

# Climate Change-Related Projects


Climate change is altering our natural hydrologic cycle, creating uncertainty when it comes to the quality and quantity of water sources. WRF research helps the water sector plan for and prevent the impacts of climate change, from understanding potential impacts to implementing adaptation strategies and mitigating root causes. WRF's research on climate change covers the key areas of:

- Climate Adaptation
- Climate Mitigation
- Climate Risk Assessment


WRF research tracks potential outcomes, considering a variety of possibilities, and provides resources and tools to help facilities identify and address risks and vulnerabilities. WRF also provides the science to help utilities create better adaptation plans, respond more effectively to severe weather, and improve infrastructure and operations to meet changing needs, including the production of onsite energy systems and back-up power to protect critical services. And by pioneering approaches to improve energy efficiency, including process optimization, improved energy management, and the use of renewable energy, WRF is also helping the water sector decrease the activity that is driving these changes.

## CLIMATE ADAPTATION


### Integrating Climate Change Impacts with Wet Weather Management, Capital Improvement, and Stream Network Enhancement [5176]




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The project objectives are: (1) to enhance precipitation projection and modeling techniques with risk-based criteria to mitigate risks for utilities (e.g., sewer overflows, flooding, stream network deterioration); (2) to advance current practices for climate change rainfall statistics and projections by region and identify research gaps and other areas for refinement; and (3) to advance an integrated and risk-based approach for adapting water infrastructure systems and capital improvement planning to climate change while enhancing the protection of stream networks to meet receiving water quality requirements and mitigate wet weather flows.


**To be completed in 2025.**

*Related Topics: Flooding, Resilience, Sewer Overflows, Stormwater, Wet Weather Management*


### Incorporating Equity and Social Dimension into Community Climate Adaptation Planning and Watershed Management [5180]




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The project objectives are: (1) to identify appropriate metrics and measures for building resilient communities with equity and social considerations that blend lived experience of the community with technical expertise; (2) to develop holistic mitigation strategies, including planning-level costs to reconcile the social inequities associated with community climate adaptation and watershed management; (3) to develop or modify an easy-to-use supporting triple bottom line (TBL) tool and analysis framework that incorporates the ability to identify who receives the benefits and who pays for them so utilities can better assess equity implications of various options; and (4) to identify the leadership roles and engagement opportunities for communities when defining resilience and desired benefits for their communities (e.g., utilities and municipalities).

**To be completed in 2025.**

*Related Topics: Community Resilience, Equity, Integrated Planning & Water Management, Social Dimension, Stakeholder Engagement*

## Making the Case for Climate-Resilient Water Infrastructure and Supporting Strategies [5222]



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The project objectives are: (1) to develop water sector-specific guidance on how to make a case for investments in climate-resilient stormwater, wastewater, and drinking water infrastructure, considering both structural approaches (i.e., physical assets) and non-structural approaches (e.g., codes and standards); and (2) to apply the guidance to at least two water utility infrastructure systems or projects.

**To be completed in 2025.**

*Related Topics: Integrated Planning & Water Management, Resilience, Triple Bottom Line Approach*

## Navigating One Water Planning through Municipal Water Programs: Meeting Multiple Objectives and Regulatory Challenges [5175]



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The project objectives are: (1) to apply One Water planning principles and holistic watershed management approaches to multiple municipal programs, enabling utilities and municipalities to meet both environmental objectives and interconnected regulatory requirements (e.g., Clean Water Act [CWA] and Safe Drinking Water Act [SDWA]); (2) to create a decision framework that can help utilities choose from and prioritize interconnected projects and initiatives at utilities; and (3) to facilitate engagement with regulatory agencies and proactively identify the priorities and benefits of various actions, including the use of incentive-based strategies like water quality trading.

**To be completed in 2025.**

*Related Topics: Holistic Watershed Management, Integrated Planning & Water Management, One Water Planning*

## WRRF 2040 [5225]



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Through a workshop, this project will outline a roadmap and framework for imagining and implementing a water resource recovery facility of the future (i.e., WRRF 2040) to (a) accelerate adoption of new treatment process technology to address influence of climate change; (b) provide new tools for utilities to address resilience and performance at affordable costs; and (c) broaden utility scope to achieve more holistic treatment operations for coming decades.

**To be completed in 2024.**

*Related Topics: Resilience, Technology Adoption, Treatment Optimization*

## Maximizing the Value of Natural Assets and Green Infrastructure at the Watershed Scale [5253]



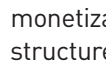
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The objectives of this project are: (a) to outline the benefits of natural asset management systems and solutions for utilities and water resource managers; (b) to incorporate assessment metrics into natural assets, which will provide a more complete accounting framework that can be scaled up to watershed and community levels, including initial capital investment and long-term impacts; and (c) to enhance an accounting and monetization framework for natural assets and green infrastructure so that an effective approach to natural asset management has the confidence of utilities, government, funders, and financial/economic managers and regulators.

**To be completed in 2026.**

*Related Topics: Green Infrastructure, Natural Assets, Stormwater*

## Quantifying the Performance of Source Water Protection Measures to Improve Utilities' Decision Making [5246]



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The objectives of this project are: (a) to advance source water protection and watershed-level point and non-point source pollution prevention, interception, and remediation strategies and to quantify the costs and benefits by focusing on high-priority situations; (b) to identify and prioritize performance measures for both point and non-point source pollution that need to be applied to different protection activities to assess the economic value, return on investment, value of ecosystem services, as well as operational, water quality and quantity, and ecological outcomes.

**To be completed in 2026.**

*Related Topics: Resilience, Source Water Protection, Watershed Management*

## Integrating Nature-based Solutions and Gray Infrastructure to Optimize Treatment Performance [5248]



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The objectives of this project are: (a) to summarize and advance the state of practice of integrating nature-based solutions with conventional/gray infrastructure treatment trains across different water matrices; (b) to assess water quality performance capabilities of mixed treatment trains using existing datasets, published literature values, and/or advanced tools such as simulation models; and (c) to identify socio-technical opportunities and barriers for better integration, and evaluate proposed solutions for energy, chemical, and/or other operation and maintenance cost savings.

**To be completed in 2026.**

*Related Topics: Green Infrastructure, Nature-based Solutions, Systems Integration*

### Diversifying Water Portfolios through Stormwater Capture and Use: Contributing to a Water Resilient Future [5236]



In the face of a changing climate, urban stormwater capture and use (SCU) has the potential to add flexibility to water resource portfolios. This project will quantify the volume of urban stormwater available for capture and use (using Colorado as an example) and contextualize it against the water supply gap, which can be extrapolated to other states. In addition, it will identify, quantify, and monetize (when possible) the co-benefits of stormwater capture and use, including highlighting existing examples where urban SCU have been successfully employed and underscore their multiple benefits. Furthermore, it will explore and conceptualize innovative approaches to operating SCU programs under water rights (using Colorado water law as an example) and regulatory frameworks.

**To be completed in 2024.**

*Related Topics: Stormwater Capture and Use, Integrated Planning & Water Management, Triple Bottom Line Approach*

### Establishing a Framework for Integrating Stormwater Capture into Water Supply Planning [5207]



The project objectives are: (1) to assess key factors of stormwater integration; (2) to showcase successful multi-agency participation and partnerships in stormwater capture and use as a new supply and other benefits; and (3) to develop a framework to evaluate the integration of stormwater as a water supply.

**To be completed in 2025.**

*Related Topics: Integrated Planning & Water Management, Stormwater, Water Supply Planning*

### Back to the Future: Guidance for Adaptive and Scenario Supply Planning Approaches [5184]



The project objectives are: (1) to identify the institutional processes and frameworks utilities are using to monitor how supply conditions change over time, identify what indicators are being tracked, considering reservoir storage, water demand, financial resources, climate, hydrology, water quality, regulations, equity, etc., and determine best practices; and (2) to describe and provide guidance on how utilities identify and monitor drivers of change, develop scenarios, and incorporate them into adaptive planning approaches.

