Appendix B

ADAPTATION ASSESSMENT GUIDEBOOK

New York City Panel on Climate Change

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New York City Panel on Climate Change

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ADAPTATION ASSESSMENT GUIDEBOOK

New York City Panel on Climate Change

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The information in this document reflects the views and opinions of the New York City Panel on Climate Change and not the City of New York.

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EXECUTIVE SUMMARY

The Adaptation Assessment Guidebook (AAG) lays out a multi-step process to help stakeholders create an inventory of their at-risk infrastructure and develop adaptation strategies to address those identified risks. The steps outlined in this document are designed to be incorporated into the risk management, maintenance and operations, and capital planning processes of the agencies and organizations that manage and operate critical infrastructure. These steps are discussed in detail throughout the guidebook.

The eight Adaptation Assessment Steps are:

1. Identify current and future climate hazards
2. Conduct inventory of infrastructure and assets
3. Characterize risk of climate change on infrastructure
4. Develop initial adaptation strategies
5. Identify opportunities for coordination
6. Link strategies to capital and rehabilitation cycles
7. Prepare and implement adaptation plans
8. Monitor and reassess

The adaptation assessment steps have been developed in substantial part through work conducted by Columbia University and New York City and regional agencies in the last decade[1]. Similar approaches can be found in many of the documents described in Annex C, "Other adaptation reports: summaries and links."

The New York City Panel on Climate Change (NPCC) frames climate change adaptation as an extension of risk management planning because it involves multiple layers of uncertainty. Traditionally, risk management has been used as a mechanism for planning in the face of uncertainties, especially in fields such as financial planning. More recently, risk management has begun to appear as a way to encourage planning for adaptations to climate change. There are at least three layers of uncertainty in climate change adaptation planning:

- Climate-related uncertainties
- Climate impact uncertainties
- Uncertainties surrounding developing and implementing adaptation strategies

To accompany the adaptation assessment steps, the AAG contains tools developed for the New York City Climate Change Adaptation Task Force by the NPCC in collaboration with the City. These are designed to help stakeholders identify critical infrastructure at risk from a changing climate, characterize the risks, and develop and prioritize adaptation strategies. They are:

[1] Rosenzweig and Solecki, 2001; Rosenzweig et al., 2007; Metropolitan Transportation Authority, 2007; NYCDEP 2008.

1. Infrastructure Questionnaires (IQ) Sector-specific questionnaires to guide stakeholders in initiating their assessment process and in beginning to create an inventory of their infrastructure at risk to climate change impacts.

2. Risk Matrix (RM) Tool to help stakeholders categorize their lists of at-risk infrastructure based on the probability of the climate hazard, likelihood of impact, and magnitude of consequence.

3. Prioritization Framework (PF) Framing tool to assist stakeholders in developing and prioritizing adaptation strategies based on selected criteria.

For each adaptation step, the Guidebook includes a description of how the principles set out in the document have been utilitized in practice by the New York City Climate Change Adaptation Task Force. In this way, the Guidebook provides not only the fundamental principles of adaptation planning, but also the basis for continuing improvements in planning as stakeholders become more experienced in the development of adaptation plans.

In addition, the Guidebook includes three annexes: the Infrastructure Questionnaires for different sectors; the treatment of the New York City experience in a recent National Resource Council report; and links to other adaptation reports.

About the New York City Panel on Climate Change

Convened by Mayor Michael Bloomberg, the NPCC advises the Mayor on issues related to climate change and adaptation. Made up of climate change and impacts scientists, legal, and insurance and risk management experts, the NPCC is modeled on the Intergovernmental Panel on Climate Change (IPCC). Among its ongoing activities, the NPCC developed climate change projections for New York City; created this set of workbooks (Appendices A, B and C) to assist the City's Climate Change Adaptation Task Force; and drafted this report on the effects of climate change on New York City—similar to the IPCC reports on global climate change. The NPCC is chaired by Dr. Cynthia Rosenzweig of NASA Goddard Institute for Space Studies and Columbia University Earth Institute's Center for Climate Systems Research, and Dr. William Solecki of CUNY Institute for Sustainable Cities at Hunter College. The NPCC is funded through a grant from the Rockefeller Foundation.

About the Rockefeller Foundation

The Rockefeller Foundation fosters innovative solutions to many of the world's most pressing challenges, affirming its mission, since 1913, to "promote the well-being" of humanity. Today, the Foundation works to ensure that more people can tap into the benefits of globalization while strengthening resilience to its risks. Foundation initiatives include efforts to mobilize an agricultural revolution in Sub-Saharan Africa, bolster economic security for American workers, inform equitable, sustainable transportation policies in the United States, ensure access to affordable and high-quality health systems in developing countries, and develop strategies and services that help vulnerable communities cope with the impacts of climate change. For more information, please visit www.rockfound.org.

1. CLIMATE CHANGE AND NEW YORK CITY

Global mean temperatures and sea levels have been increasing for the last century, accompanied by other changes in the earth's climate. As these trends continue, climate change and its impacts are increasingly being recognized as a major concern both globally and in specific regions such as New York City. An international panel of leading climate scientists, the Intergovernmental Panel on Climate Change (IPCC), was formed in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to provide objective and up-to-date information regarding the changing climate. In its 2007 Fourth Assessment Report (AR4), the IPCC states that there is a greater than 90% chance that rising global temperatures, observed since 1750, are primarily due to human activities (IPCC 2007a, 2008).

Adapting to Climate Change

Climate change adaptation is defined by the IPCC as "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" (IPCC, 2007b). Climate change adaptation is an iterative process with various elements of uncertainty at each stage. Because of these multiple layers of uncertainty, the NPCC considers climate change adaptation a risk management issue and suggests the most effective adaptation strategies are those that allow for flexibility over time, referred to by the NPCC as "Flexible Adaptation Pathways" (adapted from City of London, see Definitions and Terms, Section 2).

As had been predicted in the 19th century, the principal driver of climate change over the past century has been increasing levels of atmospheric greenhouse gases associated with fossil fuel combustion, changing land use practices, and other human activities. Atmospheric concentrations of the major greenhouse gas carbon dioxide (CO_2) are now more than one-third higher than in pre-industrial times. Concentrations of other important greenhouse gases, including methane (CH_4), ozone (O_3) and nitrous oxide (N_2O) have increased as well. Largely as a result of work done by the IPCC and the United Nations Framework Convention on Climate Change (UNFCCC), efforts to mitigate the severity of climate change by limiting levels of greenhouse gas emissions are underway globally.

Because of greenhouse gas forcing mechanisms already in the climate and the long timeframe of some climate system processes, awareness is growing that some impacts from climate change are inevitable. Responses to climate change have grown beyond a focus on mitigation to include adaptation measures in an effort to minimize the impacts of climate change already underway and to prepare for unavoidable future impacts.

To respond to climate changes in New York City and accomplish the goals outlined in PlaNYC, the City's comprehensive plan to create a greener, more sustainable city, Mayor Michael Bloomberg, in partnership with the Rockefeller Foundation, convened the New York City Panel on Climate Change (NPCC) in August 2008. The NPCC, which consists of climate change and impacts scientists, and legal, insurance and risk management experts, serves as the technical advisory body for the Mayor and the New York City Climate Change Adaptation Task Force (the "Task Force") on issues related to climate change, impacts and adaptation.

The Task Force was also launched in August 2008 to identify climate change risks and opportunities for the city's critical infrastructure and to develop coordinated adaptation strategies. The Task Force consists of approximately 40 city, state and federal agencies, regional public authorities and private companies that operate, maintain or regulate critical infrastructure in the region. In the Task Force's work, critical infrastructure is defined as systems and assets (excluding residential and commercial buildings, handled by other city efforts) that support activities that are so vital to the city that the diminished function or destruction of such systems and assets would have a debilitating impact on public safety and/or economic security.

The NPCC was charged with creating three workbooks (Appendices A through C of this volume) to guide Task Force members through the process of identifying climate risks to their critical infrastructure, creating adaptation plans, and considering the regulatory environment as it pertains to climate change adaptation. The Climate Risk Information (CRI) workbook provides a summary of climate data and projections for New York City and identifies potential risks to the City's critical infrastructure posed by climate change. This Adaptation Assessment Guidebook (AAG) guides stakeholder consideration of the climate information presented in the CRI in their risk management and planning processes. The Climate Protection Levels (CPL) report evaluates some of the policies, rules and regulations that govern infrastructure to determine how they could be affected by climate change.

2. ADAPTATION AS A RISK MANAGEMENT ISSUE

The NPCC frames climate change adaptation as an extension of risk management planning because of multiple layers of uncertainty related to climate change. Traditionally, risk management has been used to plan for uncertainties, especially in fields such as financial planning. More recently risk management has begun to appear as a way to encourage planning for adaptations to climate change. There are at least three layers of uncertainty in climate change adaptation planning:

- Climate-related uncertainties
- Climate impact uncertainties
- Uncertainties surrounding developing and implementing adaptation strategies

These are each discussed in more detail in the Definitions and Terms section. Other types of uncertainties should be considered as necessary for particular situations.

The NPCC also encourages development of flexible strategies, or “Flexible Adaptation Pathways,” for climate adaptation that can change over time as understanding of climate change science, impacts, technology and public risk tolerance evolve. This flexible approach provides a useful way to monitor climate risks and adaptation strategies, and alter responses as needed. Planning in this manner also allows for continued adjustment as understanding of risks advances.

ADAPTATION ASSESSMENT GUIDEBOOK

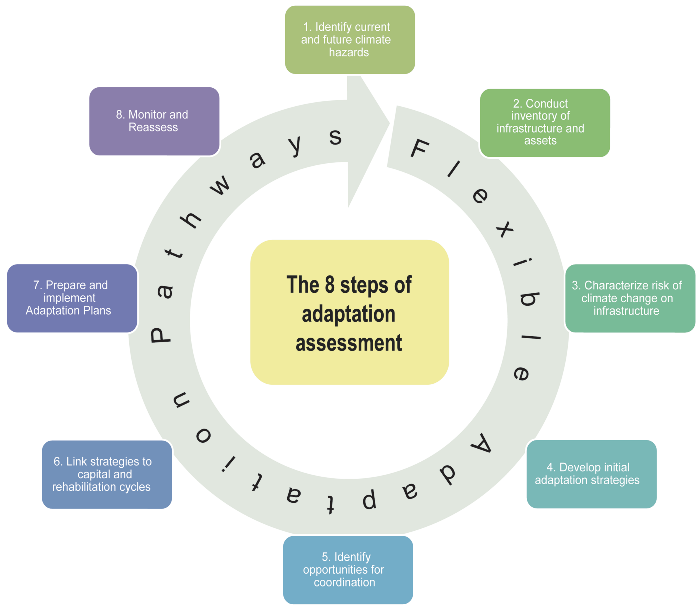
The Adaptation Assessment Guidebook (AAG) lays out a multi-step process to help stakeholders identify at-risk infrastructure and develop adaptation strategies to address those risks (Figure 1). The steps outlined in this document are designed to be incorporated into the risk management, maintenance and operations, and capital planning processes of the agencies and organizations that manage and operate critical infrastructure. These steps are discussed in detail throughout Section 3.

The eight Adaptation Assessment Steps (shown graphically in Figure 1) are:

1. Identify current and future climate hazards
2. Conduct inventory of infrastructure and assets
3. Characterize risk of climate change on infrastructure
4. Develop initial adaptation strategies
5. Identify opportunities for coordination
6. Link strategies to capital and rehabilitation cycles

7. Prepare and implement adaptation plans
8. Monitor and reassess

FIGURE 1. Adaptation Assessment Steps



The Adaptation Assessment steps are intended to be general enough to be useful for a range of jurisdictions and infrastructure sectors, yet specific enough to serve as the template for developing and implementing a sector's adaptation efforts. The guidebook may be used to assist in climate change adaptation in any urban area, with region-specific adjustments related to climate risk information, critical infrastructure, and protection levels.

These adaptation assessment steps have been developed in substantial part through work conducted by Columbia University and City and regional agencies in the last decade (Rosenzweig and Solecki, 2001; Rosenzweig et al., 2007; Metropolitan Transportation Authority, 2007; NYCDEP 2008). Similar approaches can be found in many of the documents described in Annex C, "Other adaptation reports: summaries and links." The steps reflect the fundamental nature of adaptation planning, which is in principle a highly complex, multidimensional optimization problem. They are designed to enable stakeholders to adapt to climate change in practice, while at the same time staying within a suitable conceptual framework. The application of the steps described in this document primarily reflects their use in New York City, but they are designed to be broadly applicable to climate change adaptation in many jurisdictions.

The AAG describes three tools developed for the Climate Change Adaptation Task Force by the NPCC in collaboration with the City to help stakeholders identify critical infrastructure at-risk from a changing climate, characterize the risks, and develop and prioritize adaptation strategies. These are:

1. Infrastructure Questionnaires (IQ) Sector-specific questionnaires (Annex A) to guide stakeholders in initiating their inventory and risk assessment process and creating an inventory of their at-risk infrastructure. In the Task Force's work, these are called Risk Assessment Questionnaires; the more general name Infrastructure Questionnaires is used here, to reflect the fact that in many jurisdictions planning will start with a comprehensive infrastructure inventory and then move to risk assessment.

