Adaptation Planning in Boston: Lessons Learned from New York, London, Toronto, and Beyond

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Prepared by Todd Schenk (MIT) under the guidance of Herman Karl (MIT-USGS Science Impact Collaborative), Jonathan Raab (Raab Associates and MIT), and Carl Spector (City of Boston)

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Introduction

Municipal climate change adaptation planning is still quite nascent. Very few municipalities are engaged in the task, with fewer still able to claim that their efforts are comprehensive and actionable. Nonetheless, there is value in examining existing efforts as the City of Boston initiates its own adaptation planning initiative. Boston's initiative will, indeed should, be particular to the conditions and resources of this time and place. It is, however, not in a wholly unique position and thus can learn from others. Many of the programmatic planning issues and approaches that must be considered are also more universal.

This report draws from the adaptation planning efforts of New York City, London and Toronto in particular. Much can be learned from these cities, which have similar climates to Boston, and relatively extensive adaptation planning strategies and ongoing efforts. [1] New York City and London are also both coastal cities, making sea level rise a central issue, as in Boston.[2]

The first section of this report focuses on some general observations and recommendations deduced from analysis of the London, New York and Toronto efforts and strategies, and from other research and analysis conducted by the author. These are in no particular order. Following the general observations and recommendations section are three lists of specific actions aggregated from various adaptation plans. The lists have been compiled by topic - sea level rise, heat waves and extreme storms – and ordered from the more general (i.e. policy and guidance) to the more specific (i.e. concrete infrastructural changes). These three areas are focused on as they were identified at the last subcommittee meeting as the key climate change-related threats Boston will face. The last three sections of this document are specific summaries and analyses of the New York, London and Toronto efforts respectively.

Observations and Recommendations

Enumerate the potential impacts of climate change

As a starting point, it is helpful to develop a list of the potential implications of climate change. Both the New York and Toronto strategies do this.[3] It is particularly useful to make these implications as relevant to the competencies of the city as possible. The Toronto list, for example, links hotter summers with an increased demand for water, and subsequently

[1] According to Kristina Katich's (2009) thesis - Urban Climate Resilience: A Global Assessment of City Adaptation Plans, page 37 (See: http://dspace.mit.edu/handle/1721.1/49698) - London and New York are, in fact, the only two adaptation strategies among those prepared by the world's megacities and capital cities that move beyond analysis and general statements to touch upon implementation. The Toronto strategy was not included in this analysis, but also extends to the particulars of implementation.

[2] While not directly on the coast, London faces similar problems, as the Thames is still tidal as it passes through the city.

[3] Page 27 of the New York City Climate Risk Information document introduced below, and page 23 of the Toronto document, Ahead of the Storm.

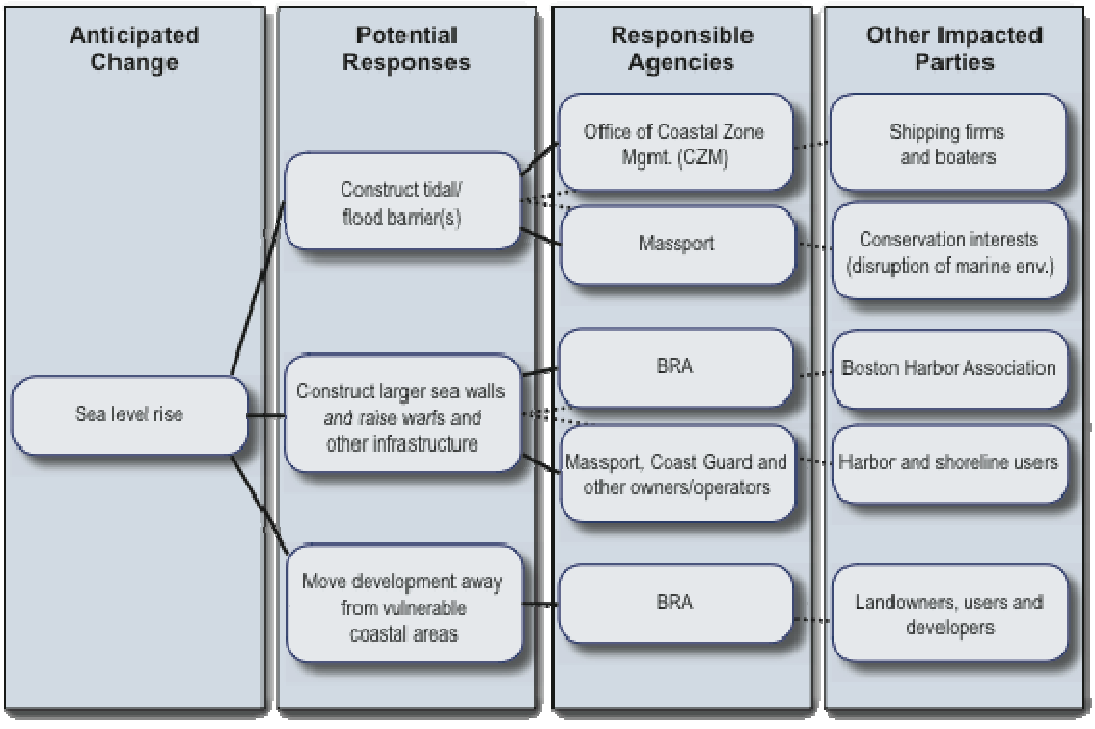
identifies Toronto Water as an affected city sector. The London strategy presents more comprehensive inventories of infrastructure at risk.[4] Some facilities – particularly those associated emergency services – may be more critical than ever in the event of climate-related catastrophes, making their resilience all the more invaluable. Of course, potential impacts identified need to be based on competent analysis and trusted data.

Clearly link proposed responses to responsible agencies and impacted parties

A weakness of many adaptation strategies is that the lines are not explicitly drawn connecting identified risks with potential solutions and subsequently through to the relevant implementing agencies and collateral impacts. The Toronto strategy is the most comprehensive in this regard, clearly linking potential actions with competent parties throughout.

