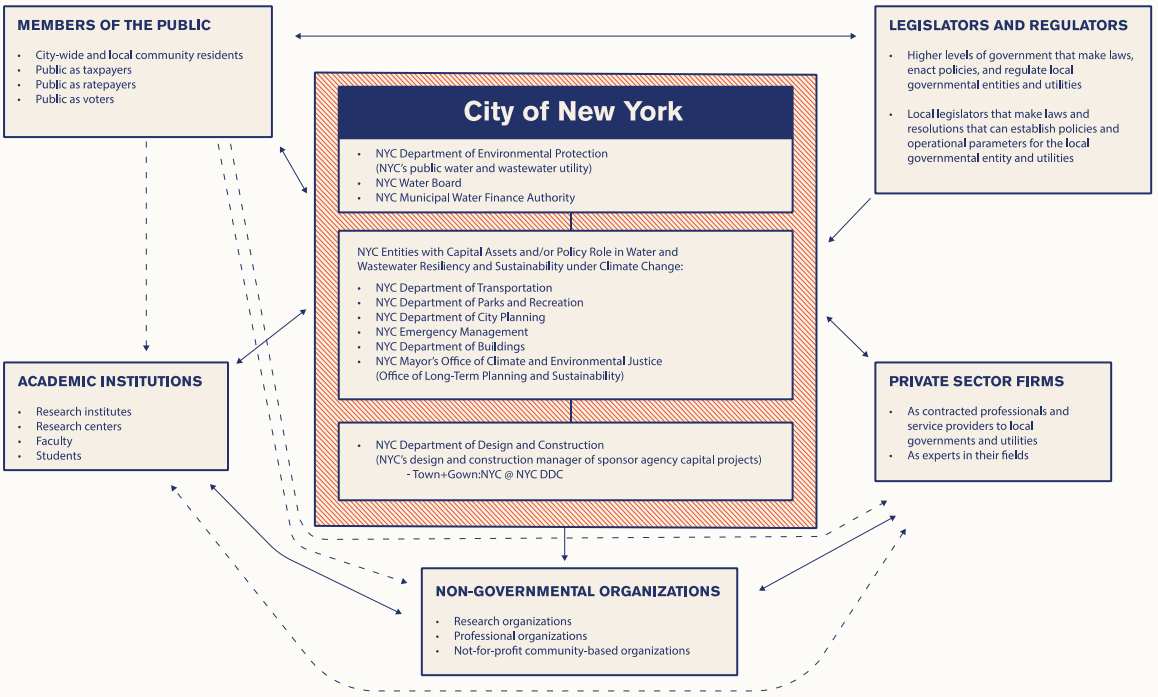
MEGACITIES

The NYC Megacity Stakeholder Network

For Water and Wastewater Resiliency and Sustainability under Climate Change



New York City

Key facts

Population: New York City (NYC) estimated population was 8,335,897, as of July 1, 2023, per U.S. Census Bureau.

Important water bodies and aquatic ecosystems:

Atlantic Ocean and the New York Bight; New York Harbor; Long Island Sound; various bays, basins and coves (e.g., Jamaica Bay); tidal straits (e.g., East and Harlem Rivers); various rivers (e.g., Hudson, Bronx and Hutchinson Rivers); various streams and kills (e.g., Spring Creek and Fresh Kills); various naturally occurring or built lakes and ponds (e.g., Kissena, Van Cortlandt and Prospect Park Lakes).

Drinking water services & access to water

- Percentage of the population with access to safe water: 100 %
- Main sources of drinking water supplies: NYC's water supply system, owned by NYC and operated as a utility by NYC Department of Environmental Protection (NYC DEP), provides potable water from a 2,000-square-mile watershed outside NYC to all NYC residents, visitors and businesses. The Catskill and the Delaware components, located in Delaware, Greene, Schoharie, Sullivan, and Ulster counties, include nine reservoirs, and the Croton Water component, located in Putnam, Westchester, and Dutchess Counties, includes ten reservoirs. NYC's groundwater supply system in southeastern Queens, purchased from Jamaica Water Supply Company in 1996, has been offline since 2007.