**To be completed in 2025.**

*Related Topics: Integrated Planning & Water Management, Water Supply Planning*

### Water Utility Resilience: A Case Study of the 2021 Marshall Fire [5192]



The project objectives are: (1) to establish a timeline of events, including emergency preparedness, response, and recovery; (2) to investigate lifeline interdependencies and impact on water utility actions; (3) to define technology investments that supported response/recovery and potential improvements; and (4) to document utility communication with the public and customers over course of recovery.

**To be completed in 2025.**

*Related Topics: Emergency Preparedness/Response/Recovery, Wildfire*

### Enhancing Drinking Water Treatment Resilience to Wildfire Events [5168]



The project's objective is to provide guidance to drinking water utilities to increase treatment resilience to wildfires. Pilot-scale and side-by-side comparisons of treatment strategies, specifically comparing conventional treatment with pre-ozonation and biofiltration compared to conventional treatment with pre-chlorination and filtration, will be conducted to provide design and operational recommendations that can be made in treatment and monitoring, so utilities can more effectively respond to a post-fire scenario.

**To be completed in 2024.**

*Related Topics: Holistic Watershed Management, Treatment Resilience, Wildfire*

### Post-Wildfire Distribution System Water Quality Impacts and Potential Responses [5106]



As a result of climate change, the number and severity of wildfires in the western United States are increasing. Volatile organic compound (VOC) and semi-VOC contamination has been found in water distribution systems after wildfires in California. Preliminary research indicates that thermal degradation of plastic assets within distribution systems may be a potential source of this contamination. This project will increase understanding of the degree to which thermally damaged plastic assets contribute to observed VOC and semi-VOC contamination and propose response and recovery actions for impacted utilities.

**To be completed in 2024.**

*Related Topics: Distribution System, Wildfire*

### Wildfire Threats to Forested Drinking Water Supplies: Recent Advances & Opportunities in Understanding & Management [5235]



The objectives of this project are to provide, discuss, and document the most up-to-date knowledge and practice regarding (a) characterization of wildfire impacts on water supplies, treatment,

and distribution; (b) proactive and reactive source watershed management strategies; and (c) strategies to increase preparedness.

**To be completed in 2024.**

*Related Topics: Source Water Protection, Water Supply, Wildfire Impact*

### Enhancement of Resilience to Extreme Weather and Climate Events: Proactive Flood Management [4842]



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Floods are among the most damaging natural disasters, and there is evidence that flood risk will increase in the future due to a warming climate, physical changes in watersheds, and continued development in flood-prone areas putting more assets at risk of inundation. Floods cause damage across the entire built environment, but they pose particular challenges for wastewater, stormwater, and drinking water utilities. While assessing flood risks is challenging, there are many tools and strategies that utilities can implement to help reduce risk and increase resilience. This project will help wastewater and stormwater utilities navigate the challenges of flood risk assessment by (1) summarizing the state of knowledge and best practices for flood risk assessment and management; and (2) developing a synthesized, easy-to-use pocket guide for enhancement of wastewater and stormwater utility resilience to extreme weather and climate events by focusing on proactive risk assessment and flood management. The pocket guide will assist utility users in selecting datasets, methods, models, and tools that are appropriate for their flood conditions, management objectives, and other factors. Originally funded as WERF project SIWM-17-15.

**Published in 2023.**

*Related Topics: Green Infrastructure, Integrated Planning & Water Management, Resilience, Stormwater*

### Holistic Approaches to Flood Mitigation Planning and Modeling under Extreme Events and Climate Impacts [5084]



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Municipalities and utilities are facing unprecedented challenges in planning for extreme precipitation and flooding events, which are occurring more frequently and unpredictably. A holistic approach to flood mitigation planning and modeling, including partnerships between stakeholders, is needed to balance competing management objectives while minimizing overall system vulnerabilities. To address this need, this project will (1) develop a comprehensive summary of the state-of-the-practice with case studies; (2) define data sources and modeling tools that can enable a holistic approach to flood mitigation planning and modeling; (3) demonstrate the application

of selected methodologies most relevant to the needs of an integrated planning framework for supporting agencies at the community level; and (4) synthesize findings into a guidance document based around state-of-the-practice integrative, holistic management approaches to planning for, and mitigating, climate change impacts. Utilities of all sizes will be able to apply the project results to incorporate climate variability and uncertainty into their holistic flood management approaches.

**Published in 2023.**

*Related Topics: Combined Sewer Overflows, Green Infrastructure, Integrated Planning & Water Management, Stormwater*

### Holistic Wet Weather Management through Adaptive Volume and Pollutant Source Control at a Community Scale: Finding the Sweet Spot [5131]



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Using a triple-bottom-line approach and extensive input from utility stakeholders, this project will synthesize holistic wet weather management strategies through adaptive volume and pollutant source control at varying scales. Strategies will be geospatially analyzed across multiple EPA regions to provide a decision-support framework for utilities and impacted communities to explore options for wet weather management based on their local context and desired goals.

**To be completed in 2024.**

*Related Topics: Combined Sewer Overflows, Green Infrastructure, Integrated Planning & Water Management, Resilience, Stormwater*

### Advancing the Disinfection from Wet Weather-Driven Sewer Overflows: Best Practice and Case Studies [5243]



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The objectives of this project are: (a) to improve receiving water quality by fostering widespread adoption of disinfection practices and technologies, when needed, at strategic locations throughout sewersheds and at potential peak wet-weather flow management points within water resource recovery facilities (WRRFs) and stormwater treatment systems; and (b) to identify cost-effective solutions and develop a user-friendly guidance document to add to a utility's decision toolbox for combined sewer overflow (CSO) and sanitary sewer overflow (SSO) mitigation strategies.

**To be completed in 2026.**

*Related Topics: Resilience, Sewer Overflows, Stormwater, Wet Weather Management*

### Optimization of Sensor Network and Advanced Sensing Techniques for Enhanced Collection Systems Management [5239]



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The objectives of this project are: (a) to advance the optimization of the layout of sensor networks and sensing techniques in collection systems to enhance One Water management; and (b) to improve data analytics, forecasting, modeling, and intelligent platform/dashboard environments to help with operations for a range of flow conditions and control schemes, preventive and in-time maintenance of collection systems, and optimization of capital improvement programs.

**To be completed in 2026.**

*Related Topics: Resilience, Sewer Overflows, Stormwater, Wet Weather Management*

### Case Studies for Successful Watershed and Sewershed Monitoring and Decision Making [5247]



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The objective of this project is to provide a comprehensive/robust compendium of case studies on management, economic, policy, and regulatory approaches showcasing an understanding of methods, parameters, and drivers that impact ecosystem health at the watershed and sewershed scale. The primary causes for the decline of ecosystem functions are the major drivers of landscape degradation and climate change that have impacted watershed structure and functionality layered on top of pollutant loading.

**To be completed in 2026.**

*Related Topics: Ecosystem Health, Sewershed Monitoring, Watershed Monitoring*

### Saltwater Threats to Drinking Water: Evaluating Risks of Corrosion and Disinfection Byproducts [5264]



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The prospect of dramatic increases in salt concentrations in freshwater supplies, as well as chronic increases in salinity, is a national concern and a pressing issue, especially in a changing climate. The objectives of this project are to evaluate water quality impacts of higher salinity concentrations in influent water on: (a) corrosion control efficacy on lead service lines and copper with leaded solder; and (b) regulated and unregulated disinfection byproducts (DBPs), especially iodinated and brominated species.

**To be completed in 2024.**

*Related Topics: Corrosion Control, Freshwater Salinization, Salinity*

### Guidance for Algaecide Application in Source Waters [5259]



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The objective of the project is to develop a guidance document that will help utilities optimize their algaecide application and develop monitoring protocols. Climate change exacerbates the problem of cyanobacterial blooms, as toxin-producing cyanobacteria blooms are increasing in more temperate regions, and droughts and heatwaves are causing areas prone to cyanobacterial blooms with increased frequencies.

**To be completed in 2026.**

*Related Topics: Algaecide, Cyanobacteria, Harmful Algal Bloom*

### Determining the Role of Spectral Imaging as an Early Warning System for Presence/Significance of Algal Blooms [5266]



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The objective of this project is to determine the role of spectral imaging as an early warning system (EWS) for the presence and significance of algal blooms in water sources. In addition, the project will use state-of-the-art chemistry and microbiology to compare them with commonly employed in-situ monitoring methods to bridge the gap between monitoring in its current state and the future.