Figure 1 below provides an example of how a fuller analysis of these relationships might be represented in the case of Boston.

Figure 1 – Making the relationship between climate change, potential responses, competent parties and collateral impacts explicit (E.g. Anticipated sea level rise)



[4] See page 15 of the London Climate Change Adaptation Strategy, for example.

Set concrete indicators and monitoring regimes

Existing strategies do a relatively poor job of setting concrete indicators (i.e. adaptation benchmarks) and plans for their monitoring and evaluation. This is perhaps not altogether surprising at this nascent stage, but nonetheless needs to be considered as planning evolves. Most plans do seem to recognize this; the Toronto plan, for example, calls for the establishment of "a formal mechanism for periodic review of progress on climate change adaptation which is communicated to decision-makers and the public to help ensure continual progress" (p.39).

Follow a strategy of adaptive management

As the Mayor of London's strategy points out, "Adaptation is a dynamic process… Measures that manage the impacts of our climate today may not provide the same level of protection or opportunity in the future, and so new measures will be needed as different thresholds are reached. There is therefore, no steady state of being 'adapted'" (xi). Efforts must be cognizant of this dynamism and subsequently flexible, learning from evolving conditions and the system's responses to adaptive measures taken.

Take a systems perspective

Any adaptive measures taken are likely to have a range of intended and unintended consequences. An increase in the use of air conditioning in response to rising temperatures, for example, leads to increased energy consumption and associated emissions, leading to further warming in an undesirable 'positive feedback loop'. Taking a systems perspective – recognizing the positive and negative feedback loops and exploiting or stymieing them as desired – can help overcome challenges and facilitate adaptive success.

What is risk?

Much of climate adaptation is risk management; there is value, therefore, in agreeing upon a common understanding of what exactly risk is. The Mayor of London's strategy breaks risk down into the *probability* of an event occurring or threshold being crossed; the *consequences* of the event (who and what is impacted); and the *vulnerability* of the people and/or assets impacted (i.e. how severely they will be impacted and their adaptive capacity).

Most adaptation strategies have done an extremely poor job of enumerating the particular risks within any given city, defaulting to general assumptions that lack the depth to be useful.[5] Rather than rallying around a few general platitudes, cities need to understand and respond to the particulars of their situations with the tools at their disposal.[6]

[5] Katich, *supra* note 1, page 73.

[6] *Id.*, page 74.

Start with a few key threats and commensurate actions

At least as a starting point, it is strategically wise to focus on a few key areas rather than on all of the possible threats associated with climate change. The Mayor of London's comprehensive strategy introduces a variety of threats, but ultimately focuses on only three: Flooding, drought, and overheating. These key areas of impact are introduced and subsequently translated into specific potential consequences upon public health, the environment, the economy (business and finance) and infrastructure (transport, energy and waste). The New York City process similarly focuses on a shortlist of impact areas: Air temperature-related impacts, precipitation-related impacts, and sea level rise-related impacts. At this nascent stage, attempting to be completely comprehensive raises the risk that adaptation planning will become overwhelming and attentions sidetracked to the detriment of the most acute risks cities face.

On the other hand, it is useful to keep other climate change-related issues on the agenda, even if they are not prioritized in the foreseeable future. The London strategy notes, for example, that the relationship between climate change and waste management is not yet well understood but that, among other things, municipalities may need to consider how an increase in refuse, resulting from more natural disasters, can be managed.

Recognize the place of city-wide adaptation planning

Managing the finer grained detail of implementing responses to climate change is impossible at the macro scale, given the complexities involved. Professionals within each respective area can and must do the technical work of fine-tuning and implementing responses. Of course, a certain degree of macro-level planning and communication remains necessary. Failing to maintain open channels of communication and coordination can, among other things, lead to actions that counteract rather than support one another. For example, land use planning changes designed to intensify development in areas less prone to flooding may work against efforts to preserve valuable green spaces if not managed properly.

How to effectively share information across siloed agencies unfortunately remains all too elusive in many cases. The Toronto strategy proposes an overall coordinating group with representatives from a wide range of agencies, plus issue-based adaptation groups that bring together the relevant agencies and other parties around the particulars of given key issues (e.g. energy). Still, work remains in terms of finding the best ways to incentivize and coordinate collaboration.

Support and integrate with broader regional planning efforts

Broader regional collaboration is also necessary for a variety of reasons. Many responses will require collaboration across jurisdictional and agency boundaries, particularly given the fragmented nature of governance in New England. Any water and sanitation changes, for example, are almost certainly going to involve the MWRA, its member municipalities and state agencies like the MassDEP. Decisions the City of Boston and its partners make can

also have consequences beyond their borders, both positive and negative. A tidal or storm surge barrier constructed on the Charles River to protect Boston and Cambridge may, for example, result in unintended consequences, such as more severe flooding, elsewhere.

Support neighborhood-level planning

At the other end of the spectrum, processes focused at the smaller (i.e. neighborhood) scale can also bring benefits, as many of the actions necessary to increase the resilience of our cities can and must be taken by – or be targeted to the particulars of - individuals and communities. For this reason, the New York process piloted adaptation planning exercises in five particularly vulnerable neighborhoods and plans to extend this work to other neighborhoods throughout the city. The Mayor of London's strategy also calls for smaller-scale planning, suggesting that each of Greater London's 32 boroughs conduct their own processes. In Boston, neighborhood level planning would be valuable given the varying risks and assets different areas face. Sea level rise may be the central issue in East Boston, for example, while overheating exacerbated by the urban heat island effect may be of greater concern in Chinatown.