2. Risk Matrix (RM) A tool to help stakeholders categorize risks based on the probability of the climate hazard, likelihood of an impact, and the magnitude of consequence should the impact occur.

3. Prioritization Framework (PF) A framing tool to assist stakeholders in developing and prioritizing adaptation strategies based on selected criteria.

Together with the adaptation steps, these process-based tools provide the foundation for the development of climate change adaptation plans for critical infrastructure in New York City.

DEFINITIONS AND TERMS

Adaptation

Climate change adaptation has been defined by the IPCC as: "Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned" (IPCC, 2007b).

The New York City Panel on Climate Change uses a more specific definition of adaptation, considering the changes made to maintenance or operations, capital investments, and policies that will minimize the potential consequences that climate change could have on New York City's critical infrastructure. The NPCC also considers specific adaptation elements such as time frame of impacts, risk thresholds, efficacy, and the persistence of impacts.

Risk

Generally the NPCC defines risk as a product of the likelihood of an event occurring (typically expressed as a probability) and the magnitude of consequences should that event occur. The CRI provides estimates of the likelihood of occurrence of projected climate changes, along with a general description of the types of potential consequences for New York City's infrastructure. It also lays the foundation for the climate risks developed with further consideration of consequences in the AAG.

The AAG provides a framework for combining the CRI's climate hazards with elements including an impact's magnitude, timing, importance of the system(s) at risk, and potential of reversibility. Assessments of risk can include the potential for adaptation to an impact, the distribution of an impact across a region and the importance of the system being affected. These risk estimates are improved as additional information becomes available.

Uncertainty & Likelihoods

When assessing climate change impacts and adaptation strategies, multiple layers of uncertainty must be considered. The first layer deals with uncertainties in the climate projections. At the global scale these uncertainties take the form of uncertainties as to future greenhouse gas concentrations and uncertainties as to how sensitive the climate system will be to greenhouse gas concentrations and other climate drivers. At the local and regional scales, uncertainties are further increased by climate variability and changes in local physical processes that may not be fully captured by the global climate models used to make projections. (See the CRI for further information on climate hazard-related uncertainties.)

The second layer is the uncertainty relating to whether and how the climate hazard will impact infrastructure. Examining how climate hazards currently impact infrastructure is a starting point, but it is uncertain if the increasing hazard will cause significant damage to the infrastructure, or what new impacts will be experienced. A question to consider is whether there are triggers or thresholds up to which infrastructure can withstand a certain hazard. In some situations, hazards may begin to have impacts not previously experienced. Additionally, climate change may have some positive benefits on infrastructure which also need to be considered. This layer of uncertainty is associated with the magnitude of consequence of various levels of impact. Generally, infrastructure is designed to withstand some level of impact or environmental stress; if that threshold is crossed, it may be challenging to estimate the magnitude of the consequences. Factors which add to this layer of uncertainty include, but are not limited to, the interconnectedness of many systems, timing of the impact, backup systems, and warning before impact.

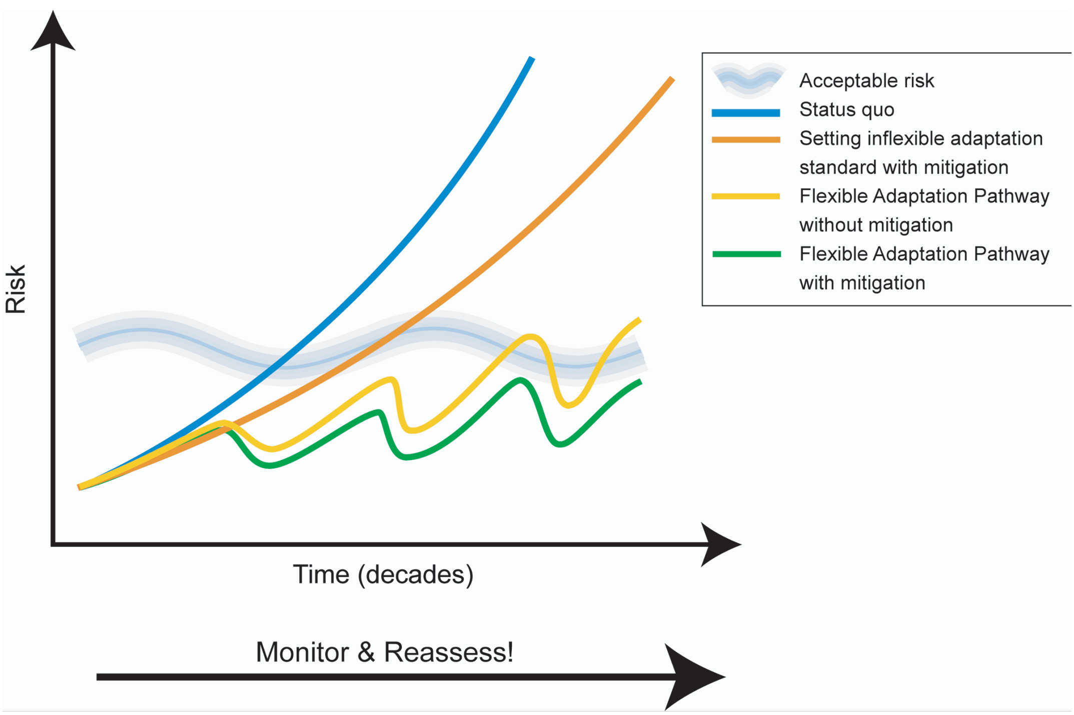
The third layer of uncertainty is related to developing adaptation strategies. Strategy feasibility will depend on external circumstances such as, but not limited to, economic growth and budgets, population growth, new technologies, and best practices from other cities which might influence strategy designs.

None of these uncertainties can be eliminated completely, so stakeholders need to consider climate change adaptation as an extension of risk management planning practices and scenarios. It may also be necessary to consider layers of uncertainty other than those listed that are particular to a given situation.

Flexible Adaptation Pathways

The term Flexible Adaptation Pathways describes an overall approach to developing effective climate change adaptation strategies for a region under conditions of increasing risk (Figure 2).[2] Flexible Adaptation Pathways are not fixed; they are ones in which adaptations are defined in terms of acceptable risk levels, and re-evaluated over time, rather than using an approach that sets inflexible standards for adaptation early in the process. More permanent, inflexible approaches are likely to be costlier and less effective ways of implementing adaptations for the dynamic and on-going climate change conditions projected than are Flexible Adaptation Pathways.

FIGURE 2. Flexible Adaptation Pathways



Graphic adapted from: Lowe, J., T. Reeder, K. Horsburgh, and V. Bell. "Using the new TE2100 science scenarios." UK Environment Agency.

Throughout time, climate hazard-related standards such as those discussed in the CPL are maintained under a society's "acceptable level of risk" (represented by the light blue wavy line in Figure 2). While it is difficult to quantify society's acceptable level of risk, especially around areas of high uncertainty, it is easy to identify certain things that would be perceived as not acceptable, such as allowing the New York City subway system to flood very frequently. Society's acceptable level of risk is also likely to change over time.

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[2] This concept has been adapted from the City of London work on climate change adaptation, in particular work done by the TE2100 project and published in "The Thames Estuary 2100 Plan", April 2009: http://www.environment-agency.gov.uk/research/library/consultations/106100.aspx

For instance, it is likely to be lower after an extreme event such as a hurricane. The light blue line in Figure 2 is wavy in order to reflect these varying factors.

The royal blue line depicts a trajectory maintaining status quo with emissions, climate change risks and adaptation policies. The orange line represents a future, even with mitigated emissions, of a one-time static or inflexible adaptation. While this is better than maintaining the status quo, this trajectory would still eventually result in crossing into an unacceptable level of risk.

The yellow and green lines depict Flexible Adaptation Pathways. The yellow line represents a future where adaptation measures are considered, but no mitigation is accomplished. The green line is an ideal in terms of risk management, creating Flexible Adaptation Pathways to adaptation alongside emission mitigation. This trajectory allows policymakers, stakeholders, and experts to develop and implement strategies that evolve as climate change progresses.

Activities that can help to develop Flexible Adaptation Pathways include ongoing and regular updates to improve understanding of: 1) current and future climate hazards, 2) regulations and design standards, and 3) adaptation strategies. Specific examples of Flexible Adaptation Pathways are building a sea wall with a strong enough foundation to support an addition of a higher wall at a later period, depending on rates of sea level rise; or purchasing inland property in the event moving infrastructure away from a flood zone becomes necessary.

Workbooks such as these developed by the NPCC can contribute to the achievement of such flexible pathways. Monitoring and reassessment of climate science, adaptation strategies and policies are critical so that responses to the evolving risks of climate change can be adjusted effectively.

Notes from the Task Force
Introduction

The New York City Climate Change Adaptation Task Force (“the Task Force”) utilized the steps outlined in the AAG in a multi-tiered eighteen-month process. Throughout the guidebook the activities of the Task Force are presented to illustrate how the AAG process was implemented in New York City

Within the Task Force four working groups were created that represented the broad categories of infrastructure included in its scope: Communications, Energy, Transportation, and Water and Waste. In addition, a Policy Working Group was convened to review the codes, rules, and regulations that govern infrastructure in New York City and to identify those that may need to be changed or created to account for climate change. Each working group provided a forum within which stakeholders could identify common vulnerabilities, share best practices, take advantage of potential synergies, and develop coordinated adaptation plans.

The Water and Waste Working Group includes agencies that handle the City’s solid waste and wastewater as well as those entities responsible for the city’s natural environment and significant portions of the city’s waterfront properties.

3. ADAPTATION ASSESSMENT STEPS

The Adaptation Assessment Guidebook (AAG) is designed to be used as a starting point for adaptation planning. The AAG provides the basis for operators and owners of infrastructure to incorporate climate change in their decision processes. It is intended to be a general roadmap for stakeholders to systematically assess the potential impacts of climate change on infrastructure and to develop adaptation strategies. The Adaptation Assessment steps can be adjusted to fit the specific needs, structure, and timing of different agencies, organizations and jurisdictions. An effective adaptation assessment framework has to be broad enough to address a wide variety of infrastructure and the differing missions of stakeholders, yet specific enough to produce consistent categorizations of risks and strategies.

The AAG is designed to be used in conjunction with the Climate Risk Information (CRI) workbook, which describes current climate trends and future projections for the New York City region, and the Climate Protection Levels (CPL) workbook, which describes how climate change may affect regulations and approaches to design standards for adaptation. Use of all three workbooks in adaptation planning provides a comprehensive approach to climate hazards, impacts, adaptations and policy.

Table 1 outlines the eight Adaptation Assessment Steps that infrastructure operators and managers should follow to assess how climate change could impact their infrastructure and to develop adaptation plans to cope with those impacts. Table 1 also suggests the NPCC resources relevant to each step. Each step is discussed in detail in this Section.

TABLE 1. Adaptation Assessment Steps and NPCC resources

Steps[1]		NPCC Resources
1	Identify current and future climate hazards	CRI, AAG
2	Conduct inventory of infrastructure and assets	CRI, AAG (IQ)
3	Characterize risk of climate change on infrastructure	CRI, AAG (RM)
4	Develop initial adaptation strategies	AAG (PF), CPL
5	Identify opportunities for coordination	AAG
6	Link strategies to capital and rehabilitation cycles	AAG
7	Prepare and implement Adaptation Plans	AAG (PF), CPL
8	Monitor and reassess	CRI, AAG, CPL

[1]These steps are flexible and meant to be adapted in different planning purposes as needed. A version of them was first developed for the Department of Environmental Protection's Climate Change Task Force (Rosenzweig et al., 2007). CRI = Climate Risk Information, IQ = Infrastructure Questionnaires, RM = Risk Matrix, PF = Prioritization Framework, CPL = Climate Protection Levels

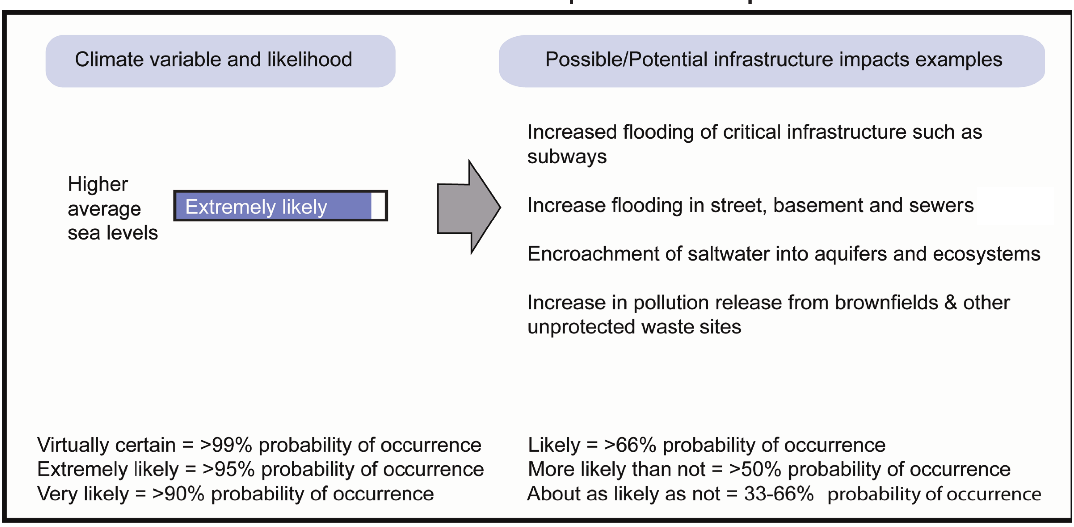
The steps are designed to be incorporated into general planning and operations within an organization so that climate hazards are considered in all capital projects, repairs, and operations. Climate change adaptation strategies must also be monitored and reassessed on a regular basis to ensure that they are responsive to developments in climate science, materials science, technology, and policies.