**To be completed in 2026.**

*Related Topics: Algal Bloom, Early Warning System*

### Evaluating Changes in Peak Water Demand and How That May Affect the Choice, Design, Management, and Evaluation of Demand Management Strategies [5265]



DRINKING WATER

The objectives of this project are to: (a) identify the different definitions of peak demand that are relevant to water utility operations; (b) document trends over time across different geographies and contexts and the drivers of peak demand patterns, including changes related to climate change/extreme weather, urbanization/densification, and other factors; (c) assess how these and additional factors may influence peak demand in the future; (d) identify peak demand strategies and also evaluate which measures should be used for evaluation; and (e) assess the potential costs and benefits of peak demand management in the context of changing trends.

**To be completed in 2025.**

*Related Topics: Demand Management, Peak Demand Strategy*

### Decision Support Framework for Drinking Water Treatment Plants Experiencing Lake Recovery [4920]



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Drinking water treatment plants were historically designed to address a narrow range of water quality parameters, and are often not easily able to adapt to changes in source water quality. Utilities need tools to help them better understand and

respond to long-term changes in water quality due to lake recovery, climate, and other drivers. This project will develop and test a decision support framework (DSF) for drinking water treatment plants undergoing changes in source water quality. The resulting DSF will help utilities continue to supply high-quality water in an environmentally and economically sustainable manner.

**To be completed in 2024.**

*Related Topics: Reservoir Management, Resilience, Source Water Protection, Water Quality*

### Long-Term Vulnerability Assessment and Adaptation Plan for the San Francisco Public Utilities Commission Water Enterprise – Phase I [4703]



Climate change, water quality, regulatory changes, growth, and economic cycles are among the many factors that create uncertainty and vulnerability for water systems and impact their ability to meet the needs of their communities. Therefore, utilities must consider these factors when planning for the future. This project developed a long-term vulnerability assessment (LTVA) of the San Francisco Public Utilities Commission's Regional Water System (RWS). The goal of the LTVA is to help quantitatively and qualitatively assess to what extent climate change will be a threat to the RWS in comparison to, or in combination with, other external drivers of change over the next 50 years. This research provides a detailed case study of a decision scaling methodology, providing a systematic approach for addressing climate change concerns while also incorporating non-climate considerations. The findings will serve as the basis for future work to explore adaptation pathways and identify investments and long-term options to increase resilience of the RWS infrastructure. Research partner: San Francisco Public Utilities Commission.

**Published in 2021.**

*Related Topics: Risk Assessment, Utility Management*

### Community-Enabled Lifecycle Analysis of Stormwater Infrastructure Costs (CLASIC) [4798]



CLASIC is a user-informed screening tool that utilizes a life cycle cost framework to support implementation of stormwater infrastructure, including green, hybrid green-gray, and gray infrastructure practices. The CLASIC tool integrates Multiple-Criteria Decision Analysis (MCDA), which enables consideration of co-benefits for green infrastructure. There are three integrated components in the CLASIC tool: life cycle cost, performance, and co-benefits.

**Published in 2021.**

*Related Topics: Green Infrastructure, Stormwater, Wastewater*



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### An Enhanced Climate-Related Risks and Opportunities Framework and Guidebook for Water Utilities Preparing for a Changing Climate [5056]



As a follow-up to *Mapping Climate Exposure and Climate Information Needs to Water Utility Business Functions* (4729), the research team partnered with WRF, Denver Water, and the San Francisco Public Utilities Commission (SFPUC) to test the 4729 framework with two Water Utility Climate Alliance members in order to enhance the framework and guidebook and to identify opportunities to accelerate the use of climate considerations and resilience into utility management. The framework was pilot tested within critical business functions at Denver Water and SFPUC. This research will be useful to water utilities as they further recognize the importance of considering the effects of climate change on their operation and management strategy.

**Published in 2021.**

*Related Topics: Risk Assessment, Utility Management*

### Mapping Climate Exposure and Climate Information Needs to Utility Business Functions [4729]



This project developed a comprehensive, enterprise-level framework and a guidebook for understanding the exposure and sensitivities of water utility business functions to a changing climate. The water utility business risk and opportunity framework was designed to be applicable to a range of utility sizes, impacts, and functions. Though this framework specifically focuses on drinking water utilities, its approach has broader applicability across a variety of utility types. The application of the framework and guidebook can accelerate the incorporation of climate considerations into everyday utility management.

**Published in 2020.**

*Related Topics: Resilience, Risk Assessment, Utility Management*

### Climate-Resilient Planning for Urban Stormwater and Wastewater Utilities: Workshop Proceedings [5001]



WRF in partnership with the New York City Department of Environmental Protection, the Water Utility Climate Alliance, NOAA's Mid-Atlantic Regional Integrated Sciences and Assessments program, and the RAND Corporation convened an invitation-only workshop in July 2019 in New York City. The workshop brought together leaders from 15 major metropolitan water utilities in the U.S. and Canada, and other international experts to discuss current practices, lessons learned, and new ideas for developing actionable rainfall projections and incorporating climate-informed stormwater flows into planning processes. In addition, the workshop offered an opportunity to lay the

groundwork for future progress on this critical issue, including gaps in the existing best practice, critical research needs, and suggested next steps. The research report provides an informative summary of the workshop proceedings that will be useful to utilities and municipalities as they examine climate-resilient planning for urban stormwater and flood management. The supplemental project paper, *An Action Agenda for the Water Sector to Advance Methods for Achieving Integrated Climate Resilience* (project 5058), expands on the next steps identified in the workshop proceedings, and proposes an action agenda to further advance existing best practices, field testing of new approaches, and critical research needs for utilities wanting examples for their own application of climate data, as well as the climate science community to inform next steps in developing climate information.

**Published in 2021.**

*Related Topics: Combined Sewer Overflows, Green Infrastructure, Integrated Planning & Water Management, Resilience, Stormwater*

### An Action Agenda for the Water Sector to Advance Methods for Achieving Integrated Climate Resilience [5058]



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WRF in partnership with the New York City Department of Environmental Protection, the Water Utility Climate Alliance, NOAA's Mid-Atlantic Regional Integrated Sciences and Assessments program, and the RAND Corporation convened an invitation-only workshop in July 2019 in New York City. The workshop brought together leaders from 15 major metropolitan water utilities in the U.S. and Canada, and other international experts to discuss current practices, lessons learned, and new ideas for developing actionable rainfall projections and incorporating climate-informed stormwater flows into planning processes. In addition, the workshop offered an opportunity to lay the groundwork for future progress on this critical issue, including gaps in the existing best practice, critical research needs, and suggested next steps. The research report provides an informative summary of the workshop proceedings that will be useful to utilities and municipalities as they examine climate-resilient planning for urban stormwater and flood management. The supplemental project paper, *An Action Agenda for the Water Sector to Advance Methods for Achieving Integrated Climate Resilience*, expands on the next steps identified in the workshop proceedings, and proposes an action agenda to further advance existing best practices, field testing of new approaches, and critical research needs for utilities wanting examples for their own application of climate data, as well as the climate science community to inform next steps in developing climate information.

**Published in 2020.**

*Related Topics: Combined Sewer Overflows, Green Infrastructure, Integrated Planning & Water Management, Resilience, Stormwater*

### An Integrated Modeling and Decision Framework to Evaluate Adaptation Strategies for Sustainable Drinking Water Utility Management Under Drought and Climate Change [4636]



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This project developed an integrated framework to assess water quality and availability impacts under a suite of climate and natural hazards in the supply watershed, along with evaluation of decision options. Research partner: U.S. Environmental Protection Agency.

**Published in 2019.**

*Related Topics: Resilience, Water Supply Planning*

### Impacts of Climate Change on Honolulu Water Supplies and Planning Strategies for Mitigation [4637]



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The objective of this project is to evaluate climate change impacts on the Honolulu Board of Water Supply and its assets, and develop a suite of management and treatment strategies to address the anticipated changes. This project delivered an Adaptive Management Plan for Honolulu based on climatic and hydrologic modeling, scenario modeling, and evaluation of adaptive management strategies. Tailored Collaboration partner: Honolulu Board of Water Supply.

