
# Potential Climate Change Impacts on DEP

## 2

DEP's heightened awareness of climate change issues over the past four years has led to extensive discussions about how regional changes in temperature, precipitation, sea level, and frequency of extreme weather events will impact New York City's water supply, drainage and wastewater management systems. Impacts could be significant - new climate and sea level extremes could be experienced that the systems are not designed to accommodate. DEP's existing awareness of system vulnerabilities, from observing the effects of past climate variability and extreme weather events, has guided the Department's initial assessment of how climate change could impact DEP and its water systems.

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This chapter examines the potential impacts of climate change on the City's water systems identified to date by DEP and details the actions that DEP will take to further define and quantify the impacts. Quantification is essential, because it will allow DEP to weigh the environmental and financial costs of climate change impacts against the costs and benefits of various strategies for adapting its systems to future climate conditions. The results of such analyses will allow DEP to implement the adaptations that will most effectively and efficiently minimize the impacts of climate change and fulfill its mission of delivering drinking water to New Yorkers and effectively managing and stormwater and wastewater. The potential impacts as well as DEP's actions to further define these impacts are also summarized in Chapters 5 and 6.


Ashokan Reservoir; photo courtesy of SUNY Cortland

**Approximately 90% of the City's water supply is from the Catskill and Delaware systems.**

# 2.1 | Potential Impacts to the Water Supply System

**Drinking water supply issues for the City of New York fall into three broad categories:**

- **Quantity: Will we consistently have enough water?**
- **Quality: Will water quality be threatened?**
- **Demand: Will we use more water?**

## Sources of New York City's Drinking Water

New York City's drinking water originates from a 1,972 square mile watershed approximately 125 miles north of the City that provides approximately 1.1 billion gallons per day of safe drinking water to 8.2 million residents of New York City and an additional 1 million people in eight upstate counties each day. The surface system is comprised of a network of 19 reservoirs and three controlled lakes throughout the Croton watershed east of the Hudson River, and the Catskill and Delaware watersheds west of the Hudson.

New York City's development of these watersheds, authorized by State legislation and effected between the mid-1800s and the mid-1900s entirely with City (ratepayer) funds, allows the City to impound and take water from various streams within eight upstate counties. The Water Supply Act of 1905 and its subsequent statutes, which authorized construction of much of the City's water supply system, allow for certain municipalities and water districts in designated upstate counties where water supply facilities are located to take prescribed amounts of water from the City's system.

In addition, a U.S. Supreme Court Decree in 1954 limits how much water the City can divert from the Delaware watershed, and imposes certain additional requirements for the maintenance of flow in the Delaware River. Finally, various resolutions adopted by the Delaware River Basin Commission (DRBC) and regulations adopted by New York State require the City to make certain specified reservoir releases for fisheries protection and recreational use.


Image courtesy of the Image Science & Analysis Laboratory, NASA Johnson Space Center

**The City's drinking water originates from a 1,972 square mile watershed approximately 125 miles north of the City that provides approximately 1.1 billion gallons per day of safe drinking water.**

Approximately 90% of the City's water supply is from the Catskill and Delaware systems. The water quality from these systems meets criteria set by the U.S. Environmental Protection Agency under the Surface Water Treatment Rule. This allows the Catskill and Delaware systems supplies to be unfiltered under a series of Filtration Avoidance Determinations. The Croton system, approximately 10% of the City's supply, will be filtered upon completion of a treatment plant in late 2011. The quantity and quality of the Catskill and Delaware systems are largely determined by the hydrology and ecology of their watersheds.

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In addition to the surface supply systems, New York also obtains less than 1% of its daily water needs from its Brooklyn-Queens Aquifer. This is a groundwater system in southeastern Queens.

## Potential Water Quantity Changes

### CLIMATE CHANGE, ECOLOGICAL CHANGE, AND DROUGHT

Most of the GCM models examined by DEP indicate that New York City and its watersheds will experience higher annual rainfall by the 2050s. In addition, current climate science suggests that the rainfall events experienced now may become larger and more intense, with a longer interval between the rainfall events during this century. Climate change may also affect the length of the growing season and the ecology of the watershed (Table 2.1).

These changes could affect evapotranspiration and, thus, reservoir inflows. Longer growing seasons could increase plant uptake, reducing soil moisture and reducing the availability of groundwater and surface flows to resupply reservoirs. Also, it is observed by DEP operators that water inflows to the City's reservoirs decrease abruptly at leaf-out, i.e., during the onset of the spring growing season. Because of these potential ecological changes, New York could experience more frequent and intense droughts. A Drought Watch is declared when there is less than a 50% probability that either the Catskill or Delaware reservoir system(s) will be filled by the following June 1st. This probability factor is based on historical records of reservoir refill dating back to 1927. Going forward, this may not be an accurate predictor of future droughts.

Further compounding the water supply quantity issue is that during the winter, warmer temperatures may result in more precipitation falling as rain, with less falling as snow. Thus, there will likely be less storage of water in the form of snowpack, and therefore reduced inflows to reservoirs during the spring thawing season.

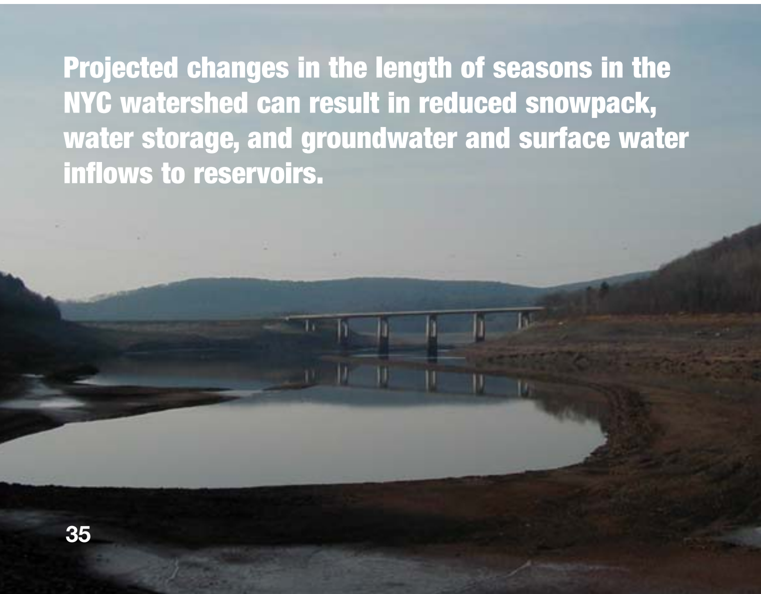
**Table 2.1**
Projected Changes (in days) in Key Indicators Related to Plant Growth in the Northeast as Simulated for Lower[1] and Higher[2] Emissions Scenarios