STEP 1: IDENTIFY CURRENT AND FUTURE CLIMATE HAZARDS

The first step in creating an adaptation plan is to identify the potential impacts of climate change. Localized or regional climate change scenarios, such as those included in the Climate Risk Information (CRI, Appendix A), are an ideal component of this, providing stakeholders with a science-based understanding of their risks and the uncertainties involved. Another important component in planning is the examination of the environmental stressors that currently affect infrastructure and operations. Using the information from existing stressors and climate risks in CRI, stakeholders can begin to develop lists of potential impacts on their infrastructure. An example of how this can be done is shown in Figure 3.

The use of uniform projections is important so that shared and overlapping infrastructure is evaluated for the same hazards, providing for consistent city-wide planning. Climate change scenarios should be revised at suitable intervals as climate science progresses, and data sets and projections improve.

FIGURE 3. Climate Stressors and Infrastructure Impacts: the example of sea level rise*



**Likelihood categories defined in NPCC Climate Risk Information (based on IPCC WG1 2007)*

Notes from the Task Force
Step 1. Identify Current and Future Climate Hazards

One of the key strengths of the Task Force is the utilization of a common set of climate change projections developed by the NPCC (see CRI). The NPCC projections allow stakeholders to gain an understanding from the outset of the adaptation process of the climate science, potential impacts, and uncertainties involved and ensures that the inventories completed and strategies developed by the stakeholders are based on the same climate change projections.

STEP 2: CONDUCT INVENTORY OF INFRASTRUCTURE AND ASSETS

The goal of this step is for stakeholders to assess how climate change might impact their infrastructure and begin to incorporate climate change information and considerations into their existing operational and capital planning processes. New York City and its surrounding region have a massive stock of infrastructure, typified by the subway system (Figure 4) and other systems represented by the Task Force Working Groups.

FIGURE 4. Map of the New York City Subway System

Source: New York City Metropolitan Transportation Authority

Stakeholders develop inventories of infrastructure potentially at risk to climate change. Using the climate hazards identified in Step 1, stakeholders should develop a series of questions, such as those included in the IQs and others as appropriate, to identify specific assets that could be vulnerable to climate change. Initially, inventories are created using existing information already available to stakeholders, such as lists of types of infrastructure (e.g., tide gates, bridges, communication towers, maintenance facilities), taking into account climate risks. An important starting point for stakeholders is to consider where climate, climate change, or extreme weather events are already affecting their infrastructure or core operations. In many cases, stakeholder organizations are already programmatically and operationally responding to the impacts of climate variability and climate change.

Stakeholder inventories can include elements such as the following (specific examples given in Table 2):

1. General listing of infrastructure classes: A broad classification of infrastructure, such as subways, in a format consistent with existing infrastructure inventories or stakeholder management and operations.

2. Detailed description of infrastructure and assets: Where possible, within each general infrastructure category, further information should be included in the inventories specifying pieces of infrastructure or assets potentially at risk from changes in the climate, such as the specific location or facility element. Examples might include drains in specified areas, subway tunnels, coastal facilities, or types of materials susceptible to extreme heat. This section could also include site-specific information or references such as “Waste Water Treatment Plant X”, or “copper wiring”. Each specific asset should be listed in a separate row.

3. Identification of potential climate hazard(s): In this section, climate hazards that may affect each piece of infrastructure should be identified and a brief explanation given as to why the infrastructure might be at risk. Where possible, the list can include specific risks to the infrastructure, such as changes in extreme events versus gradual changes in climate (i.e., a heat wave versus gradually rising temperatures) and a threshold the infrastructure can withstand before it will be impacted by climate change (i.e., a facility that will flood with three feet of sea level rise but not with less). All climate variables that might affect the infrastructure (i.e., air temperature, precipitation, sea level rise) should be considered and each climate variable listed in a separate row.

4. Potential impact of climate hazard on infrastructure: Where known, the specific impact of each climate hazard should be specified on the inventory, such as “degradation of materials” as a result of increased temperatures, or “permanent inundation” as a result of sea level rise.

5. Existing stakeholder actions, including upcoming capital projects and/or routine maintenance upgrades or repairs: Only those projects or efforts that are either in process or planned and have allocated funding that could mitigate the risks posed by climate change should be included.

TABLE 2. An Example of a Risk Assessment Spreadsheet

Infrastructure Asset	Detailed Description	Potential Climate Hazard*	Potential Impact	Planned capital projects and/or other actions
Waste Water Treatment Plant	WWTP X 10 Elm St.	Sea level rise of 10 to 15 inches and associated storm surge	Flooding	Upgrade
Subways	Subway Line Y	Increase in intense precipitation	Flooding	None
	Tunnel X under the State River	Sea level rise of 10 to 15 inches and associated storm surge	Permanent inundation through tunnel entrances	Repairs
Storm drains	Throughout the city	Brief periods of intense rainfall	Flooding	Routine maintenance

* From the CRI (NPCC, 2009)

To the extent possible, stakeholders should use consistent information and procedures throughout their adaptation planning. This is done to ensure that climate change information and assessment tools are coordinated throughout agencies and organizations, and that inventories can be regularly updated in a systematic fashion, especially as climate change science evolves or new risks are identified. Developing an inventory of at-risk infrastructure is not a static action; the inventory should be reassessed as appropriate to reflect changes in environmental conditions, climate change science, adaptation technologies, operations and/or the physical condition of an asset.

Notes from the Task Force
Step 2. Conduct Inventory of Infrastructure and Assets

Task Force members utilized the NPCC's CRI Workbook to identify critical infrastructure that may be vulnerable to climate change, and used an automated spreadsheet created by the Boston Consulting Group to complete their inventories along the lines of this step. Four of the working groups (Energy, Transportation, Communications and Water and Waste) identified sector-wide vulnerabilities and leveraged stakeholder and individual expertise to benefit the entire Task Force. The Policy Working Group was tasked with reviewing the codes, rules, and regulations that govern infrastructure in New York City to identify those policies that need to be changed or created to account for climate change.

STEP 3: CHARACTERIZE RISK OF CLIMATE CHANGE ON INFRASTRUCTURE

Stakeholders are likely to face multiple risks from climate change; however, some risks may be more likely to occur or have a greater impact if they do occur than others. Recognizing that limited resources should be directed to address the greatest needs, stakeholders should prioritize their climate change risks to identify those of most concern. Due to the multiple layers of uncertainty associated with climate change adaptation assessments, it is difficult to fully quantify the risk of any climate change impact. In partnership with the City and the Boston Consulting Group (BCG), a framework was developed to aid in assessing relative risk. The framework helps assess risk (Table 3) by evaluating:

- Likelihood of impact occurrence
- Magnitude of consequence should the impact occur

TABLE 3. Defining Risk Factors[1]

Examples of categories and definitions that can be used with a two-dimensional risk matrix to guide categorization of risk.

Factor	Description	Definitions
Likelihood of impacts	The likelihood that a given climate hazard (e.g., temperature rise) will result in infrastructure vulnerability (e.g., buckling of rail lines)	Virtually certain/already occurring High likelihood Moderate likelihood Low likelihood
Magnitude of consequence	The overall consequence, should an impact occur.	Internal operations (to the stakeholder) Capital and operating costs (for the stakeholder) Number of people affected (to the city) Public health and worker safety (to the stakeholder and city) Economy (to the city) Environment (to the city)

[1]These categories were developed in collaboration with the City and BCG.

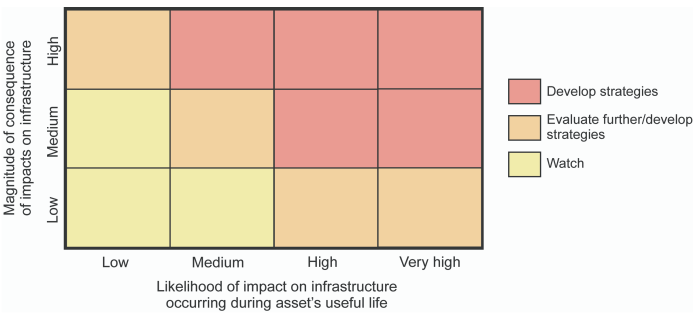
Assessment of these two criteria for each infrastructure asset and climate hazard provides the information needed to categorize and prioritize risks, a prerequisite to the formulation of an effective adaptation plan.

Stakeholders consider all the climate change impacts that may occur during the asset's rated useful life; however, in some cases an asset may be in use well beyond its expected useful life. In such cases stakeholders should use their best judgment when defining the actual useful life of that asset. It is important for stakeholders to consider not only impacts to existing infrastructure, but also to infrastructure in development that will be affected by climate change. Instances where upgrades are already underway to infrastructure should be evaluated to determine if they could incorporate adaptations to climate change.

Once each impact has been categorized for the two criteria, a two-dimensional risk matrix can be used to organize this information (Figure 5) and represent the work graphically. In the diagram, the overall relationship to increasing importance of adaptation planning is shown for each of the two dimensions. As further information is developed in planning, these relationships can be made more specific. Such a risk matrix can help to categorize the level of risk posed by climate change into categories, such as:

- **Red** category of risks for which adaptation strategies should be developed
- **Orange** category of risks for which adaptation strategies may need to be developed or for which further information is needed, and
- **Yellow** category of risks for which impacts should be monitored but that do not need actions at this time.

FIGURE 5. Two-dimensional Risk Matrix used by the Task Force



Source: The City of New York

Although the risk matrix is a tool for assessing the most significant risk exposures, adaptation strategies can be created for all infrastructure classes, not only those in the red category, as in some cases there is potential for low-cost but highly-effective adaptations in the orange and yellow categories.

"Likelihood of impact occurrence" in this procedure is defined as the likelihood that a given climate variable (e.g., temperature rise) will result in infrastructure impacts (e.g., buckling of rail lines) over its useful lifespan, should the climate change occur. For example, if it is determined that a temperature increase of 4 to 7.5 degrees Fahrenheit (projected air temperature increase for New York City and the surrounding region in the 2080s) will cause existing rail lines with a useful life of 100 years to buckle, the likelihood of impact occurrence is said to be virtually certain. The likelihood of impact occurrence is defined by the Task Force in the following categories:

- **Very high** Nearly certain likelihood of a climate variable impact occurring over the useful life of the infrastructure and/or variable may already be impacting infrastructure.
- **High likelihood** High likelihood of the impact occurring over the useful life of the infrastructure.

- **Moderate likelihood** Moderate likelihood of the impact occurring over the useful life of the infrastructure.
- **Low likelihood** Low likelihood of the impact occurring over the useful life of the infrastructure.

"Magnitude of consequence" is defined as the combined impact of the occurrence should a given hazard occur, across six categories:

- **Internal operations** (to the stakeholder), including the scope and duration of service interruptions, reputational risk, and the potential to encounter regulatory problems.
- **Capital and operating costs** (to the stakeholder), including all capital and operating costs to the stakeholder and revenue implications caused by the climate change impact
- **Number of people impacted** (to the city), including considerations related to any impacts on vulnerable populations (including, but not limited to seniors, low-income communities, mentally- or physically-disabled citizens, homebound residents, and children).
- **Public health** (to the stakeholder and the city), including worker safety
- **Economy** (to the city), including any impacts to the city's economy, the price of services to customers, and clean-up costs incurred by the public
- **Environment** (to the city), including the release of toxic materials and impacts on biodiversity, the City's ecosystem, and historic sites.

Notes from the Task Force
Step 3. Characterize Risk of Climate Change on Infrastructure

For this step in the adaptation assessment process, Task Force members measured risk as the product of the likelihood of impact occurrence and magnitude of consequence if the impact occurred. Members were encouraged to use six categories for magnitude of occurrence: internal operations; capital and operating costs; number of people impacted; public health; economy; and environment. A template was developed that automatically generated a placement on a two-dimensional risk matrix (Figure 5) taking into account all six categories. If the automatically generated risk does not align with expert judgment, the template provides the stakeholders with the opportunity to override the automated placement, with explanatory notes.