**Published in 2019.**

*Related Topics: Resilience, Water Supply Planning*

### Urban Landscape Water Use Research [4633]



DRINKING WATER

This project examined regionally specific research on urban landscape water use management strategies for water utilities. A literature review was conducted in order to formulate a preliminary research needs assessment. The project then hosted two regional interactive workshops to further inform the final analysis. The team also evaluated alternative definitions of the regions that define outdoor water use patterns and program successes, and selected a practically and theoretically satisfying definition of those regions that should be used as the basis for future research. The final report includes the following: 1) an overview of landscape water use research (particularly research that has been peer reviewed) specific to climate regions with high landscape water use, and 2) a workshop and prioritized list of research needs. In addition, a literature review database was created and is available on the Arizona State University Global Sustainability: <https://sustainability.asu.edu/dcdc/publications/technical-papers/urban-landscape-water-use-research-evaluation/>.

**Published in 2018.**

*Related Topics: Integrated Planning & Water Management, Resilience, Water Demand & Forecasting, Water Use & Efficiency*

### Adapting to Change: Utility Systems and Declining Flows [4736]



This project investigated the negative impacts observed by utilities during mandatory municipal water restrictions in California during the drought. Specifically, it looked at drinking water distribution systems, wastewater conveyance, wastewater treatment, and production of reclaimed water. A survey and utility interviews were conducted. The research found that significant reductions in water demand, along with declining flows, resulted in unintended consequences that ripple throughout California's interconnected urban water cycle. Understanding the system-wide impacts of increased conservation will help decision makers address California's current and future water challenges. This project produced two deliverables. The 2017 white paper, *Adapting to Change: Utility Systems and Declining Flows*, provides decision makers, water system managers, and other stakeholders with an understanding of the impacts of declining flows resulting from substantial reductions in indoor water use, and how utilities are adapting to these circumstances. The 2019 issue brief, *Adapting to Change: Informing Water Use Efficiency and Adjusting to Declining Flows*, builds on the white paper to inform future standards, implications, and adaptations following the 2018 California legislation that set a provisional standard for indoor residential water use of 55 gallons per capita per day. Co-funding for this project was provided by Association of California Water Agencies, California Association of Sanitation Agencies, California Water Environment Association, and WaterReuse California.

**Published in 2018.**

*Related Topics: Resilience, Utility Management, Water Demand & Forecasting*

### Advanced Techniques for Monitoring Changes in NOM and Controlling DBPs under Dynamic Weather Conditions [4422]



This project developed an effective online monitoring strategy and response system to detect changes in the character and amount of NOM and its associated DBP precursor concentration that occurs (1) during current operating conditions, (2) during extreme weather events, and (3) under future climate change scenarios. The project evaluated the ability of advanced online instrumentation utilizing UV absorbance spectral derivative measurements to detect changes in the concentration and characteristics of NOM associated with increased DBP formation potential. Research partner: New York City Department of Environmental Protection.

**Published in 2016.**

*Related Topics: Advanced Treatment, Disinfection Byproducts, Emergency Response & Preparedness, Monitoring*

### Drought Management Strategy – Learning from Australia [4640]



This project investigated the decade-long Australian Millennium Drought to compile lessons learned. The information was gathered to provide California utilities and policy-makers with helpful strategies, as the state enters its fifth year of severe drought. This report was co-authored by the Institute for Sustainable Futures (ISF) at the University of Sydney, the Pacific Institute, and the Alliance for Water Efficiency. The report was jointly funded by the Metropolitan Water District of Southern California, the San Francisco Public Utilities Commission, and the Water Research Foundation.

**Published in 2016.**

*Related Topics: Emergency Response & Preparedness, Resilience*

### Drought Management in a Changing Climate: Using Cost-Benefit Analyses to Assist Drinking Water Utilities [4546]



This project improves drinking water utility understanding of system-specific vulnerabilities to droughts by providing guidance on assessing the costs and benefits of leading practices in drought management and risk mitigation. The final report helps water customers, boards of governance, and other stakeholders better understand the total possible costs of drought and improve acceptance of drought planning and mitigation measures to minimize these costs. Project findings are also helpful to the greater scientific community in tackling fundamental questions on the application of cost-benefit tools. In addition to the report, an Example Cost-Benefit Analysis is available to download from Project Resources/Project Papers. This project is funded by NOAA. It was submitted in response to the competitive funding opportunity entitled, *Coping with Drought with the National Integrated Drought Information System (NIDIS)*, from the Sectoral Applications Research Program administered by the NOAA Climate Program Office.

**Published in 2015.**

*Related Topics: Resilience, Risk Assessment*

### Water Utility Planning Strategies to Mitigate Impacts of Climate Change in Central Ohio [4585]



This project produced a suite of management and treatment strategies that water suppliers can apply to address anticipated changes in source water quantity and quality due to climate change. The project focused on climate change impacts in central Ohio and the eastern portion of the Midwest, but the approach and considerations from this project have broad applications throughout the region and the country. Tailored collaboration partner: City of Columbus Division of Power and Water.

**Published in 2015.**

*Related Topics: Resilience, Utility Management*



## Dynamic Reservoir Operations: Managing for Climate Variability and Change [4306]



This research identified how reservoir operations can be adjusted to adapt to hydrologic changes associated with climate change and the uncertainties associated with climate variability. The project addressed issues such as developing and using dynamic rule-curves or operating criteria, and how they affect water quantity, water quality, flood management, and environmental release responsibilities of water utilities. The project produced two reports: *Dynamic Reservoir Operations: Managing for Climate Variability and Change* (4306a) and *Reservoir Operations Development Guide: The Theory and Practice of Developing Reservoir Operating Rules for Managing Multiple Objectives* (4306b). Research partner: City of Calgary Water Resources.

**Published in 2014.**

*Related Topics: Reservoir Management, Resilience, Water Quality*

## Water Quality Impacts of Extreme Weather-Related Events [4324]



This research identified and characterized water quality impacts of extreme weather-related events. In addition to the research report, the project developed an Excel-based tool to provide a means of quickly sorting and accessing case studies that may be relevant to a particular utility. Case studies can be sorted based on various criteria including geographic location, weather, water quality, year of event, and water source. The tool is available on this project page under Project Resources/Web Tools. The case studies can also be downloaded in one PDF document under Project Resources/Case Studies. Research partners: Water Services Association of Australia and WERF.

**Published in 2014.**

*Related Topics: Emergency Response & Preparedness, Resilience, Water Quality*

## Effective Climate Change Communication for Water Utilities [4381]



This project produced a guidance document to assist water utilities in communicating about climate change, with an emphasis on building support for water utility climate-related adaptation or mitigation investments or projects. A message-mapping worksheet is included within the report to help water agencies develop messages that will build long-term support for their specific climate-related actions. The worksheet is also available under Project Resources/Project Papers as a Microsoft Word template for utilities to build their own message mapping strategy. Lastly, the



WASTEWATER



STORMWATER



WATER REUSE

project produced a video to provide water professionals with the information they need to understand the relationship among water, water utility needs, and climate change.

**Published in 2014.**

*Related Topics: Customer Relations & Stakeholder Engagement, Utility Management*

## Water/Wastewater Utilities and Extreme Climate and Weather Events: Case Studies on Community Response, Lessons Learned, Adaptation, and Planning Needs for the Future [4416]



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WATER REUSE

This study discusses how water, wastewater, and stormwater utilities—and other local water resource managers—make decisions in response to recent extreme weather events. The report is based on the results of six local workshops, organized to include participants that experienced different types of extreme events throughout a river basin or watershed in various regions of the U.S. The study examines what happened, how information was used to inform decisions, what institutional dynamics helped or hindered, and how water utilities and their communities plan to manage impacts and build resiliency for future extreme events. Additionally, the case studies were published separately and are also available.