Environmental justice

The potential impacts of climate change are not shared evenly across the population. It is often those with the least access to resources and fewest choices that face the greatest risk. Recognizing the particular issues and vulnerabilities of marginalized communities is important. It is also important to recognize the potential for adaptation options to exacerbate or address these inequalities. One of the core objectives of the Mayor of London's strategy is "to reduce social inequality, including health inequality in London" (ix). The strategy identifies, for example, that the 'most deprived' are statistically more likely to live in higher risk tidal flood zones. The London strategy also notes that certain populations – including the young and old, and those without access to cooling – are at greater risk during heat waves. As noted previously, the New York City process is conducting parallel planning efforts within vulnerable neighborhoods to increase their local resilience. The Toronto strategy recognizes the municipal governments "special responsibility to assist people who are particularly vulnerable to climate change, such as isolated seniors, children, people with chronic illnesses (including mental illness), and homeless and low-income people".

Consider the negative AND positive potential consequences

The subject of climate change typically evokes doom and gloom images of the future. It is important to recognize, however, that some consequences may actually be positive. For example, as the NYC report notes, warming should lead to a reduction in heating requirements and associated energy use, and reduce the degree of road damage caused by freezing each winter. The London strategy includes an entire section on how the City can capitalize on the opportunities climate change presents, particularly if the city continues to be a world leader and can subsequently export its talent in managing climate change risks in various sectors, including law, finance, insurance, and engineering. In the case of Boston,

it is important to recognize how the opportunities might change in the city's key sectors, like healthcare and education. Recognizing that climate change may bring some positive opportunities does not mean that it is desirable; rather, it is a healthy recognition that the options available can and do shift.

Illustrate the risks with already existent examples

There is benefit in making predictions more tangible by relating them to events or conditions that have already been experienced. For example, the Toronto strategy highlights the impacts the hottest summer on record (2005) and the most expensive storm the city has ever experienced (also in the summer of 2005) had on the city and the services its government provides.

Highlight what is already being done

Highlighting what the city is already doing reinforces the notion that adapting to climate change is not overwhelming work; in fact, some of it is already underway. The Toronto strategy does this particularly well. A Heat Alert System and Hot Weather Response Plan are, for example, already in place, and the responsible department, Toronto Public Health, has considered the potential impacts of climate change within them.[7]

Why engage in climate change adaptation planning?

An important question if the goal is to motivate other cities to take action is, what motivates these early leaders? In the cases of both New York and London, a real emphasis is placed on becoming 'world leaders' in this realm. Protecting assets in the face of real dangers is also a priority. In all cases, strong political forces are driving the process; in the cases of both London and New York it is their mayors, while it is a strong mandate from the city council in the case of Toronto. One risk of motivating action via strong leadership is that it can become personality driven and platitude-focused rather than substantively meaningful. General statements are fine, particularly at this framework-setting stage in the game, but ultimately must translate into real work on the ground.

Who is involved?

The New York process has both a task force, which is comprised of approximately 40 agency employees and contractors responsible for various components of the city's infrastructure, and a smaller panel of 13 technical experts. Exactly who is behind the Greater London strategy is ambiguous, as it was officially released by the Mayor, but the Greater London Authority does coordinate a London Climate Change Partnership with the aim of "ensuring that London is prepared for climate change".[8] The Partnership is comprised of "over 30 organisations with representation from government, climate scientists, developers, finance, health, environment and communication sectors". A group

[7] See page 16 of the Toronto strategy, Ahead of the Storm (introduced below).
[8] See: http://www.london.gov.uk/lccp

of sixteen city employees, plus one member of a non-profit supporting the effort, were at the heart of the Toronto process. At this nascent stage, most adaptation efforts seem to primarily involve core groups of city staff and/or experts. Most do, however, include public consultation components and call for greater stakeholder engagement as the processes evolve. Given the wide and far-reaching impacts of both climate change and the potential responses to it, it is key that stakeholders are engaged.

External support

External organizations provided critical support to each of the adaptation planning efforts examined. In the case of the Rockefeller Foundation's support for New York's Panel on Climate Change, the support is primarily financial. In other cases, the support is technical; The Boston Consulting Group played a key role in facilitating the New York Task Force (pro bono), the Clean Air Partnership has been instrumental in supporting the Toronto process, and the UK Climate Impacts Program supports the London effort both with data and process guidance.

In general, various tools exist to support adaptation planning. Among them are:

- ICLEI-Local Governments for Sustainability's Climate Resilient Communities Program (http://www.icleiusa.org/programs/climate/Climate_Adaptation)
- The Center for Clean Air Policy's (CCAP) Urban Leaders Adaptation Initiative (http://www.ccap.org/index.php?component=programs&id=6)
- The UK Climate Impacts Programme (UKCIP) (http://www.ukcip.org.uk/)

Few municipalities seem to be following any individual one of these approaches wholesale, but rather to be taking from each as they deem appropriate, and modifying to their own needs.

Substantive Adaptation Recommendations From Various Plans

The following recommendations are aggregated from a variety of different adaptation plans *(see the 'sources' at the end of this section)*. The three substantive subsections they are clustered within – sea level rise, heat waves, and extreme storms – were identified as the climate change-related impacts of particular concern to Boston at the last meeting of the adaptation subcommittee. Within each subsection, recommendations are loosely ordered from more general to more specific.

It is notable that more global process-oriented recommendations are not included here, but were addressed in the last section. Among other things, most adaptation plans call for more research on the locally specific impacts of climate change, for the organization of ongoing adaptation planning efforts, and for flexible/adaptive management regimens in light of uncertainty and changing dynamics. The need to educate and encourage planning among private interests is also emphasized.

Sea level rise

- Assess the impacts of sea level rise on public investments and identify vulnerabilities in order to produce adaptation. These assessments should utilize longer-term planning horizons (c,g).
- Encourage spatial planning in the longer-term that is cognizant of sea level rise. Options might include: 'Risk trading' (i.e. exchanging vulnerable land in coastal areas for land elsewhere), density restrictions in vulnerable zones, rolling easements and the purchase of development rights and placement into land trusts (a,d,f,g).
- Identify where and how flooding and coastal lines themselves may be redrawn in the future (a,g). Detailed maps should be created using calibrated LIDAR (Light Detection and Ranging) surveys, or other state of the art elevation survey technology. These maps should show water levels under different sea level rise scenarios. These maps will help to identify which areas will become flooded under different scenarios, and will provide a basis for assessing risk to development and infrastructure (c).
- Conduct analysis and start to plan for the difficult decisions around what the priorities are for protection and what lies outside of those priorities (i.e. should be 'retreated' from) (d,g).
- Create a plan to locate infrastructure and development outside coastal or flood hazard prone areas using projections of sea level rise to identify those areas. Describe a transitional zone between the hazard area and the built area to be protected and prohibit incompatible land uses that would convert open lands in the transitional zone. Establish a comprehensive planning and zoning policy, such as development setbacks

and limits on density and the placement of infrastructure in coastal and transitional zones to consider vulnerability to sea level rise and saltwater intrusion (c,f).

