services can provide essential psychological and spiritual benefits that include: decreased depression and anger; reduced stress and anxiety; and increased happiness, creativity, esthetic appreciation and inspiration (Sandifer et al., 2015). The loss of biodiversity will lead to a decline in ecosystem services, which will in turn increase ecological surprises such as extreme climate events and shortages of provisioning services, causing significant negative effects to human well-being (Millenium Ecosystem Assessment, 2005). The ecosystem services concept is very important to consider for policy-makers, however, there remains a lack of accountability in political and economic policy. In 2014, the United Nations placed an estimated value of $125 trillion on ecosystem services, though without a proper accounting and tracking system to support this estimation, the investment to protect and manage the services remains insufficient (Food and Agriculture Organization of the United Nations, 2017).

Section 3 - Remedies

Mitigation and Adaptation - UHI

As discussed, the main contributor that influences UHI involves the replacement of natural vegetation with impermeable, low-albedo surfaces. Planners now realize urban greening in the city is necessary to climate change mitigation and adaptation. By replacing or covering the artificial surfaces that can contribute to UHI, urban greening can help to reduce trapped thermal heat, and help create more permeable surfaces for water absorption.

Green Roofs and Vegetation

The construction of green roofs gained popularity in the 1970s and 1980s as research demonstrated their potential environmental and economic benefits for a city (Brenneisen & Gedge, 2013). In highly built up areas such as cities, roofs can make up almost thirty-two percent of coverage (Johnson, 2015). This represents a very large area of the city that is covered by dark, absorptive (and mainly unused) surfaces. However, these surfaces also present opportunity for much needed vegetation, particularly in densely packed areas that otherwise may not have the space for green areas (Susca, 2011). A green roof is constructed on top of an existing roof covering the dark surface, and replacing it with vegetation. A typical green roof is made up of five layers: a waterproof membrane to cover and protect the existing roof; a layer of drainage materials; a layer for filtering and to protect the roof from roots; growing medium; and finally the vegetation on top (Scott, 2006).

By replacing the existing roof with a green roof, a number of environmental benefits can be achieved, and the effects of UHI can be greatly reduced. The soil and vegetation of the green roof provides a cooling effect through evaporation and transpiration, respectively (Corburn, 2009). The surface albedo of the green vegetative surface, as compared to that of a dark roof, provides for a significant amount of protection from thermal radiation of the sun. A green roof can help to reduce the temperature of a building by almost thirty degrees C, as well as helping with carbon sequestration and to filter particulate matter in the air (Scott, 2006; van Boheman, 2012).

In a modeling scenario of metropolitan New York, it was concluded that a 0.1 to 0.8 degrees C reduction in surface temperatures would result from greening fifty percent of rooftops (Brenneisen & Gedge, 2013). The reduction in temperature of the roof means that less energy is needed to cool the building, meaning less reliance on air conditioners. Not only does this help to mitigate the UHI by reducing GHG emissions, it also provides an economic incentive due to the potential energy savings. For example, a fifty percent roof coverage in Los Angeles can lead to energy savings upwards of $21M per year (Akbari, 2001), and a 100 percent roof coverage in Toronto could save approximately $12M per year in energy costs (Brenneisen & Gedge, 2013). It should be noted that the cost of retrofitting such large amounts of surfaces would be much higher than the return, yet could be offset through the gradual replacement of low-albedo surfaces, such as during routine maintenance of roofs and roads (Akbari, 2001).

Despite all the positive attributes of green roofs, they do pose some negative issues. The construction of green roofs can be costly, and they may require maintenance,

particularly during a drought. In drier climates, an irrigation system may have to be installed (Scott, 2006). Thus, green roofs need not be the only solution to UHI, and should be part of a bigger network of solutions. In some cases, white roofs may be a more feasible option, as they are cheaper to construct and maintain, and still provide significant benefits to UHI reduction (Susca, 2011). However, as white roofs may help to increase albedo, they do not provide the other benefits of green roofs such as improving air quality, health benefits, and reducing stormwater runoff (Rosenzweig et al., 2009).

Urban Tree Canopy and Greenspaces

Trees and greenspaces provide the same benefits as green roofs. Greene and Millward (2016) found that there is a positive correlation between urban tree canopy density and cooler surface temperatures. Trees provide shade on ground surfaces as well as buildings, helping to reduce overall air temperature as well as reliance on air-conditioning (Voogt, 2004). Trees play a big role in carbon sequestration which helps to filter pollution in the air (Akbari, 2001). Greenspaces, such as parks, are also very beneficial as they can provide impervious surfaces and vegetation that help with evapotranspiration and increased albedo (Johnson, 2015).

Mitigation and Adaptation – Flooding and Storm Surges

Events such as flooding and storm surges have been shown to be directly related to climate change; mitigation measures that involve increasing vegetation via green roofs, trees and greenspaces can help to decrease GHGs, and thermal radiation. In terms of adaptation measures, there are numerous ways that land-use can be adapted to help with

the management of excess stormwater. Permeable surfaces are very important for drainage, and should be considered for new development and retrofitting, particularly in vulnerable cities. High levels of impermeable surfaces resulting from development of the urban built environment is said to be the biggest contributor to extreme flooding events (Yang & Li, 2013).

Luckily, there are a number of adaptation methods. Green roofs can help to slow down rainwater and to reduce local floods (van Bohemen, 2012). Trees help to intercept rainfall before it hits the ground, which acts to decrease the rate of rainwater runoff, effectively protecting against floods (Akbari et al., 2001). Greenspaces are also very useful as the vegetation will naturally help with water infiltration. In areas where pavement is required, such as roads or parking lots, replacing the paved surface with hard yet permeable pavement is a good alternative. Additionally, constructing bioswales adjacent to roads or in greenspaces will help with faster drainage and to help filter pollutants (Tjallingii, 2012). Despite these measures, it is evident that coastal cities are vulnerable to climate change, and that perhaps the best solution is to redirect development, or even relocate infrastructure away from sensitive areas that are at a high risk of flooding (Pauleit et al., 2013). Of course, this should be a last resort as cities should avoid growing outwards, and instead focus on adapting with what they already have.

Green Infrastructure

Green infrastructure is a fairly recent concept from the last twenty years and can be defined as: “an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations” (Benedict &

McMahon, 2001, p.5). Green infrastructure involves promoting multifunctionality and connectivity of greenspaces, which include green roofs, parks, urban forests, waterways, bioswales, and other vegetation found in the city. It should be beneficial to humans and non-humans, and thereby incorporates all aspects of infrastructure, including 'grey' infrastructure such as roadways (Pauleit et al., 2013). Green Infrastructure not only produces vegetative surfaces that help provide cooler surface temperatures and water infiltration, but also provides pathways or corridors that help in the movement and dispersal of different species (such as migrating birds). Urban fragmentation caused by urban development is very detrimental, as it creates habitats too small for some species to survive. Coupled with a lack of interconnection between other habitats, urban fragmentation can quickly lead to extinction (Snep & Clergeau, 2013).

Vegetation corridors help to create connectivity for species to move freely between the fragments of ecosystems. An example of this is the Green Links Project in Vancouver (Schaefer, 2003). There are many different sorts of vegetation corridors, and perhaps the term 'greenways' is better used, as it tends to refer to a number of different types of movement corridors. The common theme with greenways is that they are primarily linear in nature, and can either be engineered or can follow preserved natural paths. For example, Toronto has preserved natural ravines that act as corridors between parks (Savard et al., 2000). An example of an engineered greenway is the High Line in Manhattan. Greenways not only help with the movement of species, but they also provide social benefits by tying communities together, providing arenas for social interaction and helping to create a sense of community (Hellmund & Smith, 2006).

Green infrastructure as a whole system is very important in providing ecosystem services. If planned properly, green infrastructure could be a self-sustaining, resilient solution to climate change adaptation and mitigation that provides a sustainable means to help alleviate flooding and UHI, and to further promote biodiversity and well-being (Connop et al., 2016). One way that cities can help to steer development in this direction, as stated by van Bohemen (2012), is to make it mandatory for developers to have a biodiversity action plan and a green infrastructure action plan to map out how their plan will incorporate the different aspects into the larger green city network. Based on this, it is evident that climate change mitigation and adaptation plans must come from the local level.

Social Equity

A number of concepts have been mentioned as being essential solutions for the proper management of threats from climate change. As well, it was discussed that land-use, biodiversity and well-being are key concepts to consider when developing the ideal plans to maintain the city as an ecosystem. The concept of social equity, however, is essential to apply as an overarching guiding principle to ensure the distribution of services is spread equitably. As Shonkoff et al. (2009) assert**:** "Climate change is not only an environmental issue; it is also a human rights, public health, and social equity issue" (p. 16). Environmental policies must be carefully drawn so as to not favour certain communities over others.

Research has shown that low-income communities often suffer most from climate change because they lack the resources to cope, resist and recover from extreme weather events. As well, climate change can be associated with economic shocks (such an increase in price for basic necessities) and economic shifts (such as threats to job loss) that negatively affect low-income and minority populations (Godschalk, 2003; Shonkoff et al., 2009). It is important for the well-being of all residents that environmental policy addresses the needs of the entire urban ecosystem, while at the same time being attentive to the needs of individual communities. According to Wachsmuth , Cohen and Angelo (2016): "Focusing on dense cities and their affluent areas ignores social movements and their advocacy for quality-of-life issues such as housing and commuting, which have direct ecological consequences" (p. 392).

Not only can underserved communities feel the brunt of climate change policy, but urban design projects that include greening efforts and climate change adaptation plans can also have potential detrimental effects. For instance, greenways were discussed earlier as being beneficial corridors that allow for the easier movement of species and that bring diverse communities together. However, as Hellmund and Smith (2006) explain, because greenways can act as economic boosters, they have the potential to cause gentrification. The newly desirable space created by greenways can cause adjacent land prices to increase, attracting new forms of business and development (such as condos), and creating a higher tax base, subsequently causing the displacement of low-income residents who are likely to be renting. Examples include the Rose Kennedy Greenway in Boston which saw property values increase by seventy-nine per cent between its inception in 1988 and 2004 (Hellmund & Smith, 2006), and the Highline in Manhattan which has "stimulated an

estimated $4 billion in private investment" (Beatley, 2011, p. 8), and saw property values spike 103 per cent between 2003 and 2011 (Madhani, 2017).

Climate change adaptation plans are also carried out in many places without consulting low-income communities first, and without regard to how these communities will be affected. In Jakarta, a plan for a series of massive seawalls involved the eviction of kampong settlements along the riverbank without any plans for re-housing. In Dhaka, embankments were constructed in one area of the city without consulting adjacent communities who suffered consequences (Shi and Anguelovski, 2016). To conclude, planners must ensure that it is not only the wealthy groups that control the decision making process who benefit from adaptive land use regulations (Wachsmuth et al., 2016).

Conclusion

The preceding discussion has made a case that the future of sustainable development in planning is to develop proper resilient plans that promote equitable adaptive measures that follow the principles of urban ecology. Climate change is having a major impact on the city and its inhabitants, manifesting in large part as extreme weather events. Unfortunately, many cities are not built accordingly to withstand the shocks of these events, and ultimately suffer catastrophic consequences. The future of cities is dependent on the proper management of land-use regulations, biodiversity and human well-being.

Plans need to base themselves on the concept of the city as an ecosystem, and to integrate nature and greenspaces wherever possible. Only then will the flows and processes that drive the city be truly understood, and managed accordingly. A comprehensive, multidisciplinary approach is vital for the proper planning of resilient,

sustainable cities. The rest of this paper will focus on a case study of the borough of Manhattan, New York City, portrayed as an urban ecosystem and guided by an unprecedented and rapidly evolving environmental strategic plan.

Chapter 2: Methodology

Rationale

The purpose of this research project is to provide an in-depth analysis of climate change mitigation and adaptation efforts, along with resilient planning strategies implemented by the City of New York. A qualitative approach is applied to examine the various plans and initiatives taken by the city and other key actors to promote sustainability and resiliency, with a specific focus on the borough of Manhattan. The intended results of this analysis will highlight the implications these initiatives will have on land use in terms of: green infrastructure and architecture, and parks and open spaces. A further analysis will focus on the city's efforts and what they mean for the promotion and conservation of biodiversity in the city. The following questions are asked: Are the initiatives affecting land use and biodiversity merely site specific or do they consider the regional, or even global, implications? Are the issues of ecological connectivity and habitat fragmentation properly addressed, through the lens of the city as an ecosystem? These questions will help to measure the extent to which the city is taking the appropriate measures to promote urban ecology, sustainability and resiliency.

The link between biodiversity and how it can affect the health, wellbeing and quality of life (QOL) is a concept that will also be examined. The reasoning for including this section of research is that it could help validate the importance of considering human well-being in the initiatives. Environmental efforts and projects may prove to be costly and, unless monetary incentives are offered, people may not see the value, as there may be no immediate economic return on investment. However, it is important for people to realize

the long-term physical and psychological benefits of living in a healthy, safe and liveable city. The importance of considering equity in the planning process will also be discussed. Next, a set of recommendations is presented for the city of New York that will focus on process, physical, and policy interventions, all based on the guiding principle of reducing the negative effects of climate, while maximizing well-being and quality of life. Lastly, the paper will examine the lessons learned for Manhattan and New York City as a whole, and considerations for other big cities.

Methods

The methodology for this research paper consists of information gathering from three main types of sources: 1) Analysis of Plans, Initiatives, and Research; 2) Correspondence with Actors; Researching Government/Non-Profit Organization's Websites; 3) On-Site Field Surveys/Observations.

1) Analysis of Plans, Initiatives and Research

The majority of this research project is based on an analysis of various plans, initiatives and research that are the most pertinent to the subject of sustainability, resiliency and climate change adaptation in New York City. **Table 1** below provides a summary of the publicly available documents deemed to be the most important:

Table 1 - Strategic plans, reports and documents consulted to study Climate Change mitigation and adaptation - NYC

Title	Date	Mandated by	Description	Goal(s)
Sustainable New York City	2006	Design Trust for Public Space; OEC	Laid the groundwork for the PlaNYC 2007 Report	Outlines and defines Sustainable Development and what it means for NYC and the future.
PlaNYC: A Greener, Greater New York	2007	OLTPS **Mayor**: Michael Bloomberg	Multi-agency effort to create comprehensive plan for a greener, more sustainable city.	To brace the city for 1 million new residents, to strengthen the economy and to deal with climate change. Specific goal to have a 30% carbon reduction by 2030.
NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterways	2010	Office of the Mayor; DEP; DOT; DPR; DDC; DCP; DOE; DSNY; DCAS; HPD; EDC; NYCHA	Builds upon and extends commitments of PlaNYC and Sustainable Stormwater Management Plan.	A critical goal is to manage runoff from 10% of the impervious surfaces in combined sewer watersheds through detention and infiltration source controls.
PlaNYC: A Greener, Greater New York (Update April 2011)	2011	OLTPS **Mayor**: Michael Bloomberg	The first required update to the 2007 PlaNYC report.	Builds upon the goals of PlaNYC 2007, adding more initiatives and milestones based on NPCC climate projections. Addresses initiatives specific to resiliency planning.
PlaNYC: A Stronger, More Resilient New York	2013	OLTPS **Mayor**: Michael Bloomberg	The Special Initiative of Rebuilding and Resilience (SIRR) was convened as a response to Hurricane Sandy.	Outlines the lessons learned from Sandy, as well as a comprehensive coastal protection plan. Includes initiatives and recommendations for rebuilding after the storm.
Biodiversity Assessment Handbook for New York City	2013	Eric Kiviat & Elizabeth A. Johnson; published by American Museum of Natural History	NYC Biodiversity Guidebook to be used by planners, land managers, researchers, consultants, students, advocacy groups, professionals and students.	To define urban biodiversity; to provide overview of NYC's ecological setting.
City Environmental Quality Review (CEQR): Technical Manual	2014	Mayor's Office of Environmental Coordination (MOEC)	Provides guidance for city agencies, project sponsors, the public, and other entities in the procedures and substance of the CEQR process.	Comprehensive discussion of the CEQR process, including simple environmental assessments and more complex analyses appropriate for EIS

PlaNYC Progress Report 2014: A Greener, Greater New York A Stronger, More Resilient New York	2014	OLTPS ORR. **Mayor**: Bill de Blasio	First progress report (update) to PlaNYC with the new mayor. Has added 'Resiliency' to its mandate.	Continue the implementation of sustainability goals. Implementation of a comprehensive coastal protection plan.
One New York: The Plan for a Strong and Just City	2015	OLTPS ORR Mayor: Bill de Blasio	Builds upon the four core challenges from past PlaNYC reports, and now includes: growing inequality, the importance of the region, and New York City voices.	A strong, sustainable, resilient and equitable city. Specific targets include: -Get 800,000 people out of poverty -Zero Waste to landfills -Reduce GHGs by 80% by 2050 -Eliminate long-term displacement after shock events -Reducing flood risks
New York City Nature Goals 2050	2015	Natural Areas Conservancy	Natural Areas Conservancy Advisory Board convened with numerous other experts, scientists and organizations to come up with a set of goals for the "function and composition of nature in NYC"	Goals include: -support for biodiversity and habitat -provision and enhancement of clean air and water -protection and resilience from coastal storms -connectivity for plants and animals -inspiration for city residents
New York City Panel on Climate Change (NPCC)	2015	Multidisciplinary team of climate scientists and academics	Convened by Mayor Bloomberg in 2008 as part of PlaNYC.	-Meet at least twice a year to review recent scientific data on climate change and its potential impacts -Makes recommendations on climate projections for the coming decades to the end of the century
State of New Yorkers – A Well-Being Index	2015	CIDI commissioned a Capstone team from SIPA	Research project that studies indicators, which help approximate the well-being of New Yorkers.	To create a place-based index of socio-economic well-being in NYC communities.

2) Correspondence; Researching Government/Non-Profit Organization's Websites

Key information was collected via email with a number of different actors. This enabled me to gain a better understanding of some key concepts and processes. For example, I wanted to know the different stages of scrutiny a climate change initiative or proposed project must pass through in order to achieve the end result of either an enacted

policy (or legislation) or a development. Through correspondence I was directed towards the proper channels to gain this information, which for the most part, is available publicly on various websites (such as the nyc.gov website, and websites of non-profit organizations and researchers).

3) On-Site Field Surveys/Observations

Information was gathered in the field through site visits. Though the entire island (and smaller off-shore islands) was not possible to visit, some key sites were observed to provide context. This included specific sites such as the Highline, Central Park, Battery Park and Collect Pond Park amongst other biodiversity corridors and havens, parks, bioswales and greenstreets projects.

Other on-site visits include attending various events during Earth Week in Manhattan, between April 18-25, such as:

- The Earth Day 5K Green Tour, hosted by Earth Day Initiative
- Interactive showcase organized by The New School of community-based participatory research that focuses on climate change and the environmental threats to community well-being and social justice.
- Lectures organized by local schools and organizations: The New School, Urban Green Council.

Takeaway

The intended result of the project is to produce a qualitative, comprehensive study that focuses on the current research being conducted, trends being followed and initiatives being implemented as they apply to Manhattan. The intention is to help contribute to the current literature, and to help summarize and simplify the complexity of this particular

subject. The hope is that from the analysis of the plans, initiatives and processes, along with the recommendations being made, that this project could help to guide further research and policies.

Limitations

Below is a list of limitations which I have identified:

- The plans are constantly being updated so access to the most recent reports is difficult, as they may not be publicly available yet.
- The reports analyzed mainly discussed city-wide initiatives, which included New York City as a whole (all five boroughs). This meant that there were a lack of borough-specific initiatives, so generalizations for Manhattan had to be made. This is problematic because Manhattan is very different from the other boroughs in terms of characteristics such as the built environment, income and density.
- Live interviews with stakeholders would have been helpful, but this was not possible due to time constraints and distance.
- Random surveys of people in Manhattan would have been beneficial to gather information on people's personal feelings and perceptions of how nature/biodiversity affects them. This would have been a useful tool to measure wellbeing and QOL and its relationship to biodiversity specifically in Manhattan. However, time constraints were a factor, and a large sample size would have been required to yield any significant results.

Chapter 3: Study Area - Manhattan, NYC

Part 1: History of the Landform

Introduction

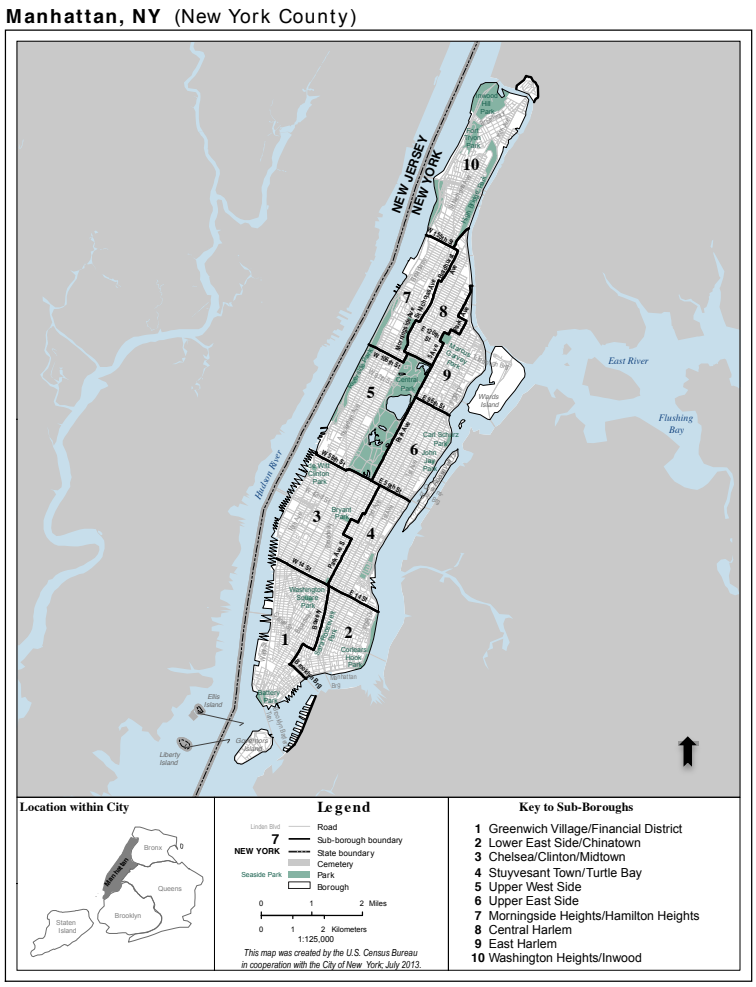
The purpose of this section is to trace the natural and ecological history of Manhattan, and how it has evolved since its discovery by European settlers 400 years ago. It is important to study the history of the landform and the environmental changes that have occurred as it provides a window into the natural processes that once existed, and which provided the necessary catalysts for life to thrive[1]. As such, this chapter will examine how the past ecological resilience of Manhattan can be used to help provide answers for future initiatives.

