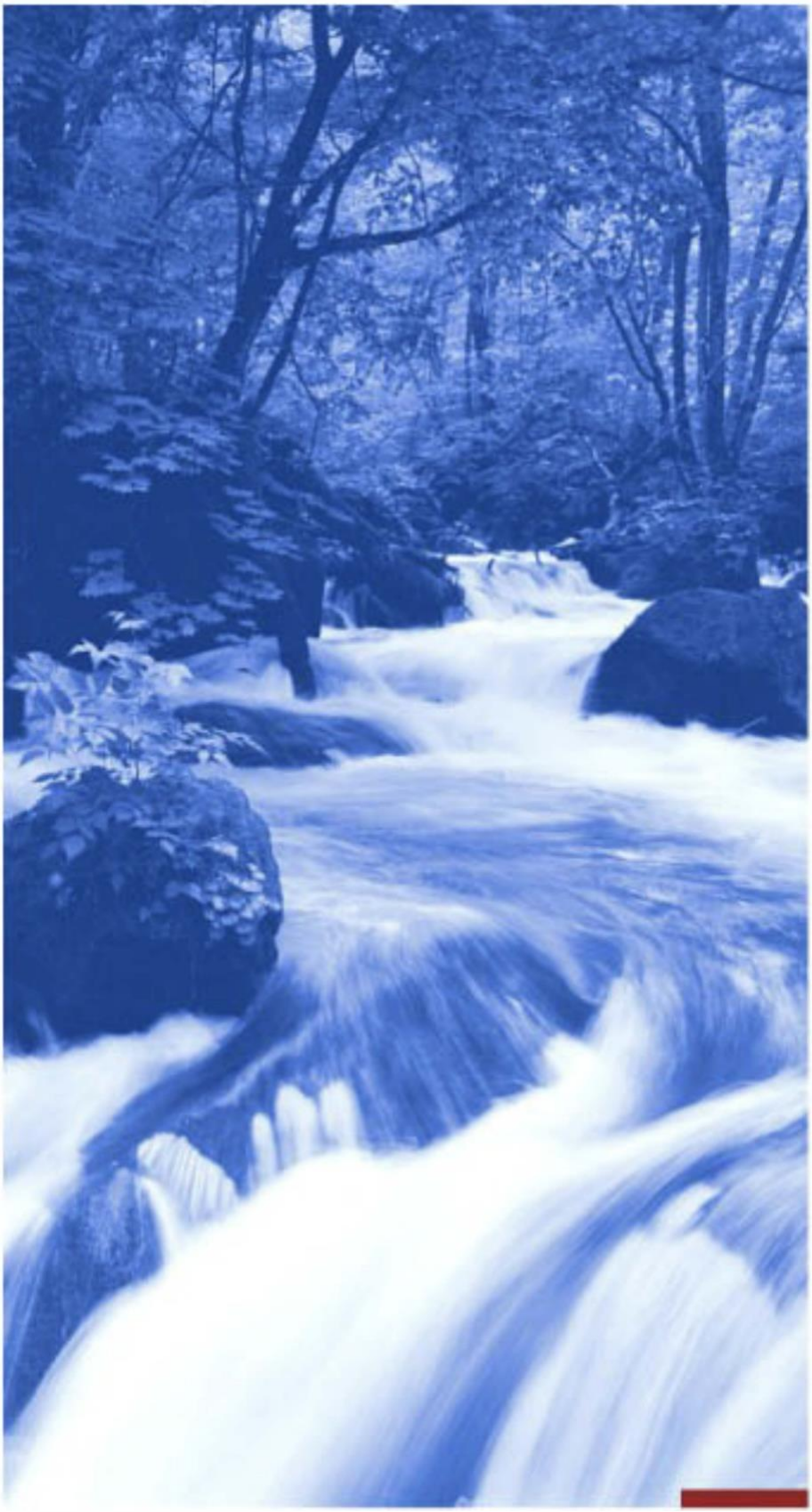
The Water Center
University of Pennsylvania



Policy Brief: The Nexus of Climate Change, Nature-based Solutions, and CSO Remediation in the Northeast MegaRegion

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Introduction

Cities across the Northeast MegaRegion[1] - from Boston to Washington DC - are grappling with the impacts of climate change including larger storm events, flooding and sea level rise. At the same time, most of these cities are served by combined sewer systems built long before the current level of development. In April 2024, EPA published a draft combined sewer overflow (CSO) policy to address what will be required of combined sewer systems at the completion of their current Long Term Control Plans (LTCP). As communities and permitting authorities plan future wet weather projects and maintain CSOs to align with LTCP objectives, the EPA advises them to consider various approaches. Among the options are enhancing resiliency through green infrastructure, utilizing smart sewer technologies, and implementing proactive asset management strategies, along with other available recommendations.[2] Many of the cities in the MegaRegion are at the forefront of incorporating nature-based solutions[3] among their strategies for addressing climate change and CSO compliance.

Given this context, understanding the role and effectiveness of nature-based solutions becomes even more critical. The Water Center at Penn's first Spring Water Policy Forum was entitled: *The Nexus of Climate Change, Nature-based Solutions, and CSO Remediation in the Northeast MegaRegion*, brought together policymakers, utility leaders, regulators, nonprofit leaders, engineers, lawyers, academics and students to discuss barriers and solutions to implementing nature-based solutions (NbS) and reducing CSOs, loading from other pollutants, and flooding in the Northeast MegaRegion. This report aims to document participants' views and outline the pathways for catalyzing change that emerged from the discussions at the Forum.