- Identify marginalized communities that are vulnerable and provide the additional assistance necessary to help them proactively adapt (d).
- Support the phasing out of insurance for developments in vulnerable areas, and revise other perverse economic subsidies that support development in vulnerable areas (d,g).
- Ensure that public access to the shoreline is not lost with sea level rise, designing access points to be resilient, requiring that new access points be constructed if existing ones are lost, and requiring that development is set far enough back that public shorelines can be maintained (d,g).
- Improve/construct coastal barriers (a).
- Secure strategic open lands to provide transition zones to accommodate retreat or spatial shifts in natural areas, such as coastal wetlands and freshwater marshes (c,f).
- Investigate the various forms of shoreline protection, including both 'hard' options (e.g. seawalls) and soft options (e.g. wetland restoration), evaluating the tradeoffs inherent in and costs associated with both and typically prioritizing the soft. Also, compensate elsewhere when (ecologically destructive) hard options are unavoidable (d,g).

Heat waves

- Modify heat alert systems and hot weather response plans, ensuring that the most vulnerable are protected and that warnings are effectively disseminated (b,f).
- Enhance the weather monitoring network across the city so that its microclimates can be better understood (a).
- Analyze how heat waves may increase crime and violence in the city, and how this can be prepared for (a).
- Institute programs to reduce electricity demand during heat waves (b).
- Potentially modify urban form over time, narrowing streets, for example, to reduce the amount of solar energy entering buildings (a).
- Provide locally-specific design guidance so that architects and developers can most effectively minimize overheating within their developments (a,b).
- Increase the proportion of, and enhance existing, urban green spaces, including street trees and 'green parking lots', to cool the city and combat the urban heat island effect (a,f). One particular option is a city commitment to 'double the tree canopy' (b). Another recommendation is to improve the care given to trees to extend their lives and thus size (b).

- Mandate that new developments contribute to offsetting the urban heat island effect by, for example, painting their roofs white or installing green roofs (a). Also, incentivize and/or mandate the installation of green roofs (b).
- Facilitate (extended) public access to cool buildings, swimming pools and misting stations during heat waves to help vulnerable people avoid and recover from the heat (a,b,f).
- Encourage passive ventilation in both building architecture and broader urban form, as mechanical air conditioning can exacerbate the problem by increasing electricity demand (a).
- Encourage 'cultural' adaptations, like shifting work hours so that workers can take refuge from the heat and relax during the hottest hours (a,g).
- The coping ability of the natural environment – including trees and grasslands within the city – should be considered and addressed (a). For example, plant trees and other vegetation with higher tolerances to a wide range of environmental conditions (f). Also, increase systemic tree pruning services, to increase their health and subsequent resistance to drought and severe weather (b).

Extreme storms

- Raise public awareness of flood risk through a coordinated information campaign (a).
- Review flood response plans to identify (inventory) and work to protect critical infrastructure and vulnerable communities at risk of flooding (a,b,e). For example, flood-proof wastewater treatment facilities by, among other things, installing watertight doors and windows, and submersible pumps (g).
- Reviews and permits for development should require an analysis of climate change-related vulnerabilities, and the elaboration of contingency plans (g).
- Implement and/or improve flood warning systems and emergency response plans, and update flood maps (a,b,f). Expand regional watershed monitoring, reporting and management plans in light of climate change (a,b). Also implement new winter weather technologies to improve the monitoring of snow and freezing rain conditions (b).
- Require that new developments consider the changing climate in their plans, and contribute to greater overall resilience rather than compromising it (a,f).
- Assess the impacts of storms on the performance of fresh water and wastewater infrastructure, including how water quality might be impacted (b,c). Also assess the impacts on solid waste management infrastructure and develop contingency plans (g).
- Conduct risk assessments on major road culverts and bridges to minimize their exposure to damage in extreme weather, and better understand the weak points in the system (b).

- Assess the impacts of extreme weather, droughts, and heat on the water quality of area watercourses and beaches (b).
- Identify ways to house the displaced, and assist them with insurance claims, post traumatic stress, unemployment and other fallout from storms (a).
- Consider the costs of and logistical issues surrounding post-storm clean up. For example, how will the landfilling of all the additional waste be managed (a).
- Move or abandon infrastructure in hazardous areas (f).
- Increase the capacity of stormwater collection systems in light of predicted increases in precipitation (f,g).
- Update the models and operating guidelines for dams and other flood control systems in light of anticipated changes (g).
- 'Green' the urban environment and design green spaces to absorb and retain rainwater (i.e. expand the implementation of 'Low Impact Development'). For example, support the installation of bio retention swales, permeable pavement, and rainwater harvesting (a,b,f,g).
- Identify sites, such as industrial land, that can be used for flood storage (a). Also, preserve ecological buffers, such as wetlands (f).
- (Re)build the regional levee system to protect person and property from more intense storms (e).
- Subsidize the installation of back-water valves and sump pumps on residential sewer connections to provide additional protection against flooding through sanitary sewers (b).
- Citywide mandatory downspout disconnection (b).
- Prohibit the construction of new reverse slope driveways (b).