Overview

Manhattan is a dense, heavily populated borough located in New York City in the northeastern United States. It has a population of 1,643,734 (U.S. Census Bureau, 2016) and is the densest of the five NYC boroughs with nearly 70,000 people per square mile (U.S. Census Bureau, 2010). The borough of Manhattan is comprised of nine islands. Manhattan Island is by far the largest and has the overwhelming majority of the population. The island is 21.6 km long and 3.7 km wide at its widest point, and is bounded by the Harlem River to the North, the Hudson River to the West, the East River to the East, and the New York Harbour to the South (McColl, Ed., 2005). The smaller adjacent islands include Ellis,

[1] This concept was first explored in detail by Register (1987), who developed innovative ideas for the planning of future green cities (what he dubbed as 'eco-cities'). Using this approach, he traced the natural history of Berkeley, California until the present day to examine and compare the changes in landform, the losses of biodiversity, and the alterations of ecological processes. From this he developed a vision to rebuild Berkeley that is not only sensitive of, but also aims to re-introduce, the natural and historical ecology of the area. Two decades later, Sanderson (2009) conducted similar research on Manhattan.

Figure 1 - Location of Manhattan



Source: New York City Housing and Vacancy Survey 2014, https://www.census.gov/housing/nychvs/data/2014/manhattan.pdf.

Governors and Liberty Islands (which are located in the New York Harbour); and Randalls, Wards, Roosevelt, U Thant and Mill Rock Islands (located in the East River). Marble Hill is also considered part of Manhattan, and is the only part of the borough located on the mainland **[Figure 1]**.

Manhattan is part of an archipelago that includes Staten Island, as well as the western part of Long Island. This archipelago is also part of an estuary, where the Hudson River meets the New York Harbour, and is home to an abundance of marine life (Sanderson, 2009). Manhattan was once an extremely ecologically diverse habitat and haven for biodiversity. At the time of its discovery in 1609 by Henry Hudson, Manhattan was home to 55 different kinds of ecological communities (neighbourhoods comprised of distinct assemblages of life). To put it into perspective, fifty-five ecological communities is more than is found in all of Yellowstone National Park (Ibid., 2009). Manhattan is a very different place today as it has witnessed an extreme alteration of the natural landscape. Streets and skyscrapers now dominate a land once covered by rich vegetation and forests. This alteration has had a very

significant environmental impact on the ecosystem that was once Manhattan, and has been a major factor in precipitating extreme events such as flooding, storm surges and the Urban Heat Island in the present day. The following section will trace the natural history of Manhattan Island, including the anthropogenic changes made since its "discovery" by European settlers.

Early Land Form - "Mannahatta"

Manhattan was once a very different place than it is today. When Henry Hudson and his crew arrived in 1609 at the mouth of the Hudson River, they were welcomed by an area filled with lush oak forests, fur-bearing animals, and a plentitude of fish swimming in the waters (Barr, 2016). They had discovered an ecologically diverse and inviting habitat rich with resources. The land was a haven for biological productivity, mainly due to its location at the mouth of the estuary, a location where "the last glacier reached its southermost extent 20,000 years ago" (Natural Areas Conservancy, 2016, p.8). The site produced a land with rich soils for plant life, vast forests, rivers, wetlands and hilly terrain.

In *Mannahatta: A Natural History of New York City,* author Eric Sanderson details a project he and his colleagues had been working on that involved tracing the history of Manhattan back 400 years, using GIS maps to re-create the old landscapes. The British Headquarters Map was used as the basis of the project, as it is the only surviving map that documents the original topography of Manhattan. Produced by the British military for use to strategize the defense of the island, the map is meticulously detailed and extremely accurate (Cohen & Augustyn, 1997). Sanderson created maps and renderings using data interpolation from the British Headquarters Map, along with geological records and other historical data. By doing so, he was able to visualize what the landforms of Manhattan once looked like, providing very useful information on how the landform has since been altered.

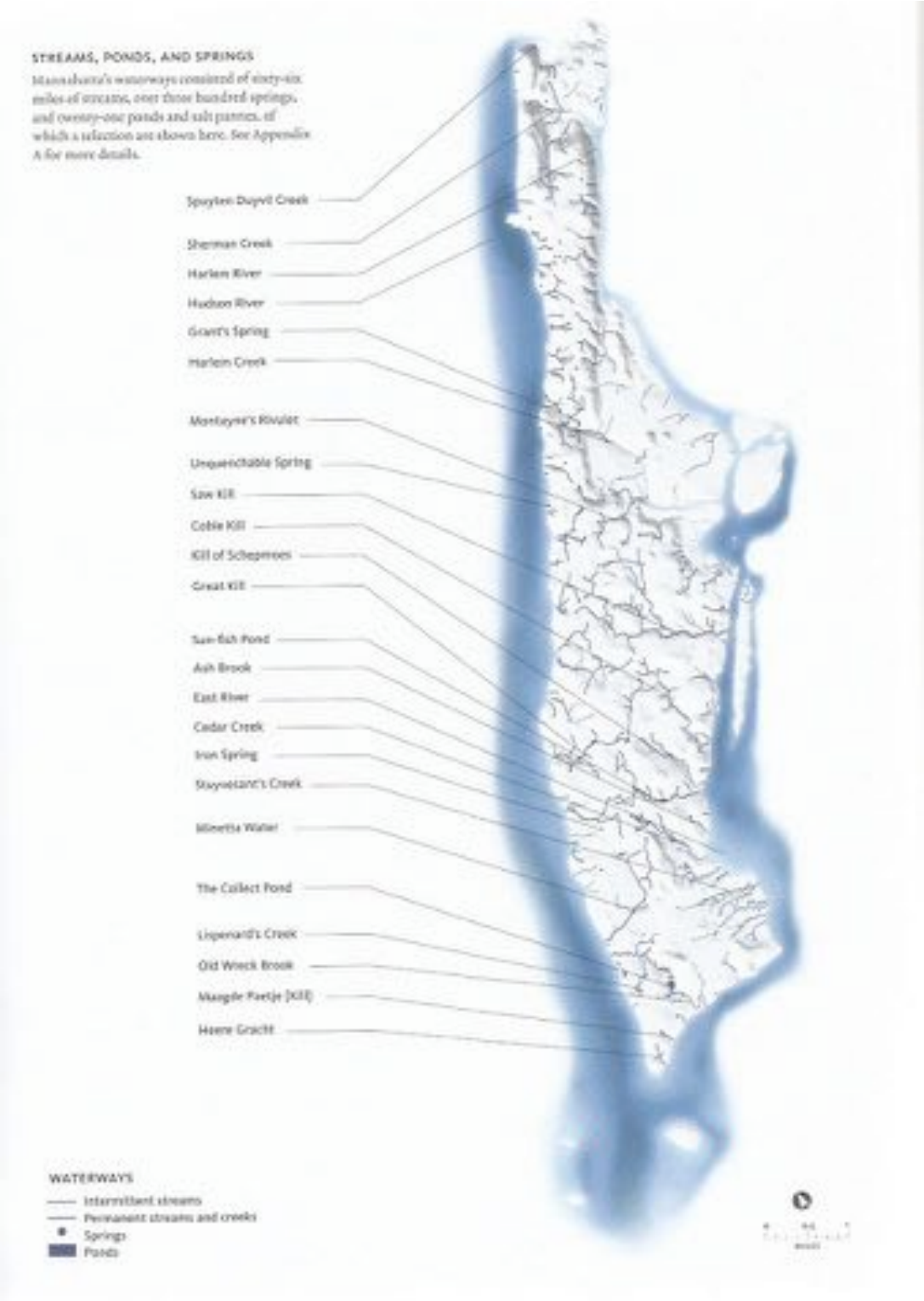
Figure 2: Topography of Manhattan (1609)

Source: Sanderson, E. W. (2009). *Mannahatta: a natural history of New York City*. New York: Abrams, 79.

For example, **Figure 2** depicts Manhattan as being a very hilly island, with around 573 peaks in total. The peak elevations vary throughout the island, ranging from 20 feet at Verlettenberg to 270 feet at Mount Washington. This shows that Manhattan was once characterized by very uneven terrain yet, as it stands today, Manhattan is a relatively flat island that lies near sea-level (McColl, Ed., 2005). The name Manhattan is actually derived from the Lenape word “Mannahatta”, which means “land of many hills” (Sanderson, 2009).

Amongst the hills was an extensive network of waterways. **Figure 3** shows a selection of the waterways that once existed, which included "sixty-six miles of streams, over three hundred springs, and twenty-one ponds and salt pannes" (Sanderson, 2009, p. 97). Today, only one salt marsh exists.

Figure 3: Manhattan Waterways (1609)



Source: Sanderson, E. W. (2009). *Mannahatta: a natural history of New York City*. New York: Abrams, 97.

The Lenape were an indigenous group who had lived on the island for thousands of years, leaving it relatively unscathed, using only approximately two percent of the land for settlements and agriculture (Barr, 2016). Once the European settlers arrived, and displaced the Lenape, they began to alter the land in a way that would have serious environmental repercussions 400 years later (NAC, 2016). The alterations that would have the greatest impact were: the flattening and excavation of the land for agriculture and roads; the infilling of waterways; the introduction of invasive species and technologies; and pollution**.** As the city's economy and population began to rise rapidly, the landform changes kept pace, mostly with the help of a comprehensive Master Plan. The following section will trace the evolution of the landform as human intervention and burgeoning urban development is transformed Manhattan from a hilly, heavily forested island with an abundance of wildlife to a flat, heavily developed metropolis.

The Commissioner's Plan of 1811

By 1790 Manhattan had become an established port city in the New York harbor, serving as a gateway to the mainland via the Hudson river. The thriving economy of the port helped to propel the city's population. The first federal decennial census in 1790 put the city's population at 32,328, with another 19,000 in the countryside. By 1810, the population tripled to 96,373, primarily due to the simultaneous tripling of the value of exports and increasing significance of the port (Ballon, 2012). At the time, the core of urbanization in Manhattan had only reached up to Canal Street, though parts had stretched

to North Street (presently Houston street). This area today is known as Lower Manhattan and acts as the city's downtown and Financial District (McColl, Ed., 2005).

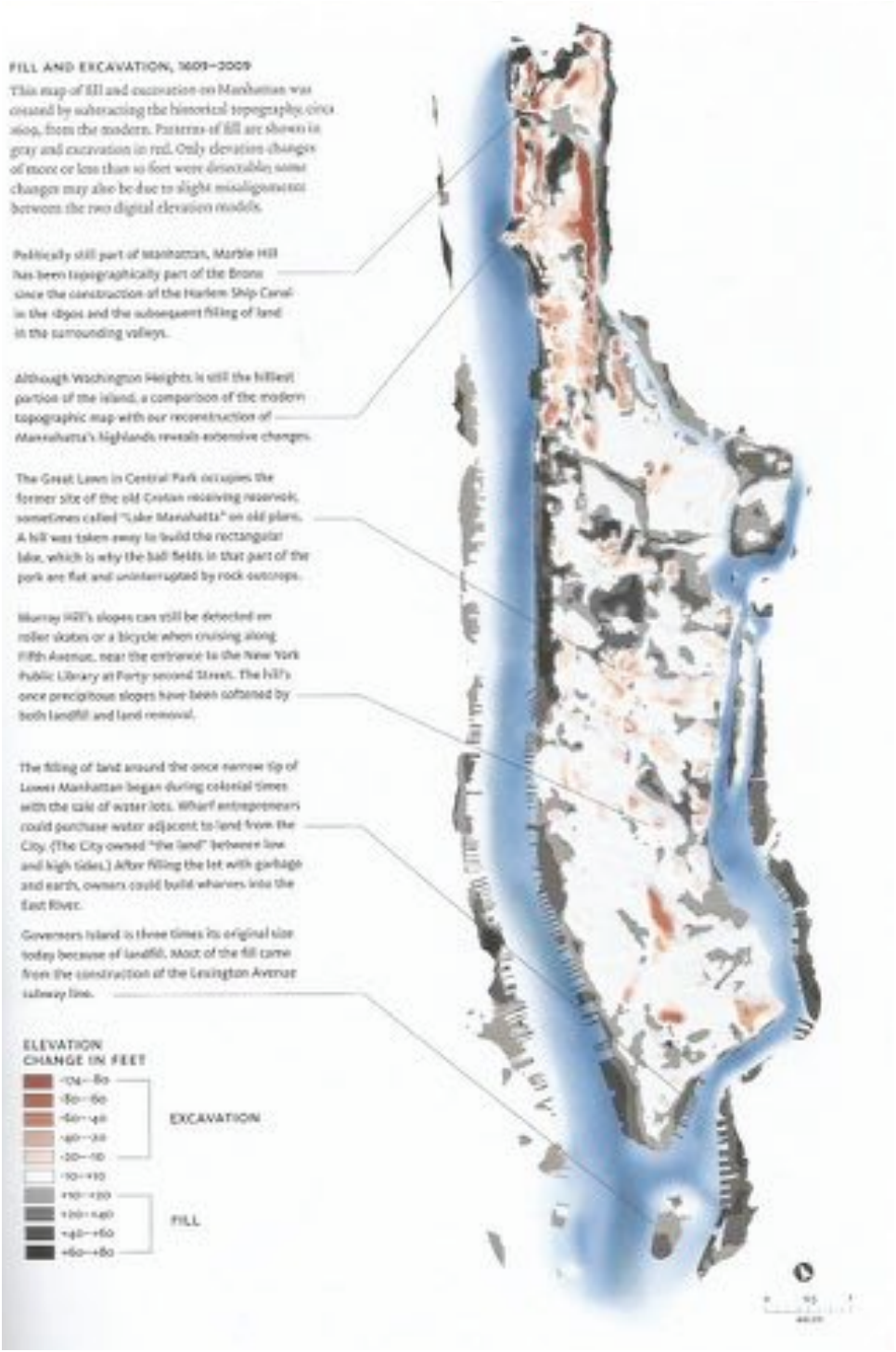
As the population continued to increase, a Master Plan was necessary to help guide this growth. In 1807, in an act of State Legislature, three commissioners were appointed to have a plan for the city ready by 1811. They based their plan, called the Commissioners' Plan on a futuristic growth scenario of a population forecast of 400,000 more people by 1860. This seemed excessive at the time, however, their forecast proved to be conservative at best since by 1870 the population had grown to over 800,000. The proposed plan consisted of a city-wide grid beginning at North Street, which would lay out blocks stretching northward all the way to 155th street. The layout consisted of "perpendicular streets and avenues that outlined rectangular blocks, all 200 feet from street to street and ranging in length from 610 to 920 feet between the avenues" (Ballon, 2012, p.27). This plan proved to be very difficult because, although the island north of North Street was not urbanized, it was still inhabited and divided up into land parcels. The plan threatened property rights and by unraveling property lines across the island (Sanderson, 2009).

The plan also threatened the environment, geology and ecosystems of the island. Streets were planned without regard for the natural contours of the environment, and, as a result, many of the natural features were destroyed. For example, if a rock outcrop got in the way of a future planned street, a steel bolt was placed to mark it for destruction. In total, 98 of these outcrops were marked. An additional 1,549 marble markers were placed at the northeast corners of street and avenue intersections. These markers indicated where streets would run over hills and valleys (Ibid.). From this point on, the landform of Manhattan began to quickly, and drastically, change into the dense city that is seen today.

Excavation and Infill

The planning of the new street grid in Manhattan meant there would be drastic changes to the social, physical, and environmental features of the island. **Figure 4** depicts the fill and excavation that occurred between 1609 and 2009 by subtracting historical topography from the modern.

Figure 4: Fill and Excavation (1609-2009)



Source: Sanderson, E. W. (2009). *Mannahatta: a natural history of New York City*. New York: Abrams, 81.

The map indicates where the most extensive alterations to the island occurred. The notable areas include the following:

1) Northern Manhattan

The northern part of the island, which begins after 155th Street, and includes the present-day neighbourhoods of Washington Heights, Hudson Heights, Inwood and Marble Hill (located on the mainland), is shown to have the most extensive amount of excavation. This area was not included in the Commissioner's Plan, and it was not until the late 1800's that the grid was eventually extended into the area due to increasing population pressures (Ballon, 2012).

Despite the extensive excavation, Northern Manhattan still remains the area with the highest elevations on the island, particularly since both Mount Washington (standing at 270 feet) and Inwood Hill (standing at 230 feet) were left untouched. It also remains the only area of the island, which has retained some of its original topography and natural environment. This is mainly due to the work of Andrew H. Green, who worked as commissioner for Central Park, and who was an opponent of the grid system. Leading the commission to develop Northern Manhattan in 1868, his plans were to preserve a large portion of the environment, and to build around the contours of the natural landscape (Ibid.). Ultimately, the pressures of urbanization were too much, and Green's plan could not stop the grid from moving north until 220th street. However, he did influence the final plan of the area, and was instrumental in the creation of both Mount Washington and High Bridge Parks.

The rough and uneven terrain of the area also proved to be too difficult to fully excavate, forcing development to follow the contours. **Figure 5** shows apartment buildings built on the edge of a steep slope, with the rear of the building being held up by stilts. Fortunately, the area now known as Inwood Park did not succumb to development pressure because of lobbying citizens and because it proved too difficult to access. The city purchased the land and by 1923 had opened it as a public park. To this day Inwood Park remains the only portion of Manhattan that contains remnants of the ancient forest, and last natural salt marsh, that existed long before the European settlers arrived (New York City Department of Parks and Recreation, n.d.a).

Figure 5 – Apartments on stilts (Inwood)

Source: Ballon, H. (2012). *The greatest grid: the master plan of Manhattan, 1811-2011*. New York: Columbia University Press, 176,

2) Central Park

Central Park is an 843 acre man-made park stretching from 59th Street to 110th Street (south-north), and 5th Avenue to Central Park West (east-west), that was built over an area once dominated by swamps and rocky terrain. Frederick Law Olmstead and Calvert Vaux were the principle architects who believed that parks were necessary for people to live and thrive in a city (NAC, 2016). Completed in 1858, the park became a peaceful getaway from the city, though it was not without its controversy. The natural landscape was altered (which included demolishing a hill) and Seneca Village, an African American community that had thrived in the area for decades, was completely demolished. Today,

Central Park acts as a biodiversity hotspot, with 275 species of birds identified in the park (Day, 2007).

3) Lower Manhattan

As the demand for prime real estate increased, so did the demand for landfill. This resulted in a much wider Lower Manhattan, and Governors Island has increased to three times its original size. Water Street once ran directly along the East River, but is now situated two blocks inland. Battery Park City, located on the west, is built entirely on landfill, mostly from the construction of the World Trade Center Twin Towers (McColl, Ed., 2005). In **Figure 6,** the present streets of Lower Manhattan are overlayed on top of the British Headquarters Map, delineating the extent of the infill that has occurred.

Figure 6: Present Day Street Overlay - Lower Manhattan

Source: Sanderson, E. W. (2009). *Mannahatta: a natural history of New York City*. New York: Abrams, 58.

4) Collect Pond

Other areas of importance that were lost due to infilling include waterways, particularly ones that provided freshwater. One example is the Collect Pond, a 28-hectare freshwater body located in Lower Manhattan that was filled by the 18th Century. As the city encroached further north, the pond succumbed to pollution, being filled with refuse and industrial waste. The pond, having once been a haven for biodiversity and a plentiful source of fish and freshwater, became so polluted that it was forced to be filled in

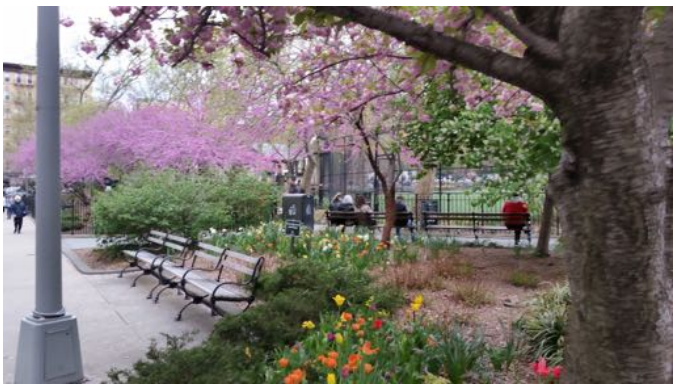
completely. Development would soon begin atop of the filled in pond but over the centuries it would begin to sink and release noxious gases, threatening the well-being of those who lived there. Eventually it would became the notorious slum known as the Five Points. It was not until 1960 that the area was stabilized and placed under the jurisdiction of the Department of Parks and Recreation (DPR, n.d.b).

Figure 7 shows Collect Pond Park, established in 2012 where the northwest area of the pond would have been. The pool of water is a testament to the old pond.

Figure 7: Collect Pond Park

Source: Beaupre, J., Photograph taken April 24, 2017.

Figure 8: Columbus Park



Source: Beaupre, J., Photograph taken April 24, 2017.

Figure 8 shows the present day Five Points area, located where the southeastern reaches of the pond had been. It is no longer considered a slum, and is now the location of Columbus Park.

As the previous maps and examples have shown, the landform of Manhattan has been drastically altered as a result of human influence. The previous examples highlighted some positive outcomes, as Manhattan was able to preserve some of its natural history,

managed to protect certain areas from being developed, and even created new parks. However, the extent of development and land alteration has made the city vulnerable to extreme events and disasters, particularly with its location on the coast. Before the European settlers arrived, the Lenape lived for thousands of years on an island that provided rich soils, an abundance of biodiversity, and deep harbours that provided natural storm protection (NAC, 2016). Learning from the mistakes of the past can also help to guide future sustainability efforts, particularly when development remains sensitive to the ecosystem functions of the specific area.

The Human Footprint

The Human Footprint measures the extent of human influence on a given ecosystem. GIS information is compiled from four types of data: population density, land use, human access and power infrastructure. This data is then overlayed on top of one another, showing which localities on the map are most heavily influenced. A score ranging from 0-100 is given for each terrestrial biome to measure the extent of human influence (Scott, 2003). For example, areas of wilderness normally yield scores of less than 10, and areas that have a high density built environment, such as Manhattan, yield scores ranging from 96 to 100 **[Figure 9]** (Sanderson, 2009). For the most part, cities normally produce a score ranging from 80 to 100 (Sanderson et al., 2002)

The Human Footprint of an area is greater where there is a larger presence of human development**.** However, human influence does not necessarily refer to areas with visible development, since even areas of wilderness can still be affected due to the negative by-products (such as pollution) of adjacent built environments. The gradient of human influence is thus regarded as the number one factor constraining planetary ecology today

(Ibid.). The Human Footprint can be used to measure certain processes such as habitat destruction, biological fragmentation, the introduction of new species, and even the effects of human-induced climate change from pollution and GHGs (Ibid.). [2]

Figure 9: Comparison of Lower Manhattan 1609 (left) and 2009 (right)

Source: Sanderson, E. W. (2009). *Mannahatta: a natural history of New York City.* New York: Abrams, 8 &11.