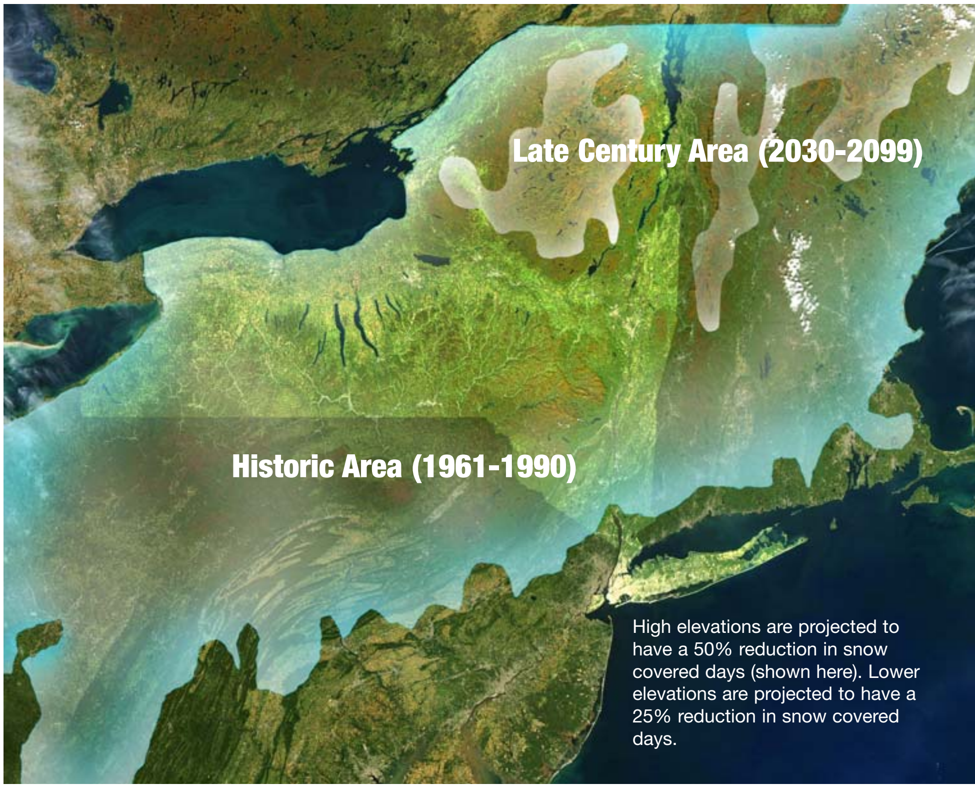
| | 2035 - 2064 | | 2070 - 2099 | |
|---|---|---|---|---|
| | **Lower Emissions** | **Higher Emissions** | **Lower Emissions** | **Higher Emissions** |
| **Onset of Summer** | -6 | -11 | -9 | -21 |
| **End of Summer** | +10 | +16 | +12 | +23 |
| **First Frost (Fall)** | +1 | +16 | +6 | +20 |
| **Last Frost (Spring)** | -8 | -14 | -16 | -23 |
| **Length of Growing Season** | +12 | +27 | +29 | +43 |
| **First Leaf (Spring)** | -3 | -5 | -7 | -15 |
| **First Bloom (Spring)** | -4 | -6 | -6 | -15 |

**(1)** Special Report on Emissions Scenarios (SRES) B1 (B1 also used for DEP projections - see Chapter 1)
**(2)** SRES A1F1 (higher than A2, which was the high scenario for DEP projections - see Chapter 1)

Source: The Northeast Climate Impacts Assessment, 2006.

**Projected changes in the length of seasons in the NYC watershed can result in reduced snowpack, water storage, and groundwater and surface water inflows to reservoirs.**






**Projected reduction in snow cover area with greater than 30 days of snow on ground.**

Peak snowmelt in the Catskills is already shifting earlier in the year, with a recent study showing that during the period 1952-2005 it shifted from early April to late March, which was consistent with other study findings including a decreasing trend in April runoff and an increasing trend in maximum March air temperature (Burns, Klaus & McHale, 2007).

### REDUCED STORAGE DUE TO FLOOD MITIGATION AND STREAMFLOW AUGMENTATION

In addition to the potential for diminished inflows to the City's water system, the likelihood of these and other climate impacts affecting other jurisdictions in the region may result in calls for the City to maintain voids in its reservoirs. Due to recent record rainfall events within the Catskill and Delaware watersheds, some have called on the City to maintain sizable voids in its reservoirs throughout the year to provide storage capacity in anticipation of storm events. The City's reservoirs were not designed as flood control structures, but they do attenuate these events. The lowering of reservoir levels to provide storage capacity in anticipation of snow melt and/or large storms may be of some value for mitigating or attenuating flooding events. In turn, however, this may reduce the statistical probability that water resources will be available to the City, especially if drought events increase or become more prolonged. Given the uncertainty of whether and when water released can be recaptured, maintaining voids throughout the year would significantly affect the ability of the City water supply system to meet the demands placed on it. The Department will have to carefully monitor and work with local and state officials to ensure that any programs implemented in the future to enhance the flood attenuation capabilities of the reservoirs do not impact water supply reliability. Warmer temperatures may also lead to impacts on fish life in watershed streams. Warmer stream water results in lower dissolved oxygen levels, and dissolved oxygen is a key determinant affecting fish life. Impacts to stream ecology might lead to more pressure for the City to make additional stream releases for environmental purposes, which would further compromise the availability of drinking water.