Sources:

a) *The London Climate Change Adaptation Strategy, August 2008 (http://www.london.gov.uk/mayor/publications/2008/docs/climate-change-adapt-strat.pdf)*

b) *Ahead of the Storm: Preparing Toronto for Climate Change, April 2008 (http://www.toronto.ca/teo/pdf/ahead_of_the_storm.pdf)*

c) *Second Report and Initial Recommendations, Presented to the Miami-Dade Board of County Commissioners, April 2008 (http://www.miamidade.gov/derm/climatechange/taskforce.asp)*

d) *Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline, April 2009 (http://www.bcdc.ca.gov/proposed_bay_plan/bp_amend_1-08.shtml)*

e) *2008 King County Climate Report, January 2009 (http://www.kingcounty.gov/exec/globalwarming.aspx)*

f) *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments (King County, Washington), September, 2007 (http://your.kingcounty.gov/exec/news/2007/0912globalwarming.aspx)*

g) *Massachusetts Department of Environmental Protection, Climate Change Adaptation Advisory Committee, Potential Strategies, October, 2009 (http://www.mass.gov/dep/public/committee/1009pres.pdf)*

New York City

Climate Risk Information
New York City Panel on Climate Change, February 17, 2009
Available online: http://www.nyc.gov/html/om/pdf/2009/NPCC_CRI.pdf

PlaNYC Progress Report 2009
Available online: http://www.nyc.gov/html/planyc2030/html/downloads/download.shtml

Climate change adaptation is a component of New York City's ambitious and comprehensive PlaNYC effort to make the city more sustainable. According to the Progress Report, both a Climate Change Adaptation Task Force and the New York City Panel on Climate Change were launched in 2008. The Panel, whose work is funded by the Rockefeller Foundation, has 13 members, largely from academia but also from the private sector. They are charged with "quantify(ing) the impacts of climate change and advis(ing) the city on adaptation" (Progress Report, 38). The Panel is a technical advisory body of sorts; the scientific data and projections it produces are intended to inform the larger Task Force of "approximately 40 members from city, state and federal agencies, regional public authorities, and private companies that operate, maintain or regulate critical infrastructure in New York City" (Id.).

Recognizing that important parts of the adaptation puzzle will necessarily happen at the neighborhood level, and that some neighborhoods are more vulnerable than others, NYC ran a pilot outreach program with five neighborhoods across the city, providing them with the necessary information and support to develop their own area-specific adaptation strategies. Workshops were held in each neighborhood in partnership with community organizations. According to the Progress Report, the city is refining its outreach program based on feedback collected via these pilots and plans to extend the program to other communities. Unfortunately, from a learning perspective, no data seems to be available on the particulars of how these pilots worked, nor lessons learned.

A 'citywide strategic-planning process' is also being launched to go beyond managing the impacts of climate change on critical infrastructure. Building on the Task Force's work, this process will look at climate change impacts in various areas, including public health, development and investment decisions.

The Panel released its first report in February 2009, providing projections and a general overview of potential risks to infrastructure. The Task Force report, which is anticipated but not yet released, is expected to translate the general risks identified by the Panel into more specific risks to infrastructure, and devise coordinated responses. Process wise, the Boston Consulting Group provided pro bono assistance in convening the Task Force. It is notable that the Panel's next report, Climate Change Adaptation in New York City: Building a Risk Management Response, is expected out this month (January, 2010).[9]

[9] See http://www.wiley.com/WileyCDA/WileyTitle/productCd-1573318000.html

According to the Panel, climate changes expected in the NYC region include increased mean annual temperatures; increased annual precipitation; and sea level rise. The report notes that extreme events associated with these larger-scale changes are also likely. These events may include: More intense, longer and more frequent heat waves; coastal storm surges; more intense precipitation and associated flooding; and more severe droughts. On the other hand, less extremely cold days and snowstorms are likely.

In terms of impacts on infrastructure, the report foresees the following potential impications (page 27):

Air temperature-related impacts

- Increase in peak electricity load, resulting in more frequent power outages
- Fluctuation in voltage, damaging equipment and interrupting service
- Degradation of and increased strain on materials
- Increase of demand on HVAC systems
- Reduction of electricity and transportation service disruptions
- Increase in construction season
- Reduction of energy/heating requirements in winter
- Reduction of road damage associated with freezing and refreezing of surfaces
- Decrease of water quality due to biological and chemical impacts
- Increase in costs associated with cooling water for power plant operations

Precipitation-related impacts

- Increase of street, basement and sewer flooding
- Increase in risk of low-elevation transportation, energy and communications infrastructure flooding and water damage
- Increase in delays on public transportation and low-lying highways
- Increase in nutrient loads, eutrophication, taste and odor problems and loadings of pathogenic bacteria and parasites in reservoirs
- Increase in Combined Sewer Overflow (CSO) events, polluting coastal waterways
- Reduction of the need for winter weather road and airport operations
- Decrease in average reservoir storage and changes in operating rules and usage
- Degradation of and increased strain on materials

- Increase in strain on upstate reservoirs

Sea level rise-related impacts

- Encroachment of saltwater on freshwater sources and ecosystems, increasing damage to infrastructure not manufactured to withstand saltwater exposure
- Increase in pollution released from brownfields and other unprotected waste sites
- Inundation of low-lying areas and wetlands, and higher rates of beach and salt marsh erosion
- Increase of inflow of seawater to sewers and Wastewater Pollution Control Plants (WPCP) and reduced ability of discharging Combined Sewer Overflows (CSO) and WPCP effluent by gravity
- Increase of salt front up the Hudson and Delaware Rivers, leading to reduced supply of drinking water
- Increase in street, basement and sewer flooding
- Increase in flood risk of low-elevation infrastructure and wastewater treatment plants
- Increase in delays on public transportation and low-lying highways
- Increase in structural damage to infrastructure due to flooding and wave action
- Increase in need for use of emergency management procedures

The panel emphasizes the need for better indicators and monitoring going forward. The climate indicators that the panel recommends are: The earth's carbon cycle, sea level, changes in polar ice, and advances in climate science. In terms of infrastructure, the panel recommends that the following impacts be monitored: CSO events, flooding and related impacts, climate-related blackouts, and changes in local ecosystems.