Wastewater management

- Wastewater collection rate: 100 %
  (not all of which is treated due to combined sewer overflow events and separate stormwater sewer infrastructure)
- Wastewater treatment level: NYC's sewer system, owned by NYC and operated as a utility by NYC DEP, consists of a 6,000-mile network of subsurface sewer pipes, 135,000 sewer catch basins and 96 pumping stations leading to NYC's 14 wastewater resource recovery facilities (WRRFs) that process the wastewater, as required by federal and New York State (NYS) law, before release into surrounding surface waters. Wastewater treatment at each WRRF before release as clean water into surrounding surface waters, as required by federal and NYS law, includes preliminary treatment (screening and pumping); secondary treatment with aeration tanks and final settling tanks; sludge processing with digestion and centrifuge-based dewatering; and disinfection to remove any remaining disease-causing microorganisms. Resulting biosolid management by private contractors include disposal at landfills or further processing for beneficial re-use, as permitted by federal and NYS law.

Water reuse:

NYC's Water Conservation and Reuse Grant Pilot Program provides commercial, industrial, and multi-family residential property owners with incentives of $10 per gallon saved to install water efficiency technologies, including on-site non-potable water reuse systems. Currently, there are approximately 30 buildings in NYC with onsite reuse systems.

Stormwater management:

NYC has a broad and integrated effort to manage stormwater to reduce pollution in surrounding surface waters and mitigate risk from flooding. Long Term Control Plans (LTCP) linked to WRRFs and the regulated surrounding surface water bodies and a city-wide LTCP identify appropriate combined sewer overflow (CSO) controls necessary to achieve waterbody-specific water quality standards, consistent with federal and NYS laws, using a hybrid "gray" infrastructure approach, including drainage pipes and underground tanks, and a "green" infrastructure (GI) approach, including (1) street, sidewalk and other public/private property hard surface installations to collect stormwater such as rain gardens, infiltration basins, green roofs, porous pavements and underground retention or detention systems[1] and (2) nature-based "bluebelt" installations connected by drainage pipes that provide open green spaces and support a diverse wildlife habitat while reducing flooding and water pollution.[2] NYC's new strategy deploys a clustered engineering approach in flood-prone communities to manage cloudbursts by combining gray infrastructure and GI to manage larger volumes to achieve both water quality and stormwater resiliency goals. A recently released Unified Stormwater Rule (USWR) expands the implementation of porous pavements and curbside green infrastructure practices on NYC streets and sidewalks and green infrastructure implementation on public and private properties as part of new and redeveloped properties, with technical guidance for developers, designers, and engineers is provided through the New York City Stormwater Manual.

Water and climate-related challenges

NYC's water supply system consists of assets constructed beginning in the middle of the 19th century and completed

approximately a century later. Its wastewater treatment facility system consists of assets placed in service in the 20th century, ending in 1987. NYC's subsurface water and sewer distribution systems were placed in service throughout that time as its population increased and its surface developed.[3] These assets were designed to acceptable engineering standards when national weather reporting was in its infancy.[4] As changes to the intensity and frequency of precipitation events occur, NYC experiences increased combined sewer overflow (CSO) events, which cause temporary increases in pollution within a context of general improvements in the monitored surrounding surface water, and increased inland flooding due to NYC's high level of impervious surfaces from surface building density and corresponding surface roads and streets.

The 1972 federal Clean Water Act and related NYS environmental laws, to which all NYS local governments are subject, resulted in significant improvements to NYC's surrounding surface water quality. As required monitoring of the surrounding surface water shows continued decreases in pollution, complying with EPA and NYS laws drives NYC and NYC DEP to implement a wide variety of infrastructural and operational responses to the impacts of changes in intensity and frequency of precipitation events.[5]

Across all utilities, infrastructural and operational changes involve an infrastructure transition that precedes implementation of those changes, while existing infrastructure is in operation, due to formal decision-making processes that involve economic, finance and political considerations.[6] Infrastructure transitions for water and sewer systems, including NYC's, require systems innovation, often supported by research, within a fixed network that is subject to financial constraints.[7] While, in 1984, creation of the New York City Municipal Water Finance Authority put financing NYC's water supply and sewer systems capital needs on a utility basis, through water and sewer service fees, NYC DEP's capital budget is constrained by utility revenues and debt service rate covenants for existing debt that limits capital funds available for the infrastructure transition.[8]