Figure 1: Cary Coglianese Edward B. Shils Professor of Law and Professor of Political Science and Director of Penn Program on Regulation, delivering welcome remarks at the Water Center at Penn's Spring Water Policy Forum on April 11, 2024

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[1] For the purposes of this forum, we roughly define the Northeast MegaRegion to include the Delaware, Chesapeake, and Hudson River Watershed.
[2] U.S. Environmental Protection Agency. (2004). *Draft guidance for future NPDES permitting of combined sewer systems*. Washington, DC: U.S. Environmental Protection Agency.
[3]As defined by the U.S. Department of the Interior, a Nature-based Solution (NbS) is an action that incorporates natural features and processes to protect, conserve, restore, sustainably use, and manage natural or modified ecosystems to address socio-environmental challenges while providing measurable co-benefits to and benefit both people and nature.

Participants

Hosts

- **The Water Center at Penn**, *School of Arts and Sciences*
- **Penn Program on Regulation**, *Penn Carey Law School*

Moderators

- **Howard Neukrug**, *The Water Center at Penn*
- **Genie Birch**, *Penn Institute for Urban Research*
- **Matthijs Bouw**, *Weitzman School of Design*
- **Ellen Kohler**, *The Water Center at Penn*
- **Cynthia Koehler**, *WaterNow Alliance*
- **Cary Coglianese**, *Penn Program on Regulation*

Contributors and Panelists

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- **Steve Tambini**, *Delaware River Basin Commission*
- **Dana Hales**, *EPA Region 3*
- **Jessica Martinsen**, *EPA Region 3*
- **Nicole Lick**, *EPA Region 3*
- **Nicole Miller**, *Jersey Water Works*
- **Angela Licata**, *New York City Department of Environmental Protection*
- **Michael Mann**, *Penn Center for Science, Sustainability, and the Media*
- **Scott Moore**, *Penn Global*
- **Susan Wachter**, *Penn Institute for Urban Research*
- **Marc Cammarata**, *Philadelphia Water Department*
- **Randy Hayman**, *Philadelphia Water Department*
- **Nancy Stoner**, *Potomac Riverkeeper Network*
- **Joseph Tate**, *RES*
- **Michael Sachs**, *RES*
- **Brenton McCloskey,** *The Water Center at Penn*
- **Brianne Callahan,** *The Water Center at Penn*
- **Jazmin Ricks,** *The Water Center at Penn*
- **Emma Denison,** *The Water Center at Penn*
- **Shipra Narang Suri**, *United Nations Human Settlements Programme*
- **Jennifer Cotting**, *University of Maryland Environmental Finance Center*
- **Skelly Holmbeck**, *Water Resources Association of the Delaware River Basin*
- **Caroline Koch**, *WaterNow Alliance*
- **Pinar Balci**, *WSP*
- **Cristi Bickham**, *WSSC Water*

The Forum had two elements: a morning session with invited participants governed by Chatham House rules and a public afternoon session framed by a globally-focused keynote presentation and three regional context-setting presentations followed by six commenters and an open discussion. Prior to the Forum, we surveyed morning participants and heard from respondents about a variety of challenges facing urban waters in the region and the ways that NbS can help address those challenges. Respondents also noted that there is not sufficient data or funding to address these significant urban water challenges. More detailed information about the survey and a full summary of the afternoon session of the forum are provided in the appendices.

Pathways for Catalyzing Change

Invited regional and national water experts across the non-profit, regulatory, utility, and corporate sectors raised specific challenges that water systems face as a result of climate change and identified pathways to address each of these challenges. We have condensed and summarized the comments into four general theme areas: policy, financing, governance, and technology / innovation.

Adapting Policy to Fit Current Challenges

Throughout the day, we heard many participants voice the need to **create an enabling policy environment that addresses regressive policies, enables NbS approaches, and equitably serves vulnerable communities**. Many of the cities in the region manage drinking water, wastewater and stormwater within their boundaries and often include areas in neighboring municipalities. In addition to complying with EPA's CSO requirements, these water systems managers are facing a wide variety of other regulatory compliance issues across these three systems, including lead service line replacement, nutrient and sediment reductions to meet stormwater requirements, and emerging contaminants, all exacerbated by aging infrastructure and climate change. The day before the forum, the EPA announced a new per- and polyfluoroalkyl substances (PFAS)[4] regulation for drinking water, noting that regulations on PFAS wastewater are also being developed. Forum participants noted that, to meet the federal PFAS regulations, the regulatory framework needs to shift the financial burden of addressing chemicals in water from utilities to the polluters. Water utilities are not the cause of the problem and do not have commensurate funding to address the PFAS problem in its entirety, let alone the other challenges they are facing. As noted above, the EPA's draft CSO guidance also came out in April and addresses multiple elements of the next phase of CSO remediation such as post construction compliance monitoring at the completion of the current long term control plans and the opportunity for integrated planning going forward while ensuring equity and climate resiliency for CSO-impacted communities. While public health is appropriately driving the concerns about lead service lines and PFAS, the impacts of climate change on the cities' water systems has not received the same level of focus both in terms of policy and financing. It is noteworthy that the draft CSO guidance does point to climate change and equity. However, to ensure that the cities of the Northeast MegaRegion can thrive economically, environmentally and socially, our policies must ensure that we invest in these communities to remediate these persistent issues.