[2] The Human Footprint is similar to the **Ecological Footprint**, which as Wackernagel et al. (1999) explain: "The ecological footprint represents the critical natural capital requirements of a defined economy or population in terms of the corresponding biologically productive areas. Evidently, the area of the footprint depends on the population size, material living standards, used technology and ecological productivity" (p. 377). The Ecological Footprint was developed as a measure for a whole country, though has been applied at the local level to a number of cities (as listed in Baabou et al., 2017).

Part 2: Overview of the Current Social, Physical, Political and Environmental Context

Social Context

The population of Manhattan peaked in 1910, with 2.33 million residents living in the borough at a density of 600-800 people per acre. Those levels have since declined significantly by nearly one half, due in part to residents leaving the city for the suburbs in the 1950s, as well as rising crime and an economic crisis in the 1970s (City of New York, 2007). Despite these drops in numbers, Manhattan still remains a densely populated area. Moreover, the population has begun to grow again. Crime has decreased significantly, and more opportunities are arising. As a result, an 18.8 percent change is expected between 2000 and 2030. The majority of that growth will come from residents aged sixty-five and over **[Table 2]** (Ibid., 2007).

Table 2 – Population growth 1950-2030, Manhattan

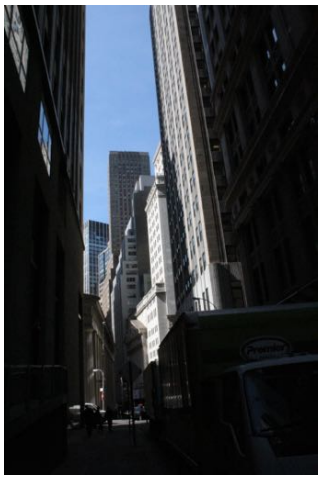
Year	Population	% Change	Median Age	% Under 18	% Over 65
1950	1.96 Mil	-	37	19.7	8.7
1970	1.54 Mil	-21.5	35	21.7	14.0
2000	1.54 Mil	-0.1	36	17.2	12.2
2030	1.83 Mil	18.8	40	15.2	16.1

Source: City of New York (2007). *PlaNYC: A greener, greater New York.* Retrieved from http://www.nyc.gov/html/planyc/downloads/pdf/publications/full_report_2007.pdf

Manhattan is known for its racial, ethnic, religious and economic diversity, with disparities present amongst its many neighbourhoods (Jackson, 2010). It is the business and financial capital of the United States and, despite the economic disparities across the borough, in 2015**,** the median household income was $72,871, compared to the national average of $53,889. That said, 17.6 percent of the population of Manhattan lives in poverty, compared to only 13.5 percent of the national average (U.S. Census Bureau, 2015).

Physical Context
1) Built Environment

The defining characteristic of Manhattan's landscape is the grid system, with the 12 north-south avenues, and 220 east-west streets. One notable exception is Broadway Ave. which runs diagonally (south-north) across the island, essentially cutting through the grid. Built along the grid are hundreds of skyscrapers, which gives Manhattan its iconic skyline. The skyscrapers are concentrated mainly in Midtown and Downtown in areas where the bedrock, known as Manhattan Schist, is closest to the surface; making it suitable for the deep foundations needed for tall buildings (McColl, Ed., 2015). At street level, the combination of the grid system and density of Manhattan skyscrapers creates "building canyons", giving pedestrians the sensation of walking through a canyon surrounded by cliffs.



"Building Canyon"
Lower Manhattan

The Zoning Restriction of 1916 (the city's first zoning law) attempted to ensure that the buildings did not completely take over the landscape, and did so by forcing setbacks and height restrictions. By 1950, the law was no longer proving to be effective to prevent building density, and by 1961 a Zoning Resolution was passed that allowed developers to build higher if they reserved an area of the lot for a park or open space. The outcome yielded tall buildings setback from the street with plazas or arcades at street level, particularly in Midtown (Ballon, 2012).

2) Infrastructure

a) Transportation

Manhattan has a very complex subway and bus system. It has sixty-seven miles of underground track that not only connects most of the island, but also with systems from New Jersey, Long Island and northern New York (Sanderson, 2009). The New York City transit system is the largest in the country, and had 1.7 billion total riders in 2013. However, it is severely outdated and in need of repair. Some tunnels, such as those running underneath the Hudson to connect New Jersey and downtown Manhattan, are over 100 years old (City of New York, 2015). **Figure 10** depicts the existing transit capacity of users entering Manhattan's CBD during rush hour, and shows how the system is running at almost full capacity. Above ground, there are over 500 miles of streets (linear), which are almost always full of traffic (Fund for the City of New York, 1998; Sanderson, 2009).

Figure 10 – Transit Capacity, Manhattan

Source: City of New York (2015). *OneNYC: the plan for a strong and just city.* Retrieved from http://www.nyc.gov/html/onenyc/downloads/pdf/publicat

Active transportation is becoming easier in the city, as new initiatives such as the DOT's Complete Streets and Safer Streets projects are being implemented throughout the

city. New pedestrian-only areas have been created on streets once dominated by traffic (for example, in Times Square), and other various traffic-calming measures are being implemented. The Greenway Plan for NYC, which began in 1993, provides 350 miles of bicycle and pedestrian paths, and is planned to completely encircle Manhattan (Sanderson, 2009). The current path is shown here [**Figure 11],** which shows the largest gap along the East River between 38th and 60th Streets. Recent developments include new plans to fill in the gap in this area, along with the smaller gaps in East Harlem and Inwood (Nir, 2017).

Figure 11 - Manhattan Waterfront Greenway

Source: Miller (2013). EDC: Phased East River greenway gaps set to be filled by 2024. *StreetsblogNYC.* Retrieved from http://nyc.streetsblog.org/2013/06/25/edc-phased-east-river-greenway-gaps-set-to-be-filled-by-2024/

b) Utilities

Water Source

As previously discussed, most of Manhattan's natural waterways have disappeared due to infilling. The Collect Pond was once a source of fresh drinking water, but like the many other natural springs on the island it was lost to pollution and development. New York City now relies on the Catskill/Delaware and Croton watersheds located in upstate New York to provide the city with water via a system of pipes and aqueducts (City of New York, 2007).

Water Drainage

There are two types of sewer systems in New York City: Separate and Combined. In separate sewer systems, sanitary waste is channeled and carried towards wastewater treatment plants, whereas stormwater is channeled directly into the nearest waterbody. Combined sewer systems, on the other hand, channel both sanitary waste and stormwater into the same treatment plant. There are also unsewered areas, mainly found in parks and wetlands, where water is absorbed directly into the ground. Almost sixty percent of the city uses the combined system; most of Manhattan does so as well, with the exception of Roosevelt/Randalls Island, and a few areas in the north and Central Park (New York City Department of Environmental Protection, 2017a).

To summarize, **Table 3** gives a breakdown of the total land use by lot area for all of Manhattan.

Table 3: Total land use by lot area - Manhattan

Land Use, 2014			
		Lot Area	
	Lots	Sq. Ft. (000)	%
1-2 Family Residential	3,719	6,567.7	1.4
Multi-Family Residential	17,000	110,251.7	23.0
Mixed Resid./Commercial	10,324	64,328.0	13.4
Commercial/Office	5,455	51,439.6	10.7
Industrial	1,026	6,382.7	1.3
Transportation/Utility	494	35,025.5	7.3
Institutions	2,501	56,233.9	11.7
Open Space/Recreation	396	121,081.4	25.2
Parking Facilities	754	6,687.9	1.4
Vacant Land	1,306	15,232.2	3.2
Miscellaneous	182	6,471.4	1.3
Total	43,157	479,702	100.0

Source: NYC Department of Urban Planning (2014). Borough of Manhattan. Retrieved from http://www1.nyc.gov/assets/planning/download/pdf/community/community-portal/profile/mnboro_profile.pdf

Political Context

1) Structure

The Government of New York City follows a centralized political structure and is made up of three branches:

I. **Executive**: Led by the Mayor, responsible for city services and enforcement of city/state laws.
II. **Legislative:** Led by City Council**,** responsible for proposing/revising bills.
III. **Judicial:** Made up of various Court systems throughout the city.
(Baruch College, 2014)

2) Planning Process

The Zoning Resolution of 1961 remains as the guidebook for development in the city. It is constantly being updated and adapted to the changing land use patterns that occur over time, yet still upholds as the primary regulatory tool that establishes limits on the use of land, building size, shape, height, and setback (New York City Department of City Planning, n.d.a).

The city itself is not in charge of spearheading major infrastructure plans, but instead provides input from public opinion to different agencies. There are two ways in which a proposed development will be processed: 1) As-of-Right, and 2) Discretionary Action.

I. As-of-Right

When a development is "As-of-Right", it means that it is compliant with the Zoning Resolution and the Building Code; and can be issued a building permit. The DOB is the lead agency responsible for issuing the permit once they deem that the proposed project meets

the compliance regulations. The project can then move forward without any further review. Most development projects are As-of-Right (DCP, n.d.b).

II. Discretionary Action

When a development involves a "Discretionary Action", it is subject to ULURP, and may also be subject to an Environmental Review (CEQR). This applies to all major public and private land use actions that include map changes, changes to existing zoning, changes to the Zoning Resolution, request site-specific land use actions, request to build affordable housing or other public facilities (as a NYC agency). The ULURP process is lengthy, is intended to involve stakeholders at multiple levels, and includes a number of public hearings. The lead agencies that oversee the whole process are the DCP and CPC. [**Appendix 1 shows the process].**

A project may also be subject to Environmental Review if it meets any of the following criteria:

a) The project needs discretionary permits or approvals from any city agency
b) The project needs city funding
c) The project is being undertaken directly by a city agency

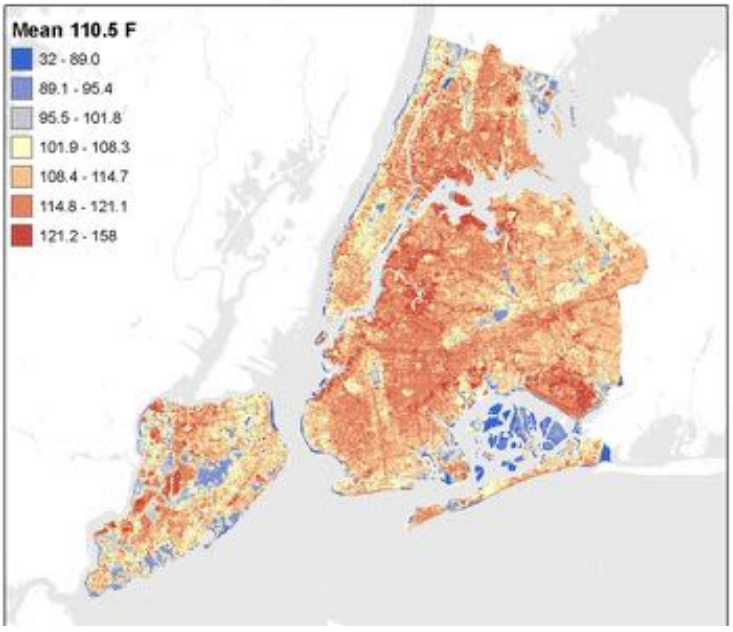
The applicants involved in the Discretionary Action that involves Environmental Review are responsible for conducting their own analysis in accordance with the CEQR Technical Manual. The MOEC is present to provide expertise and assistance. The CEQR process is a separate from ULURP, which also conducts its own public hearings **[Appendix 2]**. However, the two attempt to coincide with each other as much as possible. The CEQR is

a very robust environmental review process and is a very important opportunity for neighbourhood planning by including the public in the process. It also acts as a regulatory tool to help ensure that the goals set out in city initiatives are being met (DCP, n.d.c). For example, the CEQR Technical Manual (2014) makes suggestions that a development project should be consistent with the GHG reduction goals set out in *PlaNYC (2007)*.

Environmental Context
Climate Change

New York City's climate has been drastically changing over the past century. From 1900-2013, the mean annual temperature observed in Central Park has increased by 3.4 degrees F and the mean annual precipitation has increased by 8 inches. Sea levels surrounding New York City have been rising at a rate of 1.2 inches per decade, which is double the global amount (New York City Panel on Climate Change, 2015). The Urban Heat Island has become very pronounced. One NASA Landsat image shows the extremity of summer temperatures as a result of surface coverage from buildings, sidewalks and other non-natural surfaces (**Figure 12)**

Figure 12 - Landsat surface temperature August 14, 2002, 1030am, NYC



Source: NASA (2006). *Keeping New York City "cool" is the job of NASA's "heat seekers". Retrieved from* https://www.nasa.gov/centers/goddard/news/topstory/2005/nyc_heatisland.html

As these trends continue, the effects of climate change on the city will intensify. New York City is projected to experience the following climate change effects by 2050:

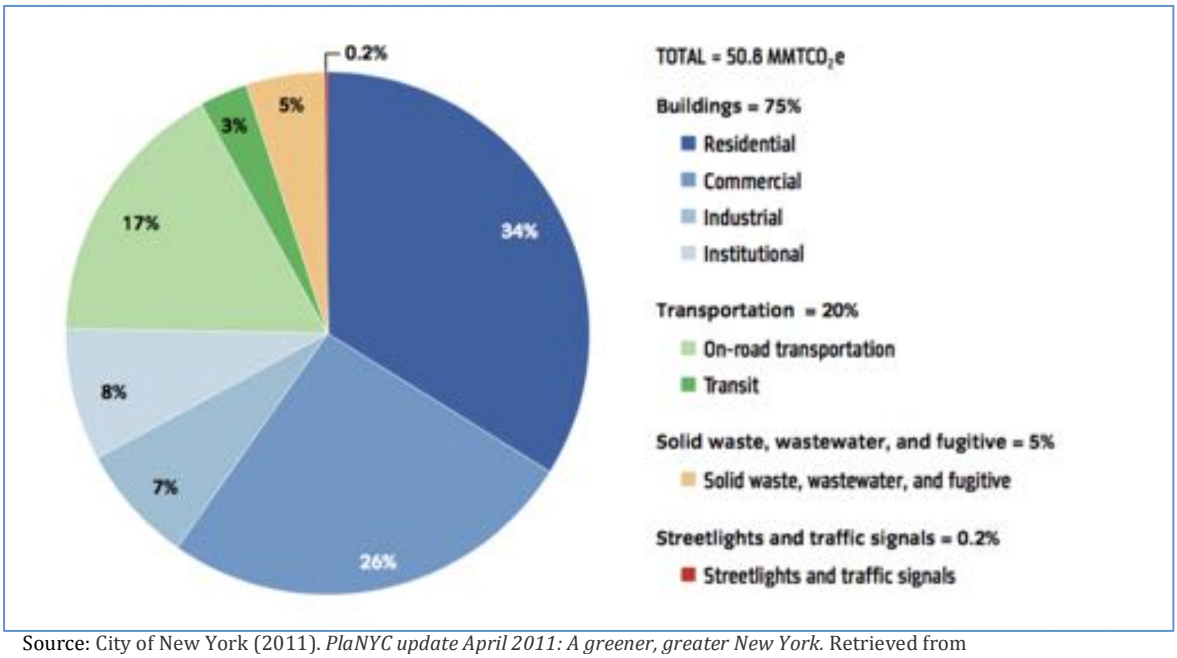
- An increase in mean annual temperatures (4.1 to 5.7°F)
- An increase in mean annual precipitation (4 to 11 per cent)
- The frequency of heat waves to triple (by 2080), and cold events to decrease
- The frequency of extreme precipitation days to increase
- A rise in sea level (11-20 inches)
- The increased frequency and intensity of coastal flooding
- More intense hurricanes on the North Atlantic Basin

(NPCC, 2015)

Emissions

New York City is one of the most energy-efficient cities in the world due to its density and reliance on mass transport, and produces less CO_2 per capita than any other American city. However, the size of NYC means that it still produces a large amount of GHGs and, as Wachsmuth et al. (2016) discussed, wealthy residents still produce large amounts of emissions from practices such as the consumption of imported goods and services and out-of-town travel. Nonetheless, in 2009 the city produced 50.8 million metric tons of CO_2 ($MMTCO_2e$), largely due to emissions produced by the building and transportation sectors (**Figure 13)** (City of New York, 2007; City of New York, 2011).

Figure 13 - 2009 Citywide GHG Emissions by sector, NYC



Source: City of New York (2011). *PlaNYC update April 2011: A greener, greater New York.* Retrieved from http://www.nyc.gov/html/planyc/downloads/pdf/publications/planyc_2011_planyc_full_report.pdf.

Conclusion

The first section of this chapter traces the evolution of Manhattan over the past 400 years to show how the large-scale alteration of the physical landform has magnified the negative effects of climate change and weather events upon the present-day city. A study of the natural and historical ecology of an area provides valuable information on the processes and organisms, which once offered natural buffers to the land. Doing so can help to guide future plans in remaining sensitive, and even re-introducing, some of these lost ecosystem functions. To help frame the analysis, the second section outlines the present-day context of Manhattan, discussing the social, physical, political and environmental. This information proves to be important, since many of the policies discussed in the next section make reference to these specific aspects of Manhattan.

Chapter 4: Analysis

Introduction

This chapter focuses on a number of climate change strategies set forth by the Mayor's Office of NYC over the last decade, and how they have helped to shape environmental policy in the city. Two strategic plans in particular will be examined and compared: *PlaNYC: A Greener, Greater New York;* and *OneNYC: The Plan for a Strong and Just City.* The former is the first urban sustainability policy framework developed by the city (released in 2007 and updated in 2011), and the latter is the most recent version of the policy framework (released in 2015). The analysis focuses on the achievements of the strategic plans to date, in particular, their role in influencing sustainable and resilient project development, climate change policy adoption and the creation of new environmental regulatory frameworks.

Section one explores significant environmental and political events that have occurred since the inception of *PlaNYC*, which have led to a changing policy environment in the city. These changes are reflected in the tone, language and strategic framework of subsequent plans released since the original in 2007**.** Thus**,** a comparison between plans will not only help to outline their progression over the last decade, but will help determine how the modifications are reflecting the changing environment**.** It must be noted that the fundamental goals are consistent throughout both plans, and they remain at the forefront of climate change policy. Using the narrative of the changing policy environment over the

past decade, sections two and three seek to evaluate what the strategic plans mean for land use, biodiversity and well-being in Manhattan. The extent to which the role urban ecology plays in the formulation of the city's environmental strategic framework will be emphasized. The analysis is divided into three parts: 1) The Evolving Policy Environment; 2) Land Use: The Plans Put Into Practice; and 3) A Case for Biodiversity and Well-Being.

Section 1 - The Evolving NYC Policy Environment: From PlaNYC to OneNYC

As Manhattan developed over the past 400 years, it is evident that the natural environment has gone through a significant alteration. This was, however, not a localized issue, as similar processes were occurring across the United States. The 1970s saw the first environmental standards set forth at the federal level, with the Clean Air Act in 1970, and the Clean Water Act in 1972. By 2006, New York politicians realized that the city needed its own regulations at the local level, since it had not managed to reach Federal air quality standards, and suffered from the worst rates of asthma in the United States. On top of that, fifty-two per cent of the city's tributaries were still highly polluted and unsafe (City of New York, 2007).

In 2005, Mayor Bloomberg signed onto the Kyoto Protocol with 131 other mayors with the idea to reduce global GHG's. Soon after, he developed a "comprehensive plan to create a greener, more sustainable city" (Solecki et al., 2015). First, he created the OLTPS, which immediately began developing a strategic plan to focus on the mitigation of GHGs and climate change adaptation. *PlaNYC* was released in 2007, which laid out 3 immediate goals:

1. The creation of a climate change adaptation task force
2. The development of adaptation plans
3. The consideration of highly vulnerable communities in the city.

(Ibid.)

The first goal was quickly attained when in 2008, an interagency Climate Change Adaptation Task Force was created to help protect the city's vital infrastructure. The NPCC, modeled upon the IPCC and made up of leading climate scientists, academics, economists and other experts, was also convened so as to provide sound expert and science-based advice to decision-makers on climate change adaptation efforts (Pelling & Blackburn, 2013). Part of the NPCCs mandate was to assess the effectiveness of current design standards and regulations related to sea-level rise and extreme weather events such as storm surges, heat waves and inland flooding. This was significant because, by providing the most up to date risk projections, the city could adjust its construction guidelines accordingly. As a result, climate change became integrated into the physical process of urbanization (Ibid.). The creation of the NPCC in 2008 was a major accomplishment that emerged from *PlaNYC* because it validated the importance of climate change policies by applying an extensive base of research and statistics from a highly credible group of experts.

The final two goals were realized by outlining a number of measures that addressed the city's growing population and infrastructure needs. *PlaNYC* laid out ten long-term goals for a sustainable future that pertain to areas of land, water, transportation, energy, air quality and climate change (**Box 2).** From these goals, 127 initiatives along with milestones for each were created, This work set the stage for NYC to become a leading green city.

Box 2: PlaNYC 2007: Long-Term Goals

1. Create homes for a million more New Yorkers, and to make housing more affordable and sustainable.
2. Ensure all New-Yorkers live within 10-minute walk from a park.
3. Clean all contaminated land in NYC
4. Reduce water pollution and to preserve natural areas, and to open waterways for recreation.
5. Ensure long-term reliability of water network by updating critical backup systems.
6. Improve travel time by increasing transit capacity.
7. Reach a full "state of good repair" on the city's roads, subways and rails.
8. Provide cleaner, more reliable power for every New Yorker by upgrading energy infrastructure.
9. Achieve cleanest air quality of any big city in America.
10. Reduce global warming emissions by 30%.

Source: City of New York (2007). *PlaNYC: A greener, greater New York.* Retrieved from: http://www.nyc.gov/html/planyc/downloads/pdf/publications/full_report_2007.pdf

PlaNYC, 2011

As a means to track the success and implementation of the initiatives, and to ensure the plan would adapt accordingly with the changing environment, the OLTPS stipulated that an updated plan be created every four years. In 2011, the new *PlaNYC* was released, which contained many more initiatives, along with progress updates from the previous 4 years. Some of these milestones included: adding over 200 acres of parkland and improving

existing parks; creating and preserving more than 64,000 affordable housing units; increasing transportation options; enacting landmark green building legislation; and reducing GHGs by thirteen percent below 2005 levels (City of New York, 2011).

