2 Climate Change & Gateway

1. Literature Review

Three key resources describe the possible climate change effects relevant to Gateway:

1. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report is the most comprehensive and widely accepted report on global climate change; however, significant new scientific information has come to light since its publication in 2007.

2. The Metro East Coast (MEC) Assessment on Impacts of Potential Climate Variability and Change is one of eighteen regional components of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change for the Nation, organized by the U.S. Global Change Research Program in 2000. This study examines the New York Metropolitan Region, supplementing the IPCC as a comprehensive guide to the response of regional wetlands, coasts and ecosystem functions.

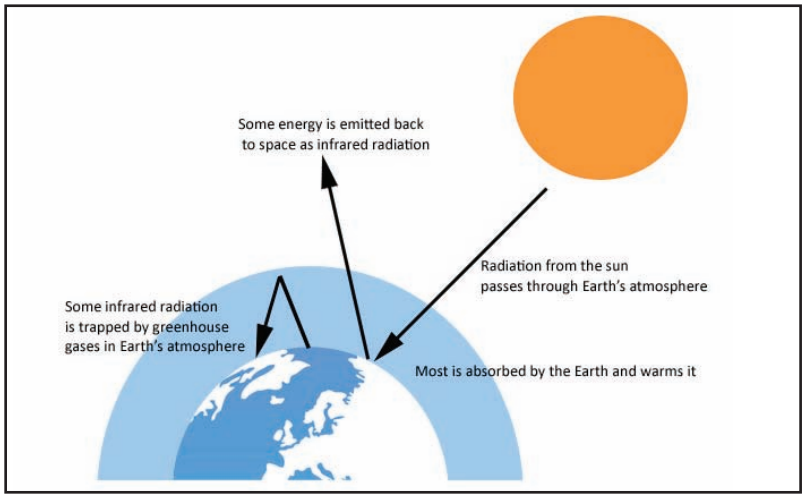

Figure 1. The Greenhouse Effect. The earth maintains a stable temperature by trapping a portion of incoming solar radiation and outgoing heat fluxes. Increased GHG concentrations will magnify this effect, resulting in higher temperatures and an unstable climate system.

3. The New York City Panel on Climate Change (NPCC) Assessment, published in 2009, which uses the same emissions scenarios as the IPCC but takes into account research published after 2007 (NPCC CRI, 2009).

2. What is Climate Change?

Climate change refers to a significant alteration of the average climate, or its variability, persisting for several decades. Climate change can occur as a result of natural processes and planetary cycles, as well as from human actions (IPCC, 2007). Modern climate change is very likely driven by increasing anthropogenic greenhouse gas (GHG) emissions. As Figure 1 illustrates, GHGs trap heat within Earth's atmosphere, causing the planet's overall average temperature to warm (IPCC, 2007). Human activities that emit these gases include burning fossil fuels, industrial and agricultural processes, and landfill decomposition. Some of the most important GHGs emitted into the atmosphere through human activities include methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2; EPA, 2009).

Carbon dioxide (CO_2) is considered the most prevalent anthropogenic greenhouse gas; atmospheric concentrations of CO_2 have increased dramatically since pre-industrial times. Global climate models predict the additional global warming effect resulting from these higher carbon dioxide concentrations (IPCC, 2007).

3. Uncertainty

Global climate models are a leading tool for understanding and predicting climate change (IPCC, 2007). However, explaining climate change to the public is often difficult due to the uncertainties

inherent in climate change science (Budescu et al., 2008). There are three main sources of uncertainty in global climate model predictions:

1. ***Future greenhouse gas concentrations and mitigation efforts.*** It is presently unclear how much societies around the world will reduce their emissions over the next 50 years. Box 1. GHG Scenarios describes the projected future GHG concentration scenarios used by the IPCC.

2. ***The sensitivity of the climate system and environment to greenhouse gas concentrations*** (NPCC, 2009). GHG concentrations will continue to grow as long as emissions exceed the environment's capacity to absorb these gases. The extent of this capacity is unknown but being studied; according to one study by a Duke University professor and United States Department of Agriculture researchers, ecosystems may be close to reaching their capacity to absorb carbon dioxide (Meredith, 2002).

3. ***The role of positive feedbacks in future warming.*** The Earth's climate system is dynamic, containing a number of processes that help maintain equilibrium. There may be a GHG concentration threshold point beyond which the climate's equilibrium will be lost (IPCC, 2007). Climate change effects, such as GHGs released from melting permafrost and decreased ice reflectivity in the polar regions, may further destabilize the climate beyond recovery. Such consequences are termed 'positive feedbacks' because they are both caused by and contribute to climate change.