### ENCROACHMENT OF SALT FRONTS

Regional drought and sea level rise could also impact the City's water supplies, both directly and indirectly. While DEP does not currently have a permit to use it, the Chelsea Pump Station on the upper Hudson River has provided an emergency supply of treated water to the City in the past. More frequent droughts and sea level rise could move the salt front up the Hudson closer to the Chelsea intake and lessen the potential viability of that emergency supply source.

Drought, sea level rise and the movement of salt fronts could also threaten other nearby


**Chelsea Pump Station on the Hudson River for emergency water supply.**

Hudson River users, as well as Delaware River users downstream of the City's Delaware watershed. If sufficiently severe, these climate impacts could affect the amount of water New York City is allowed to take from the Delaware watershed and the amount of releases by the City needed in the Delaware to keep the salt front from advancing upstream. This potential threat could be increased if water sources for those other jurisdictions are significantly impacted by climate change, and New York City actions are perceived as contributory to the problem or solution. Though many New York State communities using Hudson River water do not currently use New York City water, climate change issues could increase pressure to have the relatively larger supplies under the City's jurisdiction used for emergency or even routine use elsewhere.

### Runoff and Reservoir Turbidity

Runoff into reservoirs from extreme weather events can significantly affect the levels of turbidity, which is a measurement of cloudiness of water. Although turbidity has no health impacts, it can hinder the effectiveness of disinfection and provide a medium for microbial growth. Therefore, high turbidity levels can lead to water quality violations in an unfiltered water supply system.

The turbidity levels increase and persist much longer for the larger storm events. In the case of an April 2005 runoff event, resulting from a storm with a 25-year return period, extremely high turbidity levels above 100 Nephelometric Turbidity Units (NTU) were recorded for more than 100 days (5 NTUs is the limit under the Safe Drinking Water Act). Typically, turbidity values currently range between 0.5 and 1.5 NTU.


**Schoharie Reservoir after Hurricane Floyd. Turbidity is an issue particularly in the Catskill watershed, where the slopes are steep and there is a lot of clay soil.**

Extreme weather events that erode streambeds, streambanks and sedimentary deposits can transport glacial clays into the water supply and affect turbidity levels. When such peak turbidity levels occur, DEP has treated as much as 600 mgd in the Catskill Aqueduct with alum and sodium hydroxide to reduce turbidity levels by precipitating clay particles. In order to reduce the need for chemical treatment related to extreme weather events, DEP has conducted a study of structural and non-structural alternatives to control turbidity leaving the Schoharie Reservoir. Further, the Department has implemented a Stream Management Program in the Catskill Watershed to reduce streambed and streambank erosion and has also implemented Best Management Practices to reduce turbidity in runoff at key locations near intakes.

## Potential Water Quality Changes

A series of programs under the umbrella of the Watershed Protection Program, which includes wastewater treatment plant upgrades, stormwater controls, best management practices, and many other initiatives, has successfully protected the quality of the City's surface water supply and allowed the City to continue to enjoy high quality unfiltered water from its Catskill and Delaware watersheds. Because climate change poses a threat to water quality, successful continuation of DEP's Watershed Protection Program is essential. The main water quality concerns include:

#### CHANGES IN PRECIPITATION PATTERNS

- Changes in precipitation patterns, particularly the potential for larger and more intense storms, which could cause more erosion and increased turbidity, more debris in reservoirs (e.g., downed trees, leaves), increased loadings of pathogenic bacteria and the parasites *Cryptosporidium* and *Giardia*, more phosphorus and eutrophication in reservoirs, stimulation of blooms of blue-green algae which can cause changes in water color and taste, and increased disinfection by-product precursors that can react during disinfection to form substances harmful to human health in high concentrations

#### CHANGES IN ECOLOGY OF THE WATERSHED

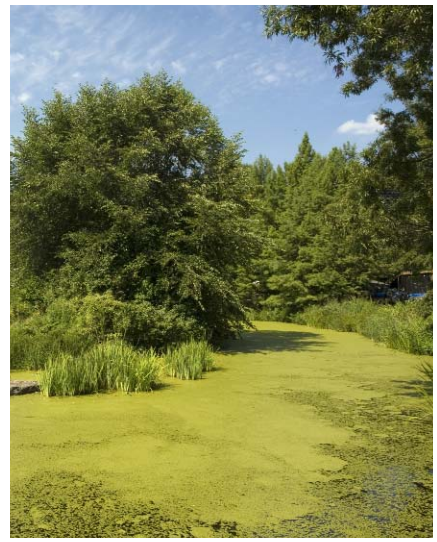
- Changes in the ecology of the watersheds, plant life, wildlife and insects, due to both temperature increases and precipitation levels and patterns may affect water quality in ways that are not presently understood

#### INCREASED WATER TEMPERATURE

- Increased water temperature in streams and reservoirs could change temperature stratification, reduce dissolved oxygen, increase algae growth which can lead to changes in water color and taste, elevate concentrations of unionized ammonia, and potentially lead to the introduction of new invasive species

- Increased water temperature in reservoirs also increases the settling of turbidity causing better quality warmer surface waters in reservoirs to be sent toward distribution which could affect downstream coldwater fisheries habitats

- Increased temperature can also alter the migration habits of waterfowl, such as Canada geese, which can have a major influence on fecal coliform levels in reservoirs (DEP currently conducts a Waterfowl Management Program to discourage the presence of geese, ducks and gulls near water intake areas)



These potential changes could stress water quality, which would require additional efforts to maintain the City's filtration avoidance status, or, alernatively, large costs for filtering the water from the Catskill and Delaware systems.

## Potential Water Demand Changes

On the demand side, though climate change concerns appear less complicated, impacts may be significant. After several decades of water usage above the system's safe yield of 1,290 million gallons a day (mgd), the City reduced demand significantly through an extensive water conservation program, such that it is now operating below this critical indicator level. In-City demand fell from 1,206 to 1,069 mgd over the past decade, while demand from communities outside the City that use City water fell from 123 to 117 mgd. DEP projects that future demand in the City could be 1,237 mgd by 2030. Although future development and population increase within the City is expected to be large, with an additional million people by 2030, the mandated use of low water use fixtures is anticipated to have a significant effect in moderating overall demand. However, these projections do not account for changes in upstate demand or other likely impacts of climate change.