London, England

The London Climate Change Adaptation Strategy
Mayor of London, August 2008
Available online: http://www.london.gov.uk/mayor/publications/2008/docs/climate-change-adapt-strat.pdf

Rising to the Challenge: The City of London Corporation's Climate Change Adaptation Strategy
Available online: http://217.154.230.218/NR/rdonlyres/7347D392-3CF3-4344-8B2D-9AF9315E8801/0/SUS_climateadapt.pdf

The Mayor of (greater) London released a draft adaptation strategy in August of 2008. The strategy is one of the most comprehensive to date at over 100 pages. The aim of the strategy is "to protect and enhance the quality of life of Londoners and to promote and facilitate the sustainable development of London by helping London and Londoners prepare for the impacts of climate change and extreme weather" (ix). The objectives undergirding this aim include: "To reduce social inequality, including health inequality in London"; "to promote and facilitate new development and infrastructure that is located, designed and constructed for the climate it will experience over its design life"; and "to help business, public sector organisations and other institutions incorporate the impacts of climate change in their business plans" (ix-x). The strategy identifies the risks London faces; sets a baseline against which changing risks can be assessed; identifies further information needs and who should be involved in the process; identifies areas in which a more precautionary approach should be taken; identifies areas in which emergency contingency plans should be prepared, even when the probabilities are low (but potential consequences high); and recommends how London can capitalize on the situation and become a world leader on adaptation.

While discussing other potential problems, the strategy focuses on three key manifestations of climate change: Flooding, drought, and overheating. It also focuses on how these manifestations will impact a few core sectors: Public health, the environment, the economy (business and finance) and infrastructure (transport, energy and waste). Recommendations made in the strategy are placed on a scale from the most preventative (proactive actions like improving flood barriers), through the preparatory (assessing and planning) and responsive (taking action in light of an event to reduce the impacts, like limiting non-essential water consumption in droughts), to recovery (actions like supporting insurance claims and rebuilding after a flood) at the most reactive end.

London is highly vulnerable to both tidal and fluvial flooding. The Thames Barrier currently provides adequate tidal flood protection to the city, though it is unclear for how long in light of sea level rise and the potential for more severe storm surges. The strategy includes a wide variety of actions that can be taken in response to the increasing risk of flooding, with the following priority actions defined as 'key to managing flood risks in London' (11):

- Review the London Strategic Flood Response Plan to identify and protect critical infrastructure and vulnerable communities at flood risk.

- Lead an 'urban greening programme' using green spaces and street trees designed and located to absorb and retain rainwater.

- Develop a strategic-level surface water management plan for London.

- Raise public awareness of flood risk through a coordinated information campaign.

- Work with the Environment Agency to improve the standard of flood risk management on London's rivers where properties are at significant risk of flooding.

The strategy identifies key social and civil infrastructure – ranging from police stations to 'gypsy and traveler sites' - at risk of flooding. It also identifies some already existing issues that may be exacerbated, like the inability to effectively get flood warnings out to people. Efforts already underway, including the Thames Estuary 2100 Project, are also introduced. This project takes a 'decision pathways' approach in light of uncertainty, setting trigger points at which different flood risk management approaches are to be implemented (e.g. when a shift from improving current defenses to constructing a new barrier). Disturbingly, the strategy identifies the fact that the 'most deprived' are statistically more likely to live in higher risk flood zones.

London's freshwater supply is surprisingly vulnerable, particularly given population increase projections. Water comes from two rivers and an aquifer under the city, all of which are rain fed. Should the volume of rainfall decrease, and/or become sporadic, the supply may become insufficient. Fortunately, at least in the medium-term, the strategy posits that quite a bit can and be done on both the demand and supply sides to make the system more resilient. In terms of managing the risks associated with drought, the strategy proposes the following key actions (29):

- Publish a Water Strategy for London and a Water Action Framework to determine what balance of demand and supply side actions will enable London to achieve a more sustainable water supply-demand balance that is resilient to a changing climate.

- Promote and facilitate the reduction of leakage from water mains in London.

- Promote and facilitate compulsory water metering in all developments where feasible, accompanied by a tariff structure that incentivises water efficiency, but protects vulnerable households.

- Promote and facilitate the retrofitting of London's homes to become more water efficient.

- Encourage rainwater harvesting and grey water recycling in new development.

A desalinization plant is currently under construction in East London to extract and treat water from the Thames. Other measures, including effluent treatment and reuse and increasing reservoir storage capacity, are also being considered.

Like Boston, dangerous heat waves are typically not associated with London's temperate climate. They have, however, become more common in recent years, with the risk that the situation will only become worse with global warming. The urban heat island effect results in even higher temperatures in the city than in outlying areas. The strategy proposes the following key actions to address overheating issues (41):

- Undertake an 'urban greening programme' to cool the city using green spaces, street trees and urban design.
- Create an 'Urban Heat Island Action Area' where new development must contribute to offsetting the urban heat island effect.
- Provide London-specific design guidance to enable architects and developers to reduce the risk of new development overheating in future summers.
- Facilitate public access to cool buildings during heatwaves to help vulnerable people avoid and recover from the heat.
- Undertake a scoping study for a London-wide network of weather stations to better understand and monitor London's climate.

Changes to address overheating are recommended at a wide range of sales and dimensions, from cultural changes (e.g. shifting work hours so that workers can take refuge and relax during the hottest hours) to building-specific changes (e.g. painting roofs white to increase reflectivity).

The potential impacts of climate change on public health are both manifold and of utmost importance to consider. According to the strategy, the direct impacts on health, both positive and negative, may include: Increased heat stress, but reduced cold stress; increased air pollution and associated health problems; more natural disasters, with accompanying morbidity; an increase in vector-borne diseases due to warming; an increase in food and water-borne diseases due to warming; an increase in cataracts, skin cancers and burns due to warming and sunnier days, leading to changes in behavior and a subsequent increase in UV exposure; and dehydration. Health inequalities may be exacerbated with climate change; for example, those that work outdoors are likely to feel the effects more acutely, as will those with poor quality and overcrowded housing. As noted previously, critical health infrastructure faces risks such as flooding that may impair its ability to provide services. Similarly, climate-related disasters may inhibit the ability of healthcare professionals and other emergency personnel to adequately respond. Research also suggests that warmer weather may lead to increased crime and aggression, which must be addressed.