Greenhouse gas scenarios describe the possible future GHG concentrations based on three different emissions scenarios and observed trends. Figure 2 shows that atmospheric carbon dioxide concentrations will continue to increase into the future. Uncertainties surround the extent of GHG concentrations, not the increase itself. As time progresses and trends in emissions and climate are observed, future projections will become more certain.

Box 1. Greenhouse Gas (GHG) Scenarios

The IPCC outlines three climate change scenarios based on past and present atmospheric GHG concentrations, and predicted future emissions. Each scenario considers different future atmospheric carbon dioxide concentrations resulting from emissions reductions or increases over time (IPCC, 2007).

- A1B: assumes rapid increases in greenhouse gas emissions and the highest overall emissions during the beginning of the 21st century and declining emissions beginning in 2050;
- A2: assumes high greenhouse gas levels by the end of the 21st century and emissions growing throughout the century;
- B1: assumes the lowest greenhouse gas emissions, with decreases beginning by 2040.

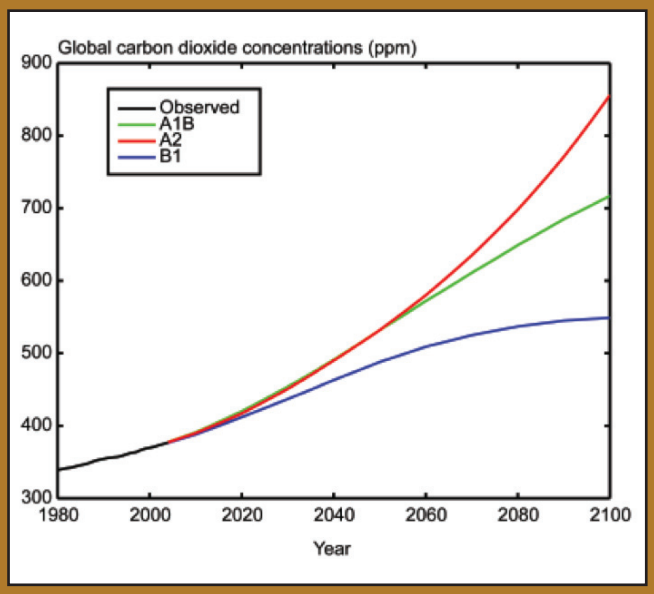

Figure 2. GHG Scenarios. Global CO_2 concentrations under different scenarios (Source: NPCC 2009; adapted from the IPCC.)

According to the NPCC, climate change projections impacting Gateway are considered at least 50% likely to be correct; some, such as temperature changes, are considered more than 90% likely to be correct. Thus, we consider these findings to be representative projections of the future conditions Gateway will face.

The IPCC uses the following terms to express uncertainty:

- "Virtually certain" (considered more than 99% likely to be correct)
- "Very likely" (more than 90%)
- "Likely" (more than 66%)
- "More likely than not" (more than 50%)

4. Local Climate Change Impacts

The findings of the three key reports mentioned above, as well as other published scientific papers, identify four climate change impacts relevant to Gateway:

- Sea level rise
- Temperature changes
- Precipitation changes
- Extreme weather events

Even if carbon dioxide emissions stopped today, warming effects would continue to persist.

Sea Level Rise

From 1932 until the present, the average rate of sea-level rise, as measured at Sandy Hook, was 3.9 cm (1.54 in) per decade (NOAA T&C, 2009). Climate change studies project rates of sea-level rise nearly doubling over the 21st century (Horton, 2007). New York City sea level rise projections expect waters to rise:

- 2 to 5 inches during the 2020s
- 7 to 12 inches by the 2050s
- 12 to 23 inches by the 2080s

Figure 6 shows the elevation of key resources at Gateway; this can be contrasted with projected sea level rise inland (see Section 4. Cultural Resources). The causes of sea-level rise that will affect Gateway include (NPCC, 2009):

- Global mean sea-level rise
- Thermal expansion of the ocean
- Melting ice-caps
- Changes in sea-ice area and volume
- Local water surface elevations
- Local subsidence

Sea-level rise is projected to increase, due to thermal expansion in the ocean, by 8 to 24 inches per 1.8°F of global warming. Sea levels will also rise 8 to 28 inches due to projected glacier and small ice cap losses. Additions to sea level rise due to melt of the Antarctic and Greenland ice sheets will be significant, although scientists still have difficulty characterizing the volume of this contribution, as well as its time scale (Solomon et al., 2009). Measurements of local subsidence and climate sensitivity are highly uncertain, as is the possibility of a "rapid ice melt" scenario (see Box 2. Subsidence).