NYC created the New York City Panel on Climate Change (NPCC) with leading independent climate and social scientists that has been analyzing climate trends (including changes to intensity and frequency of precipitation events and rising sea levels), developing projections, and exploring impacts on NYC's operations and infrastructure since 2008. The NPCC has concluded that NYC has already experienced impacts of climate change and has forecasted dramatic future impacts. Based on these NPCC's reports, NYC DEP, as part of its ongoing review of climate change impacts on its water supply and sewer systems, has been implementing infrastructure projects, in various stages of feasibility review, design and construction, to protect the systems from forecasted climate change impacts as well as to improve the resiliency of both systems to forecasted climate change impacts, the total costs of which are expected to be substantial. These capital projects also reflect NYC's integration of climate resiliency into the capital planning process based on studies of climate impacts on both NYC DEP's systems and NYC's Climate Resiliency Design Guidelines that translate NPCC's climate change projections into the design of critical public infrastructure.[9]

Research, innovation and policies on water and climate adaptation/resilience

Below are research projects and policies presented at the MAWaC-ENAR Water Research & Innovation (WRI) Workshop, March 20-21, 2023, co-organized by New York University and NYC DEP, under the auspices of UNESCO (MAWaC Secretariat), with the collaboration of other organizations. These research projects, along with others, would support innovative systemic designs, technology and planning leading to an infrastructure transition toward the next industrial paradigm under conditions of climate change.[10]

New York Stormwater Resiliency Study[11]

Jennifer Cherrier, Professor Earth and Environmental Science, City University of New York, Brooklyn College/Graduate Center. Rainfall poses a set of interwoven challenges to NYC that require coordinated solutions to improve water quality and address urban flooding. Controlling urban flooding, integrated with coastal surge event preparation, would address both flooding and coastal surge concerns simultaneously and increase safety and limit personal and property damage. NYC had been addressing how climate change would aggravate existing hazards, prioritizing many areas for coastal protection projects or drainage improvements, based on sea level rise maps developed by NYC Department of City Planning showing tidal inundation during mean high-high water events for the 2020s, 2050s, 2080s, and 2100. Even with implementation of these types of projects, however, inland areas were expected to experience increased inland flooding due to rainfall intensity and capacity constraints during high tides. The New York Stormwater Resiliency Study developed a better understanding of NYC's hydraulic and hydrologic (H&H) systems and how tidal flooding might interact with and potentially be worsened by urban flooding from rainfall to permit NYC agencies coordinate and strengthen resiliency and sustainability initiatives and further support city-wide integrated stormwater management planning. This study developed a citywide H&H model to identify priority NYC at-

risk areas. The researchers used the model to test multiple rainfall scenarios, including extreme and moderate events, with varied spatial distribution, intensity, frequency, and durations and to investigate the impact of changing climate conditions on flood conditions and stormwater management practices, based on NPCC climate impact projections. The study looked at flooding from coincident tide and precipitation and investigated geographic-specific stormwater conditions where flooding might be influenced by sea level rise, tidal inundation, and/or elevated groundwater. The research also involved community vulnerability assessment, gray/green intervention scenarios for offsetting risks, and stakeholder engagement and research, with three stakeholder workshops timed in conjunction with interim task completions. Study results provided NYC with an early indicator of at-risk areas for which enhanced modelling and intervention analysis should be prioritized. (Completed 2021)

NYC Stormwater Resiliency Mapping

Melissa Enoch, Managing Director, Green Infrastructure Planning and Partnerships, Bureau of Environmental Planning & Analysis, NYC DEP. NYC has been mapping climate threats for some time. Using outputs from the New York Stormwater Resiliency Study referenced above, NYC DEP launched an effort to expand its calibrated H&H models, used primarily for CSO LTCP regulatory analyses, to identify and map surface flooding under a variety of climate-change driven precipitation scenarios citywide. The models were enhanced by adding in additional 1D network in areas identified using topography and outputs from the prior analysis referenced above and by incorporating a 2D surface to better represent the sewer system's flooding response and spatially depict flooding. This work was essential to the maps published as part of the NYC Stormwater Resiliency Plan (https://www.nyc.gov/assets/orr/pdf/publications/stormwater-resiliency-plan.pdf), which identify areas vulnerable to flooding under moderate and extreme precipitation scenarios. NYC DEP tested different visualization options based on stakeholder feedback and post-processing of flood results to refine the resulting maps for public viewing with area and depth thresholds to smooth-out and aggregate raw results, creating two ranges of ponding from nuisance flooding (greater or equal to 4 inches and less than 1 foot) to deep and contiguous flooding (1 foot and greater). Additional H&H model improvements include increasing model construction and resolution eventually moving to a citywide rain-on-mesh approach and collecting quantitative data to validate future model by monitoring urban flooding events, placement of surface-level sensors, processing imagery to extract flood data, and additional in-sewer monitoring.