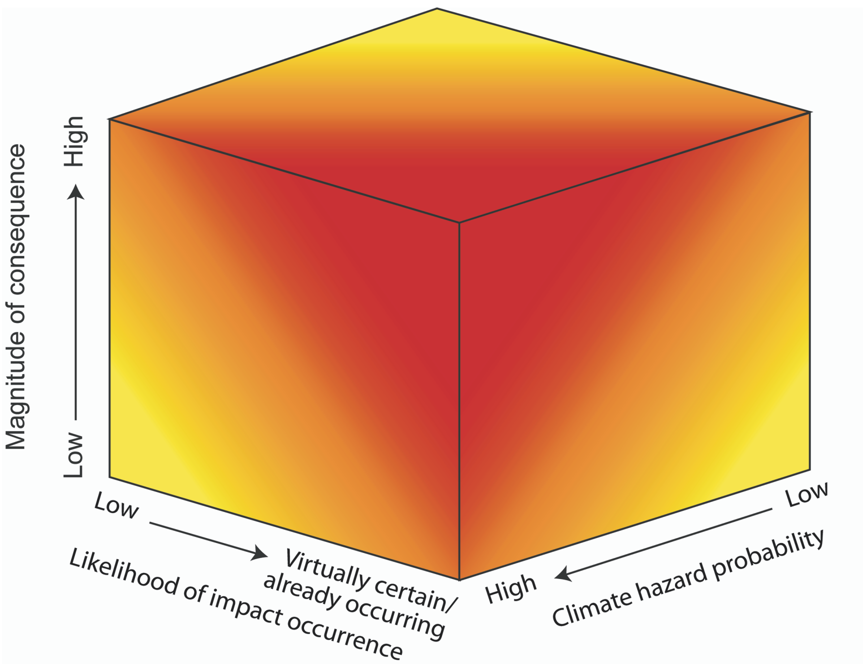
If an adaptation measure is underway or planned and fully funded, stakeholders were instructed to take into account the benefits gained from those measures when determining the likelihood of impact.

As a helpful aid in conceptualizing the process of prioritizing risk, it is useful to consider the work of the Task Force Risk Matrix in conjunction with the use of the CRI information on the probability of the climate hazards. This leads to a generalized three-dimensional risk matrix as shown in Figure 6. In application, the Task Force found it more useful to disaggregate these multiple dimensions of risk.

"Probability of Climate Hazards" can be defined as the general probability for change in a climate hazard (such as temperatures or extreme precipitation events) occurring over the lifespan of the infrastructure. Using the CRI as a guide, these can be defined as:

- **High** High probability of the climate hazard occurring
- **Medium** Medium probability of the climate hazard occurring
- **Low** Low probability of the climate hazard occurring

FIGURE 6. Three-dimensional Climate Change Risk Assessment Matrix



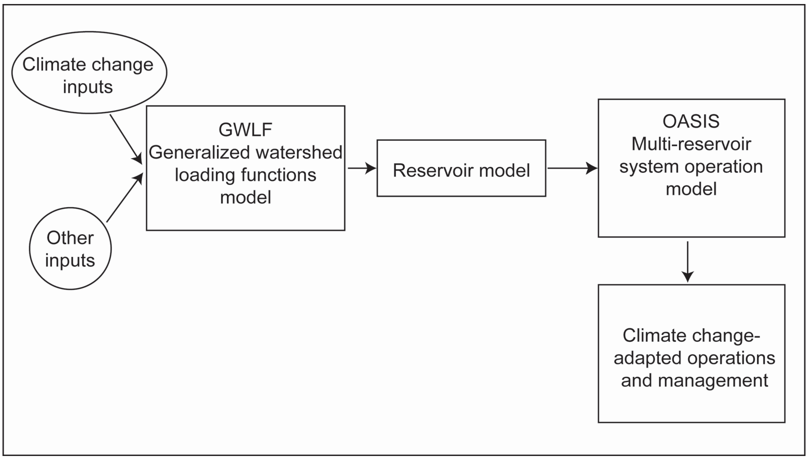
RED	*Risks for which adaptation strategies should be developed.*
ORANGE	*Risks for which adaptation strategies may need to be developed or for which further information is needed.*
YELLOW	*Risks for which impacts should be monitored but which may not need actions at this time.*

STEP 4: DEVELOP INITIAL ADAPTATION STRATEGIES

After stakeholders have associated risk levels with their inventory lists, they should develop initial ideas and plans for adaptation strategies to protect their infrastructure from climate change impacts. Adaptation strategies should be developed across an entire agency, and also in coordination with other stakeholders and as part of a city-wide effort.

Once adaptation strategies have been identified, they can be prioritized and ordered with the goal of creating an overall organization or agency-wide Adaptation Plan. Here the NPCC identifies one such approach to prioritizing strategies, which can be modified as necessary for use in different contexts. It is helpful to think of creating strategies in two parts. First, stakeholders list initial strategies and categorize them under maintenance and operations, capital investments, or regulatory. An example of adaptation through operations is given in Figure 7, which shows a reservoir model operating system based on that of the New York City Water Supply System. In the past, historical data on hydrology and other factors have been used to test systems operations; at present, the New York City Department of Environmental Protection (NYCDEP) has begun to use climate scenarios data to test possible operations under climate change (NYCDEP, 2008).

FIGURE 7. Use of Climate Change and Other Inputs in Water System Models to Guide Operations and Management Adaptations



An example of the potential role of infrastructure adaptations is shown in Figure 8, an instance of flooding at a NYC Water Pollution Control Plant. For such plants, and other coastal infrastructure, flood walls and/or pumping can be considered to protect against rising sea levels and storm surges.

FIGURE 8. Potential for Flood Protection

Treatment tanks overflowed at the Hunts Point (Bronx) WPCP during a March 2001 storm; unusually high tide elevations prevented discharge of treated sewage into the East River and caused back-up.
Source: New York City Department of Environmental Protection

Policy measures can provide potentially valuable adaptations, including joint operations of infrastructure systems with neighboring jurisdictions. Examples of general adaptation strategy categories are given in Table 4.

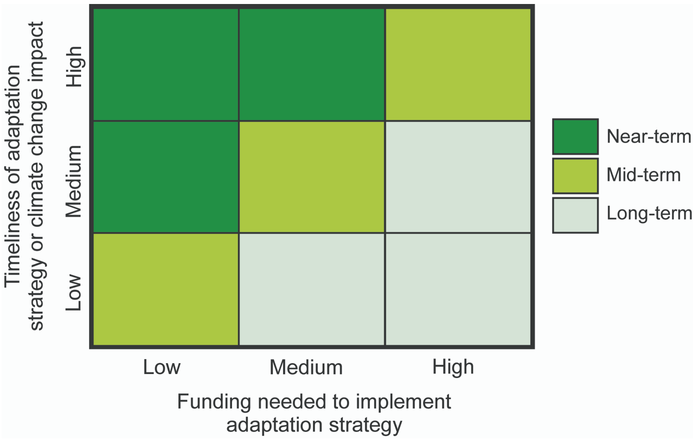
TABLE 4. General Adaptation Strategy Categories

Adaptation Categories	Examples
Maintenance & Operations	Increasing drains and gutters clearing to reduce flooding Changing reservoir systems management to reflect temperature and precipitation effects on water quality and quantity Revising bus routes to reflect changes in sea level rise, storm surge, and flooding
Capital Investments	New infrastructure Installation or increase in the height of flood barriers Relocation of critical elements or the entire infrastructure to higher ground Changes in construction materials Integrating “green” designs such as green roofs on buildings which house key infrastructure to reduce the building’s energy needs (both mitigation and adaptation) Retrofits to existing infrastructure
Regulatory	Zoning and emergency management Rules for joint operations for water, energy, transportation, and communications with neighboring administrative and political units Design specifications and standards Permitting process

Then, stakeholders can employ a prioritization framework to evaluate and rank strategies. In its most general form, the ranking of strategies over time is a complex optimal scheduling problem using multiple criteria or multiobjective planning. In practical applications, however, more straightforward assessment methods can help substantially in the ranking process. In the Task Force efforts, a Prioritization Matrix with a detailed focus on cost and timing based on stakeholder assessments was appropriate because many other elements had been considered in the Risk Matrix. The Prioritization Matrix that resulted from this process in shown in Figure 9.

- **Cost.** what are the general costs of the proposed strategy, including human and other resources? This ranking focuses on the cost to implement the strategy, in order to forestall the consequences examined earlier in the process. This can yield a rough measure of benefits and costs to the extent that the consequences are measured in economic terms. (There will, of course, be important non-economic consequences as well in most decision problems.)
- **Timing.** is this a strategy which needs to be implemented in the near-term, either because the climate impacts are already being felt or are expected to occur soon, or because there is a window of opportunity for action (i.e., an already-planned system upgrade). The timing of implementation should be considered relative to the timing of impact. Specifically, if the impact will occur in a time frame comparable to the time required for implementation, there is need for immediate consideration.

FIGURE 9. Task Force Prioritization Matrix



Source: City of New York

Notes from the Task Force
Step 4. Develop Initial Adaptation Strategies

Adaptation strategies were developed and prioritized within the Task Force. While individual Task Force members developed their own adaptation strategies, these strategies were discussed within and between working groups in order to share best practices and identify opportunities for joint action to maximize the value of adaptations to the city. Adaptation strategies beyond the scope of individual stakeholders were identified as possible city-wide strategies for further study.

A more general approach to prioritizing adaptation strategies that illustrates the issues involved is discussed here, using the steps of categorizing and evaluating strategies.

1. Categorize Strategies Building on internal risk management and assessment policies, stakeholders begin to brainstorm strategies for those infrastructure classes that fall in the red and orange categories of the Risk Matrix. These strategies are then associated with one or more of the three categories: maintenance and operations, capital investments and regulation. Table 4 gives some examples of strategies in each category, but this is not meant to be an exhaustive list.

2. Evaluate Strategies Once stakeholders have an initial list of adaptation strategies, they should evaluate these strategies in order to determine an order in which they should be implemented, and begin to create a broader agency- or organization-wide Adaptation Plan (Step 7). There are a variety of methods and perspectives available to evaluate individual actions and strategies (Table 5).

Potential elements besides cost and timing to consider as part of evaluating adaptation strategies could include:

- **Feasibility** How feasible is the strategy for implementation both within an organization and from perspectives such as engineering, policy, legal, and insurance? Are there expected technological changes that would impact future feasibility?
- **Efficacy** To what extent will the strategy, if successfully implemented, reduce the risk?
- **Resiliency** Is there the potential to install equipment or upgrade infrastructure that is designed to withstand a range of climate hazards? Are there opportunities for Flexible Adaptation Pathways?
- **Co-benefits** Will any strategies have a negative or positive impact on another stakeholder or sector? Is there potential for cost sharing? Are there impacts on mitigation of greenhouse gases? Are there impacts on the environment or a vulnerable population?

Other factors can also be taken into consideration including equity, social justice, sustainability, institutional context and unique circumstances.

TABLE 5. An Example of a Generalized Strategy Prioritization Framework

Adaptation Strategy	Strategy Cost (1 = low to 3 = high)	Strategy Feasibility (1 = high to 3 = low)	Timing of implementation (1 = high to 3 = low)	Efficacy (1 = high to 3 = low)	Resiliency rating (1 = high to 3 = low)	Co-benefits (1 = high to 3 = low)	Average*	Notes & institutional considerations
Strategy 1	1	1	1	2	2	2	1.8	
Strategy 2	3	2	2	1	3	2	2.2	

**1 = high priority strategy, 2 = medium priority strategy, 3 = low priority strategy*
Rankings are illustrative only

Weighting Strategy Elements

As a general matter of decision theory, ranking depends on the definition of elements of importance, and then their weighting in some formal or informal way. In a decision problem, weights are used explicitly or implicitly to compare the many dimensions relevant to ranking. While it is challenging to estimate such weights with any exactitude, rough weighting schemes, with appropriate overrides, can help stakeholders to visualize the internal rankings for alternative strategies. Such weights are likely to vary among stakeholders and cities, as will the elements that are important in decision-making. Moreover, as adaptation planning methods develop, jurisdictions will be able to consider weighting elements of importance more explicitly than is usually done at present.

Stakeholders can also begin to apply, to the extent feasible, detailed evaluations of adaptations. The methods include benefit-cost analysis, financial analysis, and environmental analysis. In these applications, the detailed methods applied are adjusted to the new circumstances of climate change, in particular the loss of stationarity in the estimation of changing climate parameters.

STEP 5: IDENTIFY OPPORTUNITIES FOR COORDINATION

Climate change adaptation planning can yield greater benefits if not done in isolation for many reasons. Increased coordination has the potential to lower costs for individual stakeholders, focus implementation on those strategies that could benefit multiple stakeholders, and maximize resources and knowledge. Additionally, coordination helps to avoid actions undertaken by one stakeholder that could negatively impact another if not planned carefully (i.e., covering a subway grate could prevent tunnel flooding, but shift water to adjacent roadways, causing surface flooding). Coordinated city-wide strategies are often needed because of the complexity and interconnectivity of infrastructure, the fact that some strategies provide benefits to multiple stakeholders, and because some infrastructure is operated or controlled by multiple stakeholders. For example, waterfront property may be owned by one entity, managed by another, and obtain permits for use and development from yet another. This group of waterfront decision-makers can be composed of private companies; city, state, and federal agencies; and regional authorities.