Rapid Ice Melt Scenario

Under an extreme projection, the "rapid ice melt" scenario, both the Greenland and Antarctic ice sheets melt quickly, dramatically increasing sea level rise (Pfeffer et al., 2008). This increase would cause inundation of coastal lands amplifying coastal storm effects (NPCC, 2009 and Allison, 2009). Under this scenario, sea levels rise higher than IPCC predictions: about 5 to 10 inches by the 2020s, and 41 to 55 inches by the 2080s (NPCC, 2009). Another study estimates sea-level rise will increase by 39 to 79 inches in the 21st century, roughly 3.5 times higher than IPCC projections (Pfeffer et al., 2008). The large variation in seas level rise estimates reflect the uncertainty inherent in climate change models. Integrating the most up-to-date information into planning for climate change at Gateway will be a necessity.

Box 2. Subsidence

The Earth's surface is made up of tectonic plates that move in response to below-surface pressure and temperature changes. Natural, thermally-driven tectonic movements contribute to a majority of land subsidence in New York. Thermal subsidence is the result of thinning and cooling contractions of the Earth's lithosphere and crust (Steckler and Watts, 1979).

This natural phenomenon will compound sea level rise effects as subsidence vertically shifts the ocean floor downward (IPCC, 2007). While natural rates of sedimentation and accumulation of organic matter historically offset marsh loss, accelerated rates of sea level rise from climate change can potentially inundate Jamaica Bay salt marshes (Hartig et al., 2002).

Temperature Changes

In New York City, mean annual temperatures are "extremely likely" to increase from a baseline average temperature of 55°F (NPCC, 2009) by:

- 1.5 to 3°F by the 2020s
- 3 to 5°F by the 2050s
- 4 to 7.5°F by the 2080s

In addition to these mean annual changes, Gateway is "very likely" to experience an increase in extreme temperature events. The NPCC classifies high temperature extremes as days with maximum temperatures of 90°F or higher. Heat waves are periods of at least three consecutive days with temperatures of 90°F or higher. Low temperature extremes are days at or below 32°F (NPCC, 2009).

Precipitation Changes

Although predictions indicate only slight changes in mean annual precipitation, there may be large changes in the frequency, duration, and intensity of extreme precipitation (NPCC, 2009). Precipitation changes, relative to the baseline data from 1971 to 2000, include:

- Increases by up to 5% by the 2020s
- Increases by up to 10% by the 2050s
- Increases of 5 to 10% by the 2080s (NPCC, 2009)

While the predicted changes in yearly precipitation are relatively small, annual averages do not account for the possibility of heavy downpours followed by prolonged dry periods. The inter-annual variability of precipitation creates a significant amount of uncertainty in the direction of precipitation change.

Extreme Weather Events

Extreme precipitation events occur when multiple factors of climate change combine, forming or increasing storms events including nor'easters and hurricanes. Measuring the probability of these events is difficult because they occur infrequently over long temporal scales (10, 50, or 100 years; NPCC, 2009). The most likely extreme events that Gateway will experience are increased droughts, wildland fires and coastal storms (see Box 3. Wildland Fire).

Higher temperatures may cause increased droughts during summer months, as evaporation increases at a faster rate than precipitation (NPCC, 2009). Although projections lack certainty, the effects of less snow and earlier snowmelt, combined with the changing precipitation frequency, will likely increase the probability of drought.

As temperatures rise, evaporation increases; this intensifies the hydrologic cycle, potentially increasing storm frequency and intensity (Hartig et al., 2002). However, increased storm

frequency and intensity remains relatively uncertain (Mann & Emanuel, 2006).

Nor'easters are predicted to occur more frequently than hurricanes given projected higher winter precipitation levels and warmer temperatures (NPCC, 2009; McCabe, Clark, & Serreze, 2001). Nor'easters can be equally as damaging as a mild hurricane. On December 11, 1992, a Nor'easter with wind gusts of up to 90 miles per hour hit Gateway, causing tidewaters to rise 7.7 feet above normal. Sea level rise and coastal destabilization will further augment the effects of increased coastal storms, placing humans and the ecosystems closer to the impacts of coastal storms.