FloodNet: Hyperlocal, Street-Level Flood Monitoring in New York City

Andrea Silverman, Assistant Professor, Environmental Engineering, Department of Civil and Urban Engineering, Tandon School of Engineering, New York University. NYC DEP contracted with the City University of New York, in 2023, and the FloodNet Consortium to expand a sensor network across NYC over the next five years. NYC agencies need quantitative flood data for planning and monitoring (see NYC Stormwater Resiliency Mapping summary above), emergency response, and post-flood impact cataloguing purposes; researchers need this data to validate flood predictions from the New York Stormwater Resiliency Study, flood monitoring and informing water sampling; and, community members need this data for decision-making purposes. This project will develop a water level sensor network to measure hyperlocal street-level flooding and collect and provide real-time quantitative data. The FloodNet Consortium will design, build and deploy a low-cost robust sensor network and develop a data portal to contextualize and communicate the data to stakeholders. The FloodNet hardware, consisting of an ultrasonic sensor, solar panel and data transmission antenna, will sense water depth with accuracy of +/- 5 mm, collect and transmit measurements every one minute, and operate independently and autonomously for long periods of time, providing a low-cost case study model for future flood sensor network scalability. (Ongoing)

Characterizing Current and Future Rainfall Extreme Events in New York City, Task 3 of Climate Vulnerability, Impact and Adaptation Study,[12] Patrick Gurian, Professor, Department of Civil, Architectural, and Environmental Engineering, Drexel University. Climate change requires stormwater managers to rely on highly uncertain projections of future rainfall events, since historical records may no longer apply to future conditions. The multi-disciplinary multi-institutional Climate Vulnerability, Impact and Adaptation Study will evaluate the impacts in NYC of future climate, with an emphasis on rainfall and flooding. The Task 3 team will review literature on climate impacts on precipitation, catalogue extreme precipitation events, and estimate the intensity, duration and frequency (IDF) of future rainfall events for NYC's stormwater management decision-making process. NYC has used a 5-year return period, based on IDF curves from historical (1903-1951) rainfall patterns, to design its stormwater drainage pipes. To support re-examination of design standards, the Task 3 team will develop novel IDF curves under conditions of climate change to understand future precipitation changes and evaluate how these new IDF curves could impact current stormwater management practices related to future design of these

assets. The Task 3 team will convene a stormwater subcommittee composed of NYC infrastructure design and operations experts to 1) understand how NYC uses future rainfall event projections and 2) identify how the organizational design process can most effectively accommodate updated information on future rainfall events to produce robust designs reflecting technological changes within a constrained capital budget context. (Not yet completed)

Jamaica Bay Story

Zehra Kuz, Adjunct Professor, CCE, School of Architecture, Pratt Institute. Jamaica Bay in Brooklyn and Queens, NYC's largest bay, is an estuary fed by several creeks, with barrier islands and marshlands, that extends over 25,000 acres, supporting a rich wildlife. Public and private entities have shaped and reshaped the Bay and its surrounding areas, beginning in the 20th century with a series of parks, parkways and other transportation infrastructure requiring dredging and filling that altered the original shoreline and challenged the balance between man-made and natural ecosystems. Private development of the surrounding land resulted in four Community Districts with diverse cultures and housing typologies sharing an area comprised of the same geomorphology that is vulnerable to flooding even with tidal movements. Through the RAMP (Recover Adapt Mitigate Plan) program, graduate and undergraduate students engage on interdisciplinary studio projects to address clearly defined challenges to a community posed by climate change. Examples of studio projects in Jamaica Bay area include a 2014 Pratt graduate planning studio that thoroughly studied the area's conditions and designed policy recommendations for Rockaways peninsula communities, and a 2014 undergraduate architecture studio that explored new forms of off-the-grid housing on the water during times of normalcy and disaster. The lack of connectivity to public transportation inspired design of a waterway network connecting all the Bay's protected basins and a multipurpose building imbued with economic development potential as a gateway to amphibious development with the ability to transform into a community disaster relief center when necessary. In 2019, the Delta Cities Coastal Resilience team developed design strategies in response to environmental stresses from Superstorm Sandy, envisioning flood and stormwater protection measures, identifying socio-economic opportunities, and creating spaces where innovative programs can unfold.[13] (Ongoing)