There are opportunities for coordination in many sectors. An example is the potential for joint climate change adaptations among the passenger rail systems within and converging on New York City: New York City Transit, Metro North, and the Long Island Railroad, all under the control of the MTA; Amtrak; the Port Authority's Path System, and New Jersey Transit trains. These opportunities include adaptation potentials for operations, infrastructure, and policy.

If possible, climate change adaptation should be undertaken as a city-wide strategic initiative led from a high-level city-wide office. The broad range of public and private stakeholders who own, operate or maintain critical infrastructure within city boundaries should all be included in the initiative. This allows a process through which uniform climate change projections can be distributed and a comprehensive adaptation planning process developed. It is also important that adaptation planning include coordination with a jurisdiction's budget office so that climate change adaptation becomes a fiscal priority.

Notes from the Task Force
Step 5. Identify Opportunities for Coordination

The structure of the Task Force allows for multiple opportunities for coordination and cross-stakeholder interaction. Monthly sector working group meetings enabled frequent interaction within sectors and encouraged knowledge-sharing among stakeholders. Joint Working Group meetings between sectors were also held to discuss issues that spanned multiple sectors and additional meetings were held around cross-cutting themes identified as having a similar impact on multiple sectors (i.e., coastal flooding).

While it does not own or operate critical infrastructure, New York City's Office of Management and Budget (OMB) was included as a member of the Task Force, ensuring the City's fiscal staff received climate change adaptation information and were a part of the overall adaptation planning process.

STEP 6: LINK STRATEGIES TO CAPITAL AND REHABILITATION CYCLES

Stakeholders have capital budgets that extend over a variety of time periods, in some cases decades. These budgets should be reviewed to determine which adaptation strategies can be undertaken within existing funding constraints and what additional resources need to be identified. Linking adaptation strategies to planned projects or other non-adaptation efforts can result in significant cost savings. For example, if a flood wall will eventually be needed for a wastewater treatment plant on the coast, it will usually be cheaper to provide the space and the basic structural elements for such a wall during a rehabilitation cycle, than to add it on later. In addition, there may be planned maintenance, operations and policy changes that will provide opportunities for efficient scheduling of adaptations. Stakeholders are advised to put priority on exploring low-cost adaptation strategies, especially in times of economic hardship.

Capital budgeting is a careful and complex process, and involves many billions of dollars over years of investment. An example is given in Table 6, which is a summary of one part of the long-term capital plan of just one agency, the New York City Department of Environmental Protection (NYC DEP). Integration of climate change adaptation planning with capital budgeting can be expected to be effective and economic. As climate risk management becomes incorporated into infrastructure management and operations, such implementation plans can be incorporated into capital and operating budgets over the long run.

TABLE 6. NYCDEP Capital Budgeting Plan (Thousands of Dollars)

Sewers	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Replacement or Augmentation	23,535	42,586	17,731	56,203	6,160	32,924	70,722	90,377	49,266	21,000	54,922	465,426
Extensions to Accommodate New Development	84.422	74,671	58,390	113,986	60,870	64,913	62,643	50,593	58,561	60,921	37,891	727,861
Programmatic Response to Regulatory Mandates	540	____	9,900	____	____	____	____	____	____	____	____	10,440
Programmatic Replacement and Reconstruction	196	3,456	23,871	____	15,002	3,500	____	____	9,856	18,712	____	74,593
Replacement of Chronically Failing Components	89,025	89,770	70,743	62,841	78,304	79,051	77,916	75,368	57,750	70,876	57,750	809,394
Trunks	2,881	2,489	2,775	2,371	100	1,284	____	____	9,443	____	2,224	23,567
Subtotal	200,599	212,972	183,410	235,401	160,436	181,672	211,281	216,338	184,876	171,509	152,787	**2,111,281**

Source: NYCDEP New York City Municipal Water Finance Authority Official Statement 2009 http://nycbonds.org/NYW/pdf/2009/NYW_2009_GG.pdf

Notes from the Task Force
Step 6. Link Strategies to Capital and Rehabilitation Cycles

Task Force members were encouraged to link proposed adaptation strategies to their capital and maintenance budgets, as well as rehabilitation and replacement cycles to identify resources that could be used for adaptation. This facilitates the creation of actionable implementation plans.

STEP 7: PREPARE AND IMPLEMENT ADAPTATION PLANS

Stakeholders can compile the individual strategies developed in the previous steps into fully developed, comprehensive Adaptation Plans that include timeframes for implementation and identification of opportunities for coordination. Plans may include:

- **Adaptation strategies** that could include a near–term, low–cost, easy–to–implement operational strategy; a medium–term, more aggressive capital strategy; and finally, a longer–term, if necessary, larger capital strategy
- **Specifics necessary to implement strategies**, such as processes used by stakeholders for Requests for Proposals
- **Resources committed to implement the plans**, as well as resources still needed and areas for further research
- **Timeline for implementation**
- **Metrics to measure success** including plans for reevaluation as new evidence on climate change, impacts, and adaptation strategies emerges.

Project planning may include economic benefit-cost analysis, financial analysis and environmental impact statements. Equity and environmental justice also need to be taken into consideration.

Adaptation Plans should be updated on a regular basis to ensure consistency with the latest climate science knowledge, adaptation experience and best practices. Examples of perspectives on planning that can usefully be reviewed are given in Table 7, based on some of the questions in the Infrastructure Questionnaires in regard to linking Adaptation Plans to climate change mitigation, emergency management and business continuity plans.

TABLE 7. Examples of Perspectives on Developing Adaptation Plans

Are there opportunities to build adaptation strategies into existing greenhouse gas mitigation efforts?
Are there opportunities to build in adaptation strategies to existing emergency management plans?
Is there an existing business/agency continuity plan in place or under development? • Are the base level assumptions documented in the plan? (i.e., what threat levels is it based on?) • Does the plan address management continuity and decision-making? • Does the plan include assessments of the impact of electrical and communications breakdowns?

Notes from the Task Force
Step 7. Prepare and Implement Adaptation Plans

Task Force members are developing individual Adaptation Plans using templates developed by the City and the BCG. These preliminary plans will guide future activities by the Task Force members. In addition, the Task Force as a whole is developing an overall climate resilience plan.

STEP 8: MONITOR & REASSESS

Monitoring and reassessment is an important long-term component of climate risk management and development of Flexible Adaptation Pathways; Step 8 includes monitoring and reassessment of:

- **Physical climate hazards** such as improved Global Climate Models (GCMs) and longer data sets;
- **Infrastructure impacts** such as flooding in coastal zone residential and commercial facilities and climate-related transportation disruptions;
- **Adaptation measures** including tracking of advances in technology, materials science, and engineering and changes in the regulatory environment; and
- **New research within each of these categories.**

Continuously considering these and other factors in climate change adaptation planning can influence design and planning, and potentially result in more effective actions.

Monitoring Adaptation Plans in the region should be done on a regular basis both to determine if they are meeting their intended objectives and to discern any unforeseen consequences of the adaptation strategies. Plans should be adjusted accordingly to reflect changes in environmental conditions, climate change science, regulations, engineering and materials science, and other factors. Stakeholders should continue to monitor the effects of climate on their infrastructure and use updated climate risk information to determine further vulnerabilities. Monitoring and reassessment of climate science, technology and adaptation strategies will no doubt reveal additional indicators to track in the future.

Indicator categories extend beyond physical climate data collection to include updated climate change research findings and projections (Table 8). Monitoring should also include elements not directly related to climate, such as population and income, because of the complex nature of infrastructure planning. Monitoring climate change, climate change impacts and adaptations and developing the related indices for effectively capturing their trends is a complex set of tasks. These tasks may range from assuring continuation of monitoring and tracking of existing indicators, to developing new ones, and to determining the institutions to which these new tasks can be assigned with the expectation of continuity, reliability, quality control and public accessibility.

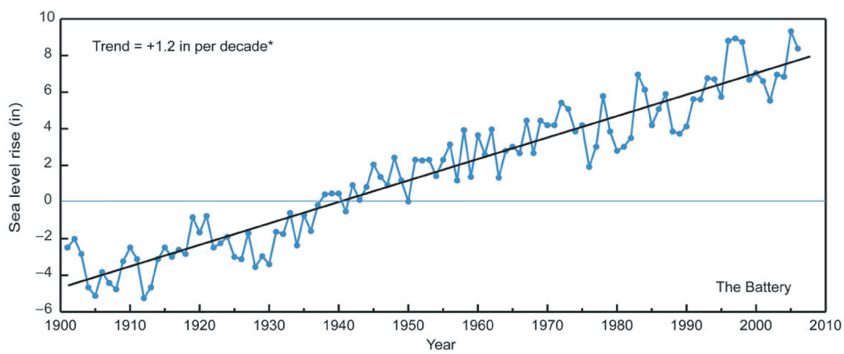
TABLE 8. Examples of Climate Variables for Monitoring and Developing Indicators

Temperature	Mean temperature	Central Park Kennedy Airport LaGuardia Airport	1876 - Present 1948 - Present 1947 - Present	Daily, Monthly Daily, Monthly Daily, Monthly	NCDC NCDC NCDC
	Days with Temp > X°F Days with Temp < X°F	Central Park La Guardia Airport	1944 - Present 1948 - Present	Monthly Monthly	NCDC NCDC
Precipitation	Total Precipitation	Central Park Kennedy Airport LaGuardia Airport	1876 - Present 1949 - Present 1947 - Present	Daily, Monthly Daily, Monthly Daily, Monthly	NCDC NCDC NCDC
	Days with rainfall > X inches	Central Park	1944 - Present	Monthly	NCDC
Sea level rise & coastal storms	Sea level rise-mean water level	The Battery Sandy Hook, New Jersey	1856 - Present 1932 - Present	Monthly Monthly	NOS NOS
	Hurricanes	Central Park	1900 - Present	Daily	NCDC

National Climatic Data Center (NCDC), National Ocean Service (NOS)

The importance of monitoring is suggested by the data on sea level rise in the 20th century. Globally, sea level rose by 7 inches; in the New York City area it rose by approximately 10 inches because of local subsidence resulting from the very long-term adjustment of the earth's surface to the glacial recession of the last ice age (Figure 10).

FIGURE 10. Observed 20th Century Sea Level Rise In New York City



Notes from the Task Force
Step 8. Monitor and Reassess

By continuing to monitor and reassess, making iterative adjustments in adaptation strategies as appropriate, New York City will be able to minimize negative impacts and maximize benefits of climate change, and increase the resiliency and effectiveness of its critical infrastructure in meeting the needs of its citizens.

4. ANNEXES

A. INFRASTRUCTURE QUESTIONNAIRES
- Communications
- Energy
- Transportation
- Water and Waste
- Policy

B. THE NATIONAL RESEARCH COUNCIL'S 2009 REPORT: *INFORMING DECISIONS IN A CHANGING CLIMATE*, AND ITS RELATION TO CLIMATE CHANGE ADAPTATION IN NEW YORK CITY

C. OTHER ADAPTATION REPORTS: SUMMARIES AND LINKS

ANNEX A
Infrastructure Questionnaires (IQs)

The Infrastructure Questionnaires (IQs) contained in this workbook were created in partnership with the City and the Boston Consulting Group to assist members of the New York City Climate Change Adaptation Task Force to identify critical infrastructure that could be at-risk to climate change impacts. These IQs were developed for the Task Force Working Groups. These IQs are broadly relevant to most cities and other planning jurisdictions, although there will be changes relating to the coverage of infrastructure, economics, geography, demography and technology between jurisdictions.

The questionnaires are not intended to be exhaustive and do not capture all of the risks posed by climate change; they are intended to be used to begin the process of identifying at-risk infrastructure and should be augmented by additional resources and processes developed by stakeholders. By incorporating these questions into their existing capital and operational planning processes, stakeholders can help to ensure that new and existing assets are built to withstand projected climate change impacts.

Task Force Working Group Infrastructure Questionnaires can be found below for the following sectors:

- Communications
- Energy
- Transportation
- Water and Waste
- Policy

COMMUNICATIONS

Communications infrastructure includes, but is not limited to, lines, cables, towers, administrative and control installations, and other facilities.