> **PATHWAY:** Ensure federal grant funding programs are sufficiently resourced to provide equitable investments for water infrastructure and climate resilience to CSO cities.

> **PATHWAY:** Elevate the public health challenges created by flooding and other climate change impacts to help drive impactful policy.

> **PATHWAY:** Create new zoning ordinances and building codes that incentivize NbS.

> **PATHWAY:** Drive adoption of policies that appropriately distribute the financial burden of water challenges, such as implementing polluter pays legislation to address PFAS and limit contamination.

Creating New Financing Structures

There is currently a lack of funding and financing for a number of water-related initiatives, including NbS and green infrastructure, operations and maintenance, and creative funding programs. This indicates a need for more inventive financing solutions. Federal dollars for water infrastructure are available, but notably 95% of all local infrastructure is funded by local ratepayers. Utilities are not getting funding from ratepayers equivalent to their current needs, especially in the wake of the multiple challenges these urban water systems face both in terms of pollution regulations and in terms of building climate resilience.

> **PATHWAY:** Enact strong rate affordability programs so that the constituents most financially at risk will not be impacted by necessary rate increases.

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[4] Please note that for the sake of simplicity, the use of the term "PFAS" in this report is meant to be an all encompassing reference to the entire family of per and polyfluoroalkyl substances, including PFOS.

PATHWAY: Ensure equitable distribution of public funding to local governments and communities with the greatest need.

PATHWAY: Encourage better communication and collaboration between sources of possible revenue streams for NbS so that communities can take advantage of multiple streams of financing and remove some of the financial burden from ratepayers.

PATHWAY: Incentivize financial collaboration between public, private, and nonprofit entities to advance NbS.

Considering Water Resource Governance

Utilities are thinking about how to manage current responsibilities while also anticipating and planning for the future. Numerous regulatory requirements exist now with more to come, given climate change impacts, aging infrastructure, and emerging contaminants. Water system managers want to achieve fishable, drinkable, and safe waterways in their cities as increased regulatory requirements create new challenges. For example, PFAS regulations require meeting a four part per trillion limit. Given the cost of current technologies, attaining the threshold is not going to happen without significant support, effort and flexibility from our regulatory agencies.

PATHWAY: Strengthen the integrated water planning approach to address the CSO, MS4, lead service line and PFAS issues facing the water sector.

PATHWAY: Strengthen governance structures that foster engagement between water utilities and the communities they serve to provide a more transparent and balanced approach to implementing water regulation and policies.

PATHWAY: Reduce barriers to allow for more collaboration between federal, state, and local governments to better prioritizes projects that advance water initiatives.

Advancing New Technologies and Innovation

Water systems need to innovate to adapt to climate change. Many climate models are underestimating the impacts of climate change.[5] In addition, existing hydraulic and hydrologic (H&H) models used for estimating stormwater pollutant loads and green infrastructure planning lack the granularity to more reliably predict flooding. For example, there is a need to update national flood mapping which is widely known to be outdated and inaccurate.

PATHWAY: Invest in improved data to be used in models that inform decisions about pollutant loads and flood risk reduction.

PATHWAY: Build buy-in among the scientific and corporate arenas to promote innovation in the hybrid, green, and blue technology sectors.

PATHWAY: Build communication strategies that highlight the success of new blue and green infrastructure technologies and innovations.

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[5] Schewe, J., Gosling, S.N., Reyer, C. *et al.* State-of-the-art global models underestimate impacts from climate extremes. *Nat Commun* 10, 1005 (2019).

On the Horizon

To meaningfully impact the imperative problems of climate change and combined sewer overflows in addition to unsustainable development, poverty, inequality, lack of housing, or lack of water and sanitation using nature-based solutions requires a holistic and interdisciplinary approach to achieve urban resilience. **We need to coordinate and accelerate efforts with key partners and address opportunities for shared NbS projects, research, and funding.**

While the Water Center works with our partners to shape our 2025 Spring Water Policy Forum, we will also be using this document as a roadmap to guide our work in this field. With the support of funding from Penn's Environmental Innovation Initiative, the Water Center will be continuing to focus on several of these pathways through graduate student research over the 2024-25 academic year. Our 2025 Policy Forum report will build on what we've learned here and the work we've done to address these issues.

Appendices

1. Survey Results
2. What the Experts are Reading
3. Spring Water Policy Forum April 2024 Afternoon Session Summary

Appendix 1 – Survey Results

Prior to the Water Center's Spring Water Policy Forum hosted on April 11, 2024, we developed a survey in coordination with our Spring Water Policy Forum Steering Committee to understand issues of consensus, concern, and interest among our attendees. This survey provided questions for attendees to consider in advance and helped to inform our group discussions, and the results, which can be seen below, were presented during the morning session of the Spring Water Policy Forum.

How would you rank Combined Sewer Overflows (CSOs) in terms of importance among water issues in the Northeast MegaRegion?

