Modeling the Effect of Climate Change on the New York City Water Supply - Emmet Owens, New York City Dept. of Environmental Protection, Kingston, NY (co-author: Allan Frei)

The City of New York's drinking water system supplies approximately 1.1 billion gallons/day (48 m3/sec) to 9 million people in New York City and upstate communities. Drinking water is supplied by a system of 19 reservoirs and 3 controlled lakes. The water supply diversion from six of these reservoirs (the West of Hudson reservoirs constituting approximately 90% of the total supply), is unfiltered and receives chlorine and ultraviolet light disinfection prior to distribution to customers. The City operates the system under a Filtration Avoidance Determination from regulatory agencies, the provisions of which require the delivery of high quality drinking water. Here we describe analyses completed to evaluate the impact of climate change on the quantity and quality of drinking water, and on the operation of the water supply system. Analysis of historic precipitation and streamflow observations in the watershed show an increase in the frequency of extreme precipitation and streamflow events during the warm season (June through October). Modeling studies utilized predictions from a selected group of Global Climate Models (GCMs). Each of the GCMs were run for a range of carbon dioxide emission scenarios, resulting in a number of time series of predicted weather, which were viewed as equally-likely predictions of future meteorology. A change factor approach was used to downscale the GCM predictions to local conditions in the watersheds. Using this approach, modeling studies were conducted to evaluate the impact of future changes in climate on the seasonal pattern of streamflow and quality, reservoir conditions, and water system operations. Hydrologic models indicate that there will be more runoff in winter, and slightly less runoff in spring. Loading of turbidity and nutrients would also increase in late winter. In the reservoirs, the temperature of reservoir surface waters and the duration of summer stratification is predicted to increase. Levels of phytoplankton abundance in the reservoir water column, quantified by chlorophyll concentration, would increase. A sensitivity analysis of this phytoplankton response showed it is largely due to warmer water temperature, with changes in hydrology and nutrient loading having a smaller impact. Application of a reservoir model capable of predicting multiple phytoplankton classes indicates that the abundance of nuisance blue-green algae in summer will increase in certain reservoirs. Operational models showed that climate change would result in increased dam releases and spill from reservoirs in the winter, and slightly reduced in summer, and a reduced number of days that the water supply system would operate under drought conditions.

Dynamic Reservoir Operations for Climate Change Adaptation in the Washington, D.C. Metro Area - Megan Rivera, HydroLogics, Columbia, MD (co-authors: C. Schultz, S. Nebiker, G. Day, B. Wright, D. Sheer)
The cooperative water supply management approach practiced for over 30 years by the Washington, D.C. metropolitan area's three main water providers--Fairfax Water, Washington Suburban Sanitary Commission, and the Washington Aqueduct--with the technical and coordination assistance of the ICPRB's Section for Cooperative Water Supply Operations on the Potomac were groundbreaking and continue to serve the region well. The development of the 1982 Water Supply Coordination Agreement, including the first of its kind computer-aided drought exercise, contributed to the formation of Shared Vision Planning and Computer Aided Negotiations, two collaborative modeling approaches used widely in both climate-change specific and general water resources planning. Over the last few years, the region has engaged in projects to better understand if the current operations are sufficiently robust, including a study funded by the Water Research Foundation on the potential of Dynamic Reservoir Operations for climate change adaptation. Dynamic Reservoir Operations (DRO) are operating rules that change based on the present state of a system, such as storage levels, current inflow, and/or forecasted conditions; water supply system operations fall along a dynamic/static continuum. We used scenario-based planning expanded to include a large ensemble of potential future scenarios without explicitly assigning probabilities to each trace. We employed a delta change method to transform historical meteorological data to an ensemble of 112 climate change inflow scenarios using RTI's Climate Change Decision Support System (CCDSS). The 112 inflow and evaporation traces were then input to an OASIS simulation model of the water supply system. Stakeholders, including key members of each water provider and the ICPRB Co-Op Section were participants in the study, but collaboration was somewhat limited. The talk will discuss the ways in which collaborative modeling principles were included and opportunities for additional engagement. Recommendations for modifications to the operations in response to climate change included adjusting storage trigger levels for implementing drought restrictions, increasing the maximum demand reduction, changing the balancing of reservoir drawdown, increasing the storage-based trigger level for reducing withdrawals, and raising the lowest stages of a seasonal rule curve. With these changes, the system did not empty under any of the 112 climate-adjusted scenarios. The primary trade-off was a substantial increase in the frequency and magnitude of predicted demand restrictions when simulated under the most extreme climate scenarios. However, the majority of potential climate-adjusted hydrology did not require onerous demand restrictions. Some stakeholders were concerned about the region's ability to realize the higher demand reductions because 1) the widespread adoption of water saving fixtures and appliances in the region has led to zero growth in system demands over the past 20 years and decreased elasticity and 2) outdoor water use is a smaller portion of demand than in other regions. The group suggested a follow-up study on the effectiveness of demand restrictions by region to provide additional confidence in the plan's feasibility.