The *PlaNYC 2011* report proposed a number of new and ambitious initiatives that were attributed to the work of the NPCC providing up-to-date, robust data and projections. A deeper understanding of earth processes, ecosystems and urban ecology was present in the new report, which had been absent from its predecessor. For example, the "Natural Systems" section in the plan recognizes that, in building the city, many of the natural systems that were destroyed had once performed essential functions, including: moderating climate, managing water and protecting coasts. Based on this, *PlaNYC (2011)* says: "We now place a higher value on preserving and reconstructing native habitats and species and on the importance of human contact with nature" (p. 167). It stresses the importance of regenerating the natural systems that once existed and that biodiversity and human well-being must be integrated into the planning process.

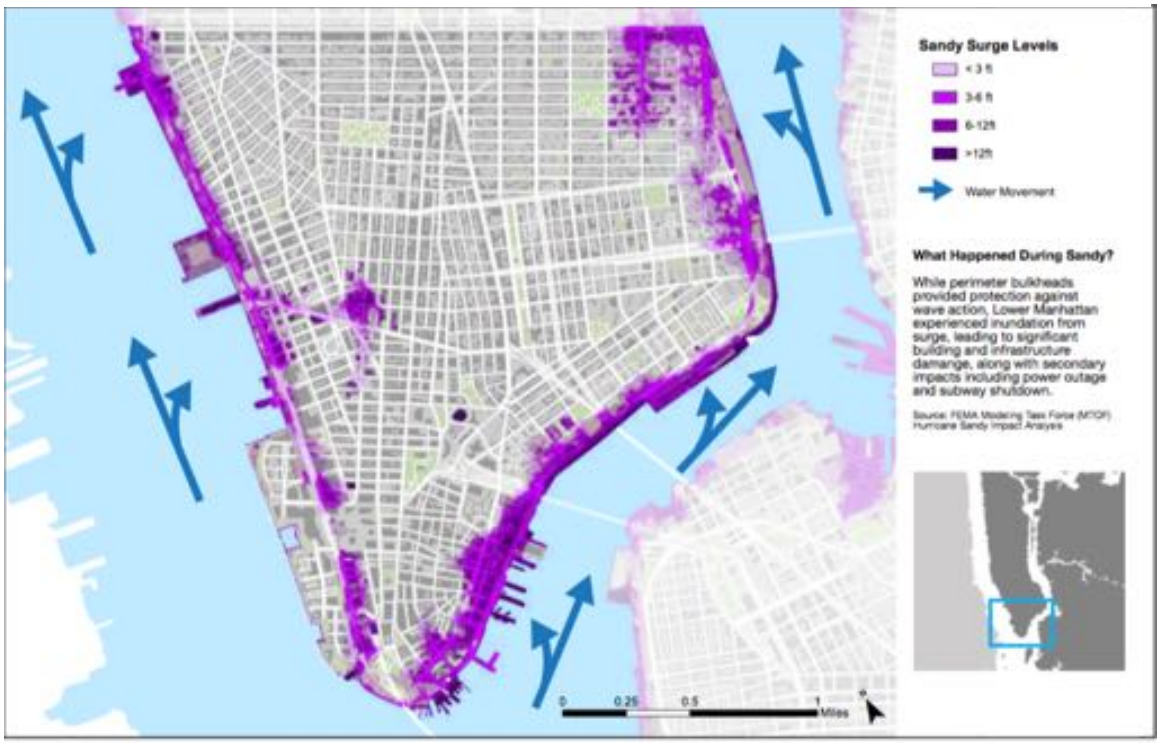
Another significant change in the updated plan was the use of the term 'resiliency', which was completely absent in the 2007 plan. Resiliency was emerging as an important topic of scientific scrutiny, and it added new elements to adaptation measures such as providing ways to cope with the inevitable stresses and shocks of an extreme weather event. Thus, the NPCC made a recommendation to form a climate resiliency program. As a result, the following new resiliency-based initiatives were established for *PlaNYC*:

-To assess vulnerabilities and risk from climate change
-To increase the resilience of the city's built and natural environments
-To enhance the city's preparedness for extreme climate events
-To protect public health from the effects of climate change

-To create resilient communities through public information and outreach (City of New York, 2011)

The importance of these new resiliency initiatives would soon be realized. Not long after the release of *PlaNYC 2011,* Hurricane Irene touched down. The city experienced only minor storm surges and damage, but much of the surrounding suburban areas endured extensive flooding. As a result, local officials and stakeholders realized the potential damage a major storm could cause if it hit the city, prompting a greater incentive to put resiliency initiatives into practice (Solecki et al., 2015). In October 2012, Hurricane Sandy hit the metropolitan region, resulting in widespread damage to buildings and critical infrastructure, and a death toll exceeding one hundred people (Pelling & Blackburn, 2013) As the storm touched down, the combination of high winds and sea-levels pushed devastating storm surges inland. Lower Manhattan was hit particularly hard with a combined storm surge/tide level of fourteen feet at the Battery **[Figure 14]** that knocked

Figure 14 - Sandy storm surge levels at the Battery



Source: New York Rising Communities (2014). *Lower Manhattan: New York rising community reconstruction plan.* Retrieved from https://stormrecovery.ny.gov/sites/default/files/crp/community/documents/lower_manhattan_nyrcr_plan_57mb.pdf

out power, flooded subway tunnels, and backed up the sewers. Sandy was a catastrophic and tragic event, though it allowed for a new and updated policy framework to take form. Sandy was living proof that extreme weather events were inevitable, and that NYC would continue to be vulnerable if it did not adapt to the changing climate.

Policy Shift

After Sandy, the policy environment in NYC began to take a new form for two reasons:

1. The occurrence of an extreme event opened new channels for policy shifts, along with new investments into large-scale infrastructure projects that involved: preparing for future climate events; fortifying critical infrastructure such as buildings and coastlines; and enhancing resources using emerging climate change information (Solecki et al., 2015). In 2012, Mayor Bloomberg created the *Special Initiative of Rebuilding and Resilience (SIRR)* who, in 2013, released *PlaNYC: A Stronger, More Resilient New York.* The report (referred to as *SIRR* for the remainder of this report) would act as a sister document to the previous two *PlaNYC* reports, but with a main focus on resiliency measures as a response to disasters and extreme events. Specifically, it outlined the lessons learned from Sandy, and included a number of initiatives and recommendations on rebuilding after the storm, as well as outlining a comprehensive coastal protection plan (City of New York, 2014).
2. Mayor Bloomberg's tenure was coming to an end, and a new administration with a very different agenda was set to take office. In 2014, Bill DeBlasio became the new mayor of NYC. He had based his campaign on progressive issues that targeted inequality in areas such as housing, education and the workforce; and with very little attention to

sustainability issues. This was a stark contrast from the previous administration that used sustainability and environmental policy as their main tool for guiding development in the city. In fact, DeBlasio's campaign had drifted so far from sustainability issues that the green building community was afraid he would abandon *PlaNYC* altogether (Werner, 2015). Mayor DeBlasio eventually remained committed to continuing *PlaNYC*; albeit in his own way. With the recent attention to resiliency measures, particularly in the wake of Sandy, he created the Office of Recovery and Resiliency (ORR). This new office would work alongside the OLTPS (which he renamed to the Mayor's Office of Sustainability (MOS)) to ensure the continued updating of *PlaNYC* every four years, with an added mandate on managing the city's coastal protection initiatives (City of New York, 2014a). In 2015, he released the required *PlaNYC* update, named *OneNYC: The Plan for a Strong and Just City.*

The title of the report does not seem to address issues of sustainability and climate change. On closer examination, the report comes across as more of a comprehensive master plan than a climate strategy due to the variety of new socially-themed content that has been added. *OneNYC* lays out the following four 'Visions':

***Vision 1 – Our Growing, Thriving City*:** Includes 30 initiatives categorized in the areas of industry expansion & cultivation, workforce development, housing, thriving neighborhoods, culture, transportation, infrastructure, and broadband.

Vision 2 – Our Just and Equitable City: Includes 22 initiatives categorized in the areas of early childhood, government & social services, healthy neighborhoods & active lifestyle, healthcare access, criminal justice reform, and traffic fatalities reduction.

Vision 3 – Our Sustainable City: Includes 29 initiatives categorized in the areas of emissions reduction (80 x 50), waste reduction, air quality, brownfields, water

management, and parks & natural resources.

Vision 4 – Our Resilient City: Includes 13 initiatives categorized in the areas of neighborhoods, buildings, infrastructure, and coastal defense.

(City of New York, 2015)

OneNYC appears to be a good plan for New Yorkers in need of support, particularly in areas such as poverty alleviation, housing, social services and jobs. It also offers a number of climate-related initiatives, such as emissions and waste reduction, water management and flood mitigation, and access to parks and open spaces. The section on resiliency addresses initiatives that mainly deal with protection against coastal flooding and storms. As a whole, *OneNYC* builds off the work of the previous *PlaNYC* reports, and adds a new position on social equity. Upon examining the structure of *OneNYC*, the first 2 Visions may seem out of place, since they cover new social issues that were not included in previous documents (with the exception of initiatives involving housing, transportation and infrastructure). That being said, *OneNYC* takes a step forward as it does a good job at integrating the social issues that were lacking from the previous *PlaNYC* reports.

One criticism of *OneNYC* could be whether or not the areas it prioritizes (and areas it de-prioritizes) are warranted. For instance, *PlaNYC* was designed to be a standalone plan that focuses on the physical city, and was intended to be used alongside other city efforts that deal with crime, poverty, education and social services. OneNYC has placed all of those topics together into one plan, raising the question of whether or not the new social-themed initiatives actually belong in a report meant to deal with physical issues regarding sustainability and climate change. This question will be discussed in further detail in later sections.

A study of the evolution of the environmental strategic plans is essential to understanding if the city is making necessary adaptations and following through on important initiatives. For one, the study helps to understand how the changing environmental processes are affecting the needs of the city. Further, it demonstrates evolving attitudes and perspectives of planners and policy-makers, and finally, it highlights how the city is reacting to these processes. The next section will look more specifically at how the strategic plans incorporate ecological designs and concepts into the development and regulation of the built environment through climate mitigation and adaptation.

Section 2: Land Use - The Plans Put Into Practice

A useful way to measure the progress of *PlaNYC* and *OneNYC* is to observe how they have influenced land use in Manhattan. This section will discuss how the plans have helped to shape different sustainable and resilient projects across the borough. An examination of building codes, zoning amendments and large-scale infrastructure projects in Manhattan can demonstrate whether or not the land use planning process has balanced the interest of individual property owners while considering the overall needs of the entire community. It is useful to assess to what extent the plans regard the city as an ecosystem and include all elements (built and natural environment, cultural and natural flows) in its planning.

One of the strengths of *PlaNYC* and *OneNYC* is that they open to both public and private investment and involvement in projects. However, public-private partnerships are rare in NYC, and normally each sector develops independently of one another. With As-of-Right zoning, the private sector has a lot more leeway in what projects can be actualized. Capital projects, on the other hand, have a lot more restrictions attached to them,

particularly environmental ones. Nonetheless**,** it is important that both entities are provided the appropriate avenues such as zoning amendments and incentives to help propel land use in a sustainable and resilient fashion. The following section will discuss sustainability-themed and resiliency-themed initiatives and projects.

Sustainability-Themed Initiatives and Projects

1. Green Infrastructure Plan

The Green Infrastructure Plan (GIP) was released in 2010 as a multi-agency effort led by the DEP to help reduce excess stormwater runoff from entering the city's sewer system through the design of sustainable green infrastructure structures that include: green roofs, blue roofs[3], rain gardens, Stormwater Greenstreets (SGSs), and Right-of-Way Bioswales (RWOBs) **[Box 3]** on city-owned

Box 3 – Bioswale Case Study
A bioswale is a sloped depression of plants, soil and stone located on the sidewalk. It is specifically designed to capture stormwater runoff. It is specially engineered to move the water slowly through the soil. Water-loving plants are chosen to provide extra filtration, as they can handle the salt and pollutants from the street. The purpose is to ensure water infiltrates into the ground to replenish the water table, opposed to flowing into the combined sewer system which can cause a CSO. Bioswales are twice as deep as regular tree pits. They are constructed in layers of gravel and sandy soil. The "swale" refers to a slight depression in the center, which diverts water to the planting area to enter the soil. The cub has two "dips" which allow water to enter from the street.
Source: Columbus Avenue Business Improvement District information sign, 2013

Layers of the Bioswale

First bioswale in Manhattan, Columbus Ave., built May 13, 2013

[3] A Blue roof, also known as a 'rooftop detention system' is designed to store water from rainfall so excess water does not enter the sewers during extreme events such as storm surges. Once the event is over, the water is slowly released to the sewer. Blue roofs have great potential to increase stormwater capture rates at a low cost (City of New York, 2011).

property. Apart from the main goal to reduce stormwater runoff, green infrastructure also works to: "reduce UHI, enhance recreational opportunities, improve quality-of-life, restore ecosystems, improve air quality, save energy, and mitigate and adapt to climate change" (DEP, 2010, p. 26).

The GIP was built off the Greenstreets Program which had been in place since 1996, and which was tasked to transform unused areas of roads into green spaces**.** Greenstreets, which was developed by the DPR and DOT, was successful in constructing a number of installations across the city that use vegetative controls to trap and store stormwater.

"Greenstreets Program – Manhattan"

The GIP adopted this focus on stormwater capture to make it the principle mandate, while building upon and extending the commitments of *PlaNYC* and the Sustainable Stormwater Management Plan (DEP, 2010). As discussed in *PlaNYC*, the need for a sustainable wastewater management plan was crucial. Most areas of New York City are served by combined sewers, where sanitary and wastewater, rainwater and street runoff all collect into one sewer and are sent to the same treatment plant.

The problem is that about seventy-two per cent of NYC is covered by impervious surfaces so, during periods of heavy rainfall and snow melt, the excess water cannot infiltrate into the ground fast enough. This causes the sewers to become overburdened, resulting in combined sewer overflows (CSOs). When this occurs, the excess water is too much for the treatment plants to handle, and is discharged directly into the waterways. A large percentage of NYC, and almost all of Manhattan, is served by combined sewers.

Initiatives laid out in PlaNYC thus focused on ways to prevent excess stormwater from entering and polluting the waterways by providing an alternative to the all-Grey infrastructure (or conventional drainage pipes and water treatment systems) in place; leading to better water quality and sustainability benefits (DEP, 2010.). PlaNYC has helped to guide the development of the GIP through two main initiatives: 1) Modifying design codes and; 2) Providing incentives.

Modifying Design Codes

Zoning amendments initiated through the DCP require:

1. New commercial parking lots to include a form of green infrastructure;
2. Buildings in lower density districts cannot pave over their entire front yard;
3. New developments must plant trees and provide sidewalk planting strips.

(City of New York, 2011)

These amendments work to incorporate GI directly into the built environment, ensuring that private developments also play a role in contributing to the goals of the GIP. However, these amendments only cover a few small areas, and are not sufficient to produce significant large-scale impacts. It is therefore imperative that these amendments are paired with incentive programs.

Providing Incentives

To complement the zoning amendments, incentives for private landowners are necessary for the city to expand the network to more areas of the City. The Green Roof Tax Abatement Program was passed through State Legislature in 2008, and implemented by the City in 2009. The program offered tax abatements to private building owners of $4.50 per square foot of green roof constructed, up to $100,000. The green roof must cover at

least fifty per cent of the surface to ensure it can contribute to proper stormwater capturing (City of New York, 2011). This program was to be completed and re-assessed by 2013. It has since been renewed and updated, and has raised the abatement to $5.23 per square foot of green roof, up to $200,000 until 2018 (New York State Assembly, 2013). This amendment, however, is not reflected in the *OneNYC*. In fact, the only mention of the program is that there were no applications for it in 2014. It is also difficult to find mention of the amendment anywhere on NYC government websites; and the application portal through the NYC Department of Buildings provides only the outdated form, which expired in 2013. It appears as though the City may not be as interested in the program anymore, or the program needs to be changed.

Another incentive program which the City has shown continued interest in, as outlined in *OneNYC*, is the Green Infrastructure Grant Program. Offered since 2011, this program offers a grant of $35,000 (minimum) to private property owners located in CSO areas to construct a project that will contribute to reducing at least one inch of stormwater runoff from the impervious area on their lot. Projects include blue roofs, rain gardens, green roofs, porous pavement and rainwater harvesting (DEP, 2017b). Though *OneNYC* remains committed to the program, it has shown only moderate success since the program's inception, as only thirty-four property owners have participated since 2011 (DEP, 2017c). The city would like to expand the program to include private property located in areas outside of CSO areas**.** However, the feasibility of this option has yet to be explored, and there are other, more pertinent social issues (such as poverty alleviation) that certainly should be prioritized.

The GIP in conjunction with OneNYC will continue to implement the program across the city with the ultimate goal of "capturing one inch of rainfall on 10% of the impervious surfaces in areas served by the combined sewer system by 2030" (City of New York, 2015, p. 204-205). The program also works to provide quantifiable sustainability benefits that include: cooling the city, reducing pollution, increasing property value, and reducing energy use (DEP, 2010).

2. Emissions Mitigation

One of the main initiatives of *PlaNYC* and *OneNYC* is to reduce emissions in the city, specifically from the 2 major sources: Buildings and Transportation. The *PlaNYC 2007* report had a goal to reduce global warming emissions by 30 percent by 2030. In the plan, buildings were identified as being the largest contributor to GHG emissions. The plan identified that the city's code had not been updated in 40 years, and that a plan for "greening the code" was essential. In 2005, the City passed one of the nation's first green building laws, requiring that building projects receiving a certain amount of public funding must meet LEED standards (New York City Mayor's Office of Sustainability, 2017a). *PlaNYC* wanted to build off this law to create a more robust regulatory framework that would include more buildings.

One way to ensure that development in the private sector would help to advance the City's sustainability goals for GHG emissions reduction was to create new building codes, regulations, standards, and enact them into legislation. This began with the *Greener, Greater Buildings Plan.* Enacted in 2009, the plan is a set of four local laws that target the City's existing building stock, specifically all buildings over 50,000 square feet. The laws

include: an annual benchmarking of energy and water consumption; energy audits and retro-commissioning every 10 years; and lighting upgrades (MOEC, 2017b.)

At the same time, Mayor Bloomberg along with the Urban Green Council, created the Green Codes Task Force (GCTF). Made up of over 200 experts, the GCTF released 111 recommendations to green the City's codes and, as of 2015, fifty-three of them have been enacted or partially enacted. This includes new laws and regulations to improve air quality, reduce carbon emissions, keep waste out of landfills and to clean the harbor by detaining more stormwater through green technologies (MOEC, 2017c).

The building sector has seen a great improvement in its energy efficiency since the induction of these laws, and the City has experienced a nineteen per cent reduction in emissions from 2005 levels (City of New York, 2014b). In fact, the policies have been so effective that *OneNYC* put forth an even more ambitious goal to reduce GHGs by eighty per cent, by 2050. Dubbed 80x50, this plan sets out to reduce emissions from four main sectors: buildings, power, transportation and solid waste. It has a specific target to reduce emissions from buildings alone by thirty percent, by 2025. A main initiative in *One City: Built to Last* is an action plan to retrofit public and private buildings to reduce GHG emissions**.** This builds upon the Zone Green Text Amendment. Approved in 2012, it acts to "remove zoning impediments to the construction and retrofitting of green buildings" (MOEC, 2017d).

Impediments include height and FAR restrictions in which some features of green buildings may exceed but, if allowed, would help to save money, energy, and improve environmental performance. With Zone Green, restrictions have been lifted to allow for the inclusion of technologies such as: energy-efficient building walls, sun control devices, solar

energy/panels, rooftop equipment such as green roofs and other stormwater detention systems, rooftop greenhouses and wind turbines.

To date, the initiatives from *PlaNYC* to *OneNYC* have been successful, yet there is still much progress to be made. Despite the new amendment, there lacks a robust incentive program for private landowners to choose to retrofit, as opposed to "demolish and rebuild". A demolition/reconstruction project releases an incredible amount of additional carbon in the atmosphere. This "embodied carbon" is not always accounted for when considering new projects. Thus, even if a new project involves the construction of a highly efficient green facility that meets all the LEED standards, the benefits of these sustainable measures would be offset by the demolition waste.

An example is the UN Headquarters decision to retrofit. The building was in great need of an update, and the initial plan was to demolish and rebuild, in which case a new, state-of-the-art, green, LEED-certified building could have been built. However, after conducting studies to assess the impacts of such a project, it was concluded that if the UN complex had been demolished and replaced with a construction of a similar size, it would have taken between thirty-five to seventy years before the improved operating efficiencies of the new complex would be achieved (Amatruda, Adlerstein & Baker, 2017).

The UN decided to partner with the City because, even though it is located on the east coast of Manhattan, it is a sovereign building. The New York City code was applied to the retrofit, which resulted in a fifty per cent reduction in overall energy consumption, and a forty-five per cent reduction in their carbon footprint. The retrofit also achieved LEED certification. This is an interesting case because the UN had the drive to choose the more environmentally-friendly path**.** In this sense, *OneNYC* needs to explicitly outline more

incentives to those property-owners who do not have that drive, and convince them to retrofit when possible (Ibid.). Though the report does discuss a number of programs that aim to promote and incentivize retrofitting, such as the Retrofit Accelerator Program and Green Housing Preservation Program, *OneNYC* does not specifically address the advantages of retrofitting over demolition/reconstruction.

3. Transportation

In NYC, the transportation sector is responsible for twenty-three per cent of GHG emissions. This includes private vehicles, freight, and the mass transit system (subway, commuter rail and bus) (City of New York, 2015). Since 2007, the Plans have put forth many initiatives to promote more sustainable methods of transportation, some of which have been met with opposition, and others that have been quite successful. *PlaNYC 2007* proposed congestion pricing where drivers would be charged to drive into the Manhattan CBD, with proceeds going towards the improvement of other forms of transportation (such as bike lanes and mass transit). This was a very controversial plan met with a lot of opposition, even though projected numbers showed it would have greatly improved traffic and transit service. The State Legislature eventually voted against it (City of New York, 2011). To date, there has been no attempt by the city to bring it back, and there is no mention of it in *OneNYC*. However, the transit advocacy group MoveNYC has been trying to push for it again, though it does not seem that Mayor DeBlasio is interested (Plitt, 2017).

Despite the lack of interest in congestion pricing, there are many initiatives that encourage multi-modal and alternate forms of transportation. *OneNYC* has laid out a plan to increase the capacity of subway ridership entering the Manhattan CBD, particularly during

rush hour. There are already a number of projects under construction, as well as a number of capital projects that have been prioritized to help expand the transit network. The projects range from softer strategies such as installing new communications and signal equipment, to harder strategies such as constructing new and extending current subway lines. This is a regional, cross-State, multi-agency strategy that is projected to increase ridership capacity entering Manhattan CBD by sixty-five per cent during rush hour (City of New York, 2015).