**Published in 2014.**

*Related Topics: Emergency Response & Preparedness, Resilience, Stormwater, Utility Management*

## Changes in Water Use Under Regional Climate Change Scenarios [4263]



DRINKING WATER

This project studied anticipated water demands and use patterns under a range of climate change scenarios, categorized by specific customer class and industry sector, so that water utilities may better plan for and respond to changing water use patterns as a result of climate change. The report provides recommendations for water utilities to plan for and respond to anticipated water use patterns, and identifies key concerns and areas for additional analysis by region.

**Published in 2013.**

*Related Topics: Resilience, Water Demand & Forecasting*

## Opportunities for Managing Climate Change by Applying Adaptive Management [4380]



DRINKING WATER

This project investigated how adaptive management techniques could be applied to managing water assets that were subject to potential climate change impacts. It was intended as an initial scoping phase, and commitment of further resources may be considered.

**Published in 2013.**

*Related Topics: Asset Management, Integrated Planning & Water Management, Resilience*

### Water Utilities and Climate Change: A Research Workshop on Effective System Adaptation [4228]



This project conducted an integrative research workshop bringing together utility managers, engineers, and planners with climate scientists and urban infrastructure planners to begin mainstreaming climate science into the complex public decision process for water utility management, rehabilitation, and expansion in coastal areas. A workshop report was published with guidelines for water utility adaptation in Florida coastal areas (and, by extension, to similar coastal areas in other states). Tailored collaboration partner: Palm Beach County Utilities Department.

**Published in 2012.**

*Related Topics: Integrated Planning & Water Management, Resilience, Utility Management*

### Building a Climate-Ready Regulatory System [4239]



This research developed (1) a summary of U.S. legislation and regulation that poses constraints to water utilities in reducing greenhouse gas emissions; (2) a summary of unique legislative and regulatory frameworks in other countries and in individual states that could be adapted to the national legislative and regulatory framework; and (3) opportunities for new legislative and regulatory options and flexibility that will help utilities optimize costs and levels of service and reduce environmental impacts. Two publications are available: *Building a Climate-Ready Regulatory System* (4239) and *An Executive White Paper and Action Plan* (4239b). Research partner: AWWA.

**Published in 2012.**

*Related Topics: Energy Optimization, Regulations, Resilience*

### Effects of Climate Change on Water Utility Planning Criteria and Design Standards [4154]



Evaluates current water utility planning criteria and design standards for their effectiveness in equipping utility facilities with the features needed to adapt effectively to future climate conditions, with the purpose of assisting water utilities in the engineering of new facilities. Builds on the previous WRF study, *Climate Change and Water Resources: A Primer for Municipal Water Providers*, and focuses on the western U.S. coastal climate variations and how utilities can modify existing planning criteria and design standards to provide the flexibility to deal effectively with the wide range of climate uncertainty predicted. Tailored collaboration partners: Contra Costa Water District, Seattle Public Utilities, Los Angeles Department of Water and Power, and San Diego County Water Authority.

**Published in 2010.**

*Related Topics: Resilience, Utility Management*

### The Future of Research on Climate Change Impacts on Water: A Workshop Focusing on Adaptation Strategies and Information Needs [4340]



Convened a joint workshop with NOAA, US EPA, NASA, and WERF to explore the implications of climate change to the water sector. Developed a final research needs report. Research partner: UCAR.

**Published in 2011.**

*Related Topics: Resilience*

### Implications of Climate Change for Adaptation by Wastewater and Stormwater Agencies [1334]



This report summarizes the current understanding of natural climate variability and the projected global climate changes over the next 20-50 years. It provides utility managers a realistic indication of potential impacts to the storm and wastewater sectors along with a strategy that can be used to evaluate the vulnerability of their facilities. The report will help utility managers understand why there is uncertainty in projections of future local climates and help them to understand the nature and magnitude of possible changes. The report emphasizes that the real task will be to develop strategies with sufficient flexibility and resilience to deal effectively with increased uncertainty.

**Published in 2010.**

*Related Topics: Climate Adaptation, Wastewater, Stormwater*

### State Survey of Climate Change Resiliency Efforts [4730]



Climate change affects many aspects of water resource management throughout the United States, through rising temperatures, drier conditions, snowpack loss, flood events, and rising sea levels. Sustainable water resource strategies, particularly water efficiency strategies, can strengthen resilience to climate change by reducing greenhouse gas emissions, improving water quantity and quality, protecting watersheds, and improving flood management. Through this project, a comprehensive review of laws, regulations, policies, and programs at the state level was conducted to catalog findings and identify trends. The researchers surveyed professionals in each U.S. state, including representatives from government and planning agencies, conservation-focused entities, and more, to augment this information. The findings shed light on current activities and provide real-life examples for states and regional entities hoping to improve their resilience to climate change.

**Published in 2018.**

*Related Topics: Resilience*

## CLIMATE MITIGATION

### Establishing Industry-Wide Guidance for Water Utility Life Cycle Greenhouse Gas Emission Inventories [5188]



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WATER REUSE

The project objective is to develop a utility-facing guidance document and a supporting spreadsheet tool that capture current best practices worldwide for developing a utility GHG inventory over the life cycle of capital and operational emissions (with a specific focus on operational emissions). A utility-facing practical guidance document (covering scopes 1, 2, and 3) with case studies will be developed, which can be used as a standardized document across geographic regions and different utility sizes. In addition, an open-access spreadsheet tool will be developed that can be further customized by an individual utility as needed.

**To be completed in 2025.**

*Related Topics: Greenhouse Gas Emission, Inventory, Life Cycle Analysis*

### Developing a Greenhouse Gas Emissions Library for Unit Processes by Water Utilities and Decentralized Systems [5255]



DRINKING WATER



WASTEWATER



STORMWATER



WATER REUSE

The objectives of this project are: (a) to develop a standardized approach for the water sector to determine baseline GHG emissions according to common unit processes and evaluate the impact of process/operational changes to their systems; and (b) to establish a “GHG Emissions Library” with a basic framework in place that allows future updates as GHG emissions data from unit processes become more available.

**To be completed in 2026.**

*Related Topics: Greenhouse Gas, Emissions Library, Standardized Approach, Unit Process*

### Advancing the Understanding of Nitrous Oxide Emissions Through Enhanced Whole-Plant Monitoring and Quantification [5251]



WASTEWATER

The objectives of this project are: (a) to provide accurate whole-plant Nitrous Oxide (N<sub>2</sub>O) emissions estimates for water resource recovery facilities (WRRFs) that employ commonly used treatment processes, by employing continuous online monitoring for a minimum one-year period; and (b) to develop guidance on process conditions that lead to high N<sub>2</sub>O formation risk at the facilities, by monitoring other process conditions alongside N<sub>2</sub>O production.

**To be completed in 2026.**

*Related Topics: Continuous Monitoring, Nitrous Oxide, Unit Process*

### Beyond Net Zero: Advancing Interdependencies Between Utility Greenhouse Gas Emission Reductions and Water-Energy-Food Nexus [5187]



WASTEWATER

The project objectives are: (1) to develop a decision support framework and operational guidelines for water resource recovery facilities (WRRFs) to achieve net-zero carbon and beyond (e.g., through water-energy-food nexus); and (2) to synthesize case studies worldwide (e.g., North America, Europe, Asia, and Australia) that can help demonstrate the applicability of decision support framework for broader uses.

**To be completed in 2025.**

*Related Topics: Carbon Offset, Greenhouse Gas Emission, Water-Energy-Food Nexus*

### Sewer Methane Methods for Everyone [5220]



WASTEWATER

Because collection system methane (CH<sub>4</sub>) is likely the wastewater industry’s largest greenhouse gas (GHG) source, a lower-tier GHG methodology is needed for utilities in the developed world. Without tools for accurate emissions quantification, appropriate goals for reduction cannot be established or met. The project will compare CH<sub>4</sub> estimates from 20 to 50 sewersheds of varying climate, size, configurations, and operation to create a simple method for adoption by GHG-accounting protocols.

**To be completed in 2025.**

*Related Topics: Climate Mitigation, Greenhouse Gas Emission, Wastewater*

### Mitigation Strategy Plan for Direct Greenhouse Gas Emissions from Biological Nutrient Removal (BNR) Processes in New York City [5072]



WASTEWATER

The objective of this project is to develop a process-specific N<sub>2</sub>O monitoring and mitigation strategy plan for BNR, which can also be followed for other processes, to control N<sub>2</sub>O production and emissions from the operations at water resource recovery facilities (WRRFs).