### Safe Yield

Safe yield is the maximum sustainable annual withdrawal from a water supply system over a period of years that will not deplete the supply during a drought with some specified probability of occurrence.

Climate change is likely to exaggerate seasonal and peak periods rather than annual average usage. Temperature effects associated with seasonal and peak usage are well documented. Hot periods exceeding 90ºF, particularly if lasting more than three consecutive days, are known to cause high demand flows from legal and illegal hydrant usage within the City. In less urbanized areas, where lawn watering and irrigation use is prevalent, temperature increases lead to increased seasonal and peak outdoor water usage. High temperatures also promote the use of central air conditioning systems, which use water to operate their evaporative cooling towers. With temperatures potentially rising by 3.0ºF to 5.0ºF by the 2050s and 5.0ºF to 8.5ºF by the 2080s, more days above 90ºF will be experienced, and seasonal and peak demands will likely increase.

Within the City, while annual average demand is currently about 1,069 mgd, peak demand flows can rise to over 2,000 mgd during heat waves and hydrant-opening episodes. For example, on August 2, 2006, which was the third successive day with temperatures in the 90s and humidity over 70%, the daily flow was 1,560 mgd, and peak flow reached 2,020 mgd. When peak flows are over 2,000 mgd during heat waves, the ability of the existing aqueducts to refill the City's main distribution reservoir is strained. As a result, water levels go down during the daytime hours of excessive peak demand, decreasing water pressures throughout the system. This impairs fire fighting, leads to low pressure complaints from upper floors of buildings without pumping capabilities and increases sediment re-suspension within water mains. Pressure effects are more pronounced in certain outlying areas of the City (Queens and Staten Island) as well as high elevation areas (Washington Heights in Manhattan).


NYCDEP, Scott Foster

### Open Fire Hydrant

Both permitted and illegal fire hydrant openings occur during sustained periods of hot weather.

Outside the City, climate-induced demand issues, in general, may be more oriented to the summer season. Longer dry periods between rainfall events and more frequent extreme heat conditions may lead to additional outdoor water usage over extended periods of time, thus having more of an effect on total demand. Since more water is used per capita for landscaping upstate than in the City, average daily use per capita during the summer season will likely increase more upstate than in the City. Out-of-City water users are subject to additional usage charges if per capita upstate usage is greater than that of City users; however, these surcharges may not be sufficient to adequately limit increases in future demand. The City has limited power to influence upstate water demand, prices, and conservation policies.

### DEP's Watershed Management Models

DEP's watershed management models simulate water quality and quantity in the NYC Water Supply system, driven by climate data. DEP is preparing to run these models with future climate projections from global and regional climate models. The climate variables applied to the watershed and reservoir models, including precipitation, maximum and minimum temperature, wind speed, solar radiation, and humidity, are all climate model outputs.

The DEP models include: GWLF (Generalized Watershed Loading Function) watershed models that predict streamflow, runoff, sediment, and nutrient loadings from a watershed to provide assessments such as the probability of high nutrient loading concentration in summer; a 1D reservoir model that outputs daily water column average phosphate, nitrogen particulates, and ultimately chlorophyll; a 2D reservoir model which is used to model turbidity transport; and OASIS, a model which is used to manage operations such as movement of water through the reservoir system.


Image courtesy of NASA


NYCDEP

# 2.2 Potential Impacts to the Drainage and Wastewater Systems

**Climate change concerns relating to the drainage and wastewater systems fall into three broad categories:**

1. **Flooding: Will there be more flooding incidents?**
2. **Regulatory Standards: Will the ability to meet wastewater treatment requirements be impacted?**
3. **Ecology: Will there be water quality impacts to receiving waters?**

## New York City Drainage and Wastewater Treatment Systems

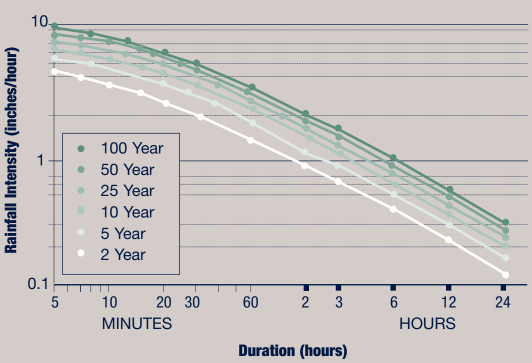
The City's drainage and wastewater system is extensive. It consists of about 6,600 miles of sewers, 130,000 catch basins, almost 100 pumping stations, and 14 WPCPs. Approximately 40% of the sewered area is drained by separate storm and sanitary sewers. The storm sewers collect runoff from rainfall events for conveyance to nearby waterways and the sanitary sewers carry sewage to the WPCPs. The remainder of the City's sewered area is served by combined sewers, which convey both sewage and stormwater runoff in a single pipe. During larger rainfall events, regulating devices in the sewer system divert excess combined sewage to receiving waters through combined sewer overflow (CSO) outfalls in order not to exceed the capacity of WPCPs. The City has several CSO storage facilities in various stages of operation, construction and planning, and various other measures have or are being implemented to reduce CSO discharges.

### Designing New York City Sewers

The City's storm and combined storm sewers are designed to convey surface stormwater runoff from rainfall events of varying intensities and durations. The methodology used to design sewers for runoff conveyance is based on precipitation intensity-duration-frequency (IDF) curves.

These diagrams are constructed from observed rainfall data of varying durations, from 5 minutes to 24 hours. The data are analyzed and arrayed graphically as precipitation intensity (inches/hour) as a function of rainfall duration (minutes or hours). Statistical procedures are used to develop a series of curves for various return periods (probabilities of occurrence).

**Rainfall Intensity and Duration**
**New York, NY 1903-1951**




The standard design criterion in New York City is to use the intensity-duration values based on a storm with a 5-year return period (e.g., 1.75 inches/hour for a one hour storm). The sewer design flow is then determined by application of an equation using a runoff coefficient, a rainfall intensity determined from an equation derived from the IDF analysis, and the contributory drainage area (NYCEPA, 1973). The design of combined sewers includes allowance for the sanitary flows.