Embedded in the transit initiatives is a housing plan that promotes transit-oriented development. This allows for rezonings in transit-rich neighbourhoods to encourage denser development for housing, thus producing walkable neighbourhoods with a lower dependency on the automobile. *PlaNYC 2011* discusses transit-oriented development in great detail, but in *OneNYC* it is only very briefly discussed. Perhaps this is because the city's housing plan, *Housing New York: A Five-Borough, Ten-Year Plan,* was released just one year prior; and discusses it as part of its plan.

Initiatives to expand the bike network have also been prioritized, and it is estimated that a total of 1,180 miles of lanes will be completed by 2018. Included in this are improvements to the Manhattan Greenway. With the increase in cyclists and the push towards sustainable transportation methods, there is a demand to fully complete the promenade (which has a large gap on the east side between 41st and 61st streets). Mayor DeBlasio has recently released a $100 million plan to fill in a gap between 53rd and 61st street. This will not only help with connectivity of cycling paths around the island, but will also create more parkland and high quality public realms. In 2010, a portion of the

Greenway on the west side between 91st and 81st streets was opened, which is now used by over 7,000 cyclists per day **(**Nir, 2017).

Resiliency-Themed Initiatives and Projects

While *PlaNYC 2011* had laid out a set of resiliency-based initiatives, it was not until after the devastating impacts of Hurricane Sandy the City realized the need for new land use policies based on vulnerability to hazards, and disaster preparedness. However, Sandy did create a policy opportunity that enabled the City to invest in new projects in affected areas that may otherwise have been overlooked. A number of initiatives and recommendations laid out in *SIRR* and *OneNYC* specifically looked at how land use policy can be a tool for resiliency. This section will focus on two major projects that are currently underway and which deal with two specific topics: buildings and coastal defense.

1. Buildings

As discussed in the previous section, buildings are a vital component to the built environment and the vitality of the City, and therefore must be managed properly. The importance of implementing the proper codes and zoning regulations is essential to guide land use in a sustainable direction. It is important to help mitigate GHG emissions from buildings, but is also equally important to protect those buildings located in vulnerable areas that are at risk of severe damage to the structure. For buildings located in flood zones, there are specific zoning requirements and building codes that should be in place, either in new-build construction or retrofit upgrades. A typical resilient building should

have raised electrical equipment (and other building systems), and floodproofing of the lower levels of buildings (City of New York, 2015).

The *SIRR* report outlined a number of initiatives aimed at updating the building code and amending the zoning resolution for new and existing buildings located in flood zones. The initiatives ultimately lead to the approval of a zoning text amendment proposed by the DCP to encourage flood-resilient building throughout the flood zones. The amendment removed regulatory barriers that would otherwise prevent storm-damaged properties from reconstructing, and would use new resilience-based measures. As it states:

> "The amendment would enable new and existing buildings to comply with new, higher flood elevations issued by the Federal Emergency Management Agency (FEMA), and to new requirements in Building Code. Building to these new standards will reduce vulnerability to future floods, as well as help avoid higher flood insurance premiums." (DCP, 2013)

One issue that both *SIRR* and *OneNYC* addressed was that the available 100-year flood maps at the time of Sandy had not been updated since 1983 (although they were in the process). As a result, many properties that were not shown to be in the FEMA flood zone were affected. One analysis found that nearly 65 percent of the areas hit across the City were not actually in the flood zone (Natural Resources Defense Council, 2014). The importance of having updated maps is critical to align policies with the most current projections. FEMA had been working on updates, but they were not released until after Sandy had hit. *OneNYC* has stressed the importance of "aligning zoning and building code updates with reforms to the National Flood Insurance Program (NFIP) and expected changes to the Flood Insurance Rate Maps FIRMS" (City of New York, 2015).

Another critical component of this alignment is to consider how land use changes can be incorporated. For example, as discussed in *SIRR*, raising the buildings in a neighbourhood a couple of feet from the sidewalk may help with flooding, but could have negative consequences on land use issues such as: streetscape, building access, public safety, ground floor activity, architectural quality, and neighborhood character. Thus, it is essential to establish urban design principles that link land use and flood-resilience design. DCP has established the following four principles to help guide design: visual connectivity, facade articulation, inviting access, and neighbourhood character (City of New York, 2013).

What emerged from this were recommendations for further study on how land use policy can be a tool for resiliency. Since different neighbourhoods with unique characteristics were affected by Sandy, a citywide zoning change would not be enough to address the specific issues of each neighbourhood. The Resilient Neighbourhoods project was therefore created to identify specific land use, zoning and resiliency. Spearheaded by the DCP, this place-based planning initiative identifies ten communities located in the floodplain that were impacted by Sandy, and that have unique characteristics that would require strategies, tailored to each individually (DCP, 2016a). From this project, *OneNYC* hopes that "the City will evaluate and establish a framework for adaptive land use planning based on a range of coastal hazards and with consideration of climate change projections" (p.233).

Over the past two years the DCP has been working closely with the affected communities, two of which are in Manhattan: West Chelsea, and the Lower East Side. Each of these communities is unique, and requires very specific recommendations to increase resiliency while at the same time supporting their vitality. For example, West Chelsea is an

economically vibrant neighbourhood with a unique built character and a thriving arts and culture scene. A once industrial area, Chelsea has since experienced a rapid condo boom, is home to the High Line, and has become one of the most chic and sought-after neighbourhoods in Manhattan. During Sandy, the buildings themselves were not damaged, though the storm did knock out a large number of electrical and mechanical systems forced a large number of people to leave their homes and businesses for an extended period of time (DCP, 2016b).

The Lower East Side is quite opposite to West Chelsea. It is a predominantly low-income, residential neighbourhood with a high percentage of people living in aging multifamily buildings. The main challenge for the neighbourhood is how to retrofit these buildings to be flood-resilient, while still preserving the area's affordable housing stock (DCP, 2016a).

Each report goes into much detail in terms of design guidelines and best practice for retrofits, along with a number of other recommendations particular to the neighbourhood. In terms of contributing to citywide standards, the DCP established a consistent planning approach that could be applied to any neighbourhood, regardless of its makeup. The approach is broken down into a four-step process, as depicted in **Table 4.**

Table 4 - Planning Approach for Resiliency

Steps	Process	
Step 1: Resiliency Assessment	Evaluates coastal risks, the capacity of neighbourhoods to adapt to these risks, and the potential to align adaptation options with other policy goals or community priorities. The objective is to determine which hazards and vulnerabilities are present within a neighbourhood and evaluate the potential for adaptive strategies, such as retrofitting buildings or creating new coastal infrastructure, to reduce these vulnerabilities.	**Ongoing Community Outreach**
Step 2: Establish Resiliency Framework	Based on the results of the assessment, a resiliency framework is created that may include: coastal protection, infrastructure investments, changes to regulations, community education and disaster preparedness.	
Step 3: Select Local Resilient Land Use Strategies	Specific strategies should be used that are appropriate for the region, or situation. Areas at risk from future frequent flooding from sea level rise, and severe flooding from extreme events may want to **limit future growth.** In communities where buildings are at risk, primarily from flooding due to extreme events, they may want to **maintain the existing density** and focus on regulations to promote retrofits. If growth can be supported, a community may want to **encourage new growth**, as investments can go towards the construction of resilient buildings.	
Step 4: Implement Resiliency Strategies	Many different tools can be used to implement resiliency strategies, including: zoning changes, changes to other City, State or Federal regulations, operational measures, education and outreach, financial assistance, construction or upgrades of infrastructure, emergency preparedness training	

Source: New York City Department of City Planning (2016a). *Resilient neighbourhoods: East Village, Lower East Side,Two Bridges*. Retrieved from https://www1.nyc.gov/assets/planning/download/pdf/plans-studies/resilient-neighborhoods/evillage-leside/resilientneighborhoods_ev_les_tb_report.pdf.

2. Coastal Defense

Another major initiative discussed in *OneNYC* is intended to strengthen the city's coastal defences. This was first outlined in *SIRR*, which prompted the city to develop a comprehensive coastal protection plan. The plan began with $3.7billion allocated to infrastructure investments, natural area restorations, and design and governance upgrades

(City of New York, 2015). The areas in Manhattan most vulnerable to flooding and sea level are the East Side (from East 25th to Montgomery street) and Lower Manhattan (south of Montgomery street up to the northern end of Battery Park City). Along with a number of specific areas across the five boroughs, this portion of Manhattan will be given special attention to strengthen its coastal defences over the next 10 years.

Much like the Resilient Neighbourhoods program, the Coastal Protection plan identifies specific areas of the City, and forms a plan that represents the social, economic and physical context of the specific community. The two communities in Manhattan, for example, are vastly different. Lower Manhattan is the financial capital of the world, and is mainly dominated by skyscrapers. In contrast, the East Side is predominantly low-income, with mainly low-rise affordable residential buildings. These communities are part of two projects outlined in *OneNYC* that will be a priority of the City: The East Side Coastal Resiliency Project (ESCR) and the Lower Manhattan Coastal Resiliency Project (LMCR).

The ESCR is a plan based on equity and inclusiveness which works closely with the community at all stages of the project to find the most ideal ways of incorporating flood protection into the community fabric. The aim is to avoid building a large flood wall, and instead to create a design that protects people while improving access to an enhanced waterfront while adding to urban ecology and urban spaces. The goals of LMCR are very similar, and are based on the same values "to protect vulnerable communities through a fair and equitable community-based plan for resilience, recovery, and vitality" (nyc.gov).

At the time of *OneNYC's* release, the City had only gained 50 percent of the funds needed to roll out the Coastal Protection plan, and therefore called for additional funding to help cover the costs. With the Department of Housing and Urban Development (HUD) as

lead agency and sponsor, and with support from the City, two different design competitions were held to develop innovative resiliency designs. This would help garner more support and funding for the projects from different sources. HUD's Rebuild By Design competition and National Disaster Resilience Competition enabled the City to secure additional funds to help establish a final plan.

The 'Big U'

The winner of the NYC Rebuild By Design (a federal initiative that brings together a collaboration of designers, researchers, community members and officials to propose creative design projects to improve coastal area resiliency) was the Bjarke Ingels Group (BIG) architecture firm. The design incorporates the goals of both the ESCR and LMCR projects and puts them into one vision. The design, which covers a 10-mile continuous radius, is meant to create a resiliency barrier for protection from storm surges and flooding, while also creating new public realms and leisure spaces. It still considers the individual typologies of the different neighbourhoods, and breaks them up into separate 'compartments'. Thus, each 'compartment' is meant to stand on its own, catering to the specific social needs of each community creating a comprehensive design with "physically autonomous flood-protection zones that can be individually isolated" (Cohen, 2016)
For example, the proposal for the compartment of East River Park is to construct a system of bridging berms over the highway. These will help to protect from storm surges and sea-level rise, as well as to provide pleasant and accessible connections to the waterfront. For the Two Bridges and Chinatown compartment, deployable walls will be attached to the elevated highway. These walls will have the ability to be flipped down during a storm to prevent flooding. Neighbourhood artists will also decorate the walls to create a more

pleasant and inviting space when not in use. For the third compartment, Brooklyn Bridge to the Battery, a different type of berm is proposed that involves a series of elevated paths and knolls that weave through the landscape (Rebuild By Design, n.d.). In terms of land use, each compartment has a very different resiliency plan from one another that is designed to fit with the neighbourhood.

This is a very bold project that is still in the planning phase (both ESCR and LMCR are currently going through ULURP), and there are some criticisms that the project may fall short of what it actually wants to accomplish. There is speculation that there are not enough funds to incorporate the different public spaces, ecological habitats and other parks and trails into the landscape. Some critics fear that the project will not be beneficial, and will create an ugly flood wall that no one wants to live near. There is also a risk that the flood protection measures for Lower Manhattan will divert excess floodwater to surrounding unprotected communities during a storm (Cohen, 2016). *OneNYC* has stated that it has taken a more regional approach, which involves coordinating with different authorities within the city, state, and cross-State, on various resiliency-themed projects. Time will tell if that is the case. The Big U is designed to protect lower Manhattan, but will that make other communities in Brooklyn, Staten Island or even New Jersey more vulnerable? It seems as though the Coastal Protection plan will be rolled out in phases, and if there is too much time between each phase that could leave many communities even more vulnerable than they already are.

This section has shown how *PlaNYC* and *OneNYC* have influenced land use in Manhattan through various plans, initiatives, regulations and incentives; all of which have had a focus on sustainability and resiliency. It is evident from the examples presented that

the City is taking great strides towards promoting environmentally-focused development and designs that are considerate of the different needs of communities, along with their built and natural environments. How biodiversity and well-being are addressed in the various plans will be the focus of the next section.

Section 3 - A Case for Biodiversity and Well-Being

Biodiversity promotion and conservation in the city is often not a top priority for policy-makers. After all, cities are built for people and, with the exception of parks, are not meant for wildlife. Manhattan was once an island teeming with different plants and animals providing natural benefits and services. With the dramatic alteration of the island, natural services such as flood protection and carbon sequestration have been greatly diminished, leaving the current population vulnerable to extreme events. The loss of biodiversity also has implications on human well-being and quality of life, as ecosystem services have the capacity to provide a wide range of benefits for people. It is not possible to return the island to what it once was, but there are ways of helping to re-integrate nature and its essential natural processes back into the city.

With the inception of *PlaNYC* and *OneNYC*, along with the multitude of other initiatives, policies and projects, New York City has the potential to regain a large portion of what was lost, as long as it takes the appropriate measures. The Natural Areas Conservancy (NAC), working alongside the DPR, is one non-profit organization which has taken great steps in promoting the restoration and conservation of biodiversity in the city urban ecological planning framework. This section will review how the efforts of *PlaNYC* and

OneNYC have helped to restore and advance biodiversity in Manhattan, using the framework set out in the *New York City Nature Goals 2050* report released by the NAC.

Natural Areas Conservancy

The NAC is composed of a multitude of scientists and experts working closely alongside the City of New York to promote nature's diversity and resiliency. In 2015, the NAC held the Nature Goals 2050 Workshop, inviting participants committed to nature conservation from non-profits, nature and cultural organizations, government, and universities from all over the city. The NAC looks beyond the assumption that the destruction of wildlife and natural habitats is "an unfortunate and unavoidable cost of life" (p. 7) and that, with proper planning, nature and the city can happily co-exist. With this objective, the *Nature Goals 2050* report presents a framework made up of 'functional goals' and 'compositional goals' to help guide the city's planning and development of urban ecological initiatives **[Box 4].**

Box 4 - Nature Goals 2050

Functional Goals	Compositional Goals
• To provide living environments for a diversity of species • To support nature's ability to absorb/filter water from runoff, and to clean the air • To enhance nature's capacity for coastal protection and resilience • To increase connectivity for plants and animals to move through the city more easily • To inspire and encourage human creativity through nature	• To promote diversity and connection of native ecosystems, species and genetic material • To provide accessibility to natural areas for all citizens • To integrate nature into urban planning • To encourage public engagement through activities

Source: Natural Areas Conservancy (2016). *New York City nature goals 2050.* Retrieved from http://naturalareasnyc.org/content/goals/nac_naturegoals_design_full_161025-compressed.pdf.

These goals set out a complex but achievable framework, as long as the initiatives set out by the City are in line with them. The question, then, is whether or not the initiatives in *OneNYC*, along with the programs and policies which have been set in place from *PlaNYC*, are on the path to achieving (or have already achieved) these goals.

Before Hurricane Sandy, climate change strategies were beginning to focus more and more on themes involving urban ecology, the city as an ecosystem, and biodiversity promotion and conservation. The *PlaNYC 2007* report began the discussion of bringing nature back to the city. Though the report never used the terms 'urban ecology' and 'biodiversity', the plan did set out initiatives to 'green the cityscape', which included planting more trees and expanding the Greenstreets program. By 2011, *PlaNYC* added a multitude of new initiatives that specifically addressed biodiversity and urban ecology. This included planting even more trees, conserving natural areas, supporting ecological connectivity and integrating sustainability into planning design guidelines**.**

After Sandy, there were more pressing needs, such as the reconstruction and reinforcement of housing and infrastructure**.** This was reflected in *OneNYC***,** as the new resilient and social initiatives were prioritized, seemingly overshadowing other themes such as biodiversity, natural areas and urban ecology. However, the plan's more comprehensive approach to social and environmental considerations may be the best path to provide equitable ecosystem services. The following section will first discuss what has been achieved so far through land use initiatives that have had an influence on natural areas planning; followed by a discussion of the regulatory framework that is in place to guide development.

Green Initiatives

1. MillionTreesNYC

In 2007, *PlaNYC* looked to expand upon the work of the DPR who, over the previous decade, had been planting thousands of street trees across the city. *PlaNYC* had stressed the importance of city trees to help mitigate urban heat and pollution, to conserve energy, and reduce stormwater runoff; therefore, planting more trees became a priority. A ten-year plan to plant one million trees by 2017 was proposed. This entailed partnering with various non-profit, community and corporate stakeholders to plant trees on private residential, institutional and vacant land properties. To ensure that trees were planted beyond just parks and sidewalks and onto various types of lots, *PlaNYC* called for a revision to the zoning code to require tree planting on new developments and construction (City of New York, 2007).

Initiatives in *PlaNYC 2011* provided updates to the program, and called for further research on how to preserve the long-term health of trees, based on different factors in the built environment that can affect the mortality rate. By this point, nearly 650,000 trees had been planted across the city, and a public-private partnership had been formed with the non-profit New York Restoration Program (NYRP). The goal was reached in 2015, when the one millionth tree was planted. This project has highlighted the importance of trees, identifying them as economic and environmental assets for the City. It was an ecological capital improvement initiative never before seen which not only helped to promote biodiversity and bring nature to the City, but also encouraged public engagement through its stewardship program (NAC, 2016).

2. Green Infrastructure Plan

The benefits of GI were discussed earlier in terms of the functional capabilities to manage stormwater runoff. GI, however, has capabilities that stretch far beyond that, and can be used as an essential tool to help promote biodiversity and to create new ecosystems in the city. PlaNYC was instrumental in promoting GI for the sustainability benefits it would provide. Not only would vegetated sources such as green roofs, bioswales and street trees help to manage stormwater, but they would help to provide nesting, migratory and feeding habitats for a number of different species (DEP, 2010).

The more GI projects that exist across the city, the more chance there is of creating connections between sites to allow for plants and animals to move through the city more easily. Manhattan has great potential to create a connected green network if planned properly. With such a high density of buildings and other impervious areas, there are millions of opportunities to create green spaces on roofs, streets and lots all in close proximity to one another. *PlaNYC 2011* proposed initiatives to support ecological connectivity through GI, particularly through Greenstreets to serve as ecological respites, and green roofs as ecological links in an otherwise fragmented city.

GI is, however, only a small part of a larger network that works to promote biodiversity in the city. The expansion and enhancement of parks, greenways, waterfronts and waterways; along with zoning regulations, codes and habitat characterizations all act to complement GI to promote biodiversity in the City.

3. Parks

PlaNYC 2011 made some big steps to try and integrate nature into planning. As part of the "Parks and Public Space" initiatives, the goal was to ensure that parks were seen as valuable pieces of land that provide places for recreation, while at the same time holding the ability to detain stormwater and act as ecological corridors. Central Park is often overlooked as an important biodiversity haven, as it is a habitat for over 275 species of resident and migratory birds. It is also engineered to absorb and treat stormwater runoff with its system of lakes, large reservoir and subsurface infrastructure (Design Trust for Public Space, 2010).

Other newer parks such as the Highline and the Manhattan Greenway are important movement corridors for both wildlife (pollinators in particular) and humans, and act as stormwater management areas. The waterfront resiliency projects in the City (such as ESCR and LMCR) have great potential and opportunity to promote biodiversity along the coast while creating new public realms and providing coastal protection. Capital projects involving public parks follow specific design, construction and operational principles as outlined in the High Performance Landscape Guidelines manual (a joint effort between the City and the non-profit Design Trust for Public Space). This ensures that parks meet specific sustainability standards (City of New York, 2011). The conservation of parks to ensure that sustainability guidelines are met is also an essential initiative, particularly in areas of great ecological importance. Inwood Hill park has protected its ancient forest and restored the natural salt marsh. It is a significant site for biodiversity and ecological conservation that houses important wildlife habitats and provides natural stormwater treatment (DPR, n.d.a.).

Regulatory Framework
Zoning Resolution, Green Codes, and habitat characterizations

The New York City Administrative Code contains all the laws, codes and ordinances for the city. There are a number of enacted laws contained in the Code that address issues related to biodiversity. Some examples include: a law to create a comprehensive wetlands protection plan; the replacement of trees on public property that were damaged or removed during construction; and the creation of a sustainable stormwater management plan. These are all effective laws that, in some cases, led to the creation of comprehensive plans. However, none of these laws addressed biodiversity directly (Kiviat & Johnson, 2013).

It was not until 2013 that the first law to address biodiversity was enacted, thanks to the Green Codes Task Force. This law requires the use of native plant species on all city-owned property. Native plants are essential for promoting biodiversity and for the ongoing health of their natural ecosystem (Green Codes Task Force, 2010). The task force has also recommended prohibiting the use of turfgrass as the mandatory sidewalk plantings for new developments. This is a much more difficult law to enact as it would also affect private development. Though there does appear to be a growing movement in the private sector to adopt sustainable measures in development projects, there still remains a lot of potential for biodiversity to be overlooked. This is because the Zoning Resolution does not require ULURP for As-of-Right zoning. As a result, many private-led projects occur without going through CEQR and thus may have no consideration of the ecology of the site (Kiviat & Johnson, 2013).

To compare, the EIS process that every Capital project must go through is rigorous and detailed. It involves a habitat characterization, which is "the procedure of identifying the dominant vegetative and physical characteristics of an area to assess its value" (CEQR, 2014). The CEQR manual explains what needs to be considered at a site before construction begins. This involves acquiring all information possible relating to the site's history, geomorphology, hydrology and soil (present conditions as well as alterations that have occurred over time), climate, past and present human activity, and an evaluation of the adjacent areas surrounding the site. Identifying what type of vegetative cover exists at the site, along with the source and permanence of water, is essential to identify unique habitats or important water bodies such as wetlands. This information will have an impact on regulatory approvals, as it ensures that beneficial natural ecosystems are not destroyed.

The CEQR process has the potential to be a valuable asset to biodiversity conservation in the city. It recognizes the ecological networks and corridors that exist, and how alterations in one area can affect surrounding ecosystems. As the CEQR states: "A natural area must be evaluated in the context of contributions it makes to the ecological function and biodiversity of adjacent and proximal natural areas of higher value" (CEQR, 2014, p.295).