**To be completed in 2025.**

*Related Topics: Biological Nutrient Removal, Nitrous Oxide*

### Projecting Energy and Greenhouse Gas Emissions Implications of Capital Improvements Projects: Developing a Framework for Quantifying Energy Optimization Reporting [5091]



WASTEWATER

The objectives of this project are to estimate the energy implications of planned capital improvement projects and to document potential energy, greenhouse gas emissions, and cost savings.

**To be completed in 2025.**

*Related Topics: Capital Improvement, Energy Optimization*

### Balancing Carbon Management, Energy Production, Nutrient Removal and Densification [5271]



WASTEWATER

The objective of this research is to frame the redefinition of the wastewater industry with a focus on the activated sludge process. Systematic testing of several biological nutrient removal configurations will quantify the impacts of influent carbon use and diversion on energy production, nutrient removal, and sludge densification.

**To be completed in 2026.**

*Related Topics: Carbon Management, Energy Production, Nutrient Removal*

### Conveyance Asset Prediction System: Modeling and Mitigation [4885]



WASTEWATER

This research project sought to develop a tool, as well as measures and techniques for improving the assessment and proactive planning for corrosion, odor, and greenhouse gas (GHG) evolution in sewer collection systems. A predictive model for a system-wide estimate of GHGs was developed to create comprehensive planning tools that holistically evaluate a utility's collection system to help make decisions, adopt mitigation methods, and implement capital programs in a coordinated, prioritized, science-based approach. It is important to understand and address the physical, chemical, and biological influences in the sewer within a single, comprehensive model. The research team calibrated such a model based on collected full-scale data from a segment of a regional sewer. In addition, the project addressed production of methane (CH<sub>4</sub>) in sewers and its potential contribution to the overall GHG emissions inventory. The model is used as a basis to develop a simplified methodology for estimating gravity sewer CH<sub>4</sub> production.

**Published in 2020.**

*Related Topics: Climate Mitigation, Greenhouse Gas Emission, Wastewater*

### N<sub>2</sub>O and CH<sub>4</sub> Emission from Wastewater Collection and Treatment Systems State-of-the-Science Report – Report of the GWRC Research Strategy Workshop [1336]



WASTEWATER

This research focused on the possible contribution by the urban water sector to the direct emission of greenhouse gases (GHG). The objective was to collect and develop knowledge needed to understand and manage the emission of N<sub>2</sub>O (nitrous oxide) and CH<sub>4</sub> (methane) by wastewater collection and treatment systems. The participating GWRC members bundled their individual research programs, aligned methodologies used, and exchanged information. These activities resulted in two reports: a state of the science report which presents an overview and synthesis of the current knowledge regarding the emissions of N<sub>2</sub>O and CH<sub>4</sub> by wastewater collection and treatment systems and a technical report (CC6C10b) which

includes the details, facts, and data from the underlying studies used to develop the state of the science report.

**Published in 2011.**

*Related Topics: Climate Mitigation, Wastewater*

### N<sub>2</sub>O and CH<sub>4</sub> Emission from Wastewater Collection and Treatment Systems Technical Report [1337]



WASTEWATER

This research focused on the possible contribution by the urban water sector to the direct emission of greenhouse gases. The objective was to collect and develop knowledge needed to understand and manage the emission of N<sub>2</sub>O (nitrous oxide) and CH<sub>4</sub> (methane) by wastewater collection and treatment systems. The participating GWRC members bundled their individual research programs, aligned methodologies used, and exchanged and discussed information. These activities resulted in two reports: a state of the science report which presents an overview of the current knowledge regarding the emissions of N<sub>2</sub>O and CH<sub>4</sub> by wastewater collection and treatment systems and a technical report which includes the details, facts, and data from the underlying studies used to develop the state of the science report.

**Published in 2011.**

*Related Topics: Climate Mitigation, Wastewater*

### Evaluation of Greenhouse Gas Emissions from Septic Systems [1362]



WASTEWATER

The objective of the research was to obtain more accurate data on greenhouse gas emissions from septic tank systems, focusing on methane emissions from conventional septic systems. The project consisted of a literature review, construction of flux chambers, development of sampling techniques and protocols for gas sampling from septic tank system and ventilation systems, identification and selection of field sites, collection of gas samples, data analysis, and estimation of the GHG emission rate values.

**Published in 2010.**

*Related Topics: Climate Mitigation, Wastewater*

### Evaluation of Performance and Greenhouse Gas Emissions for Plants Achieving Low Phosphorus Effluents [1523]



WASTEWATER

This project evaluated operational practices and performance results for water resource recovery facilities designed to meet very low effluent total phosphorus (TP) concentrations, focusing on what can be learned from existing facilities to help utilities operate more sustainably while achieving the necessary level of performance. The researchers identify design and operating practices that impact phosphorus removal performance and consumption of resources.

**Published in 2015.**

*Related Topics: Climate Mitigation, Wastewater*

### Methane Evolution from Wastewater Conveyance [1776]



WASTEWATER

Wastewater collection systems could be a significant source of methane (CH<sub>4</sub>) emissions with readily biodegradable organic waste conveying through predominantly anoxic and anaerobic conditions in well-insulated, below-ground infrastructure. However, the Intergovernmental Panel on Climate Change (IPCC) published the 2006 IPCC Guidelines for National Greenhouse Gas Inventories which states that “In most developed countries and in high-income urban areas in other countries, sewers are usually closed and underground. Wastewater in closed underground sewers is not believed to be a significant source of CH<sub>4</sub>.” This project attempts to understand CH<sub>4</sub> evolution by measuring and modeling methane emissions from a few collections systems to confirm or refute the hypothesis supported by the IPCC. The report documents the research methodology, data collection effort, and results of the study.

**Published in 2012.**

*Related Topics: Climate Mitigation, Wastewater*

### Methane Evolution from Lagoons and Ponds [1778]



WASTEWATER

The objective of this research study was to examine greenhouse gas (GHG) emissions from facultative sludge lagoons and oxidative ponds through direct measurement of CH<sub>4</sub> flux from these systems under operating conditions. The report summarizes and documents the research methodology, data collection effort, and results from the work conducted under this study in order to provide a better understanding of the wastewater treatment industry's GHG emissions.

**Published in 2013.**

*Related Topics: Climate Mitigation, Wastewater*

### Flare Efficiency Estimator and Case Studies [1779]



WASTEWATER

This research increases awareness about the combustion efficiency of candlestick flares and advances understanding of the fugitive emissions from gas flaring operations. As part of this work, the research team created the Flare Efficiency Estimator (FEE) tool that can be used to input local operating conditions and parameters to estimate flare efficiency. The report provides the details of the FEE including a brief overview of prior research on flares, the calculation methodology, and a description of the user interface for the estimator tool. Two case studies provide examples of where the FEE was used to estimate fugitive GHG emissions using actual site data and conditions.

**Published in 2013.**

*Related Topics: Climate Mitigation, Wastewater*

### Greenhouse Nitrogen Emissions from Wastewater Treatment Operation: Phase I – Molecular Level through Whole Reactor Level Characterization [1791]



WASTEWATER

This project is one of the first attempts to characterize nitrogenous greenhouse gas (N-GHG) emissions from wastewater treatment plants using a standard analytical approach to collect full-scale plant data from BNR facilities in the United States. The results of this study will be integrated into mechanistic activated sludge process models, which will be refined by the addition of autotrophic pathways for N<sub>2</sub>O and NO emissions. The refined mechanistic models will allow the wastewater industry to mitigate N<sub>2</sub>O and NO emissions from a range of wastewater treatment processes by understanding the pathways leading to N<sub>2</sub>O generation and emissions. With this understanding, the wastewater sector will be able to engineer strategies for wastewater treatment that minimize gaseous nitrogen oxide emissions. Originally funded as WERF project U4R07.