Most Significant Obstacles in Advancing NbS for Addressing Urban Water Challenges

- Funding
- Political will
- Available land
- Community acceptance
- Poor design
- Insufficient maintenance
- Valuing and facilitating large-scale NbS in land use planning and public procurement
- Lack of understanding in the approach, scale, and intended outcomes
- Competing needs
- Limited data

Most Important / Realistic Strategies for Diversifying Funding to Implement NbS

- Transparency around federal and state funding
- Providing grant funding through SRFs
- Private sector water and carbon neutrality fund
- Infrastructure financing
- ESG investment portfolios
- New funding sources
  - Stormwater fee, Development fee
- Looking at co-benefits to find new funding sources
- Change the Benefit-Cost Analysis

Key Urban Water Challenges that NbS are well positioned to address

- Flooding
- Water Quality
- Heat Island Effect
- Access to Green Space
- Affordability
- Green Jobs
- Air Quality
- Stormwater Runoff
- Biodiversity
- Climate Resilience
- Habitat Restoration
- CSOs

Defining Nature-Based Solutions

- Adaptive measures to conserve, sustainably manager or restore ecosystems
- Outside of typical gray infrastructure
- Use soil and vegetation to address stormwater pollution
- Relies on natural processes to accomplish restoration or water quality outcomes
- Complimentary or alternative interventions to gray infrastructure
- Actions to address societal challenges through protection, sustainable management, and restoration of ecosystems
  - From International Union for the Conservation of Nature

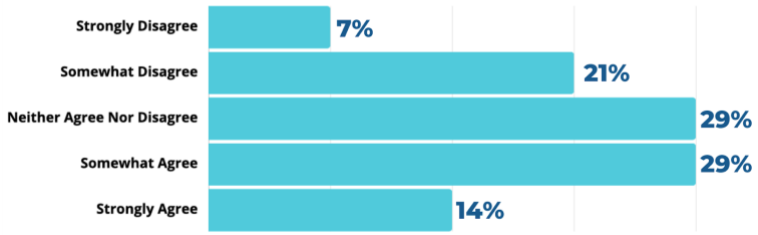
Rank the following pathways for catalyzing change in order of importance:

1. Policies (Including Land Use Policies)
2. Financing
3. Governance
4. Emerging Technologies
5. Other:
   a. Funding Support
   b. Data
   c. Strategic Partnerships
   d. Collaborative Practices
   e. Lack of budget alignment that fails to take advantage of NbS outcomes

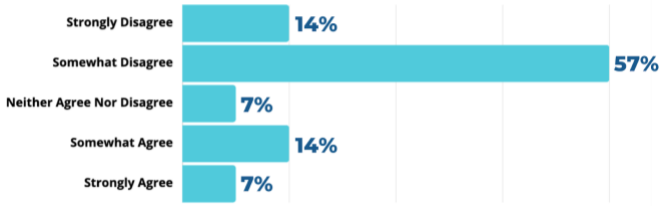
Top Urban Water Challenges Facing the Region

- Climate Change
- Aging Infrastructure
- Funding
- CSOs
- Flood Management
- Water Quality
  - Regulations / Compliance
  - Emerging Contaminants
- Lack of Community Engagement
- Workforce Development
- Ecosystem Services
- Equity Issues
  - Affordability, Access, Workforce

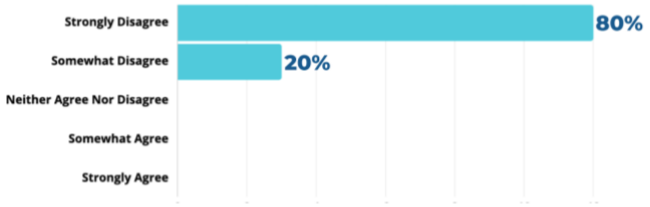
Cost effectiveness should be a top priority in project selection:



There is enough data currently available to address urban water challenges:



There is sufficient funding for urban water challenges in the Northeast region:



Appendix 2 – What the Experts are Reading

Journal Articles

- Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (eds.) (2016). *Nature-based Solutions to address global societal challenges*. Gland, Switzerland: IUCN. xiii + 97pp. http://dx.doi.org/10.2305/IUCN.CH.2016.13.en.
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- Madden, Sarah. (2010). *Choosing green over gray: Philadelphia's innovative stormwater infrastructure plan*.
- W.M.S. Wickramasinghe, C.M. Navaratne, S.V. Dias, Building resilience on water quality management through grey water footprint approach: a case study from Sri Lanka., Procedia Engineering, Volume 212, 2018, Pages 752-759, ISSN 1877-7058.

Institutional Reports and Resources

- 21st Century Water Infrastructure Solutions: Cynthia Koehler, and Caroline Koch. 2019. Innovation in Action: 21st Century Water Infrastructure Solutions. San Francisco, Calif.: WaterNow Alliance. tapin.waternow.org/resources/innovation-in-action-21st-century-water-infrastructure-solutions.
- BEGIN Policy Brief: 2020. *Building Green Infrastructure for Climate Resilience*. North Sea Region Programme. northsearegion.eu/media/14055/begin-policy-brief.pdf.
- Cities Alive: Arup. 2014. *Rethinking Green Infrastructure*. Arup. arup.com/globalassets/downloads/insights/cities-alive-rethinking-green-infrastructure.pdf.
- *Cloudburst Management Plan 2012*. publication. The City of Copenhagen. Available at: (Accessed: 2024).
- *Combined sewer overflow control program*, Massachusetts Water Resources Authority. (Accessed: 2024).
- *Green Banks and Nature-Based Solutions :How to Make the Most of the Greenhouse Gas Reduction Fund*. Matthew Carney. 2023. March 30, 2023. Water & Climate Finance. Quantified Ventures.
- *Regenerative Nature-Based Solutions: The Missing Link in Solving the Climate Polycrisis*. KenCairn, B. Center for Regenerative Solutions. Retrieved from *https://naturebasedclimate.solutions/news/polycrisis-solutions* (Accessed: 2024).
- State of Finance for Nature in Cities: United Nations Environment Programme (UNEP), The Nature Conservancy, and Penn Institute for Urban Research. 2024. State of Finance for Nature in Cities. penniur.upenn.edu/sites/default/files/2024-10/State-of-Finance-for-Nature-in-Cities.pdf.