A variety of ecosystem services – from reduced flood risk to recreational opportunities – are provided by the pockets of nature in our cities, from large green areas to street trees. Enhancing and protecting natural features can combat some of the effects of climate change. For example, as mentioned previously, green roofs can both reduce the heat island effect and need for air conditioning, and capture stormwater that might otherwise lead to flooding. Many of these natural features are, however, also vulnerable to climate change;

most species of flora and fauna have adapted to the local climate and are likely to face stress with temperature and precipitation changes. Among other things, the strategy recommends increasing the proportion of green spaces in the city and improving their management; freeing rivers from the artificial barriers constricting them and allowing natural processes like flooding to occur; and planting street trees appropriate to a changing climate.

London's economy is naturally vulnerable to flooding, drought and overheating-associated risks to the degree that they can impede work and discourage investment in the city. The impacts of climate change beyond the city's borders must also be considered, particularly given the global reach of London-based firms and financial markets. On the other hand, by London becoming a global leader in adaptation, the strategy asserts that firms in a variety of sectors, including law, finance and engineering, can become world leaders in their respective areas, providing new opportunities.

The impacts of climate change on infrastructure are of particular importance to the municipalities that are, at least in part, typically responsible for their provision. The function of modern cities is highly contingent on complex and comprehensive foundations of infrastructure, including water and sanitation, waste management, electricity and transportation. London's transportation infrastructure faces a variety of climate change-related threats, including the flooding of subway stations, and the thermal expansion of rails, bridges and other infrastructure, which can lead to damage and the need to restrict speeds or close lines. On the up side, warmer winters will decrease the damage caused to infrastructure by freezing, snow and ice.

High electricity demand during heat waves, caused by increased air conditioning use, can put stress on the network and lead to blackouts in extreme cases. This is exacerbated by the fact that much of the power generation and transmission infrastructure is less efficient under higher temperatures. A significant proportion of the infrastructure is also vulnerable to the impacts of climate change, including flooding, susceptibility to drought (i.e. dependence on water) and overheating. One recommendation the strategy makes is that generation be decentralized and diversified to increase resilience.

The impacts of climate change on waste management are not well understood, but the strategy predicts potential changes in the profile and volume of waste, and impacts on how waste can be managed. Longer growing seasons may, for example, increase the volume of organic waste and thus the importance of composting programs. An increase in the frequency or scope of natural disasters may necessitate planning around how the extra 'waste' created by these events can be handled.

The Mayor of London's strategy is designed to serve as an overarching analysis and initial approach to planning for greater London, and calls on each of the 32 boroughs, plus key stakeholders, to develop their own risk assessments and adaptation action plans. The strategy recommends that these adaptation plans seek out the most appropriate strategies, identify what level of adaptation is required and the potential consequences of over or under adapting, and is cognizant of how costs can be minimized. Recognizing that it is a work in progress, the strategy also concludes each section with a set of 'consultation

questions', like "Have we appropriately assessed the flood risk to London?" (27) and is designed to serve as the starting point for a broader consultative process.

The City of London is a different entity than the Greater London Authority and Mayor of London that prepared the above mentioned strategy, serving as the local government for the small (quarter mile) core of the larger metropolitan area, but also providing a number of services beyond its boundaries, such as five of the Thames River bridges, three of the key vegetable wholesale markets that serve the entire region, and the quarantine station at Heathrow airport. The City released its own climate adaptation strategy in January of 2007. The strategy is built on UKCIP02 climate change scenarios and the impacts identified via the London Climate Change Partnership's London's Warming publication.[10] The strategy groups adaptation options into research and monitoring, policy and political actions, and then categorizes them into 'no-regrets' options (those for which the benefits outweigh the costs regardless of the extent of climate change); 'low-regrets' options (those with relatively low costs and significant benefits should climate change scenarios manifest); 'win-win' options (those that support adaptation but also bring collateral benefits in other areas); and 'flexible' responses (those that are easily modifiable in light of an uncertain future).

One significant risk identified is flooding. The following recommendations are made in terms of 'managing flood risks':

- Businesses should relocate flood-sensitive equipment and archives out of London to areas with lower flood risks, or at least out of more vulnerable locations such as basements.

- The city should incentivize developers to install 'sustainable drainage systems' and green roofs to better manage water and reduce the risk of flash floods, and the City should do the same on its own buildings and parking garages.

- The City should increase its temporary flood water storage capacity.

- Properties at risk of flooding should be made more resilient via such modifications as the use of flood-resilient materials, the installation of removable flood barriers, and the installation of one-way valves on drainage pipes to avoid back-ups.

- A flood recovery plan should be developed by the City and incorporated into the emergency plan, with an officer assigned to overseeing flood risk management.

As mentioned previously, London is a surprisingly dry city that is already concerned with freshwater supply shortages. Climate change may exacerbate the situation. In terms of 'managing water resources', the strategy makes the following recommendations:

[10] See http://www.london.gov.uk/lccp/publications/impacts.jsp. The London Climate Change Partnership (http://www.london.gov.uk/lccp/index.jsp) is an initiative of the Greater London Authority that has produced a rich collection of documents and held various events on the issue. The steering group is comprised of representatives from a range of public and private agencies and organizations.

- An awareness raising campaign should be launched to encourage greater water efficiency, and plumbers trained in water conservation.

- Contingency plans should be made in coordination with the water utility for meeting vital functions in the case of extreme drought.

- Rainwater harvesting for use in cleaning, toilets, irrigation, and so on should be encouraged. Prime buildings for harvesting include transit stations and market buildings. Flood prone areas should be targeted first, as capturing rainwater will also reduce flooding.