The IDF curve currently used by New York City is based on historical data from 1903-1951. With climate change, the intensity and duration of a storm with a 5-year return period is likely to increase, therefore the current curve may not be adequate for designing infrastructure that is to last decades. However, recent studies using rainfall records from 1948-2002 (Vieux, 2006) have shown that the intensity and duration relationships actually decreased somewhat during that period.

### Water Pollution Control Plants

1. Bowery Bay
2. Hunts Point
3. Tallman Island
4. Wards Island
5. Newtown Creek
6. North River
7. Oakwood Beach
8. Port Richmond
9. Red Hook
10. 26th Ward
11. Coney Island
12. Jamaica
13. Owls Head
14. Rockaway

## Flooding Incidents

The City is vulnerable to two main types of flooding events: inland flooding from excessive rainfall and coastal inundation from storm-induced high tides. For rainfall events, the City's drainage and wastewater collection system, whether storm or combined sewers, has been designed to various sizing criteria based on historical patterns and intensities of precipitation. If rainfall becomes more intense as a result of climate change, particularly during short time intervals of 5 to 15 minutes when the rate of rainfall can be extremely high, the capacity of portions of the sewer system could be exceeded (sewer flood), leading to street and basement flooding. In addition, for low-lying areas of the sewer system near the coastline, high tidal conditions can inhibit the discharge of runoff in the sewer system causing backups and resulting in localized street and basement flooding. As sea level rises due to climate change, such backups could become more widespread and severe.

For coastal inundation, more frequent and severe shoreline flooding will occur as sea level rises and, if storms become more intense, the flooding will be worsened. Storms such as Nor'easters and hurricanes that produce severe high tides and wave action and inundate low-lying coastal areas can cause physical damage to public and private property.

Nor'easters and hurricanes can also worsen inland flooding when seawater enters catch basins and manholes located near the shoreline. DEP's WPCPs and some pump stations are located along the shoreline so that gravity can drain the sewer system and treated wastewater can be discharged to the harbor. However, due to the infrastructure's location in the flood plain, it is vulnerable to direct coastal inundation with saline waters, which could submerge and damage critical equipment, particularly electric motors and pumps. In addition to the financial cost of damage, the future reliability of operations could be compromised. Outfalls, retaining walls, docks, piers and other structures are also subject to damage.

In addition, the wetlands in and around New York City, which have shrunk by almost 90% over the past century, continue to be lost due to storm damage, development, and other factors (Bloomberg, 2007). The loss of wetlands is a concern due to their natural role in conveying, filtering and storing stormwater and their ability to attenuate coastal storm surge.