R+D in the 21st Century: Cultivating a Modern Research Community

Jennifer Farmwald, Section Chief, Research Coordination, Water Innovation and Research, Bureau of Water Supply, NYC DEP. The NYC DEP Bureau of Water Supply (BWS) has developed new programs that focus on advancing research and innovation within the Bureau and across NYC DEP as new technologies and innovative solutions enter the 21st century. These efforts to organize ongoing research and create the process to advance information sharing and innovation within BWS and across NYC DEP would be replicable and scalable at other megacity water and sewer utilities. Emerging research and incorporating innovative technologies are cornerstones at NYC DEP, and in recent years, the agency has implemented organizational changes to enhance research collaboration and disseminate information widely. Fostering collaboration is not one-size-fits-all. Creating a virtual space to ask questions, share emerging research, webinars, and resources provides connection across the numerous offices in NYC and the upstate watersheds. Each month, an agency-level team convenes to discuss research or other opportunities. Conversely, these discussions and opportunities are only useful if shared more widely. Dissemination takes numerous forms: an annual BWS Conference, monthly webinars, and the publication of a research agenda along with a summary of all research taking place within NYC DEP. Taken together, these strategies increase awareness and optimize research opportunities and foster greater collaboration within and between groups at every level.

Town+Gown:NYC Master Academic Consortium Contract

Terri Matthews, Director, Town+Gown:NYC @ NYC Department of Design and Construction. The Town+Gown:NYC program is a replicable model for sustained urban practitioner + academic collaboration on applied research projects. It is a NYC-based university-community partnership bringing academics and practitioners together on Built Environment research that uses action research and collaborative inquiry principles to assure practitioners are equals in knowledge creation and active participants so that research results will be of value and use to them. The program uses two mechanisms: a faculty directed research component (funded research) supported by the Master Academic Consortium Contract (Master Contract) and an experiential learning component ("free" research). The Master Contract, with 15 colleges and universities in the academic consortium vendor pool, solved the procurement problem for NYC agencies seeking to conduct applied research with academic institutions in an easy and quick manner. This Master Contract is replicable at other U.S. states and local governments, and possibly at non-U.S. megacities, with innovative procurement features that include an open-ended procurement that brought schools on board until one year after first contract registration, deferring competition to the later RFP/Task Order stage; a long contract term with option to renew for an additional period to support sustained academic-

community partnerships; and, permitting initial schools to contribute to Master Contract drafting. The RFP, Proposal, and Task Order are template forms that focus only on the research project because Master Contract provisions are incorporated by reference; provisions for intellectual property, confidentiality, cost-accounting, collaboration and subcontracting are suitable for academic research; third-party funds can fund or supplement public funds for projects; various public entities other than NYC agencies can use it; and, academic institutions can collaborate with each other to make joint proposals to merge their research strengths.[14] The Master Contract, through which NYC DEP procured two of the research projects summarized above, would be available to multi-megacity research projects of interest to NYC DEP.

Water Quality and Natural Resource Restoration

Angela Licata, Deputy Commissioner, NYC DEP. NYC DEP has been increasingly using nature-based approaches on a larger scale to protect, preserve and improve water quality, while providing substantial ecological benefits, as a supplement to traditional gray infrastructure projects. Examples include restoration of the Alley Creek tidal wetlands that leverage salt marshes to dissipate tidal flows and allow for bacteria to be deposited, increasing the UV light exposure to remove the bacteria; a research project in February 2022 with NYS Department of Environmental Conservation, Cornell University and SUNY/Stony Brook piloting the use of the ribbed mussel (Guekensia demissa), which have the ability to filter and digest free bacteria including within the range of fecal coliform sizes, for water improvement in Bergen Basin; several completed and planned Jamaica Bay marsh island restorations to restore critical sources of habitat and improve resilience using salvaged native sod and seeding local sod species ; restoration of wetlands on both sides of Paedergat Basin with large plots of native grasses and protection and preservation of native vegetation; and, creation of a maritime forest, restoration of tidal wetlands and creation of freshwater wetland at Idlewild Park.