- Drought-resistant landscaping and efficient irrigation systems should be utilized.

- The City should consider using 'bio-bombs' to absorb nutrients and prevent algal blooms.

In terms of 'managing heat risks and air pollution', the strategy recommends that:

- The City mandate that biodiversity is increased and shade provided via increased tree planting in open spaces, and the installation of green roofs and vertical habitats.

- The City works with electricity providers to ensure that the supply, particularly to critical infrastructure, is secure given potential climate change impacts and associated changes in seasonal demands.

- Transportation for London should change its travel card policy to encourage working from home during heat waves.

- Drinking water should be made freely available on platforms in transit stations.

- Cooling centers should be provided in public buildings during heat waves, particularly for vulnerable populations.

- Emergency plans should include mechanisms for controlling air pollution during heat waves, as it exacerbates health risks.

Subsidence and heave are already problems in London – as in Boston, a city built in large part on fill – and are expected to only get worse with a changing climate. In terms of 'managing ground conditions', the strategy recommends that:

- Developments are designed to address geo-physical risks that may manifest in the future under a changing climate. In particular, foundations should be constructed in such a way that they can withstand increased subsidence and heave caused by climate change. Underpinning on existing buildings should also take increased heave and subsidence into account.

- Tree planting should be planned carefully, considering how subsidence and root penetration will be impacted by climate change.

Toronto, Canada

Ahead of the Storm: Preparing Toronto for Climate Change
The Toronto Environment Office in collaboration with the City Of Toronto Climate Adaptation Steering Group and the Clean Air Partnership, April 2008
Available online: http://www.toronto.ca/teo/pdf/ahead_of_the_storm.pdf

Toronto City Council tackled climate change by adopting the comprehensive Climate Change, Clean Air and Sustainable Energy Action Plan in 2007. While focusing most of its attention on mitigation, the plan also included adaptation elements. Among other things, it led to the creation of a Climate Adaptation Steering Group and the development of the *Ahead of the Storm* document. The steering group was comprised of 17 members from across City departments and associated agencies, plus a representative of the non-profit Clean Air Partnership, which provided support to the effort.

The climatic changes that are most likely to impact Toronto are: Temperature increases (warmer summers and winters), changing precipitation patterns (including more extreme weather events), and drops in inland lake and stream water levels. *Ahead of the Storm* predicts impacts in various areas relevant to city government, including: Public health, water supply and stormwater management, local transportation and public transit systems, electricity distribution, parks and urban forests, and social and emergency services.

Ahead of the Storm is a relatively extensive document at 46 pages, but centers around a series of 34 short term actions to start preparing the city for climate change immediately, plus 29 longer-term actions to facilitate longer term planning and subsequent resilience.

The short-term actions are designed for implementation, making both the anticipated benefits and group(s) responsible explicit. Some already had resources approved for 2008/9 while others were at the time un-funded recommendations coming from various city departments. An example of an already funded short-term action is participation in the Greater Toronto Incident Management Exchange. The anticipated benefit is that it will "Help plan for recovery from wide scale business disruptions or disasterous events including severe weather" (17). The responsible department is the Office of Emergency Management. An example of a recommended action was to 'increase systematic tree pruning services', with the anticipated benefit that "systematic maintenance promotes healthy tree growth, reducing long term maintenance costs; Stronger trees are more likely to survive climate stresses such as drought and wind" (19). The responsible department would be Parks, Forestry & Recreation. A complete list of short-term actions runs from pages 17-20 of the document.

The longer-term actions in *Ahead of the Storm* are designed to facilitate more comprehensive planning. Most are nested, more or less chronologically, within a nine-step process. The steps, with accompanying examples of proposed actions, are:

- Create the internal mechanisms and processes for the development of a comprehensive, multi-year adaptation process

    - *Example:* Make climate change a key mandate of the Executive Environment Team and commit to coordinating climate change planning across the city's agencies, boards, commissions, corporations and divisions to ensure efficient and effective implementation (#3).

- Engage the public, business and other stakeholder groups

    - *Example:* Identify and promote actions that individual households and community organizations can do to reduce vulnerability to climate change (#18).

- Incorporate climate change adaptation into city policies and high level plans

    - *Example:* Include climate change considerations and explicit goals for adaptation in plans, programs, strategies and assessment procedures, ranging from Toronto's Official Plan to the Green Development Standard and Deep Lakewater Cooling plans (#20).

- Use best available science to analyze how climate is changing locally and what the future is likely to bring

    - Undertake research to analyze key historical climate trends in the Toronto region, produce downscaled climate projections, and case studies of recent key climate events that provide local climate data and practical information on climate change and its local impacts (#21).

- Use this analysis to identify Toronto's vulnerabilities to climate change

    - Develop a citywide inventory of current climate vulnerabilities and the extent to which current activities provide protection (#22).

- Conduct a risk assessment to identify priority impacts requiring adaptation action

    - Undertake a citywide risk assessment process of identified vulnerabilities to pinpoint significant climate impacts that the city should prioritize for developing adaptation strategies (#23).

- Identify and assess adaptation options to reduce the risk

    - For high priority risks, identify and evaluate a range of adaptation options that could reduce vulnerability to specific climate change impacts, and that could be implemented in a comprehensive adaptation strategy (#24).

- Develop and implement climate change adaptation strategies

  - *Example:* All city agencies, boards, commissions and divisions should consider climate change in their emergency management and business continuity planning (#27).

- Monitor climate change, evaluate the effectiveness of adaptation initiatives in protecting the City from continuing changes, and adjust strategies when necessary

  - *Example:* Establish a formal mechanism for periodic review of progress on climate change adaptation which is communicated to decision-makers and the public to help ensure continual progress (#29).

The Toronto strategy highlights activities that the city is already engaged in that will also reduce vulnerability to climate change. Examples include the Heat Alert System and Hot Weather Response Plan; the Basement Flooding Protection Subsidy Program, which is subsidizing the costs of installing valves and pumps on household sewerage connections; and a commitment to double the tree canopy.