A	What is the nature and purpose of the infrastructure? What are the principal elements of the infrastructure, including specific elements and classes of infrastructure? ○ Is it considered critical to your mission or to the City? ○ Is it a network (e.g. a pipe, power line) or a point of production or distribution?
B	Location on land (GPS) (including distributed systems)
C	What is the shortest distance from current shoreline? (In the case of distributed networks, the shortest distance to the coast.) ○ Is this distance likely to change as a result of climate change?
D	Check the base elevation and height of infrastructure and its critical components (e.g., primary or back-up generators) against relevant markers to determine risk from flooding. ○ Does the asset currently experience coastal or storm-related flooding? ○ If so, will this be exacerbated by projected climate change impacts?
E	What is the useful life of infrastructure and current rehabilitation/maintenance schedule? ○ Are climate changes likely to occur during the infrastructure's useful life? ○ Are upgrades planned that could incorporate adaptation strategies? ○ Does the rehabilitation/maintenance schedule need to change to account for climate change impacts?
F	What is the current condition of infrastructure, including materials? ○ Will this be affected by increased temperatures and changing precipitation regimes, rising sea levels, or more frequent and severe extreme weather?
G	Is the infrastructure within any of the following defined areas that may impact potential strategies? For example: FEMA flood plain Historic Districts Wetlands and other protected interior and coastal areas
H	What impacts is the infrastructure already experiencing (and how frequently) relative to: (i) extreme temperatures, (ii) extreme and/or changing precipitation, (iii) sea level rise and/or (iv) extreme events (e.g., hurricanes, nor'easters, and droughts or intense rain events, etc)?
I	What operational practices, including interactions with regional/national systems and existing regulations, could be impacted by climate change?
J	Main climate impacts on infrastructure: Air temperature: For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of annual average temperature increases and increases in the number of extreme heat days. ○ Are infrastructure and/or materials at-risk from hotter air temperatures (e.g., wires, etc)? ○ Can the ventilation/cooling system handle the projected increase in temperatures? ○ How will increased temperatures affect operating costs? Precipitation: For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of change in annual rainfall and changes in the frequency and severity of storms. ○ Are there any IT/electrical equipment/valuable assets located in areas that could flood?

	○ Are pipes/drainage systems and entrance thresholds designed for (i) capacity intake and (ii) disposal of more rainfall, due to the potential for increased precipitation? ○ Will greater maintenance be required as a result of more frequent or intense precipitation? Sea level rise: For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of sea level rise and changes in storm surges. ○ Will the infrastructure be affected by coastal erosion? ○ Is the infrastructure more susceptible to coastal flooding and storm surges as a result of projected sea level rise? Extreme events ○ Is the system as a whole at-risk from extreme events (e.g., hurricanes, nor'easters)? ○ Is specific infrastructure (e.g., drainage systems, pipes, etc) equipped for extreme events? ○ Are you aware of new technologies or planning strategies employed elsewhere that could help mitigate the impacts of extreme events? ○ Do you have operational recovery plans in place and if so how often are drills conducted? Are the 'learning's" incorporated into operating procedures? ○ Can the asset be adequately manned for prolonged periods in extreme events and are provisions in place to ensure habitability? ○ Can your organization respond to an event that results in effects to multiple locations at the same time?
K	What current regulations and climate protection levels govern the design and/or operation of the infrastructure? ○ Are potential impacts of future climate change included when designing new or upgraded infrastructure?
L	Have any climate change protection plans been developed for this asset? Maintenance and operations Capital investments Policy/Regulatory
M	Are other agencies and/or jurisdictions involved in the operation, design, or oversight of the infrastructure?
N	Are there anticipated changes in communication technology that could impact future infrastructure needs?
O	Are there opportunities to build in adaptation strategies to existing greenhouse gas mitigation efforts?
P	Are there opportunities to build in adaptation strategies to existing hazard mitigation plans?
Q	What level of insurance coverage does the asset have?
R	Do you have an existing business continuity plan in place or under development? ○ Are the base level assumptions documented in your plan? ○ Does the plan address management continuity and decision-making? ○ Does your plan include assessments of the impact of electrical and communications break downs?

ENERGY

Energy infrastructure includes, but is not limited to, generating facilities, lines, towers, administrative and control structures, and other facilities.

A	What is the nature and purpose of the infrastructure? What are the principal elements of the infrastructure, including specific elements and classes of infrastructure? ○ Is it considered critical to your mission or to the City? ○ Is it a network (e.g. a pipe, power line) or a point of production or distribution?
B	Location on land (GPS) (including distributed systems)
C	What is the shortest distance from current shoreline? (In the case of distributed networks, the shortest distance to the coast.) ○ Is this likely to change as a result of climate change?
D	Check the height of infrastructure and its critical components (i.e., primary or back-up generators) against relevant markers to determine risk from flooding. ○ Does the asset currently experience coastal or storm-related flooding? ○ If so, will this be exacerbated by projected climate change impacts?
E	What is the useful life of infrastructure and current rehabilitation/maintenance schedule? ○ Are climate changes likely to occur during the infrastructure's useful life? ○ Are upgrades planned that could incorporate adaptation strategies? ○ Does the rehabilitation/maintenance schedule need to change to account for impacts?
F	What is the current condition of infrastructure, including materials? ○ Will this be affected by increased temperatures and precipitation, rising sea levels, or more frequent and severe extreme weather?
G	Is the infrastructure within any of the following defined areas that may impact potential strategies? For example: FEMA flood plain Historic Districts Wetlands and other protected interior and coastal areas
H	What impacts is the infrastructure already experiencing (and how frequently) relative to: (i) extreme temperatures, (ii) extreme and/or increased precipitation, (iii) sea level rise and/or (iv) extreme events (e.g., hurricanes, cyclones, and intense rain events, etc)?
I	What operational practices, including interactions with regional/national systems and existing regulations, could be impacted by climate change?
J	Main climate impacts on infrastructure: Air temperature: For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of annual average temperature increases and increases in the number of extreme heat days. ○ Are infrastructure and/or materials at-risk from hotter air temperatures (e.g., wires, etc)? ○ Can the ventilation/cooling system handle the projected increase in temperature? ○ How will increased temperatures affect operating costs? Precipitation: For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of change in annual rainfall and changes in the frequency and severity of storms. ○ Are there any IT/electrical equipment/valuable assets located in areas that could flood? ○ Are pipes/drainage systems and entrance thresholds designed for (i) capacity intake and (ii) disposal of more rainfall, due to increased precipitation? Sea level rise: For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of sea level rise and changes in storm surges. ○ Will the infrastructure be affected by coastal erosion?

	○ Is the infrastructure more susceptible to coastal flooding and storm surges as a result of projected sea level rise? Extreme events ○ Is the system as a whole at-risk from extreme events (e.g., hurricanes, nor'easters)? ○ Is specific infrastructure (e.g., drainage systems, pipes, etc) equipped for extreme events? ○ Are you aware of new technologies or planning strategies employed elsewhere that could help mitigate the impacts of extreme events? ○ Do you have operational recovery plans in place and if so how often are drills conducted. Are the 'learning's' incorporated into operating procedures? ○ Can the asset(s) be adequately manned for prolonged periods in extreme events and are provisions in place to ensure habitability? ○ Has the effect of a prolonged heat wave been analyzed for impacts to feeder cables, transformers, switchgear etc.? If so what response measures are in place? ○ If consumption temporarily exceeds capacity, are contingency plans in place that would allow local deployment of generation? Should mobile sources of generation be considered for future planning purposes? ○ Can the electrical distribution system continue to function with multiple impacted locations? ○ What sources of electrical generation outside of NYC can be relied upon to supply or supplement the loss of in-city generation? ○ Are the number of dual fueled generation sites in NYC sufficient to provide a prolonged source of power given the loss of one fuel type or the other?
K	What current regulations govern the design and/or operation of the infrastructure? ○ Are potential impacts of future climate change included when designing new or upgraded infrastructure?
L	Have any climate change protection plans been developed for this asset? Maintenance and operations Capital investments Policy/Regulatory
M	Are other agencies and/or jurisdictions involved in the operation, design, or oversight of the infrastructure?
N	Are there anticipated changes in energy technology and sources that could impact future needs?
O	Are there opportunities to build in adaptation strategies to existing mitigation efforts?
P	Are there opportunities to build in adaptation strategies to existing hazard mitigation plans?
Q	What level of insurance coverage does the asset have?
R	Do you have an existing business continuity plan in place or under development? ○ Are the base level assumptions documented in your plan? ○ Does your plan include the potential for electrical and communications break downs? ○ Does the plan address management continuity and decision making in an event?

TRANSPORTATION

Transportation infrastructure includes, but is not limited to, subways, trains, buses, airports, roads, bridges, tracks, administrative and support structures, and other facilities.

A	What is the nature and purpose of the infrastructure? What are the principal elements of the infrastructure, including specific elements and classes of infrastructure? ○ Is it considered critical to your mission or to the City? ○ Is it a network (e.g. a pipe, power line) or a point of production or distribution?
B	Location on land (GPS)
C	What is the shortest distance from current shoreline? (In the case of distributed networks, the shortest distance to the coast.) ○ Is this distance likely to change as a result of climate change?
D	Check the elevation and height of infrastructure and its critical components (i.e., primary or back-up generators) against relevant markers to determine risk from flooding. ○ Does the asset currently experience coastal or storm-related flooding? ○ If so, will this be exacerbated by projected climate change impacts?
E	What is the useful life of infrastructure and current rehabilitation/maintenance schedule? ○ Are climate changes likely to occur during the infrastructure's useful life? ○ Are upgrades planned that could incorporate adaptation strategies? ○ Does the rehabilitation/maintenance schedule need to change to account for impacts?
F	What is the current condition of infrastructure, including materials? ○ Will this be affected by increased temperatures and precipitation, rising sea levels, or more frequent and severe extreme weather?
G	Is the infrastructure within any of the following defined areas that may impact potential strategies? For example: FEMA flood plain Historic Districts Wetlands and other protected interior and coastal areas
H	What impacts is the infrastructure already experiencing (and how frequently) relative to: (i) extreme temperatures, (ii) extreme and/or increased precipitation, (iii) sea level rise and/or (iv) extreme events (e.g., hurricanes, cyclones, and intense rain events, etc)?
I	What operational practices, including interactions with regional/national systems and existing regulations, could be impacted by climate change?
J	Main climate impacts on infrastructure: <u>Air temperature:</u> For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of annual average temperature increases and increases in the number of extreme heat days. ○ Are infrastructure and/or materials at-risk from hotter air temperatures (e.g., wires, etc)? ○ Can the ventilation/cooling system handle the projected increase in temperature? ○ How will increased temperatures affect operating costs? <u>Precipitation:</u> For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of change in annual rainfall and changes in the frequency and severity of storms. ○ Are there any IT/electrical equipment/valuable assets located in areas that could flood? ○ Are pipes/drainage systems and entrance thresholds designed for (i) capacity intake and (ii) disposal of more rainfall, due to increased precipitation and/or more intense periods of rainfall? ○ Will greater maintenance be required as a result of more frequent or intense precipitation? <u>Sea level rise:</u> For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of sea level rise and changes in storm surges.

	○ Will the infrastructure be affected by coastal erosion? ○ Is the infrastructure more susceptible to coastal flooding and storm surges as a result of projected sea level rise? Extreme events ○ Is the system as a whole at-risk from extreme events (e.g., hurricanes, nor'easters)? ○ Is specific infrastructure (e.g., drainage systems, pipes, etc) equipped for extreme events? ○ Are you aware of new technologies or planning strategies employed elsewhere that could help mitigate the impacts of extreme events? ○ Do you have operational recovery plans in place and if so how often are drills conducted? Are the 'learning's" incorporated into operating procedures? ○ Can the asset(s) be adequately manned for prolonged periods in extreme events and are provisions in place to ensure habitability? ○ Can your organization respond to an event that results in effects to multiple locations at the same time?
K	What current regulations govern the design and/or operation of the infrastructure? ○ Are potential impacts of future climate change included when designing new or upgraded infrastructure?
L	Have any climate change protection plans been developed for this asset? Maintenance and operations Capital investments Policy/Regulatory
M	Are other agencies and/or jurisdictions involved in the operation, design, or oversight of the infrastructure?
N	Are there anticipated changes in transportation technology and planning that could impact future infrastructure needs?
O	Are there opportunities to build in adaptation strategies to existing greenhouse gas mitigation efforts?
P	Are there opportunities to build in adaptation strategies to existing hazard mitigation plans?
Q	What level of insurance coverage does the asset have?
R	Do you have an existing business continuity plan in place or under development? ○ Are the base level assumptions documented in your plan? (i.e., what threat levels is it based on?) ○ Does your plan include assessments of the impact of electrical and communications break downs? ○ Does the plan address management continuity and decision making in an event?

WATER & WASTE

Water and waste infrastructure includes, but is not limited to, drains, sewers, water pollution control plants, marine transfer stations, parks, wetlands, trees, and administrative and control structures and other facilities.