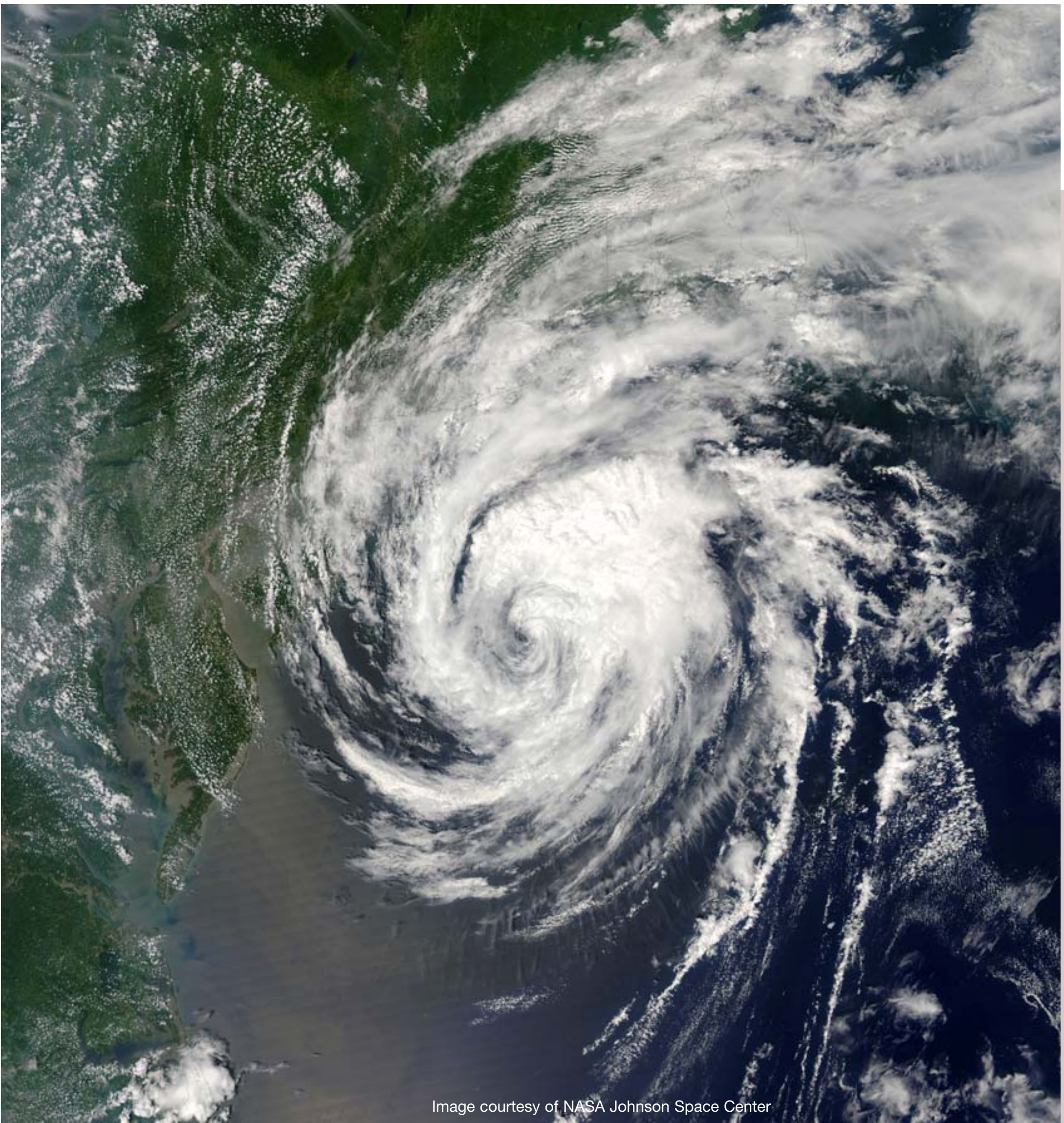


Image courtesy of NASA Johnson Space Center

### DEP's Sewershed Discharge and Harbor Water Quality Models

By using rainfall records as input to estimate wastewater discharges and pollutant loads to receiving waters from CSOs and stormwater runoff, DEP's primary landside sewer system model, InfoWorks, allows planners and engineers to predict the environmental impact following a rainfall event. DEP's harbor water quality models, the System-Wide Eutrophication Model (SWEM) and the New York Harbor Pathogens Model (PATH), compute circulation, stratification, and water quality within New York Harbor, Long Island Sound and the "New York Bight." SWEM computes the effect of various potentially polluting discharges on the harbor's dissolved oxygen resources, and PATH computes the harbor's pathogenic indicator bacteria. SWEM and PATH are influenced by freshwater boundary inflows, tidally driven surface water boundary elevations, and meteorological forces, including wind, solar radiation, ambient air temperature, precipitation, and relative humidity, many of the variables that will be altered by climate change. In an upcoming study, DEP will run these models for a range of potential future climate-related conditions to assist the Department in quantifying the impacts of future rainfall, wind, ambient air temperature, and sea level conditions on runoff loading and harbor water quality.

## Potential Impacts to Wastewater Treatment

Sea level rise represents a threat to the hydraulic capacity of WPCP outfalls. These outfalls have been designed to discharge peak influent flow to the harbor under conditions of historic high tide, and that capability is part of discharge permit requirements. Some plants are already known to be approaching their hydraulic outfall limits because, during very high tides, peak flows can be difficult to discharge. Addressing this potential impact may require effluent pumping and additional power consumption.

Sea level rise and coastal inundation may cause temporary increases in the salinity of influent to the WPCPs, which is regulated and can upset biological treatment processes and lead to corrosion of equipment. Sea water intrusion could also cause quantity concerns. Most combined sewer outfalls have tide gates to prevent the inflow of seawater directly from outfall sewers, backward to regulators, and then to treatment plants. Due to climate change, DEP may need to install tide gates at more outfalls to prevent inflows, and DEP may need to check and repair its existing tide gates more frequently.

The inability of sewers to discharge to receiving waters due to higher tidal levels during storm events could cause combined sewage to back up in the collection system, which could force more of it to the treatment plants. For the most significant storms, this could result in inundation of the WPCPs' influent wet wells, thus necessitating the throttling of flows in order to protect the plants from flooding and prevent disruptions to the treatment process. Some temporary street flooding in vulnerable areas could also result. The need to improve the reliability of throttling facilities and instrumentation related to WPCP operations could increase in order to handle significant rainfall events under conditions of higher tides. Also, pressure could increase for treatment facilities to take in more CSO flow, necessitating expansion of treatment plants, which are currently very space constrained.


**Aeration Tanks at the Hunts Point WPCP**

Treatment facilities may also be directly impacted by rising temperature. Treatment processes rely on biological and chemical reactions, some of which are temperature related. Rising temperatures could have beneficial effects by improving biological actions in some parts of the treatment process (for instance, less power may be required to heat digesters). Although it is anticipated that any adverse impacts would be minor, rising temperatures may reduce dissolved oxygen levels and transfer rates in wastewater, resulting in the need for more aeration equipment such as blowers and, therefore, for additional power.

An additional challenge is that electricity demand increases significantly during hot weather events, therefore increasing the likelihood of power outages and the need to use backup power at DEP facilities (NYCOEM, 2007). Backup power maintains essential plant operations but sensitive treatment processes such as biological nutrient removal (BNR) could be disrupted. The BNR process can take two to three weeks to recover following an extended power outage. In the interim, off-quality effluents could be discharged to harbor receiving waters and affect water quality by some amount.

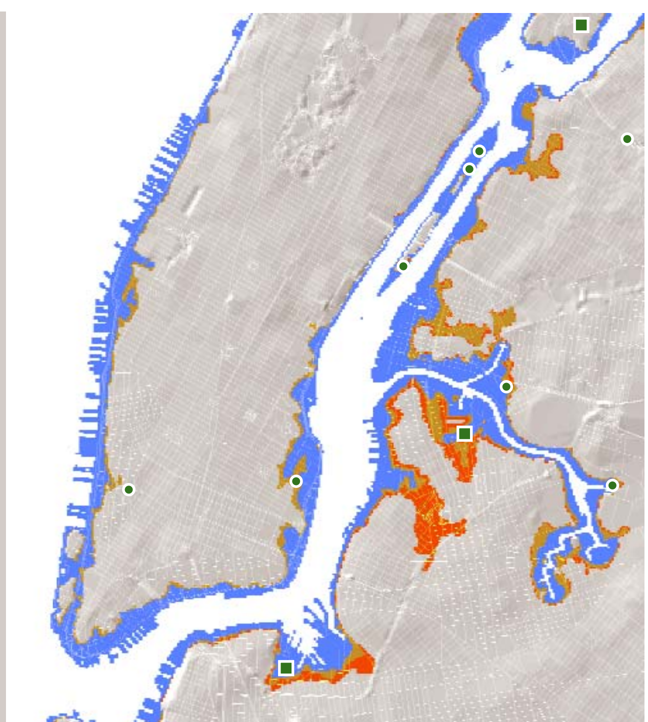
## Comparing Inundation with Current and Projected (2080s) Sea Level Estimates

CASE STUDY: 100-YEAR STORM

- Projected Inundation Zone Estimates (current sea level)
- Projected Additional Inundated Area IPCC B1 (13.8 inch sea level rise)
- Projected Incremental Additional Inundated Area IPCC A1B (16.7 inch sea level rise)
- Water Pollution Control Plant
- Pump Station

Storm Surge Data Source: FEMA Flood Insurance Study, 2/15/91
Sea level rise estimates based upon Goddard Institute of Space Studies Atmospheric-Ocean Model using International Panel on Climate Change greenhouse gas emission scenarios for 2080s.