Overall, biodiversity promotion and conservation is fairly well-represented in the City's various strategic plans and initiatives, and is making its way into enacted laws and zoning codes. Reports such as *Nature Goals 2050* and the *Biodiversity Assessment Handbook* outline the current discussions, trends and science of biodiversity management in the City, and provide sound assessments and frameworks for planners and policy makers to follow. The CEQR is a very in-depth technical manual that goes into great detail to ensure the

protection of vulnerable ecosystems. New York has taken significant strides to become one the world's leading green cities, but there is still much to be done in terms of addressing biodiversity directly, specifically in the city's strategic plans. *PlaNYC* 2007 was instrumental in laying out the groundwork for green initiatives in the city. The 2011 plan built upon this, and began to address more specific topics relating to biodiversity and the important roles it plays in the city. Accordingly, biodiversity should be valued in the planning process through the conservation and regeneration of natural systems. To quote *PlaNYC*:

> This new recognition of urban nature represents a continuum, from areas that are truly wild, to highly engineered bio-systems that recreate the functions of old natural systems within the constraints of the modern city." (p. 167, 2011)

PlaNYC 2011 demonstrated that the City was beginning to take specific steps to address biodiversity promotion and conservation through an applied urban ecology approach. However, *OneNYC* seemed to have drifted away from that approach, as very little reference to biodiversity was made in the whole report. The 'Parks and Natural Resources' section does have an initiative to 'Green the city's streets, parks and open spaces' by continuing to plant and maintain trees across the city. There is a short mention of the benefits of natural systems and ecological diversity in the city, but nothing of great detail. Initiatives from *PlaNYC 2011* that discussed 'supporting ecological connectivity' and 'creating a network of green corridors' found themselves in the "2011 Sustainability Initiatives" section at the back of the *OneNYC* report, which lists the progress of all initiatives from *PlaNYC*, most of which are either still "In Progress" or "Partially

Completed”**.** It is not as though *OneNYC* has completely abandoned these initiatives, but rather has shifted responsibility to the NAC.

OneNYC has also placed more focus on policies that deal with social equity, such as: poverty, healthcare, employment and education (to name a few). Certainly though, by linking social equity with environmental issues, Mayor DeBlasio created a more inclusive plan; one that may enable the wider access to ecosystem services across the city that are linked to improved well-being and quality of life.

Well-Being

A common theme that surfaces throughout all of the strategic plans maintains that the protection and enhancement of the city’s natural systems will result in environmental benefits such as flood resiliency, reducing UHI, stormwater management, promoting biodiversity and reducing pollution. In turn, these natural systems provide a richer interaction with nature for people living in the city. Ecosystem services go beyond merely protecting humans from extreme events, but offer a wealth of benefits that help to enhance quality of life and well-being.

The NAC report discusses three goals that relate directly to the relationship between nature and human well-being: provide accessibility to natural areas for all citizens; inspire human creativity through nature; and encourage public engagement through activities. One question that arises when examining these goals is how to incorporate social equity into urban sustainability planning. When there is no, or limited, access to quality greenspaces for certain populations, the benefits of biodiversity on quality of life and well-being are unequally distributed amongst the population. This section will

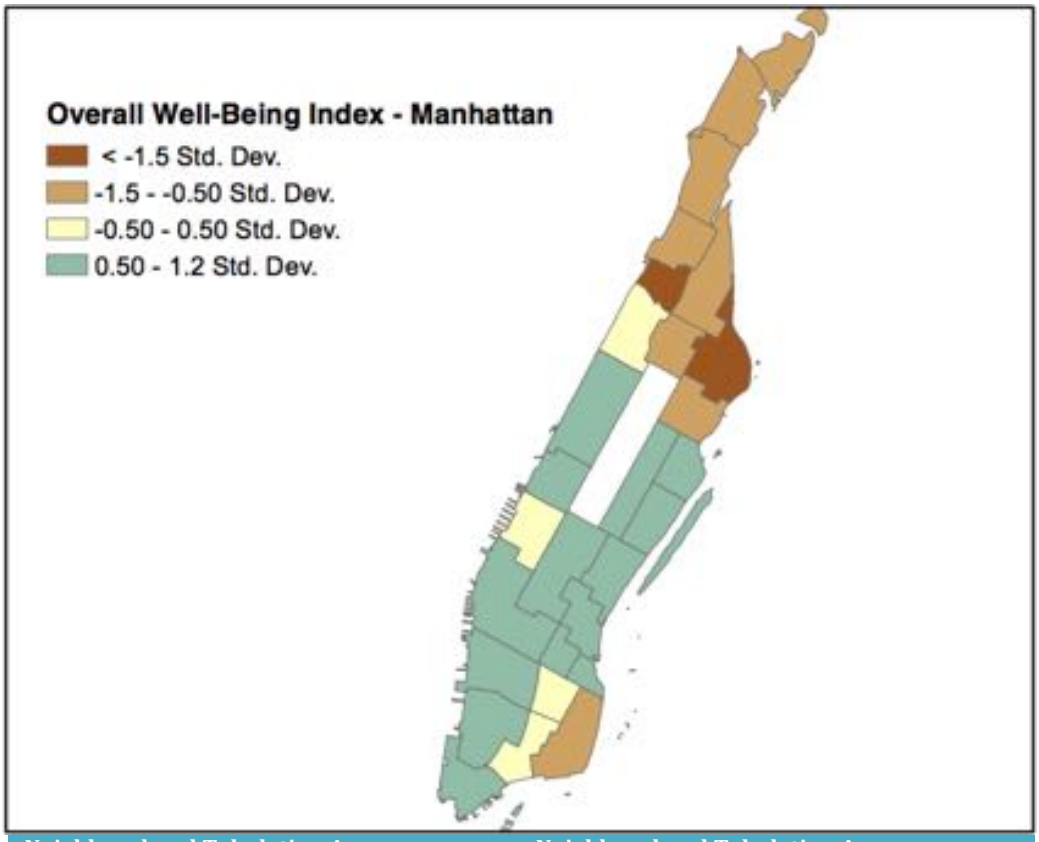
provide an overview of how the city's strategic plans are addressing the three above-mentioned goals to promote quality of life and well-being in an equitable fashion.

Measuring Well-Being

In the strategic plans, there is much discussion on how greening efforts can have positive effects on well-being. *OneNYC* talks about how parks and open spaces are important resources in the city because they can improve quality of life by helping to "reduce stress, lower asthma rates, improve focus and mood, and … (can lead to) improved academic performance" (p. 206). Though there is much evidence to validate the previous statement, well-being remains difficult to measure**.** In the *State of New Yorkers - A Well-Being Index,* well-being is defined as "a subjective perception of one's quality of life" (p. 6).

The index does not attempt to measure each individual, but rather bases the analysis upon the best set of indicators of community quality of life, which align with the major 'policy domains' of New York City. The result, twenty community well-being index indicators were created from the following six policy categories: Education; Health and well-being; Economic security and mobility; Housing; Personal and community safety; and Core infrastructure and services **(Appendix 3)**. Based on these policy categories, the index yielded results for each indicator distributed across every neighbourhood in the city. **Figure 15** shows the overall well-being for Manhattan, which combines all indicators**.** The results show that people living in the more affluent neighbourhoods of Manhattan experience an overall heightened sense of well-being.

Figure 15 - Overall well-being, Manhattan



Neighbourhood Tabulation Areas more than 1.5 SD ABOVE the mean	Neighbourhood Tabulation Areas more than 1.5 SD BELOW the mean
1. SoHo-Tribeca-Civic Center-Little Italy	**1.** Manhattanville
2. West Village	**2.** East Harlem North
3. Upper East Side-Carnegie Hill	**3.** Washington Heights South
4. Turtle Bay-East Midtown	**4**. Hamilton Heights
	5. Central Harlem North-Polo Grounds
	6. Marble Hill-Inwood
	7. Washington Heights North

Source: New York City Center for Innovation through Data Intelligence (2015). *State of New Yorkers – A Well-Being Index.* Retrieved from http://www1.nyc.gov/assets/cidi/downloads/pdfs/nyc_well_being_index_full_report_2015.pdf

Although the index does not include any indicators that measure the effects of ecosystem services directly, many of the indicators that are used can be related to the presence (or lack of) ecosystem services. Examples of indicators include asthma rates, commute times, and affordable housing. These are all issues discussed in length in the strategic plans and all have initiatives attached to them that involve a form of

environmental intervention. Though the index may not be the best representation of how ecosystem services can influence well-being, it is still useful to help identify and to prioritize the communities most in need. Providing access to greenspace is a good start, but ensuring that the appropriate types of greenspaces fit the character and needs of the community is equally important.

Accessibility to Natural Areas

When Central Park opened in 1858 it was meant to be a 'park for the people'; wherein citizens of all classes could go and enjoy the park equally. However, this was not always the case, particularly during the parks' first decade of opening. The location of Central Park was too far north for the working class population to walk to, and commuting by train was too expensive. The park thus became only accessible to the wealthy population, who began to call it their own (Waxman, n.d.). In the present-day this is no longer the case, as people from all over enjoy the park. Nonetheless, the equal access to parks and greenspaces for all citizens remains an important issue, and has been a priority initiative consistent across all the strategic plans. In 2007, PlaNYC introduced the initiative to ensure that, by 2030, every person would live within a 10-minute walk to a park. Much progress was made by 2011, which prompted an update from 'having mere access to any park', to 'access to quality parks that meet the needs of the community'.

OneNYC identified the fact that most of the parks in the city were designed 50 to 100 years ago, and are no longer compatible with the changing demographics, new patterns of development and new interests of park users. Many citizens still lack access to quality

parks and open spaces, mainly in underserved areas of the city. As OneNYC states: "(there are) more than 200 parks having received less than $250,000 each in capital investment over the last 20 years" (p. 206). It is evident that the distribution of greenspaces, parks and biodiversity is uneven across the city; and that underserved areas are less likely to be close to, or have access to, greenspace**.** However, with this being said, there are a number of initiatives currently underway that are working with underserved communities to promote biodiversity and to create high-quality recreational and living environments.

Accessibility to parks and greenspaces has been increasing since the 2007 plan. A survey conducted by The Trust for Public Land has reported that almost 97% of New Yorkers live within a 10-minute walk to a park. The problem, however, is that many of these parks do not include any sort of wild elements to them, and may contain just a playground or baseball field (NAC, 2016). In line with initiatives from OneNYC, recent efforts by NYC Parks have begun to take steps to revitalize the underserved areas of the city with the intent to create areas that help to inspire human creativity through nature while engaging the public throughout the whole process.

Community Parks Initiative

Led by NYC Parks, this program aims to revitalize parks in underserved areas that have received little to no capital investment in the last twenty years. The initiative focuses on areas with growing populations and higher-than-average poverty rates. Since 2014, the program has invested in fifty-five sites across the city, twelve of which are in Manhattan. The neighbourhoods chosen for Manhattan match the same communities reported to have

the lowest overall well-being; this includes the Lower East Side - Two Bridges, Harlem, East Harlem, Morningside Heights and Upper Manhattan.

What really makes the program successful is that it works to re-imagine the park alongside the community. Families in the neighbourhood are invited to public input meetings to provide their vision of what they would like to see in their park. This ensures that people of all ages and backgrounds can come and take part in the planning process. Examples of feedback obtained from the communities includes: more safety features, more greenspace and better accessibility for all users (DPR, n.d.c) This is truly an example of an initiative that is conducted in an equitable fashion to help strengthen community well-being through public engagement.

Parks Without Borders

An initiative of *OneNYC* to help enhance neighbourhood access and connectivity has developed into the Parks Without Borders program. Led by DPR and DOT, this strategy works towards improving accessibility by creating more inviting park entrances and boundaries. This will be done through greening, public art installations and, in some cases, removing barriers altogether. This will also help to increase connectivity with the surrounding neighbourhood, and to improve views of the park. This initiative also works to complement the Community Parks Initiative, and is already being incorporated into some of the same parks such as the Henry M. Jackson Playground in the Lower East Side.

Building Healthy Communities

As part of the 'Healthy Neighbourhoods, Active Living' section in Vision 2 of *OneNYC*, the Building Healthy Communities strategy works towards promoting healthy lifestyles through the provision of quality outdoor spaces. The strategy maintains the overarching vision that "physical health, mental health, and quality of life are critical elements for improving social wellbeing" (City of New York, 2015, p.135). It is a place-based initiative that works in concert with the Community Parks Initiative, thus targeting the same fifty-five parks. The key objective in Building Healthy Communities is to foster community involvement through activities such as "physical activity programs, cooking classes, nutrition education and farmers' markets" (Ibid., p. 135).

To conclude, the effects of urban greening and biodiversity on well-being are difficult to measure, as there are a number of other factors (such as Education, Health, Economic Security, Housing) that can be at play. However, there is mounting evidence showing that access to natural environments can help to promote healthier active lifestyles contributing to better quality of life. Ecosystem services are not readily available to all residents, as the distribution of quality greenspaces is uneven across the city. *OneNYC* and the countless other plans, initiatives and reports have made attempts towards improving equity within the city, and have worked towards making New York a true green city; however, more time and research is needed to substantiate their progress.

Conclusion

In its efforts to mitigate climate change through effective and sustainable practices, NYC has gone through significant changes in its policy environment. The primary focus of *PlaNYC* 2007 was immediate climate change adaptation and the reduction of emissions and other environmental pollutants. Over the years, the plan was updated, and greater emphasis was placed on urban ecological principles. More focus was placed on integrating biodiversity and ecology into urban design, and the interaction between humans, nature and the physical environment. Biodiversity was seen as beneficial to human well-being and quality of life, as the provisioning of ecosystem services would provide health benefits and environmental protection. This was an important connection to make, since it allowed for innovative green infrastructure projects to take form. Once Mayor DeBlasio took office, there was a significant inclusion of resilience policies and initiatives as his goals in *OneNYC* took on more of a social focus. Some critics felt that his government was taking on too much and that climate change initiatives may take a back seat. However, by linking environmental issues with social equity when determining climate change adaptation measures, his office was able to broaden its scope to address climate issues from a bottom-up approach. *OneNYC* is working towards improving the well-being of all the city's residents, regardless of income or location, with the hope that New York will become a more sustainable, resilient city.

Chapter 5 – Recommendations

This section will propose a set of recommendations that are meant to complement and contribute to the current structure of environmental strategic planning in New York City. The basis of the proposed measures will rely upon the information presented in this paper, and will cover the three main topics - land use, biodiversity and well-being. Supporting topics in this paper including the history of landform; and the current political, social, physical and environmental contexts will help to substantiate the rationale for the proposed recommendations.

As the paper suggests, sustainable and environmental initiatives and policies can have very positive effects on well-being, but they can also be counter-productive by threatening people's livelihoods through un-equitable greening efforts. It is imperative that future sustainable development be guided by recommendations, which maximize QOL for all residents while minimizing the negative effects of climate change.

The recommendations will be organized into three categories: process interventions, physical interventions and policy interventions. The focus will be on the borough of Manhattan; however, many of the recommendations will apply to New York City as a whole.

Process Recommendations

Recommendation #1: Ensure that the initiatives regarding biodiversity and natural processes in the *PlaNYC* reports are not superseded by the new initiatives in *OneNYC* through the implementation of a tracking system that monitors the two sets of initiatives in a parallel fashion.

Rationale: *OneNYC* includes a number of new initiatives, many of which that do not follow the same path as those in *PlaNYC*. The report as a whole has taken a much different approach to its predecessors, and has omitted a number of key concepts that were discussed in length in the previous documents (such as biodiversity). *OneNYC* does include a listing of the 2011 initiatives, along with their status, at the back of the report. The fact that a number of them are still listed as only partially completed does not attest to their actual progress. Along with the number of new initiatives proposed in *OneNYC*, it is unclear as to whether or not these old goals will or can be achieved. Though different administrations will inevitably have different agendas, the importance of biodiversity promotion and conservation as a strategy for climate change mitigation should not be overlooked.

Recommendation #2: Continue to support and rely upon partnering with non-profit organizations and corporate sponsors to help carry out different projects.

Rationale: The city has limited capital funds in which to carry out all the proposed initiatives from the strategic plans. It is essential that the city continue to collaborate with different stakeholders through partnerships to ensure that larger projects are financed appropriately, such as 'MillionTreesNYC'.

Recommendation #3: Continue research to identify the benefits of ecosystem services, along with best practice for the development and conservation of biodiversity and urban ecology.

Rationale: It is essential that planners and policymakers have this knowledge to help develop plans and make informed decisions that are based on sound sustainable and resilient data.

Recommendation #4: Update the NYC Well-Being Index to include indicators related to environment and healthy lifestyles. Access to quality parks and leisure and the effects that ecosystem services can have on well-being and quality of life need to be addressed.

Rationale: Research is showing that natural systems can be beneficial for the well-being and quality of life of humans. The ecosystem services that emerge from the natural systems can provide essential environmental benefits and protection against extreme weather events, along with providing people a rich and fulfilling interaction with nature. Through further research, studies and surveys, the positive effects of natural areas to residents in specific communities in Manhattan can be better understood. As a result, the communities that are underserved by quality parks, open spaces and greenspaces can be more easily identified and prioritized.

Recommendation #5: Further engage with citizens at the community level to help develop and support green initiatives that are community specific. This will ensure that the needs of the community are met first and foremost, and that greening efforts are performed at the grassroots level as opposed to a top-down approach.

Rationale: Equity is essential in all aspects of planning, particularly in lower income communities who may be at risk of displacement due to gentrification. Urban greening projects can have negative effects on the lower income population by driving up property values in adjacent areas, subsequently driving out residents who can no longer afford the rents.

Recommendation #6: Support the adoption of a New York City Climate Resiliency Indicators and Monitoring System.

Rationale: There is no rigorous standard for indicators and performance measures in the field of resiliency. The NPCC and *OneNYC* have stressed the need for a standardized monitoring system, and this should come from data collected at the community level from various working groups.

Recommendation #7: Continue to codify design standards for Green Infrastructure projects to ensure certain practices are embedded into plans.

Rationale: The DCP has already initiated zoning amendments that stipulate certain requirements for new parking lots, developments and buildings in lower-density areas. Creating standards helps to establish certainty amongst building owners and developers that the green infrastructure has a greater purpose for public benefits.

Recommendation #8: Consider ways to ensure that as-of-right and private sector development do not pose significant threats to existing biodiversity. The development of a streamlined or expedited version of ULURP and EIS applied to the private sector could be one option. Another option is to promote, encourage and develop environmentally friendly technologies and guidelines for the private sector to adopt. This would allow private entities to become innovators and leaders, thereby providing incentives without a lot of regulatory burden.

Rationale: Because as-of-right development can occur without city or public review, the ecology and biodiversity at the specific site are at risk of being overlooked. Capital projects

must go through a rigorous process of site characterization, which ensures that natural ecosystems at the site are not harmed. Since a high number of development projects (particularly in Manhattan) are private, this means that a large majority of projects are as-of-right and are being constructed with very little environmental scrutiny.

Recommendation #9: Create a city department or task force that is responsible for conducting and updating an Ecological Sustainability Index to measure the city's "ecological footprint". **Rationale:** This concept was first introduced by Mathis Wackernagel and William Rees in their book *Our Ecological Footprint: Reducing Human Impact on the Earth.* To measure the "ecological footprint", it is estimated how much land is needed to provide all food, water, material goods and waste services while sustaining a certain standard of living. The authors developed this to measure the footprint of a whole country, so this would be significant to apply it at the local level, particularly to a unique area such as Manhattan.

Policy Recommendations

Recommendation #1: Amend the Green Roof Tax Abatement Program to include support for maintenance and/or operational costs. This would help to add additional incentives to private property owners to construct and maintain a green roof on their property. **Rationale:** The current Green Roof Tax Abatement Program has not appeared to be very successful to date, and it did not have a single applicant in all of 2014. One of the

stipulations is to maintain the roof for at least 4 years, though the tax abatement has a one-year limit. This can be costly for property owners and can act as a deterrent to taking part in the program even though there may be interest.

Recommendation #2: Draft a Green Roof Bylaw that would require all new buildings (commercial, residential, institutional and industrial) to construct a green roof. A minimum roof space coverage requirement would be established based on the square footage of the building.

Rationale: The Zone Green Text Amendment has lifted zoning restrictions that once acted as barriers to the construction and retrofitting of green buildings. Private property owners can now choose to add certain green technologies (such as green roofs) if they wish, but there is no requirement. The City of Toronto has become the leader in most square feet of green roofs in North America, due mainly in part to the City's own Green Roof Bylaw which requires all new developments to allocate a certain percentage of the roof to the construction of a green roof (City of Toronto, 2017). A similar bylaw in New York City would be effective in ensuring that the private sector contributes to the environmental, sustainable and resilient efforts in the city. New York City's buildings are the highest contributors of GHG's, and therefore a rigorous standard of development needs to be implemented and embedded into the city code.

Recommendation #3: Offer incentives to property owners who choose to retrofit in order to add green elements to their building, and disincentives (such as increasing demolition fees) for those who choose to demolish and rebuild.

Rationale: The Zone Green Text Amendment has been put into effect, which allows for building owners to add certain green technologies that were previously not permitted due to height and FAR impediments. Owners now have the ability to make these upgrades, though they still may choose not to because it can be costly. Without any monetary incentive to do so, owners may not be willing to pay the upfront costs in order to attain the future cost-saving benefits that green buildings can provide. It may be seen as too risky for some. On the other hand, if building owners decide to take the cheaper (and more lucrative) option to demolish and rebuild, they should be penalized. Studies such as the UN HQ: Carbon Case for Retrofit have shown that the amount of "embodied carbon" released into the atmosphere in a rebuild project will negate the effectiveness of the new green building for 35 to 70 years.

Recommendation #4: Encourage participation in the Green Infrastructure Grant Program by providing ongoing incentives to owners such as a stormwater fee discount.

Rationale: Only thirty-four property owners have participated in the Grant program since 2011, in part because there are no ongoing incentives after the initial grant. Owners already pay a storm water fee to the DEP for the amount of potable water that is consumed and expelled into wastewater systems (Gunlach, 2017). A stormwater fee discount based on how much property is covered by green infrastructure would help offset the owners' costs of maintaining their systems. This has been done in Philadelphia with positive results.

Physical Recommendations

Recommendation #1: Ensure that city plans and designs are guided by an approach that considers past, present and future ecological and social contexts. As much as possible, plans should consider the city's past natural conditions, and attempt to bring back or restore important ecological features that were lost.