**Published in 2012.**

*Related Topics: Climate Mitigation, Wastewater*

### Greenhouse Nitrogen Emissions from Wastewater Treatment Operations – Phase II: Molecular Level through Whole Reactor Level Characterization [1792]



WASTEWATER

This project continued the research into microbiological pathways involved in the formation and emission of nitrous oxide (N<sub>2</sub>O) from wastewater treatment processes in Phase II by building on previous work by the project team (WERF U4R07). This report focuses on the impact of process conditions such as glycerol-based denitrification in a full-scale nitrification-denitrification process, anoxic-oxic cycling, and inorganic carbon limitation. Because plant operations have a key role in N<sub>2</sub>O emissions, the report provides insight into the mechanisms influencing emissions and direction to ultimately create environmentally sustainable BNR operating strategies and configurations. Originally funded as WERF project U4R07b.

**Published in 2015.**

*Related Topics: Climate Mitigation, Wastewater*

### Quantifying Nitrous Oxide and Methane Emissions from Biofilm [4873]



WASTEWATER

This research addresses the formation of nitrous oxide (N<sub>2</sub>O), a potent greenhouse gas that is formed in wastewater treatment biofilm processes. The research primarily relied on mathematical modeling, but also included lab-scale experiments and field campaigns at full-scale treatment plants. Since accurate model development takes many years to reach the goal of a fully reliable predictive model that provides value to treatment design engineers and operators, this research

provides a theoretical underpinning that can support further research on lab, pilot, and full-scale systems.

**Published in 2018.**

*Related Topics: Climate Mitigation, Wastewater*

### Greenhouse Gas Emission Inventory and Management Strategy Guidelines for Water Utilities [4156]



Provides a guidance document to assist water utilities across the United States and Canada in preparing greenhouse gas emission inventories using a systematic and consistent methodology.



Assists utilities in evaluating greenhouse gas emissions for proposed projects or alternatives and highlights emission-reduction strategies that can be incorporated into utility business and operations. Tailored collaboration partner: CUWA.

**Published in 2009.**

*Related Topics: Climate Mitigation, Energy Optimization*

### Optimization of Energy and Water Quality Management Systems for Drinking Water Utilities [4271]



This project addressed the reduction of greenhouse gases (GHGs) while optimizing the level of energy efficiency at drinking water facilities.

Specifically, this study synthesized and assessed the growing body of information on the Energy and Water Quality Management System (EWQMS) framework; developed a functional specification for a GHG module that will be incorporated into EWQMS software; and implemented a pilot version of the modified EWQMS software at water utilities. Research partner: California Energy Commission.

**Published in 2015.**

*Related Topics: Energy Optimization*

### Toolbox for Water Utility Energy and Greenhouse Gas Emission Management [4224]



This project evaluated, compared, and contrasted process models, impact assessment methods, and performance indicators used by water utilities in North America, Europe, South Africa, and Australasia to evaluate their energy use and greenhouse gas (GHG) emissions. The project also identified how these tools can be used to support management decisions at water utilities. The report discusses implications of differences, investigates opportunities towards a harmonized assessment method, and provides recommendations. Research partners: NYSERDA and GWRC.



**Published in 2013.**

*Related Topics: Energy Optimization, Utility Management*

### Building a Climate-Ready Regulatory System [4239]



This research developed (1) a summary of U.S. legislation and regulation that poses constraints to water utilities in reducing greenhouse gas emissions; (2) a summary of unique legislative and regulatory frameworks in other countries and in individual states that could be adapted to the national legislative and regulatory framework; and (3) opportunities for new legislative and regulatory options and flexibility that will help utilities optimize costs and levels of service and reduce environmental impacts. Two publications are available: *Building a Climate-Ready Regulatory System* (4239) and *An Executive White Paper and Action Plan* (4239b). Research partner: AWWA.

**Published in 2012.**

*Related Topics: Energy Optimization, Regulations, Resilience*

### Economic Framework and Tools for Quantifying and Monetizing the Triple Bottom Line Benefits of Green Stormwater Infrastructure [4852]



Many cities are adopting green infrastructure (GI) programs to reduce polluted stormwater runoff and meet water quality standards related to combined sewer overflows, municipal separate storm sewer systems, and total maximum daily load targets. GI practices can also yield many important co-benefits, including beautifying communities, reducing flooding risks, enhancing climate resilience, improving air quality, reducing respiratory and heat-related illnesses, creating jobs, and more. There is a need to better quantify and monetize these benefits through a triple bottom line (TBL) approach. This project provides stormwater managers and practitioners with a rigorous systematic approach for quantifying and monetizing the financial, social, and environmental benefits of GI at the community, watershed, or neighborhood scale. The report is accompanied by an Excel-based tool, case studies, and a guidance document that provide essential information and calculations that allow users to quantify the TBL benefits and compare benefits to costs of GI scenarios in support of holistic stormwater management.

**Published in 2021.**

*Related Topics: Air Quality, Carbon Sequestration, Green Infrastructure*

### Groundwater Degradation from Carbon Dioxide at Geological Carbon Sequestration Sites [4265]



The purpose of this project was to identify groundwater quality impacts resulting from migration of CO<sub>2</sub> from geologic carbon sequestration projects, and consider impacts of physical and chemical changes associated with varying levels of contaminant migration or displacement associated with underground storage and sequestration of CO<sub>2</sub>. An understanding of how the

chemistry of near surface groundwater may be impacted by a CO<sub>2</sub> leak from a carbon capture and sequestration project is important for monitoring near surface groundwater resources. This knowledge can be used to develop groundwater monitoring protocols and to realistically assess risk to near-surface groundwater resources.

**Published in 2013.**

*Related Topics: Carbon Sequestration, Groundwater Management & Protection*

### Effective Climate Change Communication for Water Utilities [4381]



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This project produced a guidance document to assist water utilities in communicating about climate change, with an emphasis on building support for water utility climate-related adaptation or mitigation investments or projects. A message-mapping worksheet is included in the report to help water agencies develop messages that will build long-term support for their specific climate-related actions. The worksheet is also available under Project Resources/Project Papers as a Microsoft Word template for utilities to build their own message mapping strategy. Lastly, the project produced a video to provide water professionals with the information they need to understand the relationship among water, water utility needs, and climate change.

**Published in 2014.**

*Related Topics: Customer Relations & Stakeholder Engagement, Utility Management*

### The Future of Research on Climate Change Impacts on Water: A Workshop Focusing on Adaptation Strategies and Information Needs [4340]



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Convened a joint workshop with NOAA, US EPA, NASA, and WERF to explore the implications of climate change to the water sector. Developed a final research needs report, including integrating adaptation and mitigation approaches. Research partner: UCAR.

**Published in 2011.**

*Related Topics: Climate Adaptation and Mitigation, Resilience*

## CLIMATE RISK ASSESSMENT

### Developing an Environmental, Social, and Governance (ESG) Framework for Water Utilities [5206]



The project objectives are: (1) to develop a water sector specific environmental, social, and governance (ESG) framework and address related topics; and (2) to prepare a user-friendly ESG framework report with synthesis of case studies for water utilities.



**To be completed in 2024.**



*Related Topics: Environmental, Social, and Governance (ESG), Sustainability Reporting*



### Using Climate Information in Water Utility Planning [5054]



This project convened a workshop for water utilities in the northwest United States designed to improve the delivery of resources for small- to medium-size water utilities to help them build their resilience to climate change. Through a survey, focus groups, and a workshop, an understanding of utility climate planning needs and strategies to support them was developed, and resources for climate resilience planning were provided. This effort also resulted in the webinar series, Our Changing Precipitation: A Conversation on the Science of Precipitation and Planning for the Future, hosted by NOAA and WRF.



**Published in 2021.**

*Related Topics: Climate Information, Resilience by Small- to Medium-Size Water Utilities*

### Enhancement of Resilience to Extreme Weather and Climate Events: Proactive Flood Management [4842]

See page 4.

### Holistic and Innovative Approaches for Flood Mitigation Planning and Modeling under Extreme Wet Weather Events and Climate Impacts [5084]

See page 4.

### Decision Support Framework for Drinking Water Treatment Plants Experiencing Lake Recovery [4920]

See page 5.

### Long-Term Vulnerability Assessment and Adaptation Plan for the San Francisco Public Utilities Commission Water Enterprise – Phase I [4703]

See page 6.