**Mapping by HydroQual**

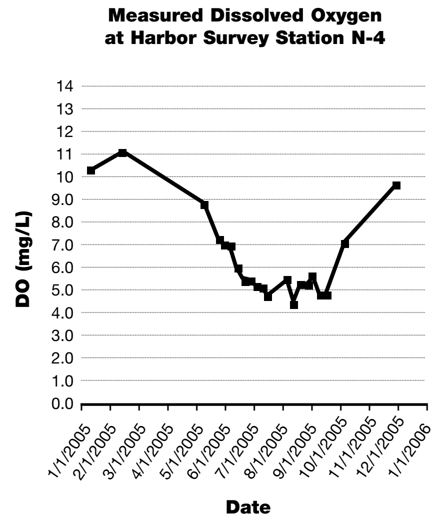


## Potential Water Quality Impacts to Receiving Waters

The waters to which DEP's drainage and wastewater management systems discharge include New York Harbor and nearby western Long Island Sound, which form an estuary (a body of water that is affected by the tidal interchange of saline ocean water and the fresh water of the Hudson River and other tributary rivers and streams). The salt content and elevation of the harbor are constantly changing from the daily and seasonal influence of tides, temperature, and precipitation. While sea level rise will likely move saline ocean waters farther upstream, the range of salinity concentrations within most of the harbor will likely remain similar to that currently experienced, although the average salt concentration at any given geographical point could increase somewhat. Sea level rise will increase water depth somewhat, and changes in precipitation patterns could result in more or less fresh water inputs from time to time. The possible ecological changes resulting from these potential climate-induced changes to the water in the harbor are not yet understood and require further study.

New York Harbor and Long Island Sound water quality may be directly impacted by temperature change. Warm waters hold less dissolved oxygen than cold waters hold, and increased thermal temperature stratification restricts the ability of atmospheric oxygen to be transferred to lower layers of the water column. Dissolved oxygen in receiving waters is a key water quality parameter regulated by State water quality standards. Low dissolved oxygen levels represent a threat to marine life, and levels must be maintained above key thresholds, depending upon the water body's use classification established by the State. A significant portion of DEP's water pollution control programs are driven by treatment requirements established to maintain compliance with dissolved oxygen standards. In the summer, receiving waters are at a low point in the annual cycle of dissolved oxygen levels, so treatment requirements are set to meet these summer lows.

Temperature rise could, therefore, potentially lead to more stringent treatment requirements. Several of the City's WPCPs already have advanced treatment requirements to remove nitrogen from wastewaters because of nitrogen's fertilizing of algae that, in turn, increases demand for oxygen in the lower layers of marine waters. State and federal regulators are currently investigating the need for more such controls. The need for even further advanced treatment requirements for nitrogen would present great challenges to DEP because of space, power and overall cost concerns.




Another water quality concern is combined sewer overflows. If precipitation patterns change such that the same or more annual rainfall is experienced through fewer but larger storms, then there is the potential that DEP will need to manage more combined sewage in order to prevent additional CSOs and the impacts to the quality of the receiving waters. It is also possible, however, that longer dry periods between storms could reduce the overall number of CSO events, therefore possibly providing better intermittent harbor water quality.

### ◂ Inundation Mapping

In order to develop maps that illustrate how much inundation areas within New York City may increase in size during future storm events, HydroQual developed a high resolution digital elevation model of the New York City topography, NYCDem, using data derived from aerial photogrammetry conducted during the 2001-2002 fly-overs for the New York City base map, NYCMap.

The Stony Brook University Storm Surge Model was used to project shoreline sea water elevations produced by historic storms, and FEMA estimates were used for 100 and 500-year storm surges. Three sea level scenarios were considered: current mean sea level, as well as current mean sea level with a 13.8 inch rise and a 16.7 inch rise (the average rise projected for the 2080s by 3 GCMs for IPCC emission scenario B1 and A1B, respectively).

### Coney Island Beach ▸

On the positive side, climate change could result in improved bathing water quality compliance. Warmer harbor waters can result in faster die-off of pathogenic organisms, which are key determinants in swimming water quality.

Discharges from WPCPs will continue to need disinfection as they do currently, and effluent from the plants will still need to meet the same residual chlorine requirement. However, the effectiveness of the pathogenic reduction in both the wastewater and receiving water should be enhanced by the higher temperatures.

P. Simmons, HydroQual

## 2.3 | Other Impacts to DEP

In addition to water supply, drainage, and wastewater issues, a number of other DEP facilities may be impacted by climate change. More intense storms and flooding in the upstate watershed could damage DEP offices, garages and other support facilities. In addition, there may be a need in the future to review dam safety criteria, as today's dams are designed for the Maximum Probable Flood based on past climate data. In the City, the vulnerability of the Department's WPCPs, pumping stations, and sewer systems to sea level rise and coastal inundation from storms has been noted. In addition, flooding events in the City from more intense rainfall could impact office buildings, field offices, repair yards, inland pumping stations, water tunnel shafts and similar facilities, as well as cause construction delays. Structural damage may also result from storms and hurricanes with increased intensity, and increased temperature could affect the durability of structures, shortening their useful life, and increase the operating cost for repair and energy needs.

In addition to the physical and environmental impacts, the fiscal impacts of climate change on water and sewer ratepayers and the Department could be significant. Climate change may cause considerable damage, and system recovery after extreme events could be very costly. In addition, the costs to managing these potential climate changes could be substantial.

Therefore, the Department needs to proceed with addressing the issue rapidly enough to minimize impacts and sustain the Department's consistently strong bond ratings, but not so quickly that DEP's funds are spent on unnecessary measures. In many instances, it is unlikely that authorization would be given to spend funds on addressing a problem that is not yet very well defined, for which there is significant uncertainty that it will in fact materialize, or for which the predicted impacts are very far in the future. Thus, understanding the extent and timing of potential impacts and critical system vulnerabilities to climate change is crucial for effective and responsible planning and decision making.