Rationale: Much research has been done on the importance of learning from a city's natural history to help guide planning and public policy. For example, Beatley (2011), Register (1987) and Sanderson (2009) have studied how elements such as past hydrological cycles and historic patterns of biodiversity can be used as significant reference points to develop future sustainable and resilient plans. When the city is studied on a larger time-frame, certain patterns begin to emerge that help to explain the environmental challenges faced today. Manhattan's past environmental features once acted as natural barriers to extreme events. The disappearance of these features has left the island quite vulnerable. It is not possible to regenerate the mountains that once existed, but efforts to restore facets of biodiversity and, to some extent, restore lost waterways are not unattainable**.** *PlaNYC* recognizes that the conservation and regeneration of natural systems will provide enormous benefits for the safety and well-being of all citizens.

Recommendation #2: Ensure the equitable distribution of greenspaces and greenways across the city.

Rationale: The distribution of green spaces, parks and biodiversity is uneven across the city. Underserved areas are less likely to be close to, or have access to, greenspace. The City

is undertaking a number of programs such as the Community Parks Initiative, Parks Without Borders and Building Healthy Communities to help underserved communities gain access to higher quality parks and greenspaces. The City must continue to expand these programs to ensure an equitable distribution.

Recommendation #3: Continue to promote alternate forms of transportation, such as cycling and mass transit, and to reduce the reliance on automobiles.

Rationale: The transportation sector is one of the main contributors to GHG emissions in the City, responsible for twenty-three percent of all emissions. By promoting other sustainable modes of transportation the City will help to reduce overall emissions while also promoting more healthy and active lifestyles.

Recommendation #4: Ensure that flood mitigation measures are developed on a regional scale, to include adjacent communities and municipalities, particularly those located downstream.

Rationale: If not planned properly, barriers such as hard seawalls built to protect the immediate municipality are at risk of displacing storm surges to neighbouring communities (Wachsmuth et al., 2016). The comprehensive coastal protection plan has prioritized the communities hardest hit by Sandy, but in particular, the plan will focus on Lower Manhattan first (as the Big U project), leaving downstream communities such as Red Hook extra vulnerable.

Recommendations – Conclusion

To conclude, **Table 5** presents the next step in moving forward with the proposed recommendations, which takes into account: timeline, relative priority, cost, benefit and political feasibility.

The rank represents a timeline of which recommendation should be focused on first before another item should be addressed. However, since the time-frame for completion of each recommendation differs, the next item may begin before the previous one is complete (note that some items are already in progress and are ongoing).

The relative priority column measures which items should be prioritized over others in terms of importance to the overall functioning of the city. Though every recommendation is important, an item with "High Priority" should, ideally, be addressed before an item of "Low Priority". However, in some instances an item that is "Low Priority" may need to be addressed first due to the level of Political Feasibility.

The political feasibility measures the level of potential that a recommendation will be accepted in the current political climate. This can be influenced by the cost-benefit ratio, however there are other factors to be considered. For instance, a recommendation may have low cost and high benefit but may be unpopular or seem unimportant amongst actors and stakeholders, and would therefore receive a low political feasibility rating. On the other hand, a recommendation that has a high cost and a high benefit may receive a high feasibility rating if the political climate deems it to be a pressing issue, despite the high cost. This usually applies to large-scale environmental projects.

The cost refers to the level of monetary investment that would be required for a particular recommendation to be realized, and the benefit measures the level of reward gained by city generated by the potential outcome of the proposed recommendation.

Table 5 – Cost-Benefit Analysis of Recommendations

Rank	Recommendation	Relative Priority	Cost	Benefit	Political Feasibility	Time-Frame
#1	Flood mitigation – regional scale	High	High	High	High	Long-Term
#2	Adopt NYC Climate Resiliency Indicators/Monitoring System	Medium	Medium	High	High	Short-Term
#3	Equitable distribution of greenways/greenspaces	High	Medium	High	High	Ongoing
#4	Develop community-specific green initiatives	High	Medium	High	High	Ongoing
#5	*PlaNYC* tracking system	Medium	Low	High	Medium	Ongoing
#6	Promotion of alternate modes of transportation	High	Medium	High	High	Ongoing
#7	Incentives to retrofit	Medium	High	High	Medium	Short-Term
#8	Stormwater fee discount	Medium	High	High	Medium	Short-Term
#9	Amend Green Roof Tax Abatement Program	Medium	Low	Medium	Medium	Short-Term
#10	Codify GI design standards	High	Medium	High	Medium	Ongoing
#11	Draft Green Roof Bylaw	High	Medium	High	Medium	Short-Term
#12	Research benefits of ecosystem services	Low	Low	High	Medium	Ongoing
#13	Public-Private partnerships	Medium	Medium	High	Medium	Ongoing
#14	Task Force/Ecological Sustainability Index	Low	Low	High	Medium	Short-Term
#15	Ecological timeframe approach	Medium	Medium	High	Medium	Ongoing
#16	Update NYC Well-Being Index	Low	Low	Medium	Medium	Short-Term
#17	Streamline ULURP/EIS for private sector	High	High	High	Low	Short-Term

Rating System **- Relative Priority:** Low, Medium, High; **Cost:** Low, Medium, High; **Benefit:** Low, Medium, High; **Political Feasibility:** Low, Medium, High; **Time-Frame:** Short-Term, Long-Term, Ongoing.

Conclusions

Lessons

NYC has become a world-leader in climate policy. Despite being highly vulnerable to climate change, NYC has been very successful through proactively promoting policies, plans and initiatives to make the city more sustainable and resilient. As such, NYCs experience presents a unique framework for other cities also considering developing a climate policy of their own. Moving forward, there are four main lessons that have emerged from this report:

First, climate change mitigation and adaptation must be a top priority for decision-makers. There must be a comprehensive approach based on solid scientific and academic research and sound practices. Policy-makers and planners must see the planning process as dynamic and ever-changing. They must be responsive to the changing environment and must be open to new research conducted by scientists, academics and other key players.

Second, there must be a unified approach. Because there are so many plans, reports, agencies, non-profits and other actors, it is imperative that transparency among actors is emphasized. With so much information being disseminated, it runs the risk of diluting what the real issues are.

Third, the human factor must be considered. Any greening initiatives must be seen as a benefit to both biodiversity and the well-being of all human beings. Greening projects must be carefully scrutinized to make sure they are being conducted in an equitable fashion, and that unwanted gentrification does not occur as a result.

Fourth, the principles of Urban Ecology should be followed at all stages of planning, and should be the underlying framework to guide future sustainable development. Thus, all organisms (human and non-human) must be accounted for in the process. Biodiversity must be embedded into plans and considered a valuable asset that plays an important role for the health of the city and the well-being of humans.

Conclusion

As NYC looks to the future, it must be even more vigilant in its efforts to adapt to the changing environment. Policy makers must remain committed to the task of creating a more sustainable, resilient city. As the threat of climate change increases, it is imperative that cities take the appropriate measures reduce the negative effects of urbanization on the environment, while at the same time restoring some of the natural defenses. To face the challenges of tomorrow, cities will require strong, visionary leadership with a deep commitment to well-being of all living organisms, human and non-human.

Reference List

Adjei, P. O., & Agyei, F. K. (2014). Biodiversity, environmental health and human well-being: analysis of linkages and pathways. *Environment, Development and Sustainability, 17*(5), 1085-1102. doi:10.1007/s10668-014-9591-0.

Ahern, J. (2007). Green infrastructure for cities: the spatial dimension. In Novotny, V., & Brown, P. R. (eds.) *Cities of the future: Towards integrated sustainable water and landscape management (pp. 267-283)*. London: IWA Publishing.

Ahern, J. (2013). Urban landscape sustainability and resilience: the promise and challenges of integrating ecology with urban planning and design. *Landscape Ecology, 28(6)*, 1203-1212. doi:10.1007/s10980-012-9799-z.

Akbari, H., Pomerantz, M., & Taha, H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy,70*(3), 295-310. doi:10.1016/s0038-092x(00)00089-x.

Amatruda, J., Adlerstein, M., & Baker, K. (2017, April 24). *UN HQ Report: the carbon case for retrofits*. Lecture presented at ARUP in Manhattan, New York.

Baabou, W., Grunewald, N., Oullet-Plamondon, C., Gressot, M., & Galli, A. (2017). The ecological footprint of Mediterranean cities: awareness creation and policy implications. *Environmental Science and Policy,69,* 94-104. doi:10.1016/j.envsci.2016.12.013

Ballon, H. (2012). *The greatest grid: the master plan of Manhattan, 1811-2011*. New York: Columbia University Press.

Barr, J.M. (2016). *Building the skyline: the birth and growth of Manhattan's skyscrapers.* Oxford Scholarship Online. Retrieved from http://www.oxfordscholarship.com/view/10.1093/acprof:oso/9780199344369.001.0001/acprof-9780199344369.

Baruch College (2014). *New York City (NYC) governmental structure.* Retrieved from http://www.baruch.cuny.edu/nycdata/nyc-government/index.html.

Beatley, T. (2011). *Biophilic cities: integrating nature into urban design and planning*. Washington, DC: Island Press.

Benedict, M.A. & McMahon, E.T. (2001) *Green infrastructure: smart conservation for the 21st century.* Washington D.C.: Sprawl Watch Clearing House. Retrieved from http://www.sactree.org/assets/files/greenprint/toolkit/b/greenInfrastructure.pdf

Blackburn, S. & Marques, C. (2013). Mega-urbanisation on the coast: global context and key trends in the twenty-first century. In M. Pelling & S. Blackburn (eds.), *Megacities and the coast: Risk, resilience, and transformation* (pp.1-21). London; New York: Routledge.

Brenneisen, S. & Gedge, D. (2013). Green roof planning in urban areas. In V. Loftness and D. Haase. *Sustainable Built Environments (pp. 268-281).* New York Dordrecht Heidelberg London: Springer. DOI 10.1007/978-1-4614-5828-9.

Burkholder, S. (2012). The New Ecology of Vacancy: Rethinking Land Use in Shrinking Cities. *Sustainability,4*(12), 1154-1172. doi:10.3390/su4061154.

Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P… Naeem, S. (2012) Biodiversity loss and its impact on humanity. *Nature,486*, 59-67. doi:10.1038/nature11148.

Carrus, G., Scopelliti, M., Lafortezza, R., Colangelo, G., Ferrini, F., Salbitano, F., . . . Sanesi, G. (2015). Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas. *Landscape and Urban Planning, 134*, 221-228. doi:10.1016/j.landurbplan.2014.10.022.

City of New York (2007). PlaNYC: A greener, greater New York. Retrieved from http://www.nyc.gov/html/planyc/downloads/pdf/publications/full_report_2007.pdf.

City of New York (2011). *PlaNYC update April 2011: A greener, greater New York.* Retrieved from http://www.nyc.gov/html/planyc/downloads/pdf/publications/planyc_2011_planyc_full_report.pdf.

City of New York (2013). *PlaNYC: A Stronger, More Resilient New York*, retrieved from: http://s-media.nyc.gov/agencies/sirr/SIRR_singles_Lo_res.pdf.

City of New York (2014a). *PlaNYC progress report: a greener, greater New York, a stronger more resilient New York.* Retrieved from http://www.nyc.gov/html/planyc2030/downloads/pdf/140422_PlaNYCP-Report_FINAL_Web.pdf.

City of New York (2014b). *One city: built to last (transforming New York City's buildings for a low-carbon future.* Retrieved from http://www.nyc.gov/html/builttolast/assets/downloads/pdf/OneCity.pdf.

City of New York (2015). *OneNYC: the plan for a strong and just city.* Retrieved from http://www.nyc.gov/html/onenyc/downloads/pdf/publications/OneNYC.pdf.

City of Toronto (2017). *Green roof bylaw.* Retrieved from https://www1.toronto.ca/wps/portal/contentonly?vgnextoid=83520621f3161410VgnVCM10000071d60f89RCRD.

Cohen, M. (2016, July 6). NYC may get a big ugly flood wall instead of Bjarke Ingels' storm protection system. *6sqft.* Retrieved from https://www.6sqft.com/nyc-may-get-a-big-ugly-wall-instead-of-bjarke-ingels-proposed-big-u-storm-protection-system/.

Cohen, P.E. & Augustyn, R.T. (1997). *Manhattan in maps: 1527-1995.* New York: Rizzoli International Publications Inc.

Connop, S., Vandergert, P., Eisenberg, B., Collier, M. J., Nash, C., Clough, J., & Newport, D. (2016). Renaturing cities using a regionally-focused biodiversity-led multifunctional benefits approach to urban green infrastructure. *Environmental Science & Policy,62*, 99-111. doi:10.1016/j.envsci.2016.01.013.

Corburn, J. (2009). Cities, Climate Change and Urban Heat Island Mitigation: Localising Global Environmental Science. *Urban Studies,46*(2), 413-427. doi:10.1177/0042098008099361.

Day, L., & Klingler, M. A. (2007). *Field guide to the natural world of new York City*. London: Johns Hopkins Univ. Press.

Design Trust for Public Space (2010). *High performance landscape guidelines: 21st century parks for NYC.* Retrieved from https://www.nycgovparks.org/sub_about/sustainable_parks/design_guidelines.pdf.

Díaz, S., Fargione, J., Chapin, F. S., & Tilman, D. (2006). Biodiversity Loss Threatens Human Well-Being. *PLoS Biology, 4*(8). doi:10.1371/journal.pbio.0040277.

Environmental Protection Agency (n.d.). *What is climate change?* Retrieved from http://www.epa.ie/climate/communicatingclimatescience/whatisclimatechange/

Food and Agriculture Organization of the United Nations (2017). *Ecosystem services and biodiversity (ESB).* Retrieved from http://www.fao.org/ecosystem-services-biodiversity/en/

Forgione, H. M., Pregitzer, C. C., Charlop-Powers, S., & Gunther, B. (2016). Advancing urban ecosystem governance in New York City: Shifting towards a unified perspective for conservation management. *Environmental Science & Policy,62*, 127-132. doi:10.1016/j.envsci.2016.02.012.

Fuller, R.A., Irvine, K.N., Devine-Wright, P., Warren, P.H. & Gaston, K.J. (2007). Psychological benefits of greenspace increase with biodiversity. *Biology Letters,3, 390-394.* doi:10.1098/rsbl.2007.0149.

Fund for the City of New York (1998). *How smooth are New York City's streets?* Retrieved from http://www.fcny.org/cmgp/streets/pages/1998PDF/Report/1998totalrept.pdf.

Godschalk, D. R. (2003). Urban Hazard Mitigation: Creating Resilient Cities. *Natural Hazards Review,4*(3), 136-143. doi:10.1061/(asce)1527-6988(2003)4:3(136).

Greene, C. S., & Millward, A. A. (2016). Getting closure: The role of urban forest canopy density in moderating summer surface temperatures in a large city. *Urban Ecosystems,20*(1), 141-156. doi:10.1007/s11252-016-0586-5.

Grifo, F. & Rosenthal, J. (Eds). (1997) *Biodiversity and human health: a guide for policymakers.* [Pamphlet]. New York: Center for Biodiversity and Conservation, American Museum of Natural History. Retrieved from **http://www.amnh.org/content/download/35213/519257/file/Biodiversity%20and%20Human%20Health:%20A%20Guide%20for%20Policymakers.pdf**.

Grimmond, C.S.B. (2013). Contributions of coastal megacities to environmental changes at regional and global scales. In M. Pelling & S. Blackburn (Eds.), *Megacities and the coast: Risk, resilience, and transformation* (pp.100-129). London; New York: Routledge.

Gundlach, J. (2017). *Putting green infrastructure on private property in New York City.* Columbia Law School: New York. Retrieved from http://columbiaclimatelaw.com/files/2017/06/Gundlach-2017-05-GI-in-NYC.pdf.

Haase, D. (2013). Landscape Planning/Design of Shrinking Landscapes. In V. Loftness and D. Haase. *Sustainable Built Environments (pp. 373-393).* New York Dordrecht Heidelberg London: Springer. DOI 10.1007/978-1-4614-5828-9.

Heisler, G. M., & Brazel, A. J. (2010). The urban physical environment: temperature and urban heat islands. In J. Aitkenhead-Peterson & A. Volder (Eds.). *Urban Ecosystem Ecology, 55* (pp. 29-56). Madison, WI: American Society of Agronomy. doi:10.2134/agronmonogr55.c2.

Hellmund, P. C., & Smith, D. S. (2006). *Designing greenways: sustainable landscapes for nature and people*. Washington. D.C.: Island Press.

Hostetler, M., Allen, W., & Meurk, C. (2011). Conserving urban biodiversity? Creating green infrastructure is only the first step. *Landscape and Urban Planning,100*(4), 369-371. doi:10.1016/j.landurbplan.2011.01.011.

ICLEI – Local Governments for Sustainability. (2010). Local Action for Biodiversity Guidebook: Biodiversity Management for Local Governments. Laros MT and Jones FE (Eds). Retrieved from http://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwj_z9OGsr_VAhUUXWMKHSoEC6EQFgguMAE&url=http%3A%2F%2Fcbc.iclei.org%2Fwp-content%2Fuploads%2F2016%2F06%2FLAB_Guidebook_sm.pdf&usg=AFQjCNHH6zLEHaljaJvuny6tGF0CPeu5rg.

Intergovernmental Panel on Climate Change (2014a). Summary for policymakers. In Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (*pp. 1-32). Cambridge: Cambridge University Press. Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf

Intergovernmental Panel on Climate Change, (2014b) Summary for Policymakers. In Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (Eds.), *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. Retrieved from https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_summary-for-policymakers.pdf

Intergovernmental Panel on Climate Change (2014c). In R.K. Pachauri and L.A. Meyer (Eds.), *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1-151) Geneva, Switzerland. Retrieved from https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf

Jackson, K. T., & New-York Historical Society. (2010). *The encyclopedia of New York City*. New Haven: Yale University Press.

Johnson, C. (2015). Green networks: a solution to the Urban Heat Island effect. In C.A. Brebbia and W.F. Flores-Escobar (Eds.), *The Sustainable City X (pp. 205-214).* WIT Press. doi: 10.2495/SC150191.

Kiviat, E. & Johnson, E.A. (2013). Biodiversity assessment handbook for New York City. *American Museum of Natural History, Center for Biodiversity and Conservation*. New York; Annandale: Hudsonia Ltd. Retrieved from http://www.amnh.org/content/download/59221/959699/file/BiodiversityAssessmentHandbk.pdf.

Lamond, J. (2013). Reducing risk from natural hazard, pollution and climate change in megacities and associated networks. In M. Pelling & S. Blackburn (Eds.), *Megacities and the coast: Risk, resilience, and transformation* (pp.130-171). London; New York: Routledge.

Lin, N., Emanuel, K., Oppenheimer, M., & Vanmarcke, E. (2012). Physically based assessment of hurricane surge threat under climate change. *Nature Climate Change,2*(6), 462-467. doi:10.1038/nclimate1389.

Lin, N., Kopp, R.E., Horton, B.P., & Donnelly, J. (2016). Hurricane Sandy's flood frequency increasing from year 1800 to 2100. *PNAS, 113(43),* 12071-12075. Retrieved from http://www.pnas.org/content/113/43/12071.full.pdf.

Madhani, A. (2017, June 25). As cities look to get greener, lower-income residents fear gentrification. *USA Today.* Retrieved from https://www.usatoday.com/story/news/2017/06/25/high-lines-green-space-spur-gentrification-displacement/103140856/.

Mawdsley, J. R., O'Malley, R., & Ojima, D. S. (2009). A Review of Climate-Change Adaptation Strategies for Wildlife Management and Biodiversity Conservation. *Conservation Biology,23*(5), 1080-1089. doi:10.1111/j.1523-1739.2009.01264.x

McColl, R.W. (Ed.). (2005). *Encyclopedia of world geography.* New York: Facts on File, Inc.

Mcdonnell, M. J. (2015). Journal of Urban Ecology: Linking and promoting research and practice in the evolving discipline of urban ecology. *Journal of Urban Ecology*, 1(1). doi:10.1093/jue/juv003.

Mcdonnell, M. J., & Pickett, S. T. (1990). Ecosystem Structure and Function along Urban-Rural Gradients: An Unexploited Opportunity for Ecology. *Ecology*, 71(4), 1232-1237. doi:10.2307/1938259.

McPhearson, T., Maddox, D., Gunther, B. & Bragdon, D. (2013). Local Assessment of New York City: Biodiversity, Green Space, and Ecosystem Services. In T. Elmqvist et al. (Eds.), *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment* (pp. 355-383). Dordrecht Heidelberg New York London: Springer. DOI 10.1007/978-94-007-7088-1_19.

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: Biodiversity Synthesis*. Washington, DC.: World Resources Institute.

National Weather Service (n.d.). *Introduction to storm surge.* Retrieved from http://www.nws.noaa.gov/om/hurricane/resources/surge_intro.pdf

Natural Areas Conservancy (2016). *New York City nature goals 2050.* Retrieved from http://naturalareasnyc.org/content/goals/nac_naturegoals_design_full_161025-compressed.pdf.

Natural Resources Defense Council (2014, April 8). Report: nearly 300,000 New Yorkers Flooded in Sandy lived outside FEMA flood zones. *NRDC.* Retrieved from https://www.nrdc.org/media/2014/140408.

New York City Center for Innovation through Data Intelligence (2015). *State of New Yorkers – A Well-Being Index.* Retrieved from http://www1.nyc.gov/assets/cidi/downloads/pdfs/nyc_well_being_index_full_report_2015.pdf

New York City Department of City Planning (n.d.a). *About zoning.* Retrieved from http://www1.nyc.gov/site/planning/zoning/about-zoning.page.

New York City Department of City Planning (n.d.b). *Zoning process.* Retrieved from http://www1.nyc.gov/site/planning/zoning/zoning-process.page.

New York City Department of City Planning (n.d.c). *Applicants - overview.* Retrieved from https://www1.nyc.gov/site/planning/applicants/overview.page.

New York City Department of City Planning (2013). *Flood resilience zoning text amendment.* Retrieved from http://www1.nyc.gov/assets/planning/download/pdf/plans/flood-resiliency/flood_resiliency.pdf.

New York City Department of City Planning (2016a). *Resilient neighbourhoods: East Village, Lower East Side,Two Bridges*. Retrieved from https://www1.nyc.gov/assets/planning/download/pdf/plans-studies/resilient-neighborhoods/evillage-leside/resilientneighborhoods_ev_les_tb_report.pdf.

New York City Department of City Planning (2016b). *Resilient neighbourhoods: West Chelsea*. Retrieved from https://www1.nyc.gov/assets/planning/download/pdf/plans-studies/resilient-neighborhoods/west-chelsea/summary-report-west-chelsea.pdf.

New York City Department of Environmental Protection (2010). *NYC green infrastructure plan: a sustainable strategy for clean waterways.* Retrieved from http://www.nyc.gov/html/dep/pdf/green_infrastructure/NYCGreenInfrastructurePlan_LowRes.pdf.