5. Other Stressors and Synergistic Impacts

Gateway's ecosystems face numerous stressors besides changing local climate conditions. Climate impacts will interact with, and in some cases exacerbate, existing pressures that threaten species, ecosystems and cultural resources. A successful adaptation plan will also consider other stressors that increase the park's vulnerability to climate change. Major stressors include:

- Land-use change and urbanization
- Invasive species
- Ocean acidification
- Nitrogen loading and eutrophication
- High visitation rates

Land-Use Change

Much of the land and waters comprising Gateway have a long history of human use and alteration. One example is Miller Field in the Staten Island Unit. Originally wetland, the area was farmland until it was converted to an airfield in 1919, and now consists of grass-covered sports fields. Species composition and ecosystem functions have changed to a significant extent in many areas. Land-use outside of the park boundary also influences Gateway. Species habitat fragments or shrinks as developers convert beaches, fields, and open spaces to built environment. Urban development, including new buildings and pavement with impervious materials, decreases groundwater recharge and accelerates water runoff into storm drains and streams. Replacing vegetation with pavement and other unreflective, impermeable surfaces increases urban air temperatures, known as the urban heat island effect (Rosenzweig et al., 2005.)

Invasive Species

Invasive plant and animal species are present throughout Gateway. These species can drastically reduce species diversity, disrupt food webs and suppress or prevent native plant growth. In many cases, invasive species are better able to adapt to changing temperatures or harsh environmental conditions, and therefore may pose an increasing threat under climate change (Neckles et al., 2001).

Box 3. Wildland Fire

Longer droughts, combined with increasing temperatures may lead to increased wildland fire events. Wildland fire consequences include greater demand on emergency services, disruption of recreation and outdoor activities, poor air quality and unplanned park expenditures (Maunsell Sustralia Pty Ltd, 2008).

Gateway already experiences relatively high numbers of small wildland fires; visitor and staff education and response plans can play a critical role in preventing an escalation in occurrence. Gateway may consider coordinating with adjoining counties to help educate neighboring residents on the dangers of wildland fires at Gateway. Further, the Gateway Fire Management Plan could be periodically reviewed to see if measures to prepare for and respond to "red flag" days continue to be appropriate, given climatic changes.

A common invasive species at Gateway is common reed (*Phragmites australis*), which chokes out other plant species, forming areas where common reed persists in isolation (mono-dominant stands). This greatly lowers the numbers and kinds of species present by eliminating both the native plant species and the faunal species that depend on native vegetation (Jodoin et al., 2008).

Feral and house cats pose a direct threat to Gateway's bird populations (NPS, 2000). Similarly, raccoons prey on the endangered Diamondback terrapins' eggs, consuming up to 92% of eggs laid (Feinberg & Burke, 2003). Competition with invasive species and non-native birds, such as the European mute swan (*Cynagus olor*) also threatens native waterfowl populations (NPS, 2000).

Ocean Acidification

Like climate change, rising ocean acidity results from high concentration of atmospheric carbon dioxide. The ocean absorbs a large proportion of the CO_2 emitted into the atmosphere; dissolved CO_2 lowers the ocean's pH, making the water more acidic (Caldeira & Wickett, 2003). One study estimates approximately 40% of CO_2 emitted in the past 200 years is now stored in the oceans, increasing acidity by a third (NPCC, 2009).

Nitrogen Pollution

Nitrogen pollution heavily impacts water quality within Gateway. Sources of excess nitrogen in Gateway's waters include:

- Residential development and the associated increase in wastewater.
- Water runoff containing fertilizer from lawns, golf courses, and ball fields.
- Nitrogen transfer from the atmosphere (Neckles et al., 2001).

The main nitrogen source in Jamaica Bay's estuaries are discharges from four nearby New York City waste treatment plants, especially during major storm events when the plants exceed their capacity to treat storm and sewer water. Pristine estuaries can absorb low levels of excess nutrients without major ecological consequences; however, excessive nutrient inputs will lead to dense algal growth and eutrophic conditions (See Box 4. Eutrophication).

Box 4. Eutrophication

Eutrophication occurs in water bodies loaded with high nutrient concentrations. These nurtrients trigger extreme algal growth, depleting oxygen availability in the aquatic habitat.

Extreme surface algal growth blocks sunlight from reaching algae and plants located at deeper depths, causing plants to die and decompose. Higher rates of decomposition deplete the oxygen supply and create an uninhabitable aquatic habitat (Smith & Smith, 2003).