Green Infrastructure Research & Development

Miki Urisaka, Bureau of Environmental Planning & Analysis (BEPA), NYC DEP. NYC DEP engages in GI research and development (R&D) to measure the performance of constructed GI installations, improve GI designs to maximize stormwater capture, support long-term functionality, develop new technologies and inform future stormwater programs and policies.[15] BEPA's technical R&D approaches include continuous real-time monitoring, simulated runoff testing, surface infiltration testing, computational fluid dynamics modelling, soil sampling, post-construction field testing protocols and H&H modelling. For example, data collected from monitoring rain gardens over three seasons with 653 rain events using rain gauges, soil moisture sensors and pressure transducers, supplemented with flow-controlled tests as well as feedback from construction contractors, maintenance staff, and residents, resulted in a variety of new and enhanced design changes.[16] New standard rain gardens have modified inlet designs to increase stormwater capture, a sediment capture ring behind the inlet, concrete strips in place of stone strips and new planting plans. New infiltration basin designs match existing sidewalk conditions with an inlet apron slope dependent on sidewalk curb reveal. In another study, green roof retention benefits were quantified using U.S. Environmental Protection Agency's Storm Water Management Model designed for users, such as local governments, to predict runoff quantity and quality from drainage systems,[17] to evaluate cost-benefits for a range of green roof systems, and used to develop a new NYC-specific green roof incentive schedule to maximize cost effectiveness and provide upfront certainty to applicants to NYC DEP's green roof retrofit grant program.[18]

Innovative Stormwater Management Solution Using Existing Street Medians

Thewodros Geberemariam, Director, In-House Design, Bureau of Environmental Planning & Analysis, NYC DEP. NYC, like other megacities, faces technical challenges to stormwater management including drainage issues affecting water quality and flood impacts, lack of biodiversity within the urban environment, and lack of space for stormwater management techniques in built-up areas. NYC has a total of 693 acres of existing local street median area which is an untapped resource for nature-based stormwater management solutions. Of the total existing street median area, research indicates that 435 acres are potential areas for GI applications such as green street medians and green urban squares. Installing GI in street medians involves administrative challenges requiring multi-agency collaboration and coordination with utilities whose subsurface utility infrastructure runs beneath the median areas, however, overcoming these challenges and continuing to implement innovative stormwater management solutions will help towards water quality improvements and flood mitigation, enhanced biodiversity, and possibly socioeconomic benefits such as increased property values and neighborhood beautification.

DDC Coastal Resiliency Program

Eric Macfarlane, First Deputy Commissioner, NYC Department of Design and Construction (NYC DDC). NYC DDC is responsible for the design and construction of three capital projects budgeted with a combination of federal and local funds to protect 70 percent of the Lower Manhattan shoreline, which suffered significant damage when

Hurricane Sandy hit NYC on October 29, 2012, and one capital project budgeted with the same combination of funds for Red Hook, Brooklyn, which also experienced significant damage from Sandy. These projects are in various stages of development with the $1.45 billion East Side Coastal Resiliency (ESCR) project the furthest along in construction. The other projects are the Brooklyn Bridge Montgomery Coastal Resiliency project, the Bellevue Campus Coastal Resiliency project and the Red Hook Coastal Resiliency project, totalling $869 million. The ESCR project is a 2.4-mile protection system against high water levels from coastal storms of up to 30 inches sea level rise based on 2015 baseline projections and NPCC low probability sea level rise projections for 2050s. It includes raising adjacent parkland, which is an important local community waterfront open space amenity, exposed floodwalls with roller and swing gates to cross roadways, floodgates, and infrastructure improvements such as increased interior drainage capacity to reduce inland flooding, transferring stormwater to the Manhattan pump station, and two interceptor gate buildings to block sewer system overflows to adjacent areas and the East River. Expected to be completed in 2026, the ESCR project is the first step in NYC's larger coastal resiliency plan that emerged from a winning proposal from the 2014 U.S. Department of Housing and Urban Development's "Rebuild by Design" competition and works in tandem with surrounding resiliency initiatives such as those of the New York City Housing Authority, Con Edison, and Lower Manhattan community.