A	What is the nature and purpose of the infrastructure? What are the principal elements of the infrastructure, including specific elements and classes of infrastructure? ○ Is it considered critical to your mission or to the City? ○ Is it a network (e.g. a pipe, power line) or a point of production or distribution?
B	Location on land (GPS) (including distributed systems)
C	What is the shortest distance from current shoreline? (In the case of distributed networks, the shortest distance to the coast.) ○ Is this distance likely to change as a result of climate change?
D	Check the base elevation and height of infrastructure and its critical components (i.e., include primary or back-up generators) against relevant markers to determine risk from flooding. ○ Does the asset currently experience coastal or storm-related flooding? ○ If so, will this be exacerbated by projected climate change impacts?
E	What is the useful life of infrastructure and current rehabilitation/maintenance schedule? ○ Are climate changes likely to occur during the infrastructure's useful life? ○ Are upgrades planned that could incorporate adaptation strategies? ○ Does the rehabilitation/maintenance schedule need to change to account for climate change impacts?
F	What is the current condition of infrastructure, including materials? ○ Will this be affected by increased temperatures and precipitation, rising sea levels, or more frequent and severe extreme weather?
G	Is the infrastructure within any of the following defined areas that may impact potential strategies? For example: FEMA flood plain Historic Districts Wetlands and other protected interior and coastal areas
H	What impacts is the infrastructure already experiencing (and how frequently) relative to: (i) extreme temperatures, (ii) extreme and/or increased precipitation, (iii) sea level rise and/or (iv) extreme events (e.g., hurricanes, cyclones, and intense rain events, etc)?
I	What operational practices, including interactions with regional/national systems and existing regulations, could be impacted by climate change?
J	Main climate impacts on infrastructure: Air temperature: For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of annual average temperature increases and increases in the number of extreme heat days. ○ Is infrastructure and/or materials at-risk from hotter air temperatures (e.g., wires, etc)? ○ Can the ventilation/cooling system handle the projected increase in the number of hotter days? ○ How will increased temperatures affect operating costs? Precipitation: For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of change in annual rainfall and changes in the frequency and severity of storms. ○ Are there any IT/electrical equipment/valuable assets located in areas that could flood? ○ Are pipes/drainage systems and entrance thresholds designed for (i) capacity intake and (ii) disposal of more rainfall, due to increased precipitation and/or more intense periods of rainfall?

	○ Will greater maintenance be required as a result of more frequent or intense precipitations, e.g. to clear brush from drainage channels? Sea level rise: For inventory purposes and for the time periods of the 2020s, 2050s, and 2080s, refer to the Climate Risk Information (CRI) for ranges of sea level rise and changes in storm surges. ○ Will the infrastructure be affected by coastal erosion? ○ Is the infrastructure more susceptible to coastal flooding and storm surges as a result of projected sea level rise? Extreme events ○ Is the system as a whole at-risk from extreme events (e.g., hurricanes, nor'easters)? ○ Is specific infrastructure (e.g., drainage systems, pipes, etc) equipped for extreme events ○ Are you aware of new technologies or planning strategies employed elsewhere that could help mitigate the impacts of extreme events? ○ Do you have operational recovery plans in place and if so how often are drills conducted? Are the 'learning's" incorporated into operating procedures? ○ Can the asset(s) be adequately manned for prolonged periods in extreme events and are provisions in place to ensure habitability? ○ Can your organization respond to an event that results in effects to multiple locations at the same time?
K	What current regulations govern the design and/or operation of the infrastructure? ○ Are potential impacts of future climate change included when designing new or upgraded infrastructure?
L	Have any climate change protection plans been developed for this asset? Maintenance and operations Capital investments Policy/Regulatory
M	Are other agencies and/or jurisdictions involved in the operation, design, or oversight of the infrastructure?
N	Are there anticipated changes in water and waste technology that could impact future infrastructure needs?
O	Are there opportunities to build in adaptation strategies to existing greenhouse gas mitigation efforts?
P	Are there opportunities to build in adaptation strategies to existing hazard mitigation plans?
Q	What level of insurance coverage does the asset have?
R	Do you have an existing business continuity plan in place or under development? ○ Are the base level assumptions documented in your plan? (i.e., what threat levels is it based on?) ○ Does your plan include assessments of the impact of electrical and communications break downs? ○ Does the plan address management continuity and decision making in an event?

POLICY

A	What policies, guidelines, or regulations do you follow/oversee that govern infrastructure and development in New York City (i.e., energy regulations, zoning, building and construction codes, drainage specifications)? ○ To what extent do these currently reflect the risks of climate change impacts? ○ Are there elements that need to be changed to reflect risks of climate change impacts?
B	How does climate change adaptation relate to existing hazard mitigation efforts? ○ Are there synergies between the two efforts that could be taken advantage of in order to economize on time and/or money?
C	What existing policies, guidelines or regulations may conflict with any changes to or new policies, guidelines or regulations reflecting adaptation to risks of climate change impacts?

ANNEX B

The National Research Council's 2009 Report: *Informing Decisions in a Changing Climate*, and its relation to climate change adaptation in New York City

This report of the National Research Council (2009) provides a summary and evaluation of Best Practice approaches to climate change, including actions in New York City (Appendix A, Climate Change and the New York Metropolitan Region). Throughout, this report relates to the methods used by the Climate Change Adaptation Task Force. Three elements of the report, cited here, make this clear. The first is a key recommendation of the study:

> Agencies in their own decision support activities and in fostering decision support by others should use the approach of deliberation with analysis when feasible. This is the process most likely to encourage the emergence of good climate-related decisions over time (pg. 3).

Second, conclusion 1 of the report states:

> "The end of '*Climate Stationarity*' requires that organizations and individuals alter their standard practices and decision routines to take climate change into account. Scientific priorities and practices also need to change so that the scientific community can provide better support to decision makers in managing emerging climate risks (p. 16)."

This conclusion embodies the main thrust of New York City climate program (Rosenzweig et al., 2007).

Third, the Report's Six Principles for Effective Decision Support Capabilities (pp. 40–41) are:

> *1. Begin with users' needs:* Decision support activities should be driven by users' needs, not by scientific research priorities. These needs are not always known in advance, and should be identified collaboratively and iteratively in ongoing two-way communication between knowledge producers and decision makers. The latter can usefully be thought of as constituencies—collections of decision makers who face similar climate-related choices and, therefore, have similar information needs.
>
> *2. Give priority to processes over products:* To get the right products, start with the right process. Decision support is not merely about producing the right kinds of information products. Without

attention to process, products are likely to be inferior—although excessive attention to process without delivery of useful products can also be ineffective.

3. Link information producers and users: Decision support systems require networks and institutions linking information producers and users. The cultures and incentives of science and practice are different, for good reason, and those differences need to be respected if a productive and durable relationship is to be built.

4. Build connections across disciplines and organizations: Decision support services and products must account for the multidisciplinary character of the needed information, the many organizations that share decision arenas, and the wider decision context.

5. Seek institutional stability: Decision support systems need stable support. This can be achieved through formal institutionalization, less formal but long-lasting network building, establishing new decision routines, and mandates, along with committed funding and personnel. Stable decision support systems are able to obtain greater visibility, stature, longevity, and effectiveness.

6. Design for learning: Decision support systems should be structured for flexibility, adaptability, and learning from experience.

Although couched in different terms during the course of New York City's climate change adaptation process, these six principles are closely linked to that experience throughout.

ANNEX C
Other Adaptation Reports: Summaries and Links

Climate change adaptation efforts are currently underway across the world. This Annex provides an overview of selected adaptation planning documents, including those reviewed in developing approaches for New York City.

Canadian Communities' Guidebook for Adaptation to Climate Change, First Edition
Livia Bizikova, Tina Neale, Ian Burton.
Adaptation and Impacts Research Division (AIRD) Environment Canada.2008
http://www.forestry.ubc.ca/LinkClick.aspx?fileticket=xsexCSatHjo%3D&tabid=2455&mid=5415&language=en-US
This study focuses on Canada, with the intention of influencing local governments within that country. Sectors include water, infrastructure, forestry, farming, coastal areas, public health, energy, industrial and recreation. The basic process consists of identifying SAM (Sustainable development, Adaptation and Mitigation) initiatives, assessing their current state, developing a future vision then setting a path to achieve the initiative. Criteria are proposed to help evaluate SAM initiatives and case studies are used to illustrate promising initiatives. The process is intended to include policy makers, local governments, community leaders, researchers and experts in the climate science field.

The London Climate Change Adaptation Strategy 2008
Greater London Authority
http://www.london.gov.uk/mayor/publications/2008/docs/climate-change-adapt-strat.pdf
The London report lists a variety of risks associated with climate change that are relevant to London, along with the Mayor of London's recommendations of how these risks should be addressed. The Mayor's strategy is composed of the following steps: identifying the likelihood of impacts, establishing a risk baseline, identifying where more information is needed, providing policy and guidance where precautionary action is needed, recommending where emergency plans need to be developed, and recommending areas where London can set an example as a climate change adaptation leader. The sectors on which the report focuses include public health, environment, transportation, energy, business finance and waste.

Chicago Climate Action Plan
Chicago Climate Task Force
Co-Chairs: Sadhu A. Johnston, Adele Simmons.
The World Conservation Union, International Institute for Sustainable Development, Stockholm Environment Institute, InterCooperation
2008

http://www.chicagoclimateaction.org/filebin/pdf/finalreport/CCAPREPORTFINAL.pdf
The Chicago plan focuses on 5 main strategies, 4 of which are intended to mitigate climate change. These strategies promote energy efficient buildings, clean & renewable energy, improved transportation options and waste reduction, all within the City of Chicago. The fifth strategy deals with adaptation and proposes measures to address heating and cooling, air quality and stormwater, green urban design, engaging businesses and the public and planning for the future. The adaptation portion of the report describes the steps the City of Chicago is taking in working with various stakeholders to develop strategies for the city.

Climate Change 101: Adaptation
Pew Center on Global Climate Change
2009
http://www.pewclimate.org/docUploads/Climate101-Adaptation-Jan09.pdf
The Pew report gives an overview of climate change science and the associated risks for the entire United States, including Puerto Rico and U.S. territories. Projected climate impacts are listed by region (e.g. West, Southwest, Mid-Atlantic) and by sector. The sectors addressed in this report include freshwater, agriculture, coastal zones, forestry, tourism and recreation, public health and transportation. The report puts forth a general process for developing adaptation strategies consisting of the following steps: recognize that development must take place on a local level, identify key vulnerabilities, identify all key stakeholders, set priorities for action, and choose adaptation options based on careful assessment.

Adapting to Climate Variability and Change
United States Agency of International Development
2007
http://www.usaid.gov/our_work/environment/climate/docs/reports/cc_vamanual.pdf
The USAID study focuses on the effects of climate change on countries throughout the world. The report is intended to help planners and stakeholders in any country to develop their own adaptation strategies. Recommendations and explanations span a variety of sectors, including agriculture, environment, economic growth and trade, energy, industry, public health, and peace and security. USAID puts forth a 6-step process; screen for vulnerabilities, identify adaptations, conduct analysis, select course of action, implement adaptations, and then evaluate adaptations. Several case studies of adaptation strategies are presented and evaluated using an analysis matrix based on the following components: effectiveness, cost, cultural feasibility, adequacy, speed of implementation and consistency with state policy.

Cities Preparing for Climate Change
The Clean Air Partnership—P.I.: Eva Ligeti.
Authors: Jennifer Penney & Ireen Wieditz.
Advisory committee:
Ian Burton (Environment Canada),
Monica Campbell
(Environmental Protection Office, Toronto Public Health),
Priscilla Cranley

(formerly Office of the City Manager, City of Toronto),
Martin Herzog (Office of the City Manager, City of Toronto), Christopher Morgan (Toronto Environment Office)
2007
http://www.cleanairpartnership.org/pdf/cities_climate_change.pdf
This report is an analysis of six regional climate reports from the following cities: Boston, Halifax, London, New York (MEC), Seattle and Vancouver. Best practices and successful strategies were drawn from each of the reports and compiled. The basic, successful adaptation process described consists of the following steps: awareness and engagement of stakeholders, assessment of current conditions, historical trends, climate change projections and potential impacts, identification of adaptation options, establishment of institutional mechanisms, formulation of policy, and explicit implementation of adaptation measures. Adaptation options were identified for the following sectors; water supply, stormwater systems, energy, transportation, buildings, urban ecosystems and public health.

Infrastructure Systems, Services and Climate Change: Integrated Impacts and Response Strategies for the Boston Metropolitan Area (a.k.a Climate's Long-term Impacts on Metro Boston or CLIMB)
P.I.'s: Paul Kirshen (Boston University) and Matthias Ruth (University of Maryland)
Major Faculty: William Anderson (Boston University) and T.R. Lakshmanan (Boston University)
2004
http://www.publicpolicy.umd.edu/faculty/ruth/CLIMB_exec_summ.pdf (exec. summary only)
The majority of this report focuses on impacts to infrastructure, however, one public health aspect is analyzed, heat-related mortality. The report is intended for local, regional, state and national decision-makers, as, it is argued, the former two typically make infrastructure decisions while the latter two design related policy. The regional scope of the report focuses exclusively on the metropolitan Boston area. The basic process proposed for adaptation is as follows: document and analyze the state of existing infrastructure systems, determine the direct and indirect impacts of climate change on those systems, identify and prioritize policies that will meet stakeholder needs regarding the provision of infrastructure services, and collaborate with the Metropolitan Area Planning Council to ensure stakeholder needs are being addressed and properly communicated to decision-makers and the public.