- *The State of Public Sector Green Stormwater Infrastructure: 2022. Advancing Equitable GI Implementation*. Green Infrastructure Leadership Exchange. giexchange.org/wp-content/uploads/TheStateOfPublicSectorGSI.pdf.
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City Climate Action Plans in the NorthEast MegaRegion

WASHINGTON DC
https://doee.dc.gov/sites/default/files/dc/sites/ddoe/service_content/attachments/CRDC-Report-FINAL-Web.pdf (2016)
Climate Ready DC provides a comprehensive overview of Washington DC's adaptation strategies in the face of climate change. The report highlights the district's recent climate risks and vulnerabilities, addressing challenges in infrastructure challenges and the natural environment. The district's outlined actions cover transportation and utilities, buildings and development, neighborhoods and communities, and implementation.

NEW YORK CITY
https://climate.cityofnewyork.us/wp-content/uploads/2023/06/PlaNYC-2023-Full-Report.pdf (2023)
New York City's climate plan, PlaNYC 2023, is a blueprint for tackling the challenges of climate change. This report details the city's strategies to mitigate and adapt to rising temperatures, sea level rise, and extreme weather events. From enhancing infrastructure resilience to promoting renewable energy and equitable policies, PlaNYC 2023 outlines actionable steps across multiple sectors to build a more sustainable and resilient future for NYC.

PHILADELPHIA
Philadelphia Climate Action Playbook (English) PDF (January 2021)
Philadelphia's Climate Action Playbook offers the city's strategy to confront climate challenges. It outlines key risks and proposes a range of measures spanning infrastructure, energy, transportation, and community engagement. This document provides a roadmap towards a more resilient and sustainable future for the city.

CAMDEN
https://www.camdencounty.com/wp-content/uploads/files/CamdenCountySustainablePlan2018.pdf (2018)
The Camden County Sustainable Plan provides a robust framework for addressing environmental challenges in the region. This strategic document outlines key priorities and strategies across various sectors, including transportation, energy, land use, and community engagement. As stakeholders convene to discuss future actions, this comprehensive plan serves as a vital resource for fostering sustainability and resilience throughout Camden County."

BALTIMORE
https://baltimoreplanning.konveio.com/baltimore-climate-action-plan-update (2023 draft)
Baltimore's Climate Action Plan charts a strategic course for addressing environmental imperatives in the city. This document delineates key objectives and initiatives spanning transportation, energy, land use, and community engagement. This plan stands as a cornerstone for advancing sustainability and resilience throughout Baltimore. As an update to the city's original 2018 plan, this draft just recently closed their public comment period.

Appendix 3 – Spring Water Policy Forum April 2024 Afternoon Session Summary

Cary Coglianese, Edward B. Shils Professor of Law and Professor of Political Science and Director of the Penn Program on Regulation welcomed participants to the afternoon session of the Water Center's Spring Water Policy Forum. He noted that the National Oceanic and Atmospheric Administration (NOAA) released its latest air sampling of greenhouse gas emissions showing no decline in emissions. Climate change is here. The floods and storms that will impact and burden our existing infrastructure system, water infrastructure systems included, are a reality we need to confront now.

Following Cary's welcome remarks, the afternoon session consisted of a keynote address that provided a global context for the nexus of nature-based solutions and urban water resilience, followed by three context-setting presentations and concluded with reflections from practitioners and a dialogue with audience members.

Five Key Takeaways from the Afternoon Session

1. **Nature-Based Solutions' Evolving Role**: While nature-based solutions offer many proven benefits, their role in effectively addressing the increasing scale of global challenges needs to be better defined.
2. **Power of Partnerships**: Diverse partnerships will be necessary to drive the implementation of nature-based solutions and support water utilities in managing their expanding, complex responsibilities.
3. **Community Engagement by Water Utilities**: Water utilities must elevate their role as anchor institutions by continuing to actively engage with communities and taking a proactive approach to address shared challenges.
4. **Financing Challenges and Realities**: Innovative financial solutions are crucial. While federal funding exists, 95% of local water infrastructure is still funded by local ratepayers, underscoring the need for sustainable funding strategies.
5. **Interconnectedness of Water Challenges**: Water issues extend beyond water, influencing climate, land use, energy, equity, public health, and more. The next generation of water leaders must adopt broader perspectives and embrace diverse, innovative solutions.

Keynote

Dr. Shipra Narang Suri, Chief, Urban Practices Branch of UN-Habitat[6] started her keynote address by acknowledging that:

- 3.45 billion people are considered highly vulnerable to climate change.
- 4.4 billion people live in cities, among which half a billion people live in coastal urban areas.
- 25 of the world's megacities are around coastlines and are at a very high risk of sea level rise and flooding.
- Two-thirds of the world will be living in urban areas by 2050.