## 2.4 DEP Actions to Enhance its Understanding of the Potential Impacts of Climate Change on DEP

To quantify, better understand, and monitor the impacts of climate change on DEP and its water supply, stormwater, and wastewater management systems, DEP will:

### ACTION 1

**Conduct a phased integrated modeling project to quantify and provide a comprehensive understanding of the potential impacts of climate change on drinking water quality, supply, and demand.**

Working with Columbia University, DEP has developed a plan for a modeling project that will integrate climate change projections with the Department's watershed management models, including its water quality, quantity, and system operations models, in order to quantify and provide a comprehensive understanding of the potential impacts of future climate change scenarios on the City's water supply system. The modeling will aim to determine the extent to which changes in temperature, precipitation, extreme events, and other climate changes will impact the following key elements:

- Water quantity
- Probabilities of refill and drawdown (which are drought indicators)
- Probability and quantity of spill
- Water quality at key system locations to assess compliance with applicable regulatory and operational water quality standards
- Water demand

The project will have two phases:

**Phase I**
Phase I will use a series of sensitivity analyses to 1) test how DEP's water supply system may be impacted by a range of climate change projections, and 2) identify the key climate influences or concerns that DEP should closely track. DEP's watershed management models will be run with climate projection data in order to simulate a range of future water supply, quality, and demand under various future climate conditions.

Phase I will focus on the Catskill-Delaware watershed. The possible water supply impacts due to potential changes such as increased evapotranspiration due to warmer temperatures and longer growing seasons, and changes in precipitation, snowpack, and runoff will be studied. Relevant pressures and rules of the system, including reservoir release requirements to maintain downstream ecological flows, plus a range of future water demand estimates, will be taken into account. The potential water quality impacts due to such factors as possible pollutant loading and atmospheric changes will be studied for "indicator" reservoirs (Schoharie Reservoir in the Catskill system and Cannonsville Reservoir in the Delaware system).

**Phase II**
Phase II tasks will be structured according to the findings from Phase I and will utilize model enhancements and more refined climate projections. Phase II may also study how the salt front in the Hudson and/or Delaware Rivers may be impacted by climate-induced changes in flow and sea level. Alternative operating procedures will be modeled to determine how operational changes may be used as a tool to optimize quantity and quality and understand the limits in the resilience of the system. The review of operating procedures will take into consideration how regulations may change in the future. For example, how diversions from reservoirs may be altered or increased for ecological flow requirements to maintain healthy fisheries.

The results of this effort will support the recommendations for prioritizing proactive strategies that will maintain watershed operations at acceptable levels in a changing climatic regime.

## ACTION 2

### Conduct a project to quantify and provide a more comprehensive understanding of the potential impacts of climate change on drainage, wastewater treatment processes and infrastructure, and harbor water quality.

DEP will initiate a multi-year project to identify system vulnerabilities, and quantify the range of potential impacts of current extreme weather events and future sea level rise, coastal flooding, and precipitation changes on the Department's in-City infrastructure and its ability to drain storm water and treat wastewater. This will be achieved by running the Department's sewershed discharge and harbor water quality models with climate change data, assessing past trends, performing sensitivity tests, developing inundation maps, and performing cost/benefit analyses.

As part of this project, DEP will:

■ Identify, tabulate, and centralize the elevations of outfalls and the critical flood elevations (the lowest point where flooding occurs and may worsen) at DEP facilities in particularly flood prone areas; identify and map the current and potential range of future sea levels and 100-year flood inundation areas at the various infrastructure components; and compare the elevations of the outfalls and the critical flood elevations with the updated sea levels and inundation areas to identify the areas of the system that are flood-prone and/or susceptible to sediment deposition and sewer capacity reductions.

■ Attempt to estimate how the intensity and frequency of rainfall will change within short durations in order to assess the impacts of climate change on urban drainage (the amount of rain that falls within 5 or 15 minutes is one factor that guides sewer sizing). Climate models are currently unable to project the amount of rainfall within a period of time shorter than three hours. Thus, a methodology will need to be developed to extrapolate data from the climate models. This will likely require collaboration with other utilities that have been developing or plan to develop such estimates. However, it is possible that this will prove to be unachievable until further developments are made in climate science.

■ Evaluate to what extent street and basement flooding and CSOs will be exacerbated by climate change due to changes in rainfall intensity, duration, and frequency.

■ Estimate the probability that various costs may be incurred due to potential damage to DEP's in-City infrastructure.

■ Estimate changes in groundwater levels due to sea level rise and changing precipitation patterns and the potential for greater infiltration or inflow of groundwater into the wastewater conveyance system.

■ Estimate potential changes in harbor water quality indicators.

The findings will guide the development of a long-term plan for gradually implementing system management that will better enable DEP to provide drainage and wastewater services in the face of climate change, while making the systems more resilient to current weather extremes.

## ACTION 3

**Establish a uniform Department-wide system for documenting and reporting the occurrence, levels, and impacts of flooding and other extreme weather incidents on DEP's systems in the watershed and in the City.**

This will allow DEP to determine the degree to which the potential impacts to DEP operations and programs identified in this Report and in future studies are occurring, as well as to detect impacts that have not yet been identified.

## ACTION 4

**Conduct additional and more detailed interviews with system operators, and catalog all known system vulnerabilities.**

This will allow DEP to supplement existing in-house knowledge about current system vulnerabilities with a more targeted focus once potential future climate change challenges are better defined.

## ACTION 5

**Track published studies and identify opportunities for collaborating with researchers on future studies that will enhance DEP's understanding of the potential impacts of climate change on DEP's water systems.**

DEP is not able to study all of the potential impacts of climate change that may require systemic or operational modifications, particularly those that are not fully understood by the global scientific community, such as the ecological impacts of climate change. Tracking scientific advances in the understanding of climate change impacts may reveal data gaps and additional monitoring needs for future DEP studies. Examples of topics that may require additional study in the future include:

- Ecological changes to the watershed
- Effects of sea level rise and precipitation changes on the potential for salt water intrusion into groundwater within the City, particularly in areas targeted for increased groundwater utilization as part of auxiliary supplies
- Impacts to dams and other facilities that contribute to the impoundment and transmission of water, the hydrological changes that would be necessary to cause damage, and the probability that damage would occur based on various climate change projections and factors
- Ecological changes resulting from climate-induced changes to the water environment in New York Harbor