A Screening Tool to Identify Watersheds Most Vulnerable to Climate Exacerbated Debris Load - A Statistical Approach - Mathini Sreetharan, Dewberry, Fairfax, VA (co-authors: S. Lawler, J. Giovannettone, M. Mampara)

Stream-carried wooden debris is a leading cause of stream crossing failure. Projected increases in stream flow due to climate change is likely to exacerbate this debris-load. Debris accumulation at bridges and culverts reduces the flow carrying capacity of the structure, increases flow velocity, contributes to scour and increases the lateral forces on that infrastructure and may lead to failure. A pressing need remains for state DOTs to have improved prediction methods to identify the stream crossings and stream reaches where debris accumulation risk is high. DOTs also need to be able to make informed design decisions in light of changing conditions due to climate change. Debris risk identification on a HUC12 Watershed Basis: Based on a study for New York watersheds, this presentation gives useful insight into how historical debris removal permits, future discharge estimations, and channel/watershed characteristics can be combined to estimate risk factors for future debris-load impacts on
stream crossings. The presentation summarizes the risk factors identified as contributing to debris generation and transport. These factors, computed at the States' over 10,000 bridge crossings, include, piers, channel slope, sinuosity index, and discharge. Debris risk for each HUC12 watershed is ranked as low, moderate, based on the number of debris removal permits issued by the State, and the average risk factors calculated for the watershed. Climate Change: Future flow estimates were computed using a web based tool developed by the USGS in cooperation with NYS DOT (http://ny.water.usgs.gov/maps/floodfreq-climate/). Future flow index was developed at each bridge crossing based on the highest change in projected flow through different periods in the future until 2100. Risk associated with future flow increase is also ranked as low, moderate and high. This presentation introduces an approach where past history and risk factors such as bridge and channel characteristics are used to develop a screening tool to rank debris load risk.

Preparing for Extreme Rain Events: New York City's Cloudburst Resiliency Planning Study - Alan Cohn, New York City Department of Environmental Protection, Flushing, NY (co-author: T. Staasgaard Munk)

New York City faces increasing risks from the impacts of global climate change. Recent storms, including heavy rain events and coastal flooding, demonstrate that the city's water and wastewater system has risks from extreme weather that must be addressed through implementation of further climate adaptation interventions. Heavy rainfall events ('cloudbursts') can inundate urban areas and potentially cause severe damage. The NYC Department of Environmental Protection (DEP), in cooperation with the City of Copenhagen, have started to develop innovative solutions to heavy rainfall and associated physical and societal impacts by conducting the Cloudburst Resiliency Planning Study, focusing on a pilot area in Southeast Queens. Through inland flood risk analysis and planning that integrates flood protection by enhancing stormwater management through storage and surface flow conveyance, DEP is seeking to address intense rainfall through integration of grey and green strategies in coordination with ongoing urban infrastructure planning. The Cloudburst Resiliency Planning Study aimed to assess the potential impacts and interventions within our pilot study area so that opportunity areas for site specific interventions could be identified. GIS data acted as the foundation for this assessment and was crucial in providing a solid basis for informed decision making, by allowing us to overlay datasets and perform multiple levels of analyses that were linked in order to identify potential synergies and cumulative effects. These analyses consisted of land-use and landscape analysis, developing flow lines through terrain-based hydrologic analysis, identification of relevant capital projects, and risk mapping and flood damage estimates. Several flood mapping scenarios were developed to illustrate spatial flood dynamics over time. ESRI GIS-based programs were used, such as MIKE FLOOD, which combines a GIS model of the sewer network in Mike Urban with a 2D digital terrain model in MIKE 21. These models simulate spatial flood dynamics over time, both in the sewer network and in the terrain. Complex GIS models were also used for risk mapping, looking at the probability of flooding with consequence on a cell-by-cell basis in order to estimate the yearly damage costs associated with flooding over time. The outcomes of these analyses were combined into multiple scenarios for potential interventions and tied to investment and damage cost reductions in a cost-benefit analysis model. Each scenario also highlighted additional opportunities including other relevant urban planning processes and strategies and upcoming infrastructure upgrades. This effort analyzes best-available data related to New York City rainfall, recommends methodologies for incorporating findings into ongoing resiliency planning initiatives, and identifies best practices for considering climate change in future neighborhood-specific planning studies. As an outcome of the Cloudburst Study, opportunities for intervention have been identified within the designated pilot study area to provide retention and conveyance for extreme conditions, while also offering community and environmental benefits in normal conditions. This project can provide insight on ways to advance climate resiliency projects and traditionally-used stormwater solutions to mitigate
inland flooding and accommodate future increased rainfall intensity through integration with ongoing urban planning and development.