While climate change is caused in some way by urbanization with greenhouse gas emissions coming from buildings, transport and industrialization, cities and urban communities also bear the brunt of climate change. More than 2 billion people around the world are without safe water. At least 350 million more people - about the population of the United States - will be exposed to water scarcity with warming of 1.5

[6] The United Nations Human Settlements Programme (UN-Habitat) is mandated by the UN General Assembly to promote socially and environmentally sustainable towns and cities. UN-Habitat works with partners to build inclusive, safe, resilient and sustainable cities and communities and promotes urbanization as a positive transformative force for people and communities, reducing inequality, discrimination and poverty. See https://unhabitat.org/.

degrees C. And a third of the world's major cities may run out of water by 2050. Even without climate change, urbanization has an impact on our water systems. A lot of urbanization is unplanned and blocks natural water systems. Urban land exposed to floods and droughts will increase more than 2.5 times. The combination of climate change and unplanned urbanization will result in human loss, economic losses, infrastructure damage and greater health burdens.

Dr. Suri noted that nature-based solutions benefit both people and nature. She observed that "[t]he potential is huge but it's really about political will and having the courage and ability to take a decision and start a process which turns a system inside out, upside down, and challenges conventional wisdom and perhaps goes against established law and norm to say 'we're going to do it differently.'" With this background, she shared three relevant projects as examples of the path forward.

- Al Zohour Green Triangle, Amman, Jordan
- Sungai Ara Linear Park, Penang Island, Malaysia
- Nairobi Rivers Regeneration, Nairobi, Kenya

Dr. Suri concluded, stating the water resilience challenge is about so much more than water; it is a challenge that connects everything. She shared four lessons from UN-Habitat that she asserted should be global priorities:

1. Implement feasible, bankable, cutting-edge nature-based solutions targeting the most vulnerable communities;
2. Create an enabling policy environment
3. Address climate finance paradoxes
4. Coordinate and accelerate efforts of key partners for urban resilience.

Context-Setting Presentations

In the first context-setting presentation, Marc Cammarata, Deputy Commissioner, Planning and Environmental Services for the Philadelphia Water Department (PWD) provided a water utility perspective. With a history of providing water services for more than 200 years, PWD manages 7,000 miles of pipe, six treatment plants (three on the water side, three on the wastewater side), and pump stations everywhere. In terms of perspective, Philadelphia sits at the bottom of a very large watershed and only owns 2% of the land area that provides drinking water for 1.6 million people in this region. At the hyper-local scale, PWD manages distributed stormwater infrastructure throughout the City. Mr. Cammarata noted that the department thinks about integrating across all of these responsibilities and providing services today while also focusing on tomorrow. The department thinks about the basin scale for drinking water, the river reach scale for the effects of stormwater and wastewater treatment, and the sewershed scale for combined sewer overflow (CSO) mitigation.

The department has spent $4.5 billion to invest in the assets necessary to deliver on the core services. Any financing through bonds and loans has a rate impact because we have to pay that money back. We raise rates every single year.

The Green City Clean Waters is PWD's 25-year plan for mitigating or eliminating the effects of about 8 billion gallons of combined sewer overflow. While the plan includes implementing green stormwater infrastructure, PWD is also making major investments in treatment plants to increase capacity, increase redundancy, and increase the ability to deal with effluent. PWD is also making modifications to the collection system to deliver more flow to the wastewater treatment plants and optimize what stays in the system. These efforts include pump station modifications, transmission improvements, in-system storage expansion and collection system improvements.

Interception, infiltration, transpiration, harvest and reuse, and slow release all need to be in the toolbox to think about how to implement green stormwater infrastructure at scale to manage stormwater, to alleviate stress on the system that causes combined sewer overflows, and ultimately improve water quality. How does PWD deliver thousands of projects and hopefully eliminate billions of gallons of CSO using these tools? There are three different approaches: stormwater regulations, incentivized retrofits, and public retrofits. Philadelphia now requires all new developments to manage stormwater. A stormwater fee is married to a crediting program that allows landowners to change the way they impact the stormwater management system and get a fee reduction. We incentivize that with a competitive grant program to kick start those projects even more. Finally, PWD makes direct public investments using ratepayer dollars to invest in critical locations throughout the city to maximize stormwater runoff management. These projects are implemented on public lands like streets, parks, libraries and recreation centers. There are over 3,000 greened acres on our way to the target of 10,000 greened acres in the combined sewer area with another 500 greened acres in the separate sewer section of the city. More than 500 RainCheck installations (rain barrels, rain gardens, downspout disconnects and porous pavement removal at the house scale) have been implemented. PWD has more than 2,500 greened acres currently in planning, design and under construction.

How do you actually deliver on all the obligations, requirements and necessities that we have with a severely limited ability to pay here in the City, given 25% of the population in Philadelphia is below the poverty line? PWD is also managing aging infrastructure, including 3,000 miles of water mains of which 20% were installed before 1900. The average age of our infrastructure in the city is about 75 years. In addition to remediating CSOs, there are stormwater management permit obligations through the MS4 program and other water quality challenges. On the drinking water side, there are the challenges of lead line identification and replacement as well as PFAS monitoring and treatment. The department is also managing for climate change impacts on its water system infrastructure and on neighborhoods.

Mr. Cammarata concluded his remarks by coming back to the “One Water" premise, noting PWD’s responsibility to think about adaptation, to think about integrated planning, to think about beyond core services and focus on the value to our communities. PWD is committed to aquatic health improvements, public health, partnerships and stakeholder engagement while still trying to deliver the services we provide at affordable rates. The department is tapping nature-based solutions where and when it can to remediate CSOs and other water management issues. Overall, the multiple challenges facing the department are testing our ability to make sure the department is focusing on the right things and constantly thinking about solutions that benefit people and nature.