### Community-Enabled Lifecycle Analysis of Stormwater Infrastructure Costs (CLASIC) [4798]

See page 6.

### An Enhanced Climate-Related Risks and Opportunities Framework and Guidebook for Water Utilities Preparing for a Changing Climate [5056]

See page 6.

### Mapping Climate Exposure and Climate Information Needs to Utility Business Functions [4729]

See page 6.

### Climate-Resilient Planning for Urban Stormwater and Wastewater Utilities: Workshop Proceedings [5001]

See page 6.

### An Action Agenda for the Water Sector to Advance Methods for Achieving Integrated Climate Resilience [5058]

See page 7.

### An Integrated Modeling and Decision Framework to Evaluate Adaptation Strategies for Sustainable Drinking Water Utility Management Under Drought and Climate Change [4636]

See page 7.

### Impacts of Climate Change on Honolulu Water Supplies and Planning Strategies for Mitigation [4637]

See page 7.

### Assessment of the Impacts of Climate Change on Reservoir Water Quality [4468]



This project produced a comprehensive assessment of the impacts of climate change on reservoir water quality under a range of climatic scenarios. The aim of the project was to determine how risks will propagate and change with a changing climate. Risks to reservoir water quality include both those that are generated externally and enter during rain event inflows and those that are generated within the reservoir. Research partner: Water Research Australia.

**Published in 2018.**

*Related Topics: Reservoir Management, Resilience, Risk Assessment, Water Quality*

### Urban Landscape Water Use Research [4633]

See page 7.

### Adapting to Change: Utility Systems and Declining Flows [4736]

See page 8.



### Advanced Techniques for Monitoring Changes in NOM and Controlling DBPs under Dynamic Weather Conditions [4422]

See page 8.

### Drought Management Strategy – Learning from Australia [4640]

See page 8.

### Impact of Climate Change on the Ecology of Algal Blooms [4382]



This project describes how climate change may affect the frequency, severity, and types of algal blooms that impair water quality in reservoirs and lakes that serve as sources of drinking water.

**Published in 2015.**

*Related Topics: Cyanobacteria & Cyanotoxins, Integrated Planning & Water Management, Nutrients, Reservoir Management*

### Drought Management in a Changing Climate: Using Cost-Benefit Analyses to Assist Drinking Water Utilities [4546]

See page 8.

### Water Utility Planning Strategies to Mitigate Impacts of Climate Change in Central Ohio [4585]

See page 8.

### Developing Robust Strategies for Climate Change and Other Risks: A Water Utility Framework [4262]



This project identified the most likely vulnerabilities typically associated with climate change, provided utilities with a tool to assess their own utility-specific vulnerabilities, and produced a suite of risk management tools to assist utilities in identifying appropriate strategies and actions to respond to the vulnerabilities that are identified. Research partners: NYSERDA and WSAA.

**Published in 2014.**

*Related Topics: Resilience, Risk Assessment*

### Dynamic Reservoir Operations: Managing for Climate Variability and Change [4306]

See page 9.

### Water Quality Impacts Of Extreme Weather-Related Events [4324]

See page 9.

### Water/Wastewater Utilities and Extreme Climate and Weather Events: Case Studies on Community Response, Lessons Learned, Adaptation, and Planning Needs for the Future [4416]

See page 9.

### Changes in Water Use Under Regional Climate Change Scenarios [4263]

See page 9.

### Effects of Lake Erie Water Quality Changes on Disinfection Byproduct Formation [4302]



This purpose of this project was to understand the relationships between Lake Erie algal population, dissolved organic matter, and DBP formation and if water quality can be attributed to climate change. The work documents how water quality changes can impact treated drinking water quality and helps to better prepare water agencies for such changes. Tailored Collaboration partner: City of Cleveland Division of Water.

**Published in 2013.**

*Related Topics: Disinfection Byproducts, Water Quality*

### Joint Front Range Climate Change Vulnerability Study [4205]



This project assessed changes in the timing and volume of hydrologic runoff that might be expected from several climate change scenarios for years 2040 and 2070 for the Front Range of the United States. Two hydrologic models, the WEAP (Water Evaluation and Planning) model and the Sacramento Soil Moisture model, were calibrated and implemented, and drew on historical streamflow data from the Colorado Water Conservation Board, regionally downscaled projections from the Bureau of Reclamation, and discussions with Western Water Assessment. Tailored Collaboration partners: City of Aurora Utilities, Colorado Springs Utilities Department, City of Boulder, Denver Water, City of Fort Collins Utilities, and Northern Colorado Water Conservancy District.

**Published in 2012.**

*Related Topics: Resilience, Source & Receiving Waters*

### Building a Climate-Ready Regulatory System [4239]

See page 10.

### Estimating Salinity Effects Due to Climate Change on the Georgia and South Carolina Coasts [4285]



This project studied the effects of potential changes in the frequency and magnitude of salt-water intrusion events under forecasted climatic and sea level conditions on stakeholders in the

Pee Dee and the Lower Savannah River basins of North Carolina, South Carolina, and Georgia. This information can be used to assess the potential impacts of global climate change on salt-water inundation of the water intakes of coastal utilities. Tailored collaboration partner: Beaufort-Jasper Water & Sewer Authority.

**Published in 2012.**

*Related Topics: Risk Assessment, Source Water Protection*

### Groundwater Sustainability Under Climate Change: A Literature and Research Review [4325]



This research provides a preliminary evaluation of potential impacts of climate change on groundwater resources, identifies potential impacts for groundwater systems, and develops recommendations for further investigation. Published in 2012. Includes an Annotated Bibliography under Project Papers.

**Published in 2012.**

*Related Topics: Groundwater Management & Protection, Resilience, Risk Assessment*

### Climate Change in Water Utility Planning: Decision Analytic Approaches [3132]



Identifies vulnerabilities of drinking water utilities to changing climate conditions and the adaptations drinking water utilities will need to make to manage risk, given unavoidable uncertainties regarding the specific nature of future changes in local hydrologic conditions. Also develops flexible and responsive short- and long-term management strategies to help utilities deal effectively with this new source of uncertainty when planning for and implementing changes in response to climate change. Research partner: NCAR.

**Published in 2011.**

*Related Topics: Risk Assessment, Resilience, Utility Management*

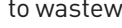
### Technical Briefings for Navigating Climate Change Information and Data [4204]



This project provides a set of technical briefing fact sheets describing the scale of the challenge, robust approaches, and resources available to U.S. water and wastewater utilities seeking to increase their resilience to climate change risks over the next 20-50 years. The technical briefings will help utilities to match their individual needs to available data and technical capacities. Research partners: UKWIR, WERF, and NCAR. This series of 10 fact sheets guides readers through the terminology, concepts, models, and observations relevant to climate change, particularly as it relates to wastewater and stormwater. It provides wastewater and stormwater service providers a summary of information



WASTEWATER



STORMWATER

and resources available on the effect of climate change in the areas of water quality, hydrology, sea level, and vulnerability to risk.

**Published in 2010.**

*Related Topics: Integrated Planning & Water Management, Resilience, Risk Assessment, Stormwater*

### The Future of Research on Climate Change Impacts on Water: A Workshop Focusing on Adaptation Strategies and Information Needs [4340]

*See page 10.*

### Potential Groundwater Quality Impacts Resulting From Geologic Carbon Sequestration [4203]



Assesses potential impacts of underground carbon sequestration on the quality of groundwater supplies and identifies related knowledge gaps and research needs. Research partner: AWWA.

**Published in 2009.**

*Related Topics: Groundwater Management & Protection, Integrated Planning & Water Management, Risk Assessment, Water Supply Planning*

### Climate Change and Water Resources: A Primer for Municipal Water Providers [2973]



Summarizes the best available scientific evidence on climate change, including both natural changes and changes that may be caused by human activities. Focuses on what is known about the implications of climate change for the water cycle and the availability and quality of water resources. Also provides guidance on planning and adaptation strategies. Includes a CD-ROM. Research partner: NCAR.

**Published in 2006.**

*Related Topics: Resilience*

### State Survey of Climate Change Resiliency Efforts [4730]

*See page 10.*

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