New York City Department of Environmental Protection (2017a). *Types of sewer drainage areas in New York City.* Retrieved from http://www.nyc.gov/html/dep/html/stormwater/sewer_system_types.shtml.

New York City Department of Environmental Protection (2017b). *Grant program for private property owners.* Retrieved from http://www.nyc.gov/html/dep/html/stormwater/nyc_green_infrastructure_grant_program.shtml.

New York City Department of Environmental Protection (2017c). *NYC green infrastructure*: *2016 annual report.* Retrieved from http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2017.pdf.

New York City Department of Parks and Recreation (n.d.a). *Inwood Hill Park.* Retrieved from https://www.nycgovparks.org/parks/inwood-hill-park/history.

New York City Department of Parks and Recreation (n.d.b). *Collect Pond Park.* Retrieved from https://www.nycgovparks.org/parks/collect-pond-park/history.

New York City Department of Parks and Recreation (n.d.c). *Community parks initiative.* Retrieved from https://www.nycgovparks.org/about/framework-for-an-equitable-future/community-parks-initiative.

New York City Mayor's Office of Environmental Coordination (2014). *CEQR*: *City environmental quality review - technical manual.* Retrieved from http://www1.nyc.gov/assets/oec/technical-manual/2014_ceqr_technical_manual_rev_04_27_2016.pdf.

New York City Mayor's Office of Sustainability (2017a). *LEED® Law (Local Law 86).* Retrieved from http://www.nyc.gov/html/gbee/html/public/leed.shtml.

New York City Mayor's Office of Sustainability (2017b). *Greener, greater buildings plan.* Retrieved from http://www.nyc.gov/html/gbee/html/plan/plan.shtml.

New York City Mayor's Office of Sustainability (2017c). *GCTF enacted proposals.* Retrieved from http://www.nyc.gov/html/gbee/html/codes/enacted.shtml.

New York City Mayor's Office of Sustainability (2017d). *Zone green.* Retrieved from http://www.nyc.gov/html/gbee/html/codes/zone.shtml.

New York City Panel on Climate Change (2015). 2015 Report: Executive Summary. *Annals of the New York Academy of Sciences,1336*(1), 9-17. doi:10.1111/nyas.12591.

New York (State). Legislature. Assembly. *An act to amend the real property tax law, in relation to a green roof tax abatement for certain properties in a city of one million or more persons.* (AB7058). 2013-2014 Regular Sessions (April 30, 2013). *New York State Assembly.* Retrieved from http://assembly.state.ny.us/leg/?default_fld=&bn=AB7058&term=2013&Actions=Y&Memo=Y&Text=Y.

Nir, S.M. (2017, April 25) City commits $100 million to narrowing a gap in Manhattan greenway. *The New York Times*. Retrieved from https://www.nytimes.com/2017/04/25/nyregion/city-commits-100-million-to-narrowing-a-gap-in-manhattan-greenway.html?_r=2.

NYC Green Codes Task Force (2010). Executive summary. *Urban Green Council.* Retrieved from http://urbangreencouncil.org/sites/default/files/greencodestaskforce_exsummary.pdf.

Oleson, K. W., Bonan, G. B., & Feddema, J. (2010). Effects of white roofs on urban temperature in a global climate model. *Geophysical Research Letters,37*(3). doi:10.1029/2009gl042194.

Palliwoda, J., Kowarik, I., & Lippe, M. V. (2017). Human-biodiversity interactions in urban parks: The species level matters. *Landscape and Urban Planning, 157*, 394-406. doi:10.1016/j.landurbplan.2016.09.003

Pauleit,S., Fryd,O., Backhaus, A & Jensen, M.B. (2013). Green Infrastructure and Climate Change. In V. Loftness and D. Haase (Eds.). *Sustainable Built Environments* (pp. 224-248). New York Dordrecht Heidelberg London: Springer. DOI 10.1007/978-1-4614-5828-9.

Pelling, M. (2012). *The Vulnerability of Cities: Natural Disasters and Social Resilience*. Hoboken: Taylor and Francis.

Pelling, S. & Blackburn (2013). Case studies: governing social and environmental transformation in coastal megacities. In M. Pelling & S. Blackburn (Eds.), *Megacities and the coast: Risk, resilience, and transformation* (pp.200-236). London; New York: Routledge.

Plitt, Amy (2017, June 5). NYC congestion pricing is being pushed by transit advocates again, but will Mayor DeBlasio get on board? *Curbed New York.* Retrieved from https://ny.curbed.com/2017/6/5/15740726/nyc-congestion-pricing-move-new-york-mayor-de-blasio.

Rebuild By Design (n.d.). The big U. Retrieved from http://www.rebuildbydesign.org/our-work/all-proposals/winning-projects/big-u.

Register, R. (1987). *Ecocity Berkeley: building cities for a healthier future.* Berkeley: North Atlantic Books.

Robine, J., Cheung, S. L., Roy, S. L., Oyen, H. V., Griffiths, C., Michel, J., & Herrmann, F. R. (2008). Death toll exceeded 70,000 in Europe during the summer of 2003. *Comptes Rendus Biologies,331*(2), 171-178. doi:10.1016/j.crvi.2007.12.001.

Rosenzweig, C., Solecki, W. D., Cox, J., Hodges, S., Parshall, L., Lynn, B., . . . Dunstan, F. (2009). Mitigating New York City's Heat Island: Integrating Stakeholder Perspectives and Scientific Evaluation. *Bulletin of the American Meteorological Society,90*(9), 1297-1312. doi:10.1175/2009bams2308.1.

Sachindra, D. A., Ng, A. W., Muthukumaran, S., & Perera, B. J. (2015). Impact of climate change on urban heat island effect and extreme temperatures: a case-study. *Quarterly Journal of the Royal Meteorological Society,142*(694), 172-186. doi:10.1002/qj.2642.

Sanderson, E. W. (2009). *Mannahatta: a natural history of New York City*. New York: Abrams.

Sanderson, E. W., Jaiteh, M., Levy, M. A., Redford, K. H., Wannebo, A. V., & Woolmer, G. (2002). The Human Footprint and the Last of the Wild. *BioScience,52*(10), 891. doi:10.1641/0006-3568(2002)052[0891:thfatl]2.0.co;2

Sandifer, P. A., Sutton-Grier, A. E., & Ward, B. P. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Ecosystem Services,12*, 1-15. doi:10.1016/j.ecoser.2014.12.007

Savard, J. L., Clergeau, P., & Mennechez, G. (2000). Biodiversity concepts and urban ecosystems. *Landscape and Urban Planning,48*(3-4), 131-142. doi:10.1016/s0169-2046(00)00037-2.

Schubert, C.E., Busciolano, R., Hearn, P.P., Jr., Rahav, A.N., Behrens, R., Finkelstein, J., Monti, J., Jr., & Simonson, A.E., (2015). Analysis of storm-tide impacts from Hurricane Sandy in New York. *U.S. Geological Survey Scientific Investigations Report 2015–5036*, (pp.1-75). http://dx.doi.org/10.3133/sir20155036.

Scott, M. (2003, February 23). *The human footprint.* NASA Earth Observatory. Retrieved from https://earthobservatory.nasa.gov/Features/footprint/.

Scott, M. (2006). *Beating the heat in the world's big cities.* Retrieved from https://earthobservatory.nasa.gov/Features/GreenRoof/greenroof.php

Schaefer, V.H. (2003, April 1). *Green Links and Urban Biodiversity—an Experiment in Connectivity.* Proceedings of the Georgia Basin/Puget Sound Research Conference, Vancouver, BC.

Shi, L., Anguelovski, I.M.S. (2016, June 19). Climate adaptation plans can worsen unequal urban vulnerability. *The Nature of Cities.* Retrieved from https://www.thenatureofcities.com/2016/06/19/climate-adaptation-plans-can-worsen-unequal-urban-vulnerability/.

Shonkoff, S. B., Morello-Frosch, R., Pastor, M., & Sadd, J. (2011). The climate gap: environmental health and equity implications of climate change and mitigation policies in California—a review of the literature. *Climatic Change,109*(S1), 485-503. doi:10.1007/s10584-011-0310-7.

Snep, R.P.H., & Clergeau, P. (2013). Biodiversity in cities, reconnecting humans with nature. In V. Loftness and D. Haase (Eds.). *Sustainable Built Environments (pp. 31-51).* New York Dordrecht Heidelberg London: Springer. DOI 10.1007/978-1-4614-5828-9.

Solecki, W., Patrick, L., & Sprigins, Z. (2015). Urban Climate Change Policy Transitions: Views from New York City and London. In K. O'Brien and E. Selboe (Eds.). *The Adaptive Challenge of Climate Change.* (pp. 41-62). New York: Cambridge University Press.

Spirn, A. W. (2014). Ecological urbanism: a framework for the design of resilient cities (2014). *The Ecological Design and Planning Reader,*557-571. doi:10.5822/978-1-61091-491-8_50.

Steiner, F. R. (2009). Nature and the city: changes for the first urban century in the United States. *Ciudades, 12, 13-31.*

Susca, T., Gaffin, S., & Dell'Osso, G. (2011). Positive effects of vegetation: Urban heat island and green roofs. *Environmental Pollution,159*(8-9), 2119-2126. doi:10.1016/j.envpol.2011.03.007.

The World Bank (2010). *World Development Report 2010: Development and Climate Change.* Washington D.C.: The International Bank for Reconstruction and Development / The World Bank. Retrieved from http://documents.worldbank.org/curated/en/201001468159913657/pdf/530770WDR02010101Official0Use0Only1.pdf.

Tjallingii, S. (2012). Water flows and urban planning. In: van Bueren E., van Bohemen H., Itard L., Visscher H. (Eds) *Sustainable Urban Environments* (pp.91-112). Dordrecht; Heidelberg; London; New York: Springer.

United Nations (1987). *Our Common Future - Brundtland Report*. Oxford University Press. Retrieved from http://www.un-documents.net/our-common-future.pdf.

United Nations (1992). *Convention on biological diversity.* Retrieved from https://www.cbd.int/doc/legal/cbd-en.pdf.

U.S. Census Bureau (2010). *Population per square mile, 2010.* Retrieved from https://www.census.gov/quickfacts/fact/table/newyorkcountymanhattanboroughnewyork/INC110215.

U.S. Census Bureau (2015). *Median household income (in 2015 dollars), 2011-2015.* Retrieved from https://www.census.gov/quickfacts/fact/table/newyorkcountymanhattanboroughnewyork/INC110215.

U.S. Census Bureau (2016). *Population estimates, July 1, 2016.* Retrieved from https://www.census.gov/quickfacts/fact/table/newyorkcountymanhattanboroughnewyork/INC110215.

Van Bohemen, H. (2012). (Eco)system thinking: ecological principles for buildings, roads and industrial and urban areas. In: van Bueren E., van Bohemen H., Itard L., Visscher H. (Eds) *Sustainable Urban Environments (*pp.15-70). Dordrecht; Heidelberg; London; New York: Springer.

van Bueren E. (2012) Introduction. In: van Bueren E., van Bohemen H., Itard L., Visscher H. (Eds) *Sustainable Urban Environments (*pp.1-14). Dordrecht; Heidelberg; London; New York: Springer.

Voogt, J.A. (2004). Urban Heat Islands: Hotter Cities. *American Institute of Biological Sciences.* Retrieved from http://www.actionbioscience.org/environment/voogt.html

Wachsmuth, D., Cohen, D. A., & Angelo, H. (2016). Expand the frontiers of urban sustainability. *Nature,536*(7617), 391-393. doi:10.1038/536391a.

Wackernagel, M., Onisto, L., Bello, P., Linares, A. C., Falfán, I. S., García, J. M., . . . Guerrero, M. G. (1999). National natural capital accounting with the ecological footprint concept. *Ecological Economics,29*(3), 375-390. doi:10.1016/s0921-8009(98)90063-5.

Waxman, S. (n.d.). *History of Central Park, New York.* Retrieved from https://www.ny.com/articles/centralpark.html.

Werner, W. (2015, April 29). PlaNYC expands to OneNYC – how did we get here and what's new? *Urban Fabrick, Inc.* Retrieved from https://urbanfabrick.com/planyc-expands-to-onenyc/.

Wiens, J. J. (2016). Climate-Related Local Extinctions Are Already Widespread among Plant and Animal Species. *PLOS Biology,14*(12). doi:10.1371/journal.pbio.2001104

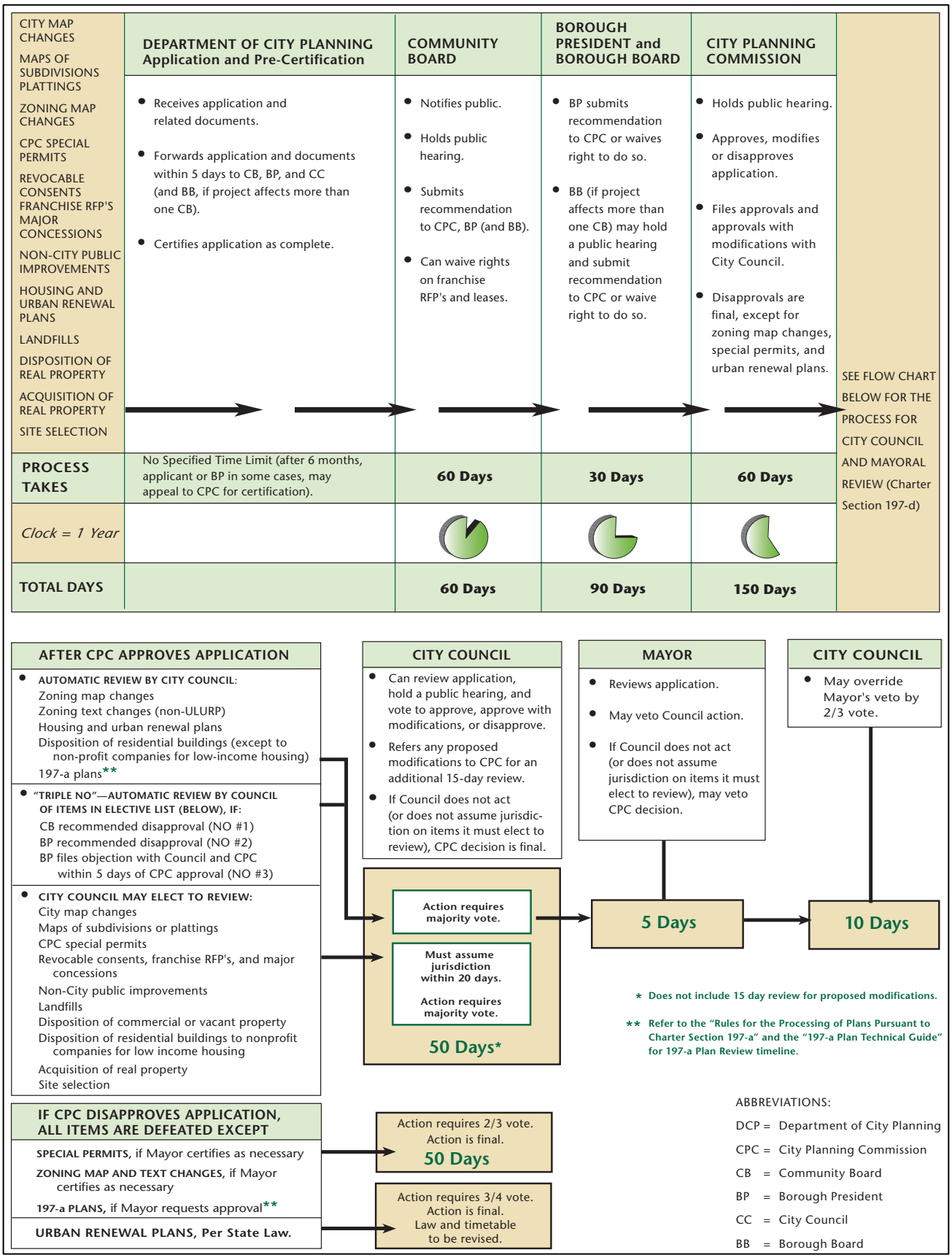
Wu, J. (2014). Urban ecology and sustainability: The state-of-the-science and future directions. *Landscape and Urban Planning,125*, 209-221. doi:10.1016/j.landurbplan.2014.01.018.

Yamamoto, Y. (2006). Measures to Mitigate Urban Heat Islands. *Distribution*, 18(2), 65-83.

Yang, B., & Li, S. (2013). Green Infrastructure Design for Stormwater Runoff and Water Quality: Empirical Evidence from Large Watershed-Scale Community Developments. *Water, 5*(4), 2038-2057. doi:10.3390/w5042038

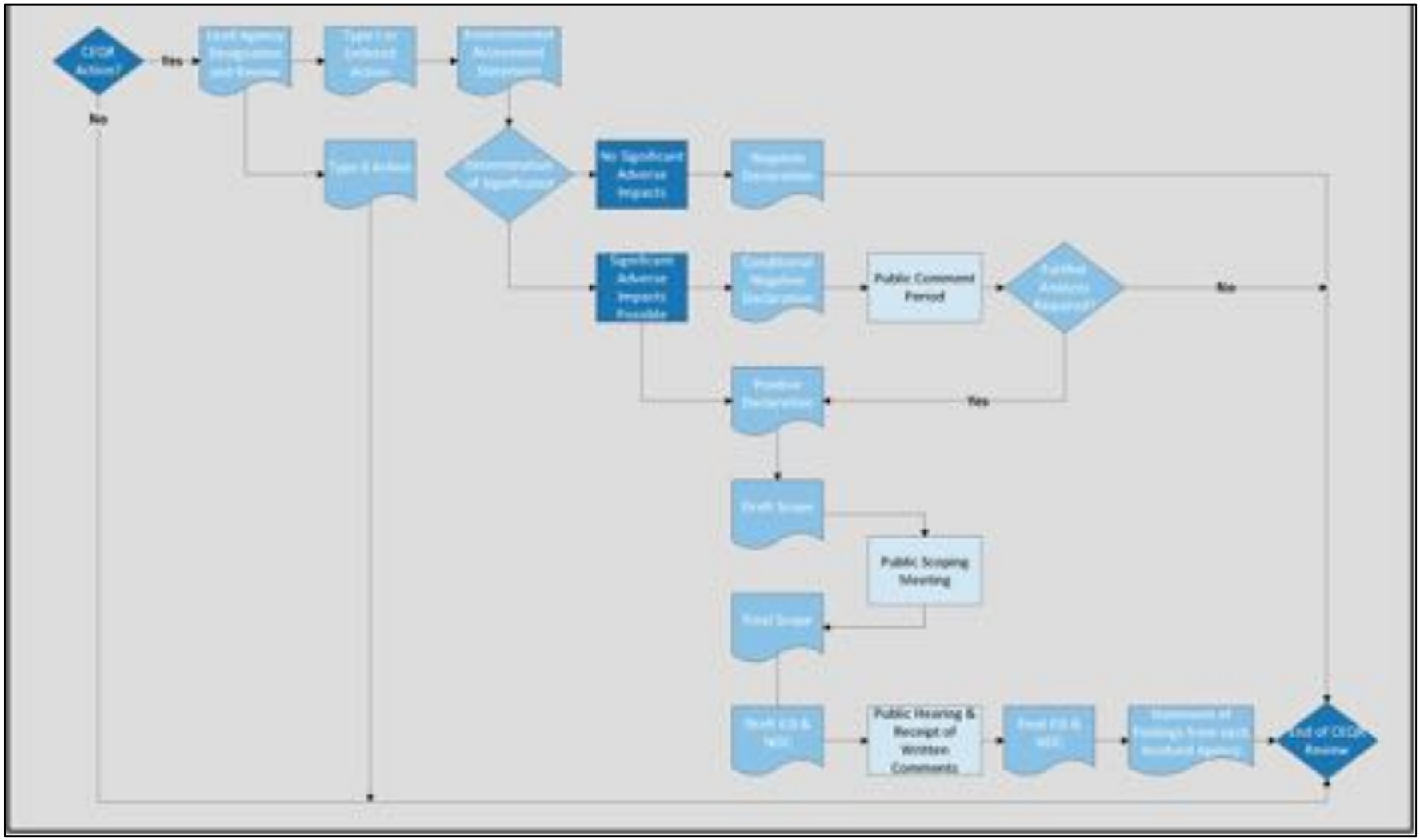
.

Appendix 1 – Uniform Land Use Review Procedure (ULURP)



Source: https://www1.nyc.gov/assets/planning/download/pdf/applicants/applicant-portal/lur.pdf

Appendix 2 – CEQR Process



Source: http://www.nyc.gov/html/oec/downloads/pdf/2010_ceqr_tm/2010_ceqr_tm_ch01_procedures_and_documentation_map_ceqr_process.jpg

Appendix 3 – List of well-being indicators aligned with New York City's policy domains

NYC Policy Domain[1]	Well-Being Index Indicators
Education Increase early learning opportunities; academic achievement; graduation rates; parent access, and promotes holistic education approaches.	1. Percent enrolled in pre-school 2. Percent of population with Bachelor's degree or higher 3. Percent of students proficient in ELA and Math
Health and wellbeing Ensure that all New Yorkers have healthy lives, with access to high-quality medical care and reduce disparities health outcomes.	1. Asthma-Composite 2. Poor Health- Composite 3. Self-Reported Health Status 4. Healthy Eating Habits 5. Teen Pregnancy 6. Low Birth Weight 7. Insurance Coverage 8. Medical Care Receipt
Economic security and mobility Improve conditions for low-wage workers; help people prepare and find jobs; raise the floor on wages; build a diversified economy that creates jobs for all New Yorkers, and connect families to the stabilizing benefits for which they are eligible.	1. Median Income level 2. Employment and Unemployment Rate
Housing Reduce homelessness and improve the conditions and availability of public and affordable housing.	1. Housing Cost Burden (Renters) 2. Housing Cost Burden (Owners) 3. Housing Maintenance Code Violation Rate 4. Homeless Shelter Entry Rate
Personal and community safety Ensure that all New Yorkers feel safe and secure on their street and in their homes, schools, neighborhoods, institutional settings and places of work and have confidence in the fairness of the justice system.	1. Index Crime Rate 2. Victimization rate (Abuse/neglect investigations)
Core infrastructure and services Ensure that all New Yorkers, regardless of where they live, enjoy a clean, healthy and safe environment and that the City's viability and growth are supported by core infrastructure and basic services.	1. Commute Time

Source: New York City Center for Innovation through Data Intelligence (2015). *State of New Yorkers – A Well-Being Index.* Retrieved from http://www1.nyc.gov/assets/cidi/downloads/pdfs/nyc_well_being_index_full_report_2015.pdf , p. 10