The next presentation from Michael Sachs, Northeast General Manager, Resource Environmental Solutions (RES), provided a private sector perspective on scaling nature-based solutions through funding and partnerships. RES was created in 2008 and initially focused on responding to regulatory mandates. Their work has evolved to include projects pursued voluntarily because of more political will and community interest in nature-based solutions over the last 10 or 15 years. Public and private landowners, private companies, and municipalities are incentivized in a different way than they would be in the traditional design-bid-build-procurement process.

Mr. Sachs focused on floodplain restoration as a particularly impactful nature-based solution. These projects deliver multiple benefits. If the site is carefully selected and properly designed with the right performance criteria, it can be self-sustaining without significant maintenance expenses because it is a natural system that provides ecosystem services. Shoreline stabilization projects also deliver significant benefits. Nature-based solutions can be significantly less expensive than gray infrastructure strategies in reaching water quality and water management goals. Mr. Sachs shared multiple examples including

projects in the Paxton Creek watershed, the Delaware Bay, St. John's River, and the Rappahannock River watershed.[7]

Mr. Sachs noted that the way private companies behave, private landowners behave, public agencies behave can be altered by how contracts are structured and outcomes are measured. The best use of available funding sometimes is to pay for the exact outcome you want. You may give up control over the project specifics and the project location but you get the ecosystem outcomes you are seeking. These pay for performance contracts can also drive creative partnerships.

The final context-setting presentation was provided by Franco Montalto, Professor of Civil, Architectural and Environmental Engineering, Drexel University. He provided a research perspective on climate impacts in the Northeast Mega Region. He focused on the role of nature-based solutions in managing both smaller storm events to help reduce the potential for CSO events and also increased flood risk from larger storm events. He made three observations:

- Climate change is increasing the burden on urban drainage systems in complex ways, and we need to adapt faster.
- The tools used to make decisions regarding pollutant loads need to be modified if they are to help plan flood risk reduction.
- Successful adaptation requires a multi-pronged approach including both incremental and transformative solutions.

Dr. Montalto noted that the region is getting wetter overall. The days with heavy precipitation have increased by 60% in the last few decades. When studying flood events, conditions can change within a day, within an order of minutes. Some of these extreme precipitation events are massive downpours that happen in a very small amount of time. Researchers don't have that fine, temporal resolution data for a long enough period to tell us what the trends are for short duration precipitation events. These extreme events are much bigger than the types of events that we've used to think about for pollutant reduction, water quality, volume, and the forest flush. Our water infrastructure was not designed to manage these kinds of events.

Relative sea level rise looks at the increase in sea level and the change in vertical motion of the land. Current models for this region indicate about 4 feet of sea level rise by the end of the century. Increase in sea level can result in increase in water table in coastal areas, which can then cause water tables to intercept or intersect with subsurface infrastructure. It could be infiltration into pipes, basements, and subway tunnels. Also, it is more difficult for precipitation that is trying to flow away from an area. As that water table goes up, it intersects with the roots of vegetation in coastal zones, so it is difficult to predict the future vegetation composition.

Dr. Montalto observed that, when we talk about flooding, we have to understand the differences between pluvial flooding (high intensity rain that can't infiltrate or flow away, so it pools on the surface) and fluvial flooding (the base flow of the stream over tops its banks and shows up on flood maps). The pluvial flood risk could cover a much larger area, as we see in New York City with the recently released Stormwater Resiliency Flood Maps.

Together changes in precipitation and sea level rise can impact all four types of flooding - pluvial, fluvial, coastal, and groundwater - as well as the compounding impacts where they overlap. For example, higher sea levels cause surges pushing against the coast and makes it more difficult for the water to leave. Again, our current infrastructure was not designed to deal with these kinds of events. So, we can't use existing tools to make decisions about water management infrastructure for the future. More specifically, existing

[7] For information about RES projects, see https://res.us/home/places/find-projects/

hydrologic and hydraulic (H&H) models used for estimating stormwater pollutant loads and green infrastructure planning lack the granularity to predict flooding. These models need to be updated to add two dimensional surfaces, add obstructions, look at the flow in the sewer system, and include data about flooding on the surface. This is a nationwide problem; there is not good data on flooding and, as a result, it becomes difficult to validate these types of models.

To consider a nearby example, given what we know about the Eastwick neighborhood in Southeast Philadelphia and the Cobbs Creek watershed, there is nowhere near the amount of stormwater management that's needed. According to modeling, green stormwater infrastructure would need to be scaled up by more than a factor of 5 of what is currently planned for stormwater permit compliance to meaningfully reduce downstream fluvial flooding. Another example in Camden is the specific area of Harrison Avenue that floods regularly. Camden County Municipal Utilities Authority (CCMUA) has some interesting solutions to adjusting the sewer system to remove and eliminate the flooding on that street. However, CCMUA's modeling includes a 50% increase in precipitation to account for climate change and, for the same street, the Delaware River goes up and the area still gets swamped by coastal flood risk despite these innovative strategies to address pluvial flood risk.

In considering the role of Nature-based Solutions, natural systems flood. Adding climate change creates unavoidable risk. Superimpose urbanization in the same landscape and the unavoidable flood risk becomes even higher and may reach the point of being unacceptable. This raises the question of what the future acceptable flood risk is and what are alternative adaptation pathways that we might think about to get there. These conversations involve not just the governmental stakeholders, but also community stakeholders, practitioners, and others. We need to consider all kinds of solutions and how we can overlay on top of one another to create the best adaptation strategies.