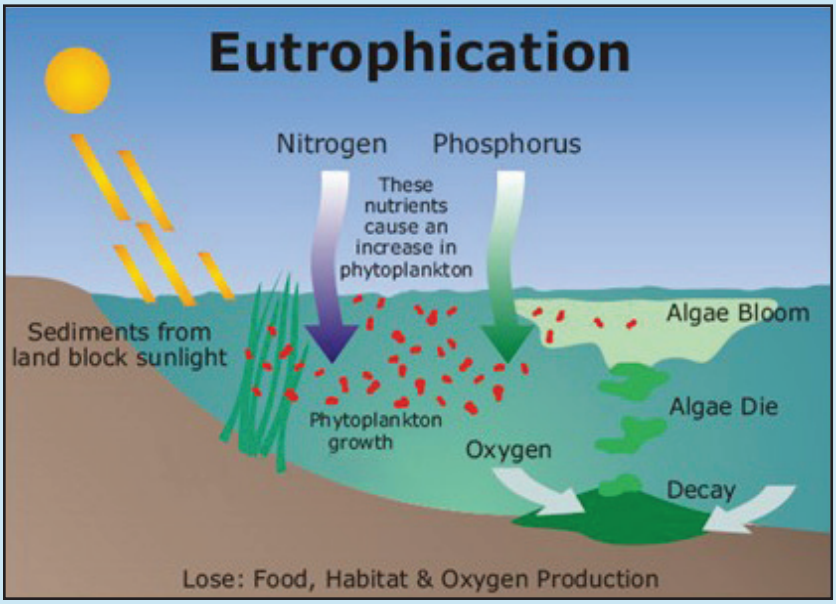

Figure 3. A Model of Eutrophication. (Source: City of Lincoln Watershed Management: Education Website)

Box 5. Public Opinion on Climate Change

Creating a climate change adaptation plan includes convincing the public that this is a wise investment in Gateway's future. The first challenge may be educating the visitor about climate change.

Many factors shape the public's understanding and interpretation of climate change, including political debates, the news, extreme weather events and natural disasters.

Some evidence suggests the public is increasingly understanding and accepting climate change realities. Figure 4 shows responses to three questions on climate change in 2008:

- Do you think that global warming is happening? (Yes, no, don't know.)
- If yes: How sure are you that global warming is happening?
- If no: How sure are you that global warming is not happening?

Part of Gateway's responsibility in creating a climate change adaptation is incorporating public education on climate change impacts.

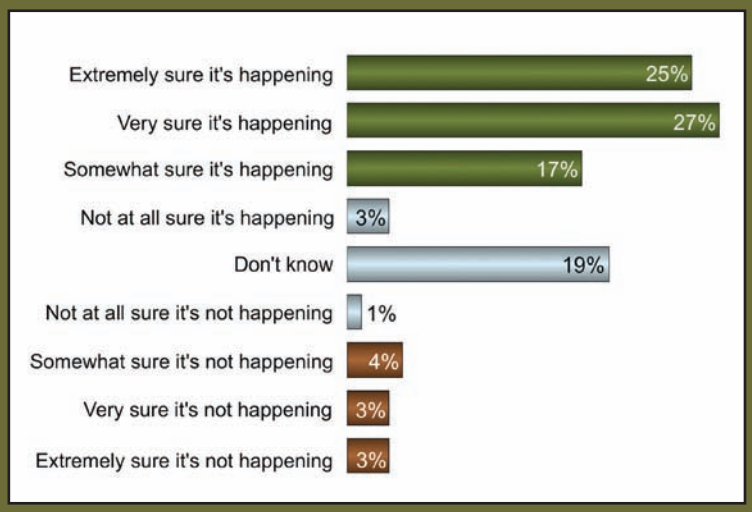

Figure 4. Public Perception of Climate Change. Adapted from "Climate Change in the American Mind" (2009).

High Visitation Rates

Gateway's mission includes providing opportunities for visitors to enjoy natural, cultural and recreational resources. However, visitors also constitute a stressor on park ecosystems. Visitors, if not properly informed and managed, may contribute to trash, remove individual plants or animals from the park, carelessly or accidentally damaging habitat. Gateway experiences the third-highest visitation of all NPS units, likely because it is located in a densely populated metropolitan region. Rising temperatures in and around the New York-New Jersey Metropolitan Area may lead to increasing use of Gateway for recreation, particularly during the summer, if increased heat waves lead to increased beach use. Milder winters could also increase year-round visitation.