Conclusions

As the megacities participate in the post WRI Workshop planning activities within the MAWaC-ENAR framework aiming at future multi-megacity research projects, these projects would need to reflect NYC's capacity to act[19] and what NYC DEP and/or other NYC agencies deem relevant in practice.[20]

References

[1] See https://www.nyc.gov/site/dep/water/green-infrastructure.page accessed 07-10-23 6:18 p.m.
[2] See https://www.nyc.gov/site/dep/water/the-bluebelt-program.page accessed 07-10-23 6:18 p.m.
[3] See https://www.nyc.gov/site/dep/water/water-supply.page, https://www.nyc.gov/site/dep/water/history-of-new-york-citys-drinking-water.page, https://www.nyc.gov/site/dep/water/wastewater-treatment-system.page, and https://www.nyc.gov/site/dep/water/sewer-system.page accessed 07-10-23 1:00 p.m.; Joanne Abel Goldman, *Building New York's Sewers: Developing Mechanisms of Urban Management* (West Lafayette IN: Purdue University Press, 1997), pp. 70-72.
[4] See https://www.weather.gov/timeline accessed 06-26-23 12:21 p.m.
[5] See https://www.dec.ny.gov/chemical/77733.html accessed 07-10-23 6:25 p.m. and https://www.dec.ny.gov/chemical/102611.html accessed 07-10-23 6:25 p.m.
[6] Martin V. Melosi, *Effluent America: Cities, Industry, Energy, and the Environment* (Pittsburgh PA: University of Pittsburgh Press 2001), p. 119, 137-140).
[7] Hodson, Mike, Simon Marvin, Blake Robinson, and Mark Swilling. 2012. "Reshaping Urban Infrastructure: Material Flow Analysis and Transitions Analysis in an Urban Context." Journal of Industrial Ecology 26 (6).
[8] Official Statement, dated March 9, 2023, for $1,293,395,000 New York City Municipal Water Finance Authority Water and Sewer System Second General Resolution Revenue Bonds, Fiscal 2023 Series DD, p. 7 https://emma.msrb.org/P21674766-P21288759-P21718406.pdf accessed 06-26-23 1:23 p.m.
[9] *Ibid.,* pp. 54-55.
[10] Melosi, *op. cit*., p. 138.
[11] Town+Gown Master Contract RFP at https://www.nyc.gov/assets/ddc/downloads/town-and-gown/active-rfps/Citywide%20Stormwater%20Resiliency%20Study%20T+G%20RFP.pdf. See also https://www.nyc.gov/site/ddc/about/press-releases/2021/pr-062921-TG.page
[12] Town+Gown Master Contract RFP at https://www.nyc.gov/assets/ddc/downloads/town-and-gown/DCAS_MOCR_VIA_RFP.pdf.
[13] Other Pratt Institute RAMP workshop and studio projects are abstracted at https://www.nyc.gov/assets/ddc/downloads/town-and-gown/TownGownInventoryofResearch.pdf, as material provided at the 2022 WRI Workshop; see also https://ramp-pratt.org/story_page/.
[14] See https://www.nyc.gov/site/ddc/about/Faculty_Research.page accessed 07-10-23 6:44 p.m.
[15] See https://www.nyc.gov/site/dep/water/green-infrastructure.page accessed 07-10-23 6:37 p.m.

[16] See https://www.nyc.gov/assets/dep/downloads/pdf/water/stormwater/green-infrastructure/green-infrastructure-standard-designs.pdf accessed 07-10-23 6:38 p.m.

[17] See https://www.epa.gov/water-research/storm-water-management-model-swmm accessed 07-10-23 6:39 p.m.

[18] See https://www.nyc.gov/site/dep/water/green-infrastructure-grant-program.page accessed 07-10-23 6:39 p.m.

[19] Stephen Hammer, "Capacity to Act: The Critical Determinant of Local Energy Planning and Program Implementation," Working Paper, Columbia University Center for Energy, Marine Transportation and Public Policy. Presented at the World Bank's 5th Urban Research Symposium (Cities and Climate Change), Marseilles, France, June 28-30, 2009, p. 1.

[20] Tabory, Samuel, Terri Matthews, Richard Feiock, and Anu Ramaswami, "What Cities Want to Know: A Practitioner-Derived Research Agenda for Sustainable Urban Infrastructure Transitions" (unpublished paper conducted through Sustainable Healthy Cities sustainable research network supported by the U.S. National Science Foundation's Sustainability Research Network program, award No.14447450). Tabory, Samuel, and Anu Ramaswami, "Considering the role of urban types in coproduced policy guidance for sustainability transitions," Urban Transformations (2020) 2:8.