Dr. Montalto asked if we were having the right conversations. What can we reasonably expect from Nature-based Solutions given the scale of the risks?

- Coastal wetlands need to be high, wide, and continuous to reduce storm surges (1-15 inches per mile of wetland) and to keep out rising seas.
- Green infrastructure practices need to be scaled up and more hydraulically efficient.
- Green infrastructure needs to be integrated into the urban matrix.
- Managed retreat needs to be on the table but implemented equitably, ideally as part of a multi-decadal sequence of actions, accompanied by extensive community engagement and equitable compensation.

He concluded by noting that the conversation is just beginning, and for the partners in the room and others, this is going to be what we work on for the rest of our careers.

Reflections

With these three presentations setting the context, six panelists provided their reflections.

PINAR BALCI, New York City Water Lead and East Water Deputy Lead, WSP USA focused her reflections on four points:

- We must integrate across different competing water management because there isn't enough public or private funding. Looking at the competing needs between water, wastewater, and stormwater added on top of climate change is going to require out of the box thinking rather than siloed regulations.
- The beauty of NbS, unlike gray infrastructure, is that it really welcomes innovation and changing the basis of design is key.
- We don't have time to dive deep into the data, but it would be beneficial to spend time at the front-end planning and improving the modeling predictions that we all rely on. It is important to make our predictive tools more accurate to help us on the back-end infrastructure planning.

- We have to be passionate about nature-based solutions and never give up.

NANCY STONER, President of Potomac Riverkeeper Network, addressed the students in the room as the next generation of problem solvers. The problems are big and getting bigger. We need people of varied talents who come from different disciplines with different strengths who are up for the challenge and ready to take them on and work in partnership with others and utilize every tool in the toolbox. The benefits of nature for our collective humanity are huge and it's worth being a part of that work.

ANGELA LICATA, Deputy Commissioner of Sustainability, New York City Department of Environmental Protection noted that she relies on engineers, lawyers, scientists, and communication specialists every day and it has been powerful. For her, nature-based solutions defend and promote nature for aquatic organisms and wildlife but also for human health and quality of life. New York City is 70% impervious cover so a lot of what's happening is underground promoting water infiltration and detention creating the capacity to polish the water before it gets to our rivers. The system serves 9 million people, and these shareholders are the ratepayers. They are starting to feel the pressures from the changing climate, and they want solutions. It is shifting the nature of the work from being regulatory driven to helping people cope with the climate crisis.

ADAM SCHELLHAMMER, Mid-Atlantic Regional Director, American Rivers remarked that water service providers have obstacles to overcome in the next 10, 20, and 30 years. We are challenged to understand our strengths and where we can add value. American Rivers is leaning into our strengths, understanding how we can be a catalyst for these partnerships and how we can fill in gaps, whether it is advocating for more progressive funding, adding communications support for Philadelphia Water Department, or bringing together partners that have barriers to partnerships. Being a catalyst in that regard and helping to facilitate NbS is a good way for us to move forward. The most powerful part and takeaway from today is that as a person, as an organization, know your niche in the ecosystem and go forward with confidence.

NICOLE LICK, Senior Life Scientist, US EPA Region 3 shared her perspective on the role of human behavior in this discussion. Humans procrastinate and cast floods as a once-in-a-lifetime event. We have very short memories, we want to recover and move on, never think about it again. It creates a disconnect in considering long-term solutions. Human psychology plays a major role in how we have to present these issues, talk about them, and make them real for people. Nature-based Solutions are effective; we should continue to implement them to reduce stormwater runoff and pollutant loads. Their co-benefits are critical right now as we tackle climate change and environmental justice issues. These strategies offer community amenities that traditional gray infrastructure cannot offer. But there is no one-size-fits-all answer for Nature-based Solutions. But their success depends on the unique characteristics of the site, existing collection system, land use, development patterns, stakeholder priorities, and governance structures.

The EPA recently published a draft guidance for future National Pollutant Discharge Elimination System (NPDES) and permits for combined sewer systems for combined sewer system communities who are nearing the end of their long-term control plans. The policy includes two recommendations directly relevant this discussion. First, water infrastructure planning going forward must include transparent and robust public engagement. A lot of people have been left out of the conversation about addressing aging water infrastructure. As we rebuild, water utilities must implement approaches to remedy disproportionate impacts, including the impacts of CSOs basement backups. We must know who is being impacted day to day. Second, we need to improve our models and tools. What are the projected changes in our precipitation patterns and sea level rise due to climate? How will it affect performance objectives in the long-term control plans? Do we need to think about different design storms?

SKELLY HOLMBECK, Executive Director, Water Resources Association of the Delaware River Basin observed that the Delaware River basin has benefited from the Delaware River Basin Commission that

allows stakeholders to legally collaborate on sharing water and it can keep us pointed in the right direction. She noted that, despite the influx of significant federal funding, there are still hurdles for communities to secure the funding for their water systems. Her final comment was about data and tools. While the NOAA maps are outdated, First Street Foundation has come up with a new set of maps but it's not clear how to test their work and update their models. She asserted that while we don't have the right tools we need for each situation right now - we are developing them- and we need to ensure that they are readily available and understandable to everyone.