Climate Resilient Cities—A Primer on Reducing Vulnerabilities to Disasters
The World Bank
Authors: Neeraj Prasad, Federica Ranghieri, Fatima Shah, Zoe Trohanis, Earl Kessler and Ravi Sinha
2009
http://siteresources.worldbank.org/INTEAPREGTOPURBDEV/Resources/Primer_e_book.pdf
This World Bank report was prepared as a climate change adaptation guide for local governments in East Asia and is applicable for cities that are in any stage of climate change policy development. Both mitigation and adaptation strategies are discussed, with a focus on the following sectors: water, ecosystems, food, coastal zones, public health, infrastructure, transportation and energy. While a basic framework for developing and implementing adaptation strategies is provided, the bulk of the information comes in examples of adaptation strategies that are considered to be "sound practices." The basic framework for

planning is described as follows: review and confirm the city's climate change team, review and discuss climate change preparation strategies, identify partnerships, discuss and develop specific adaptation measures, prepare a program to document the results of the plan, and identify start-up activities.

Survey of Climate Change Adaptation Planning
The H. John Heinz III Center for Science, Economics and the Environment
2007
http://www.heinzctr.org/publications/PDF/Adaptation_Report_October_10_2007.pdf
The Heinz study is a general survey designed to help generate discussion and the sharing of ideas regarding climate adaptation strategies, rather than to serve as a comprehensive assessment of best practices. The report provides an assessment of several other adaptation reports that ranks the usefulness of reports based on eight factors: applies to different levels of government and different environmental challenges, provides sufficient detail for policy construction, provides a decision-making framework, includes the means to assess variable factors, suggests steps for adaptive actions, covers implementation, provides links to additional resources, and includes stakeholders. This assessment covers several reports that focus on local, regional and global planning, so the audience for this report is quite varied. The report also highlights some adaptation plans in a variety of cities throughout the world.

New York City Department of Environmental Protection (DEP) Assessment and Action Plan, Report 1
Kate Demong, Gary Heath and Constance Vavilis
(New York City DEP),
John Atchley and Rose Marabetti
(Bureau of Communications and Intergovernmental Affairs),
Cynthia Rosenzweig, David C. Major, Radley Horton, Vivien Gornitz, Christina Stanton, Melissa Stults, Asher Siebert
(Columbia University Earth Institute Center for Climate Systems Research),
John P. St. John, William M. Leo and Phil Simmons
(HydroQual Environmental Engineers and Scientists),
Roger Meyer (Level M Alternative Brand Communications),
Warren Kurtz, P.E.
2008
http://www.nyc.gov/html/dep/pdf/climate/climate_complete.pdf
The NYCDEP report provides a very comprehensive assessment of climate change impacts in the New York City area, with a focus on water resources. Specifically, the scope is on climate impacts on water quality, water supply, coastal and inland floods, droughts, and water-related infrastructure. A detailed adaptation plan is laid out in 11 steps, from assessment to implementation, that proceeds as follows: identify the impact, quantify the impact, evaluate the likelihood of the impact occurring, estimate timeframe for occurrence, identify various adaptation strategies, quantify the cost and effectiveness of each strategy, evaluate the risks of implementing the strategy compared to not implementing it, develop a financial model that will sustain the strategy's investment, develop indicators that would trigger implementation, implement

and monitor adaptations, and reevaluate needs periodically. The report serves to illustrate NYC DEP's approach to adapting to climate-related impacts on local water systems, and can serve as both an educational tool and a planning template for other agencies and jurisdictions.

Preparing for Climate Change:
A Guidebook for Local, Regional, and State Governments
The Climate Impacts Group of the University of Washington, King County, Washington, and ICLEI — Local Governments for Sustainability
Dr. Amy K. Snover, Lara C. Whitely Binder and Dr. Jennifer Kay (Climate Impacts Group),
Ron Sims, Jim Lopez and Elizabeth Willmott (King County),
Michelle Wyman, Margit Hentschel and Annie Strickler, (ICLEI)
2007
http://cses.washington.edu/db/pdf/snoveretalgb574.pdf
The purpose of this report is to help decision-makers in local, regional, or state governments prepare for climate change and its related impacts. It is open-ended and can be used by a variety of policy makers in different regions. The report focuses on many sectors including water resources, agriculture, biodiversity, forests, recreation, energy, transportation, infrastructure, coastal zones, aquatic ecosystems, business, public health, and emergency response. The structure of the report divides different steps of the planning and adaptation process into different chapters. The sequence of this process, and the chapters, is as follows: identify climate change impacts to major sectors, build and maintain support for climate change action, build a climate change preparedness team, identify planning areas relevant to climate change, conduct a climate change vulnerability assessment, conduct a climate change risk assessment, set goals and develop preparedness plan, implement the plan, and measure progress and update plan.

National Climate Change Adaptation Framework
Council of Australian Governments
Australia
2007
http://www.coag.gov.au/coag_meeting_outcomes/2007-04-13/docs/national_climate_change_adaption_framework.pdf
As part of its Collaborative Action on Climate Change, The Council of Australian Governments requested this National Adaptation Framework for climate change. This report will guide jurisdictions over the next five to seven years in climate change-related actions that include: providing tools and guides to decision-makers, establishing a climate change information clearinghouse, providing climate projections at a regional scale, generating knowledge to manage climate impacts, working with stakeholders to evaluate risks, and assessing climate change implications. The report covers several sectors throughout Australia, including water resources, coastal regions, biodiversity, agriculture, fisheries, forestry, public health, tourism, infrastructure, and disaster management. In each of these sectors, risks are identified and examples of potential adaptation responses are suggested.

Vulnerability and Adaptation to Climate Change in Europe
European Environment Agency
Project Manager: André Jol
Alison Colls (Tyndall Centre, the United Kingdom),
Markus Erhard
(IMK-IFU, Forschungszentrum Karlsruhe, Germany),
Uta Fritsch (Potsdam Institute for Climate Impact Research),
Jelle van Minnen
(Netherlands Environmental Assessment Agency, the Netherlands),
Thomas Voigt (Umweltbundesamt, Germany).
2005
http://www.eea.europa.eu/publications/technical_report_2005_1207_144937/at_download/file
The EEA report provides an overview of key vulnerabilities and risks regarding climate change, as well as adaption strategies and their associated challenges. The report focuses exclusively on Europe; the sectors covered include agriculture, water, coastal zones, human health, tourism ecosystems, fisheries, and energy. Case studies are presented that document existing adaptation strategies in European countries, highlighting the successes and challenges faced by each. This report provides information on climate change risks and examples of adaptation methods.

Adapting to Climate Change—A Queensland Local Government Guide
Local Government Association of Queensland, Inc.
2007
http://www.lgaq.asn.au/lgaq/publications/LGAQ_Climate%20Change%20Adaptation%20Guide.pdf
The Queensland report provides a decision-making framework, checklists and other specific tools to help local Australian governments identify and respond to climate change impacts. The sections of the report are structured by specific climate change impacts (e.g. sea level rise, temperature increase, cyclones) and for each one a process for adaptation is provided. While the details of each process are different, a general framework is developed that consists of the following four basic steps: identify the risks, prioritize the risks, select response and adaptation measures, and implement an action plan. The risks and adaptation strategies presented are those faced by Queensland, so while some of the information provided can be applicable for any region, most information is relevant to regions with climates similar to Queensland's. The report covers a variety of sectors including public safety, environment, community and lifestyle, essential infrastructure, economic development, and financial and legal liabilities.

CRiSTAL: Community-based Risk Screening— Adaptation and Livelihoods, User's Manual
The World Conservation Union, International Institute for Sustainable Development, Stockholm Environment Institute, Inter Cooperation
2007
http://www.iisd.org/pdf/2008/cristal_manual.pdf
CRiSTAL is a decision support tool designed jointly by the aforementioned organizations that seeks to provide a logical, user-friendly process to help decision-makers better understand climate-related risks and

their effects on people's livelihoods. The user's manual provides an outline of the tool and details on how to use it correctly. The tool itself has two modules. The first one helps to collect and organize information on the climate and livelihood impacts of proposed projects, such as the goals, key questions, users, methodology, and time needed. This gives the project managers the chance to reassess and redesign adaptation measures as appropriate. The second module uses the information from the first to help decision-makers understand how the project's activities affect resources vulnerable to climate risks. The tool can be used for a variety of sectors in essentially any location, and seems particularly relevant for use by decision-makers who have direct influence over project development, implementation and management.

5. GLOSSARY & ABBREVIATIONS

** As defined by, or derived from, definitions used by the IPCC 2007.*

Adaptation*
Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change impacts. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, the substitution of more temperature shock resistant plants for sensitive ones, etc.

AR4
The Fourth Assessment Report of the IPCC, released in 2007.

Baseline*
The reference for measurable quantities from which an alternative outcome can be measured, e.g. a non-intervention scenario is used as a reference in the analysis of intervention scenarios.

Carbon Dioxide (CO_2)*
CO_2 is a naturally occurring gas, and a by-product of burning fossil fuels or biomass, of land-use changes and of industrial processes. It is the principal anthropogenic greenhouse gas that affects Earth's radiative balance.

Climate Change*
Climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climate Forcing*
Any mechanism that alters the global energy balance, causing the climate to change. Examples of climate forcings include variations in greenhouse gas concentrations and solar radiation.

Climate Hazards*
Climate variables which could have particular consequence for New York City and the surrounding region or other specified geographical areas. The main climate hazards discussed in this document are related to temperature, precipitation, sea level rise, and extreme events.

Critical Infrastructure
For the efforts of the New York City Climate Change Adaptation Task Force, critical infrastructure is defined as systems and assets (excluding residential and commercial buildings, handled by other city efforts) that support other activities which are so vital to the city that the diminished functioning or destruction of such systems and assets would have a debilitating impact on public safety and/or economic security.

Emissions Scenarios (see SRES)*

Global Climate Models (GCMs)*
A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity, i.e. for any one component or combination of components a hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which the parameters are assessed empirically. Coupled atmosphere/ocean/sea-ice Global Climate Models provide a comprehensive representation of the climate system. There is an evolution towards more complex models with active chemistry and biology.

Greenhouse Gases (GHGs)*
Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. This property causes the greenhouse effect. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine and bromine-containing substances, sulphur hexafluoride, hydrofluorocarbons, and perfluorocarbons.

HVAC
Heating Ventilation Air Condition Systems of key importance to many industrial and office buildings. These systems are especially important to maintaining proper temperature of vital system equipment as well as maintaining temperatures suitable for work forces.

Intergovernmental Panel on Climate Change (IPCC)
The IPCC was formed in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), and is the international advisory body on climate change.

Likelihood of Occurrence Ranges*
>99%: Virtually certain
>95% Extremely likely
>90% Very likely
>66% Likely
>50% More likely than not
33 to 66% About as likely as not
<33% Unlikely
<10% Very unlikely
<5% Extremely unlikely
<1% Exceptionally unlikely

Mitigation*
Technological change and substitutions that reduce resource inputs and emissions per unit of output. Several social, economic and technological policies would produce emissions reductions; with respect to climate change analysis, mitigation means implementing policies to reduce GHG emissions and enhance sinks.

New York City Climate Change Adaptation Task Force (Task Force)
The New York City Climate Change Adaptation Task Force is composed of approximately 40 stakeholders from city, state, and federal agencies; regional authorities; and private sector companies that operate, maintain, or regulate critical infrastructure in the region. The Task Force was launched in August, 2008 by Mayor Michael Bloomberg.

New York City Panel on Climate Change (NPCC)
The New York City Panel on Climate Change is the technical advisory body of the Task Force, and is composed of climate change and impacts scientists, and legal, insurance, and risk management experts.

Paleoclimate
Paleoclimate research uses the earth's historical climate archives from geophysical, geochemical and sedimentological data analyses to reconstruct various time periods and events in Earth's climate history prior to the modern instrumental record.

Risk
Risk is the product of the likelihood of an event occurring and the magnitude of consequence should that event occur. For the purposes of this report, likelihood is defined as the probability of occurrence of a climate hazard.

Scenario*
A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are useful to provide a view of the implications of developments and actions.

SRES*
The IPCC's Special Report on Emissions Scenarios, released in 2000. Each emissions scenario presented in the SRES makes different assumptions about population growth, economic growth, technological change, and land-use change, that lead to greenhouse gas emissions and atmospheric concentration trajectories. While no one single future emissions scenario or global climate model projection will occur exactly as specified, a combination of a suite of global climate model simulations and greenhouse gas emissions profiles provides a range of possible outcomes that can be expressed as a set of projections that reflects the current level of expert knowledge.

Timeslice
Projections in the CRI are given in three timeslices, 2020s, 2050s and the 2080s. The projections are a 30-year average, centered around each of the given timeslices (10-year for sea level rise scenarios). Climate models cannot well predict what the specific climate will be in any given year, due in part to the interannual variability of the climate variables, so the given projections are averages of future climate.

Uncertainty*
An expression of the degree to which a value is unknown (e.g. the future state of the climate system). Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or projections of human behavior. Uncertainty can be represented by quantitative

measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgment of a team of experts).

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